LUMILOOP

User's Manual

—— LSPM 1.0$^{(+)}$/1.1/2.0$^{(+)}$/2.1 ——

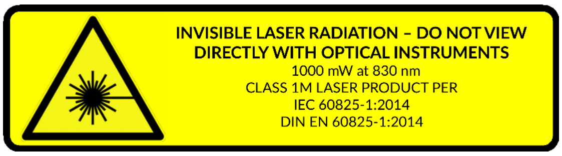
RF-POWER METERS

Contents

1 Safety Instructions

You have purchased a high precision measurement system. Please read the LSPM User's Manual carefully before operating the power meter. 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 power meter. 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 LSPM 1.1/2.1 Power Meter 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*"), LSPM 1.1/2.1 Power Meters feature Automatic Power Reduction (APR). If there is an interruption of the communication between power head 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 3.2.4). Interrupting optical connections during this time is dangerous!

2 System Overview

The Triple High-Speed LSPM Power Meter Family enables continuous RF power measurements with high resolution, high speed and low noise. LSPM 1.x/2.x power meters are not limited to the acquisition of quasi-static power levels. With their sampling rate of up to 2 MSamples/s, LSPM Power Meters are also able to measure rapidly changing RF signals. The power meters' large dynamic range and fast pulse response make them ideally suited for the analysis of pulsed signals and sweep measurements.

Every LSPM Power Meter comes with a complete set of factory calibration data for high linearity, fine-grained frequency compensation and, in case of LSPM 1.1/2.1 Power Meter, temperature stability. Additionally, device version specific wideband calibration data for a range of wideband values are supplied for LSPM 1.x power meters. The high-accuracy factory calibration data can be further enhanced by correction factors of accredited calibration laboratories.

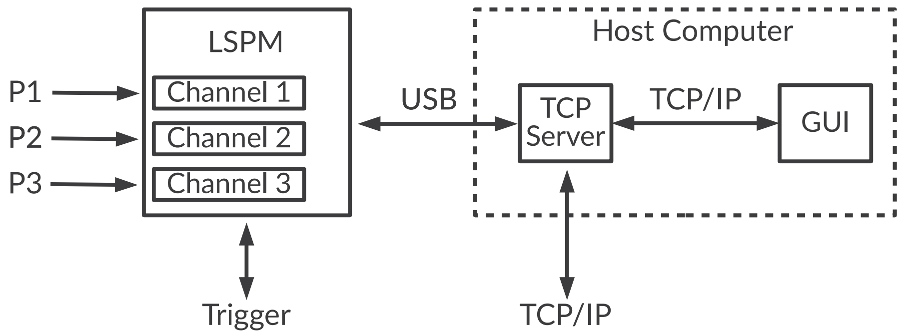


Figure 2: *LSPM 1.0/2.0 system block diagram*

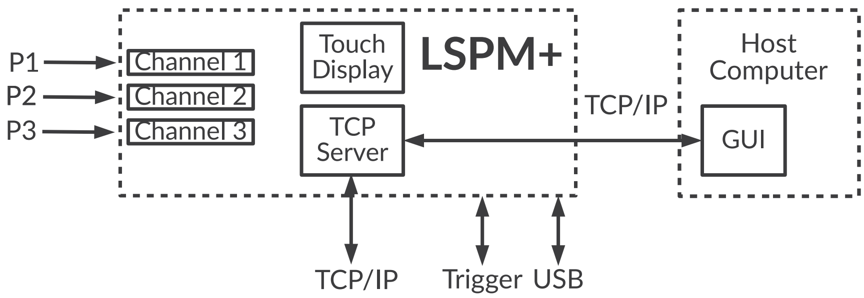


Figure 3: *LSPM 1.0$^+$/2.0$^+$ system block diagram*

LSPM devices feature up to three channels which record power values using logarithmic power detectors and dedicated analog-to-digital converters. As shown in Figures 2 and 3, the LSPM 1.0$^{(+)}$/2.0$^{(+)}$ consist of a single hardware unit, which also handles external trigger signals. Temperature stability is guaranteed by actively controlling the power detector and ADC's temperature.

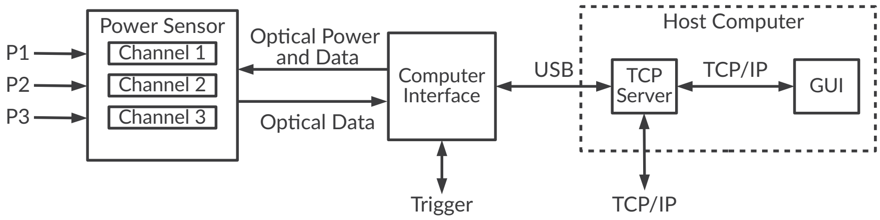


Figure 4: *LSPM 1.1/2.1, CI250 system block diagram*

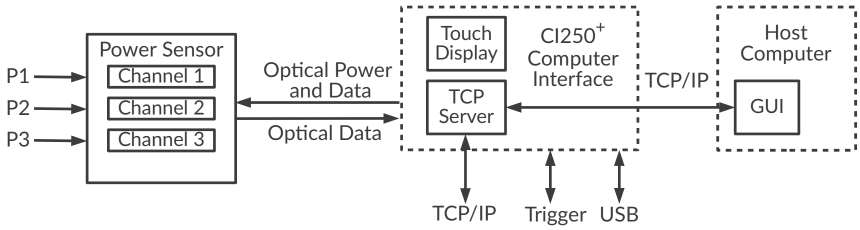


Figure 5: *LSPM 1.1/2.1, CI250⁺ system block diagram*

As shown in Figures 4 and 5, LSPM 1.1/2.1 Power Meter systems consist of power detectors which record power 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 power head optically and handle external trigger signals. Instead of active temperature regulation, the optical powered LSPM Power Meter feature a temperature compensation through calibration.

LSPM 1.0/2.0 and CI250 devices attach to a host computer via USB. LSPM 1.0^{+}/2.0^{+} and 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 LSPM 1.0/2.0 and CI250, the LUMILOOP TCP Server runs on the host computer, for the stand-alone devices LSPM 1.0^{+}/2.0^{+} and CI250^{+} the LUMILOOP TCP Server runs directly on the **+** Device and is automatically started after power-up.

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

Multiple LSPM Power Meters may be connected to one TCP server instance to form a LSPM Multi-Power Meter System consisting of synchronized power meters.

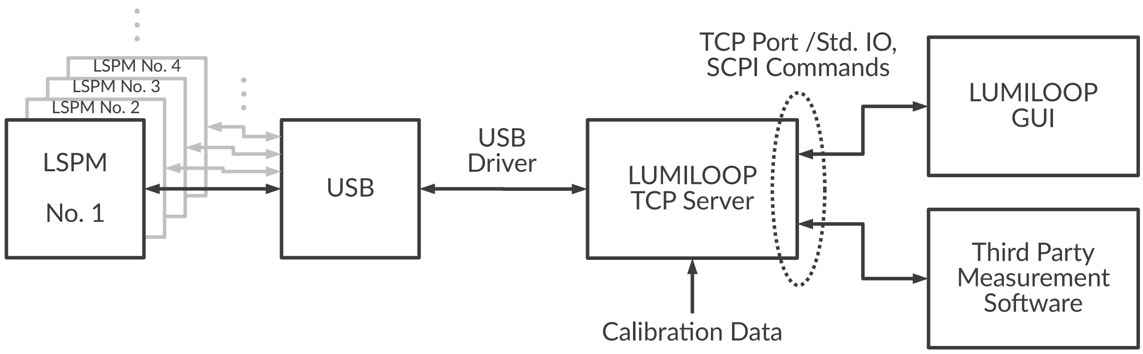


Figure 6: *LSPM software block diagram*

2.1 Data Acquisition and Processing

The software delivered with the LUMILOOP LSPM power meter 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 6, one instance of the LUMILOOP TCP Server communicates with all LSPM/CI-250 devices which are connected to the host computer via USB 2.0. For LSPM$^+$/CI-250$^+$ devices the USB connection is realized within the device. Additional LSPM/CI-250 devices can be connected to the "+"device via USB. The TCP server configures the device, streams all power and auxiliary data, applies calibration data to the received power 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 11. 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 LSPM$^+$/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 Power Value Generation

The fundamental function of the LUMILOOP TCP Server is the conversion of the sample values originating from the power meter to power values for direct readout or further processing as discussed in the following sections. Figure 7 gives an overview of the data flow within the LUMILOOP TCP Server.

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

2.3 Power Values

Instantaneous power values can be read out for each channel. Optionally, a low-pass filter, which is separate from the software-based video bandwidth reduction, can be applied to the power values for noise reduction.

The step-wise statistics feature, described in Section 5.7 on page 84, 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 power value for each interval and makes them available through a value FIFO.

2.4 Power Waveforms

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

Power waveforms are stored upon receiving a trigger event. They can be queried until they are replaced by a newly recorded power waveform. Waveforms are recorded relative to a trigger event. Trigger events can be generated by software, by crossing a specified power value threshold or by externally generated trigger signals. See Section 5.4 on page 65 for further details.

Note that power waveforms require memory in proportion to the recorded duration of time, i.e., approximately 12/52 MB per second for LSPM x.0$^{(+)}$/x.1 devices. For a single power meter setup this limits the maximum waveform length to approximately 150/50 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 power 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 power value for each step. For the precise control of timing, the signal generator generating the sweeps and power meter are typically synchronized using a hardware trigger line when acquiring power waveforms for sweep analysis. See Section 5.4.5 on page 73 for further details.

2.6 High Resolution Waveforms Using Oversampling

LSPM x.0$^{(+)}$/x.1 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 LSPM, i.e., 0.5 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 power value noise. See Section 5.5 on page 76 for further details.

2.7 Statistical Analysis

The LUMILOOP TCP Server is able to perform a statistical evaluation of power data originating from one or more power meters. 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 7. See Section 5.6 on page 80 for more details.

2.7.1 Continuous Statistics

Continuous statistics are based on three histograms generated from all incoming power values. There is one histogram for each power input. 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 3.4. 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 power 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 power meters can be synchronized using dedicated signal lines as detailed in Section 3.4. In contrast to software-based snapshot creation, synchronized, hardware-based snapshot creation ensures that statistics of power meters 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 channel 1, 2 and 3 power 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 power meters 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 channel 1, 2 and 3 power 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 power values for virtually unlimited durations of time. Streams can be recorded for one or multiple power meters. The LSPMs' trigger signals can be employed to synchronize multiple streams. In this case, one LSPM acts as the stream master, sending one synchronization rising edge on the trigger line for every 512 µs. All other LSPMs act as stream slaves and use the master's synchronization pulses to match the sampling rate prescribed by the master. See Figures 23, 24 and 25 for the required physical connections to the BNC connector or Ext1 RJ45 socket. See Section 5.8 on page 85 for further details.

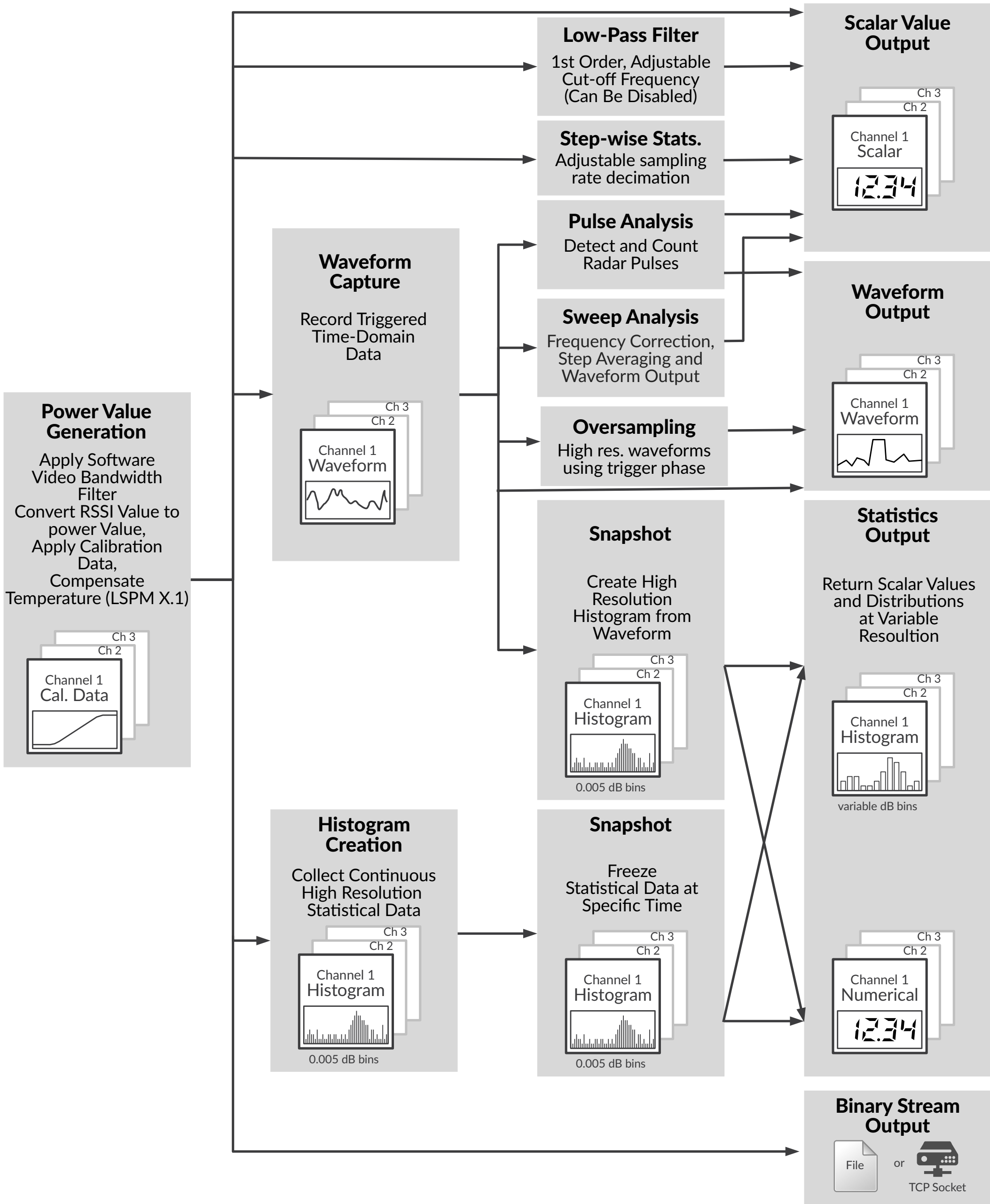


Figure 7: *Data flow diagram of power value processing*

3 LSPM Hardware

3.1 LSPM Power Meter Principle of Operation

LUMILOOP offers two types of power meters. Coventional LSPM power meters consists of a single LSPM unit of either version 1.0$^{(+)}$ or version 2.0$^{(+)}$. The hardware of the optically powered power meter system consists of an LSPM power head of either version 1.1 or version 2.2, with a fixed length of fiber optic cable, a CI-250$^{(+)}$ Computer Interface (CI) and optional accessories, such as fiber-cable extensions.

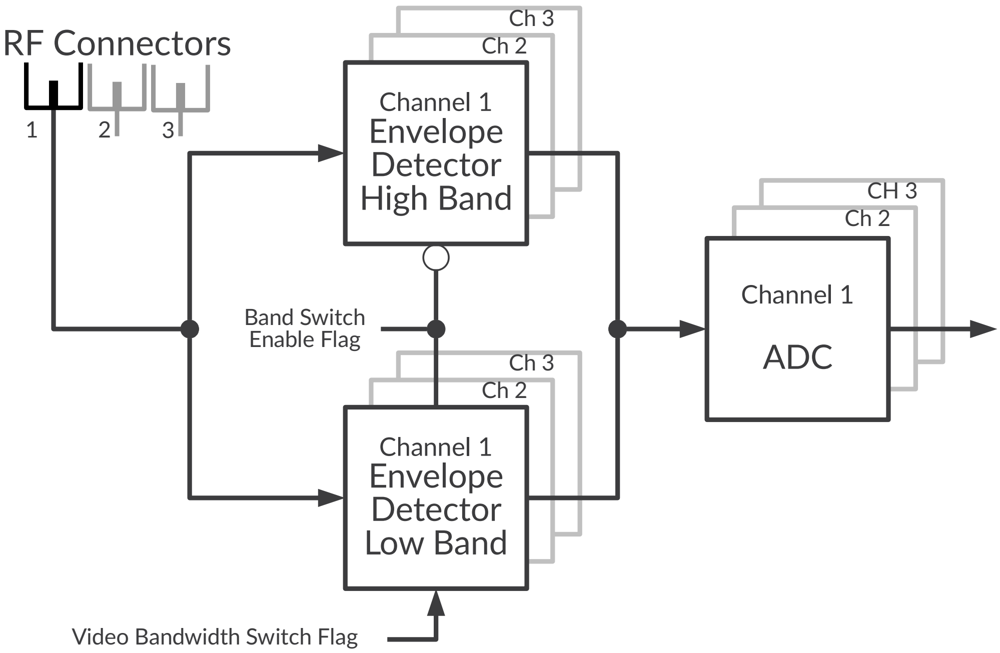


Figure 8: *Power meter front-end block diagram*

The basic structure of the analog front-end is identical for all LSPM Power Meters and only differs in regard to the detector ICs and ADCs used. Each power meter consists of one to three RF front ends, which detect and digitize the RF power level. Each front end has got one dedicated low-band and one dedicated high-band logarithmic power detector, of which one is selectable at a time using a mode flag (see the corresponding mode tables below).

For each channel a 14 bit analog-to-digital converter (ADC) is used to digitize the detected signal level. The digitalized detector output levels called RSSI values are send to the digital part of the LSPM Power Meter, which differs between the two major variants. The conventional LSPM 1.0/2.0 Power Meters incorporate the power detectors and the computer interface within a single housing, providing direct connection of the RF signal and USB data. For stand-alone operation, the "+"variants combine an LSPM 1.0 or 2.0 power meter with a single board computer, a touchscreen and a built in power supply. For optical linked LSPM 1.1/2.1 power meters the detectors are contained in the power head.

LSPM 1.x covers frequencies between 9 kHz and 8.2 GHz, LSPM 2.x covers frequencies between 9 kHz and 26.5 GHz.

3.1.1 Conventional Power Meters LSPM 1.0/2.0

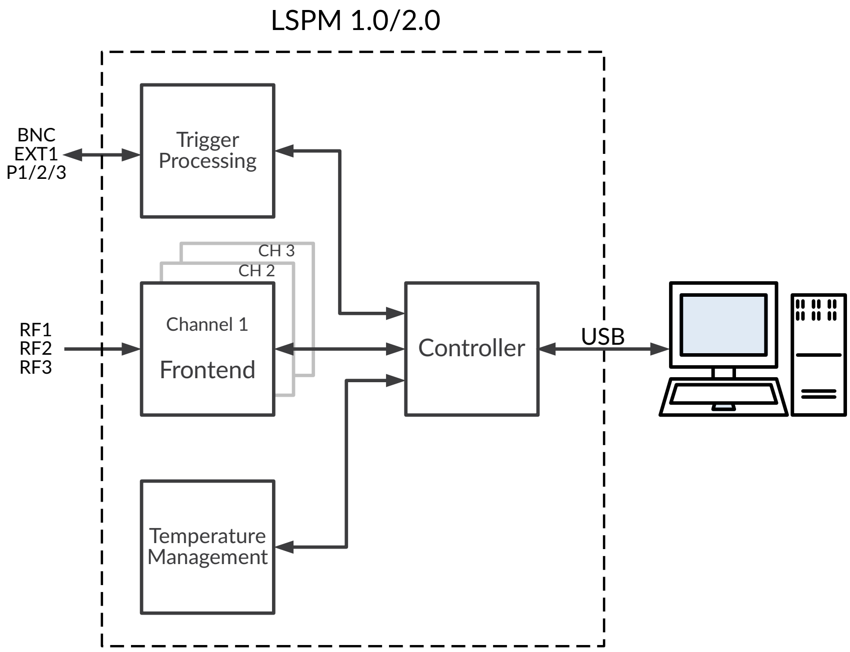


Figure 9: *LSPM 1.0/2.0 power meter block diagram*

Figure 9 shows the simplified block diagram of an LSPM 1.0/2.0 Power Meter. Three 50 Ω sockets, N-type for LSPM 1.0, 2.92mm for LSPM 2.0 devices, feed the power signals to dedicated detectors. The corresponding frequency ranges for the low and high-band detector are shown in Table 1 for LSPM 1.0 Power Meters and Table 2 for LSPM 2.0 Power Meters. The active detector's output, selected by setting the corresponding operating mode, is fed to a dedicated ADC for each channel. To ensure accurate measurement independently of the ambient temperature, the temperature of the RF front ends is actively controlled using a thermoelectric Peltier module. Temperature regulation is handled by the controller, which also processes the trigger signals.

The LSPM 1.0/2.0 Power Meter offers four operating modes, each mode is characterized by a specific frequency range, video bandwidth, sampling rate and sample timing. Device version specific overviews are given in Table 1 and Table 2. In mode 0 only the high band detector is active, while in mode 2 and 3 only the low band detector is active. In mode 1 the appropriate power detector is chosen by the software according to the set frequency. Mode 1 spans the power meter's entire frequency range. The crossover frequency between the two detectors can be changed via the SCPI command »:SYSTem:LHFrequency <Frequency>[,<MPMeter>]«. A frequency out of the overlapping frequency range of the high and low band detector must be set. 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.

Table 1: *LSPM 1.0 Power Meter measurement modes overview*

Mode	Min. Frequency	Max. Frequency	VBW	Sampling Rate	Effective Sampling Rate	Sample Timing
0	30 MHz	8.2 GHz	2.0 MHz	2 MS/s	2 MS/s	continuous
1	9 kHz 30 MHz[1]	$29.\overline{9}$ MHz[1] 8.2 GHz	460 Hz 2.0 MHz	2 MS/s	2 MS/s	continuous
2	9 kHz	400 MHz	510 kHz	2 MS/s	2 MS/s	continuous
3	9 kHz	400 MHz	460 Hz	2 MS/s	2 MS/s	continuous

Table 2: *LSPM 2.0 Power Meter measurement modes overview*

Mode	Min. Frequency	Max. Frequency	VBW	Sampling Rate	Effective Sampling Rate	Sample Timing
0	700 MHz	26.5[2] GHz	70 MHz	2 MS/s	2 MS/s	continuous
1	9 kHz 1 GHz[1]	$999.\overline{9}$ MHz[1] 26.5[2] GHz	400 Hz 70 MHz	2 MS/s	2 MS/s 2 MS/s	continuous continuous
2	9 kHz	1 GHz	850 kHz	2 MS/s	2 MS/s	continuous
3	9 kHz	1 GHz	400 Hz	2 MS/s	2 MS/s	continuous

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

[1]Operation up to 40 GHz with reduced performance

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

3.1.2 Stand-alone power meter LSPM 1.0^{+}/2.0^{+}

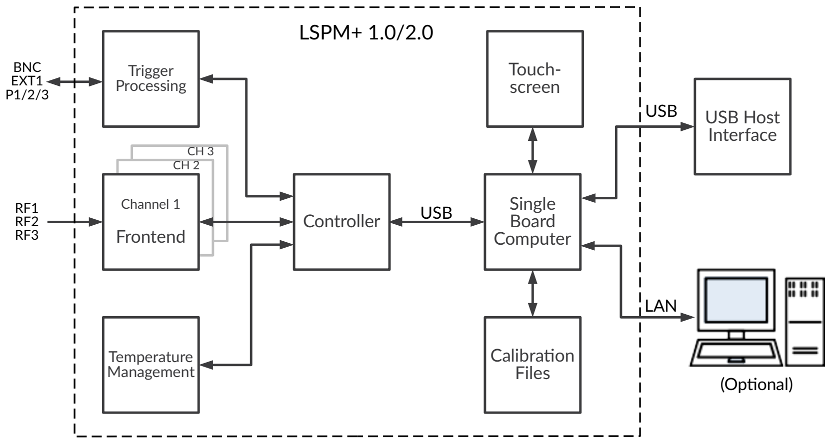


Figure 10: *LSPM 1.0^{+}/2.0^{+} power meter block diagram*

Figure 10 shows the simplified block diagram of an LSPM 1.0^{+}/2.0^{+} Power Meter. Its basic working principle is identical to the LSPM 1.0/2.0 Power Meter, therefore all measurement parameters of the conventional power meters can be applied to their "+" variants (see Table 1 and Table 2). The "+"devices add a single board computer (SBC) and a touchscreen to the power meters and unite all components in one housing, turning the power meters into a stand-alone device. The single board computer is running an instance of the LUMILOOP TCP Server and "+"Device GUI. Standalone power meters attach to a host computer using an Ethernet connection. See Section 6.5.1 on page 101 for further details.

3.1.3 Optical Linked Power Meters LSPM 1.1/2.1

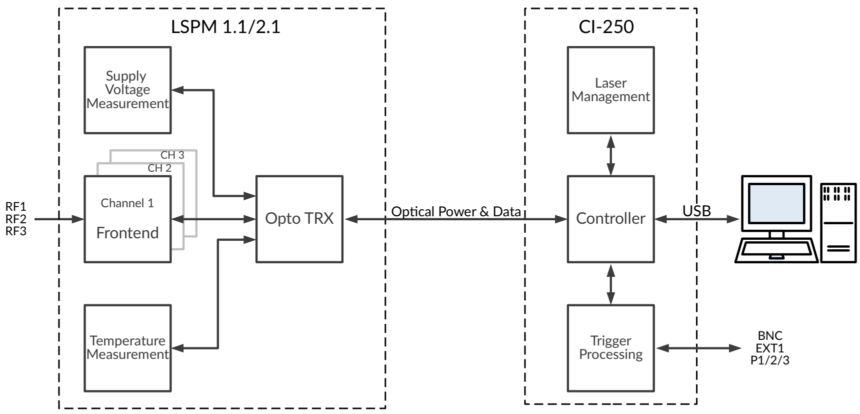


Figure 11: *LSPM 1.1/2.1 Power Meter block diagram*

Figure 11 shows the simplified block diagram of an LSPM 1.1/2.1 Power Meter. Its basic structure differs from the LSPM 1.0/2.0 Power Meter. The RF power detection, its digitization, the computer connection and trigger processing are split into two separate devices, the measurement head and the CI-250$^{(+)}$ Computer Interface.

The power head features three 50 Ω 2.92 mm sockets, which feed the power signals to dedicated detectors. Each channel has got one dedicated low-band and one dedicated high-band logarithmic power detector, with two switchable video bandwidths for the low-band and a fixed video bandwidth for the high-band detector.

The laser powered LSPM 1.1/2.1 Power Meter offers a total of 8 modes. Each mode is characterized by a specific frequency range for the low and high-band detector, video bandwidth, sampling rate and sample timing. An overview is given in in Table 3 and 4. In modes 0, 4, 8, 10, 12, only the high band detector is active, while in mode 2 and 3, only the low band detector is active. In mode 1 both detectors are active in an interleaved fashion. Modes 1 spans the power meter's entire frequency range but only offer a reduced sampling rate. The crossover frequency can be changed with the SCPI command »:SYSTem:LHFrequency <Frequency>[,<MPMeter>]«. The new detector switch frequency must lie within the overlap of the high and low band frequency range. 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.

For each channel a 14 bit analog-to-digital converter (ADC) is used to digitize the detected signal level. The digitized power levels are transmitted via fiber optic to the CI-250$^{(+)}$ Computer Interface. In return, the CI-250$^{(+)}$ Computer Interface delivers power via fiber optic to the power head. The CI-250$^{(+)}$ Computer Interface also processes trigger signals and controls the laser for the power supply of the power head. Since no active temperature regulation is possible when using power over fiber, the power head measures it's temperature constantly. In conjunction with our factory temperature calibration, the effect of temperature drift is being compensated. The CI-250 delivers the RSSI values via USB to the TCP Server running on the connected computer for further processing and displaying.

3.1.4 Video Bandwidth Considerations

The video bandwidth of LSPM Power Meters is defined as the -3 dB cut-off frequency of the first order low pass filter operating on the envelope of each logarithmic power detector. For accurate operation the measured frequency should be at least ten times larger than the video bandwidth. The low-band detector allows to choose between low and high video bandwidth using a mode flag (see the corresponding mode tables Table 1, 2, 3, 4). The high-band detector has a fixed video bandwidth.

As highlighted in Figure 12, Figure14, Figure 13 and Figure 15 most applications are covered by operating modes 0, 1 and 3. For the frequency ranges covered by these modes the respective de-

[1] Crossoverfrequency can be altered via software within the overlapping frequency range of the high- and low-band detector

[2] Operation up to 40 GHz with reduced performance

[3] Crossoverfreuency can be altered via software within the overlapping frequency range of the high- and low-band detector

Table 3: *LSPM 1.1 Power Meter measurement modes overview*

Mode	Minimum Frequency	Maximum Frequency	Video Bandwidth	Sampling Rate	Effective Sampling Rate	Sample Timing
0	30 MHz	8.2 GHz	2.0 MHz	1 MS/s	1 MS/s	continuous
1	9 kHz 400 MHz[1]	399.$\overline{9}$ MHz[1] 8.2 GHz	210 Hz 2.0 MHz	1 MS/s 500 kS/s	36.2 kS/s 72.4 kS/s	continuous, interleaved
2	9 kHz	400 MHz	500 kHz	500 kS/s	500 kS/s	continuous
3	9 kHz	400 MHz	210 Hz	500 kS/s	500 kS/s	continuous
4	30 MHz	8.2 GHz	2.0 MHz	2 MS/s	598 kS/s	burst
8	30 MHz	8.2 GHz	2.0 MHz	2 MS/s	2 MS/s	cont. Channel 1
10	30 MHz	8.2 GHz	2.0 MHz	2 MS/s	2 MS/s	cont. Channel 2
12	30 MHz	8.2 GHz	2.0 MHz	2 MS/s	2 MS/s	cont. Channel 3

Table 4: *LSPM 2.1 Power Meter measurement modes overview*

Mode	Minimum Frequency	Maximum Frequency	VBW	Sampling Rate	Effective Sampling Rate	Sample Timing
0	700 MHz	26.5[2] GHz	40 MHz	1 MS/s	1 MS/s	continuous
1	9 kHz 1 GHz [1]	999.$\overline{9}$ MHz[1] 26.5[2] GHz	210 Hz 40 MHz	1 MS/s 500 kS/s	36.2 kS/s 72.4 kS/s	continuous, interleaved
2	9 kHz	1 GHz	500 kHz	500 kS/s	500 kS/s	continuous
3	9 kHz	1 GHz	210 Hz	500 kS/s	500 kS/s	continuous
4	700 MHz	26.5[2] GHz	40 MHz	2 MS/s	598 kS/s	burst
8	700 MHz	26.5[2] GHz	40 MHz	2 MS/s	2 MS/s	cont. Channel 1
10	700 MHz	26.5[2] GHz	40 MHz	2 MS/s	2 MS/s	cont. Channel 2
12	700 MHz	26.5[2] GHz	40 MHz	2 MS/s	2 MS/s	cont. Channel 3

tectors' video bandwidths are sufficient. However, some combinations of power meter mode and measurement frequency require software-based low-pass filtering of RSSI values in order to guarantee aliasing-free measurement values. For example, mode 2 of LSPM 1.0(+) has a video bandwidth of 510 kHz and will only yield sufficiently ripple-free results for frequencies larger than 5.1 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 automatically applied. Tables 1, 2, 3, 4 summarize the supported operating modes. Bandwidth reduction is also required in mode 2 when operating below the excluded frequency range. The excluded frequency range for the LSPM 1.0(+) Power Meter is 500 kHz to 5.1 MHz for Mode 2, for the LSPM 2.0(+) Power Meter 800 kHz to 8.5 MHz for Mode 2. The excluded frequency range for the LSPM 1.1/2.1 Power Meter is 400 kHz to 5.0 MHz for Mode 2.

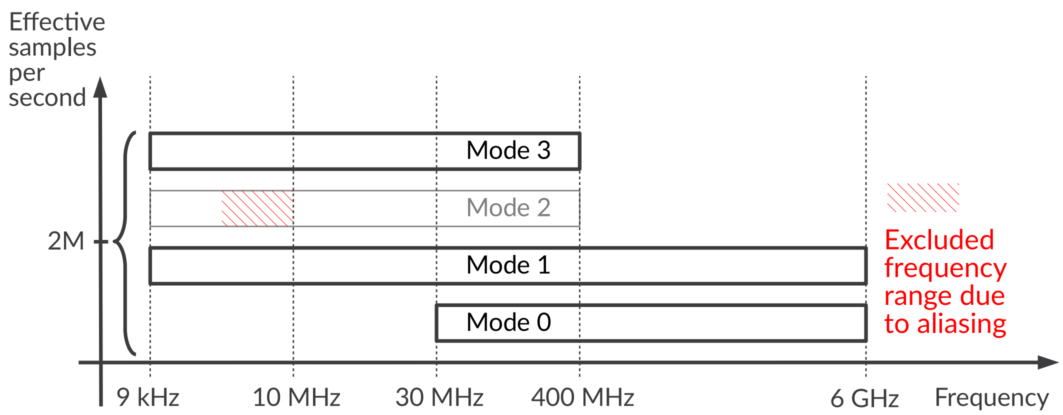


Figure 12: *Operating modes versus frequency and sampling rate for the LSPM 1.0*

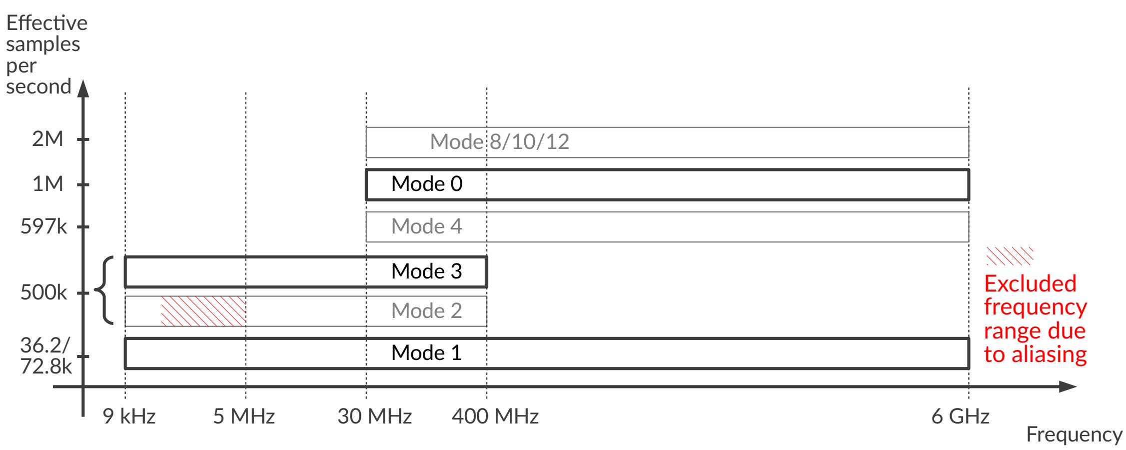


Figure 13: *Operating modes versus frequency and sampling rate for the LSPM 1.1*

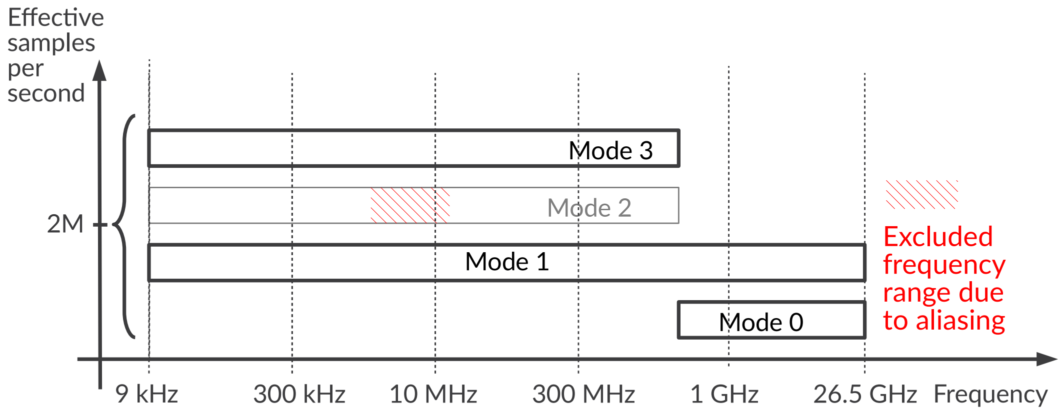


Figure 14: *Operating modes versus frequency and sampling rate for the LSPM 2.0*

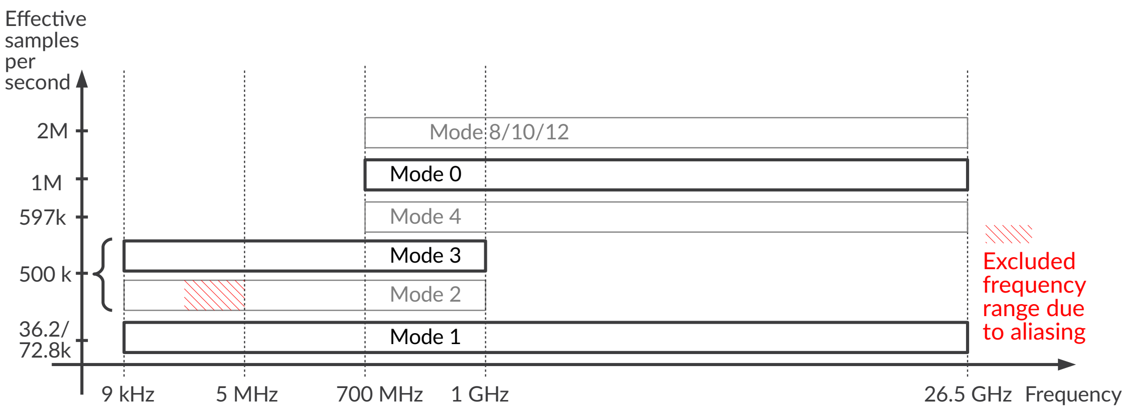


Figure 15: *Operating modes versus frequency and sampling rate for the LSPM 2.1*

3.1.5 LSPM 1.0$^{(+)}$/2.0$^{(+)}$ Power Meter Sampling Rate Reduction

A continuous USB data rate of approximately 13 MB/s is required for operating the LSPM 1.0$^{(+)}$/2.0$^{(+)}$ Power Meter at its nominal sampling rate of 2 MSamples/s. If the host computer is unable to sustain the required USB data rate, the LUMILOOP TCP Server will automatically reduce the sampling rate by increasing the sample skip count setting by one. E.g. first the sampling rate will be reduced to 1 MSamples/s with setting the skip count from zero to one sample. If this data rate is still unsustainable, the sample skip count will be set to two with a resulting sampling rate of to 667 kSamples/s and so on. The LUMILOOP TCP Server will throw a system error as shown in Figure 16 upon each sampling rate reduction caused by slow USB link.

Insufficient USB speeds can be caused by connecting too many high data rate USB devices to the same bus. Moving the LSPM Power Meter to a different USB root hub or adding a USB root hub can help to fix this issue. Additionally, many USB extension products are known for being unable to operate at full USB 2.0 speeds for prolonged periods of time.

The currently set skip count and resulting sampling rate can be queried using the SCPI commands »:SYSTem:SSKip? [<MPMeter>]« and »:SYSTem:SRAte? [<MPMeter>]«.

In case of the stand alone LSPM 1.0⁺/2.0⁺ Power Meter with its internal connection between the power meter PCB and the single board computer, the problem of reduced data rate is not expected under normal operation. However, if multiple USB high speed devices are connected to the single board computer, its USB data rate might drop.

For the optical linked power meters, this feature is not available. In case of insufficient USB data rates (approximately 6.5 MB/s), FIFO data overflow may occur, with the TCP Server receiving incomplete data. A system error will be thrown upon occurrence.

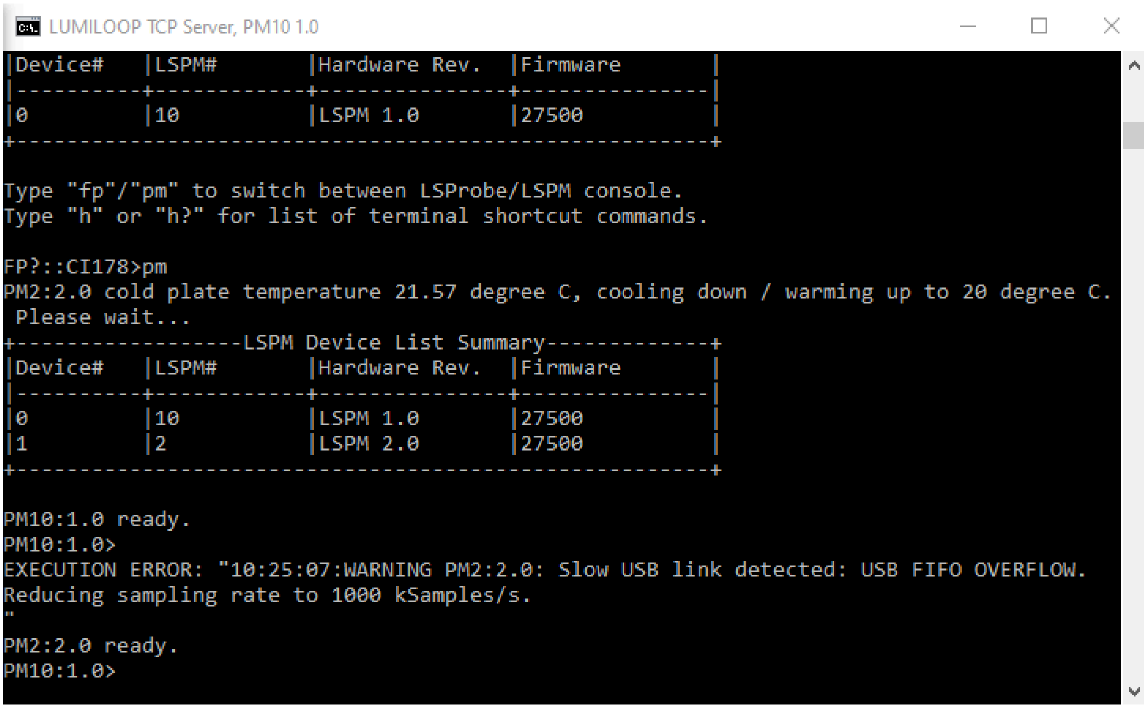


Figure 16: *LUMILOOP TCP Server, LSPM 2.0 sampling rate reduction due to slow USB link*

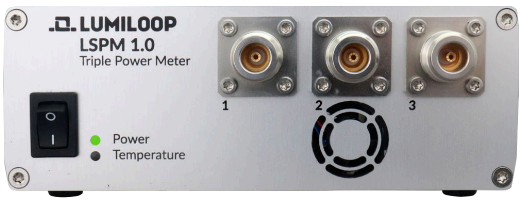
3.2 Components, Connectors and Indicators

3.2.1 LSPM 1.0/2.0 Power Meter

The LSPM 1.0 Power Meter's and LSPM 2.0 Power Meter's housing contains:

- up to three power detectors,
- a thermoelectric temperature controller for maintaining a constant detector temperature,
- a BNC and RJ45 trigger input/output connector for synchronization and
- a USB 2.0 interface connecting to the host computer.

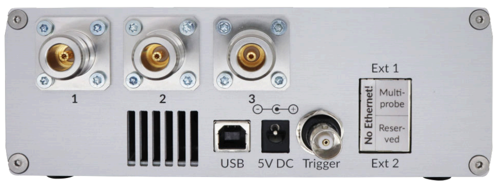
As shown in Figure 17(a) and (b), the main switch is located on the left side of the front panel. In "0" position, it disconnects the power meter's external 5 V supply. The right side of the front panel is occupied by the N sockets (LPSM 1.0) or 2.92 mm sockets (LSPM 2.0) and the air outlet of the detector temperature controller, the latter must not be obstructed. Two labeled LED indicators display the LSPM's operating state as follows:



(a) LSPM 1.0 Power Meter front panel

(b) LSPM 2.0 Power Meter front panel

(c) LSPM 1.0/2.0 Power Meter back panel



(d) LSPM 1.0 Power Meter back panel with Connectors at Rear Panel

Figure 17: *LSPM 1.0/2.0 front an back panel view*

Power (green)

Flashing
Main switch is on, power meter is inactive.

Continuously on
USB connection to TCP server has been established.

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

Temp (red)

Continuously off
Temperature is being controlled within the power detectors' optimum operating temperature range.

Continuously on
Temperature of the power detectors is above its optimum operating range, detectors are being cooled.

Flashing
Temperature of the power detectors is below its optimum operating range, detectors are being heated.

The LSPM Power Meter's back panel shown in Figure 17(c) contains the air inlet of the power detector temperature controller and must not be obstructed.

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

USB
USB B connector attaching the power meter 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 systems with multiple LSPM Power Meters and LSProbe E-Field Probes. ***No Ethernet interface!***

Ext 2
Reserved for future use. ***No Ethernet interface, do not connect!***

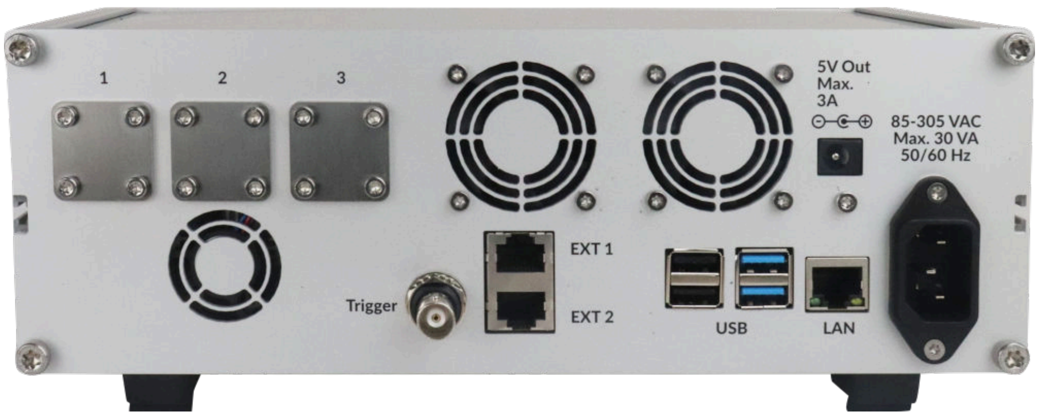
The position of the RF input connectors can be changed from the front panel to the back panel as a factory option as depicted in Figure 17(d). The unused cutouts on the front or back panel are covered with a blind cover.

3.2.2 LSPM 1.0+/2.0+

The LSPM 1.0+/2.0+ housing contains:

- the hardware of a conventional LPSM 1.0 or 2.0 power meter
- a single board computer (SBC)
- a power supply unit
- a touch screen
- an RJ45 Ethernet connector
- a BNC and RJ45 trigger input/output connector for synchronization and
- 5x USB-A connectors for external peripherie

(a) LSPM 1.0+ Power Meter front panel



(b) LSPM 1.0+ Power Meter back panel

Figure 18: *LSPM 1.0/2.0 front an back panel view*

As shown in Figure 18(a), the left half of the front panel is mostly occupied by the 4.3" LCD touch-screen. Next to the touchscreen, the main switch is located on the far left side of the front panel. In “0” position, it disconnects the power meter's internal power supply. An indicator light is build in the main switch, showing the connection to the mains electricity. On the right side of the front panel, the up to three RF-Connectors (N sockets for LSPM 1.0+, 2.92mm sockets for LSPM 2.0+) are located, as well as the air outlet of the detector temperature controller. The latter must not be obstructed. Right in the middle of the front panel, a USB-A connector and two labeled LED indicators are located. As the hardware is identical to the conventional LSPM 1.0 or 2.0, the LEDs display the LSPM's operating state the same way as described above.

The LSPM $1.0^+/2.0^+$'s back panel is shown in Figure 18(b). On the left side of the back panel, the air inlet and three alternative positions for the RF input connectors are located. The position of the RF input connectors can be changed from the front panel to the back panel as an factory option. The unused cutouts on the front or back panel are covered with a blind cover. The air inlet must not be obstructed.

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

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

Ext 1
: RJ45 extension connector for systems with multiple LSPM Power Meters and LSProbe E-Field Probes. ***No Ethernet interface!***

Ext 2
: Reserved for future use. ***No Ethernet interface, do not connect!***

USB
: 4x USB A connector for attaching peripheral devices, such as mouse, keyboard or CI-250 computer interface.

LAN
: RJ45 socket for Ethernet connection. Do not confuse with EXT1/EXT2 connector.

Power
: IEC 60320 C16 inlet providing mains electricity to the internal power supply. Rating 85-305VAC, 50/60Hz, max 30VA.

3.2.3 LSPM 1.1/2.1 Power Meter

The hardware of the LSPM 1.1 and 2.1 Power Meter consists of a measurement head with a pair of fiber optic cable attached to it and a CI-250$^{(+)}$ Computer Interface (CI-250). Figure 19 shows the front and back of a LPSM 1.1 or 2.1 measurement head. On the front, three 2.92mm sockets act as the RF input for the logarithmic power detectors. On the rear of the measurement head, the optical connectors as well as a status LED are located. When the optical fibers are disconnected, connectors must be covered with the supplied dust caps as shown in Figure 10. The FC connector on the right is the power laser input. The ST connector on the left is the data laser output. Both connectors are secured against unintended manipulation with a plastic cover. The LED on the far right side displays the LPSM 1.1 or 2.1 operating state and active mode as given in Table 5.

(a) LSPM 1.1/2.1 Power Meter front panel

(b) LSPM 1.1/2.1 Power Meter back panel

Figure 19: *LSPM 1.1/2.1 front an back panel view*

Table 5: *LSPM 1.1/2.1 Power Meter measurement mode led states overview*

Mode	LED color	Blinking pattern
off	none	continuously off
start-up	red,blue & purple	alternating colors
0	blue	continuously on
1	blue & purple	alternating colors
2	red	continuously on
3	purple	continuously on
4	blue	slowly flashing
8	blue	1x flashing fast
10	blue	2x flashing fast
12	blue	3x flashing fast

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

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

- a supply laser powering and transmitting data to the power meter,
- a thermoelectric temperature controller for cooling or heating the supply laser,
- an optical receiver for power meter 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 20 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 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:

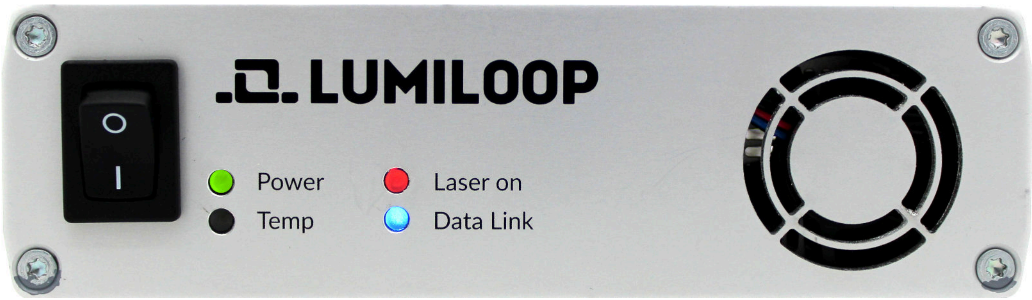


Figure 20: *CI-250 front panel*

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 power meter 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 power meter 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 power meter.

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 power meter.

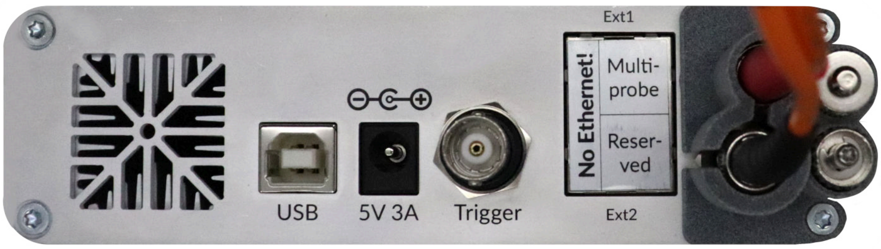


Figure 21: *CI-250 back panel*

The CI-250(+) Computer Interface's back panel shown in Figure 21 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 21.*** 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 22 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 22: *LSPM x.1 Identifier (ID).*

3.3 Trigger Inputs and Outputs

The LSPM 1.0$^{(+)}$/2.0$^{(+)}$ or CI-250$^{(+)}$ device features two independent trigger inputs and outputs. The BNC connector on the back of the LSPM 1.0$^{(+)}$/2.0$^{(+)}$ or CI-250$^{(+)}$ device uses a single-ended 5 V CMOS logic trigger signal. Figures 23 and 24 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 LSPM 1.0$^{(+)}$/2.0$^{(+)}$ or CI-250$^{(+)}$ device or an electrically compatible third-party device.

The Ext1 RJ45 socket on the back of the LSPM 1.0$^{(+)}$/2.0$^{(+)}$ or 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 LSPM 1.0$^{(+)}$/2.0$^{(+)}$ or CI-250$^{(+)}$ devices as shown in Figure 25. When an LSFrame 1.0 Product Integration Frame - Basic is used, all LSPM 1.0$^{(+)}$/2.0$^{(+)}$ or 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.

3.4 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 26.

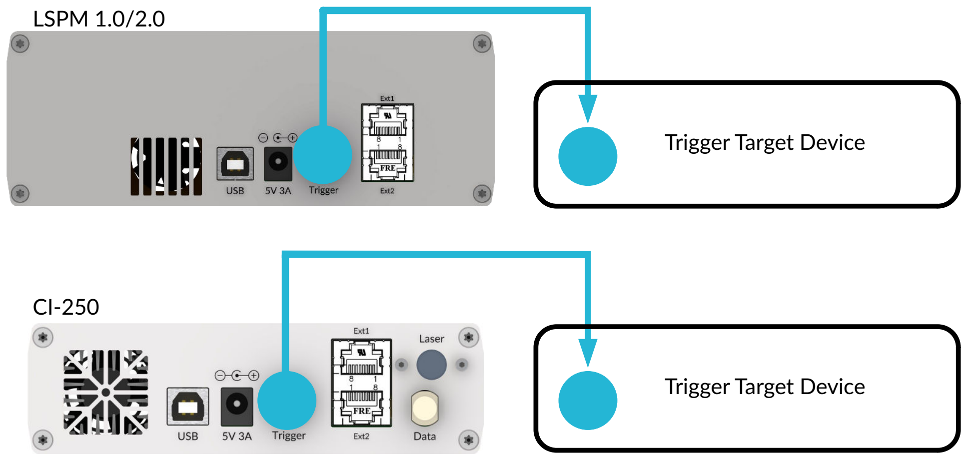


Figure 23: *External trigger output using BNC connector*

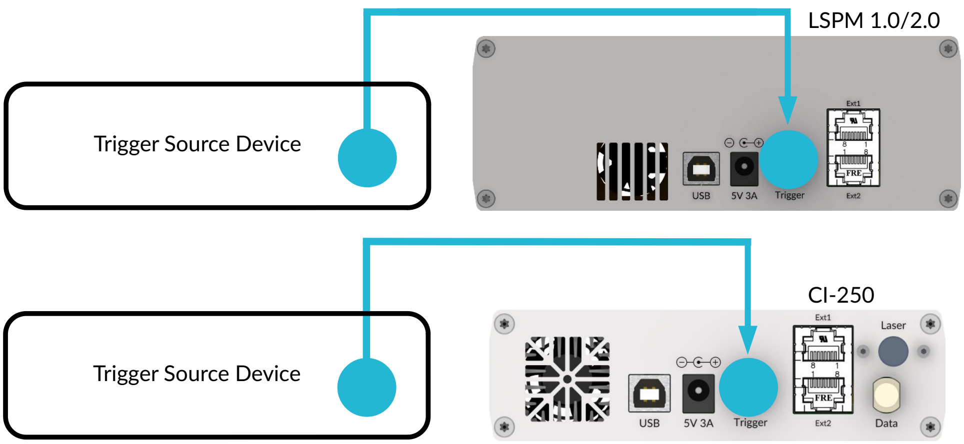


Figure 24: *External trigger input using BNC connector*

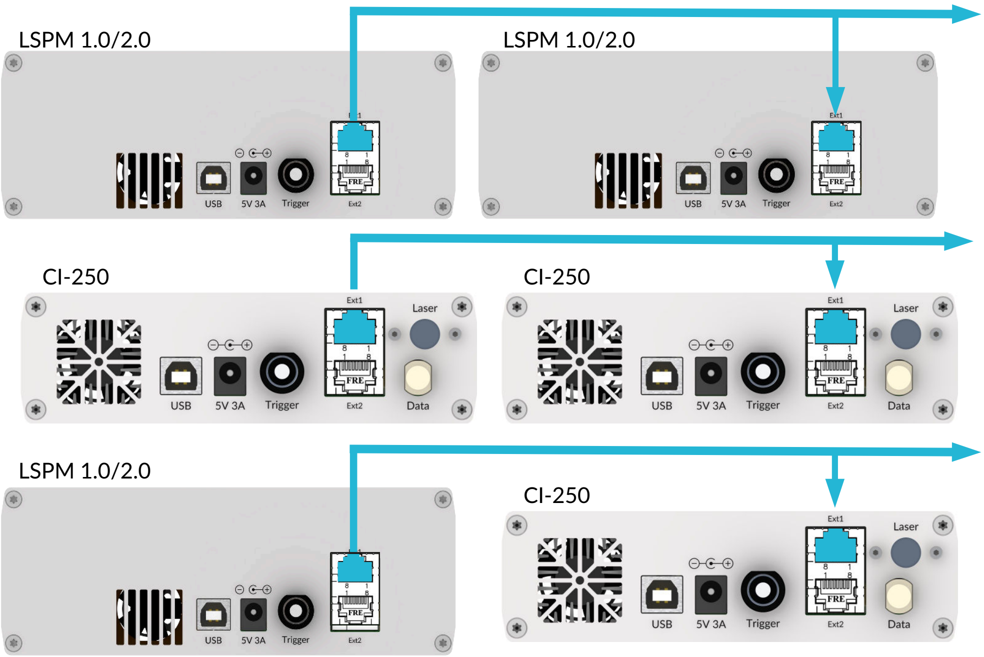


Figure 25: *External trigger input and output using Ext1 RJ45 sockets*

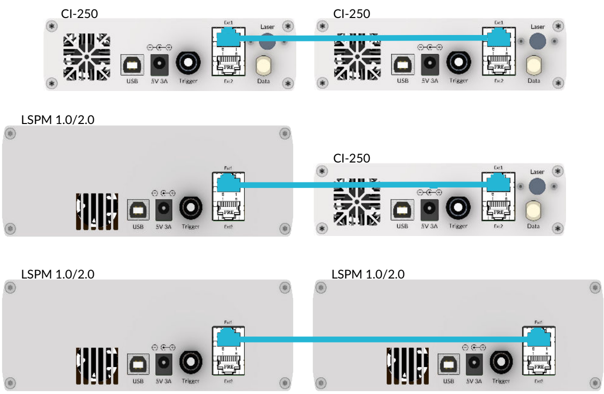


Figure 26: *Multiprobe connection for two CI-250 devices, two LSPM 1.0/2.0 devices, one LSPM 1.0/2.0 and CI-250 device.*

For larger Multi Device Systems, an LSFrame 1.0 Product Integration Frame - Basic as shown in Figure 28, 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.

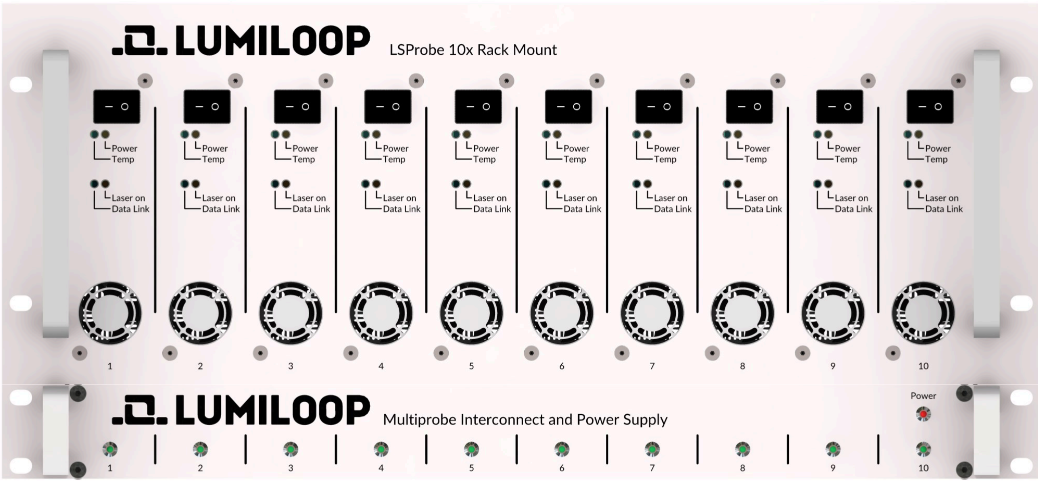


Figure 27: *LSFrame 1.0 Product Integration Frame - Basic with ten CI-250(+) Computer Interfaces*

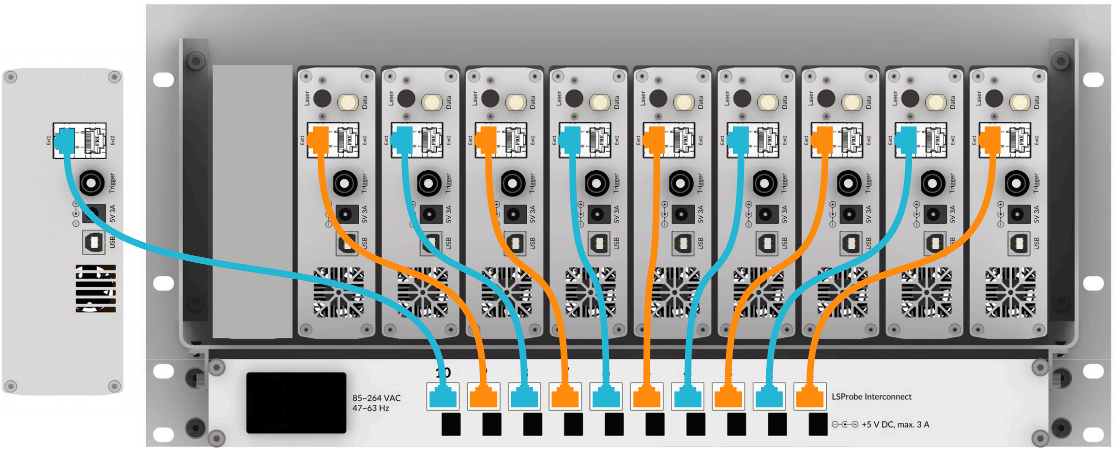


Figure 28: *Multi Device connections for nine CI-250(+) Computer Interfaces and one LSPM 1.0/2.0*

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>«. For synchronized 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 27 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 for LSProbe devices.
2. Copy the supplied calibration data into the `lspm` 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\lspm` directory. Repeat the procedure for all LSPM x.0/x.1 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 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 serial number and version separated by a ":" defined for this name and ISO setup

ISO_11451-5

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

GUI Plot Configurations

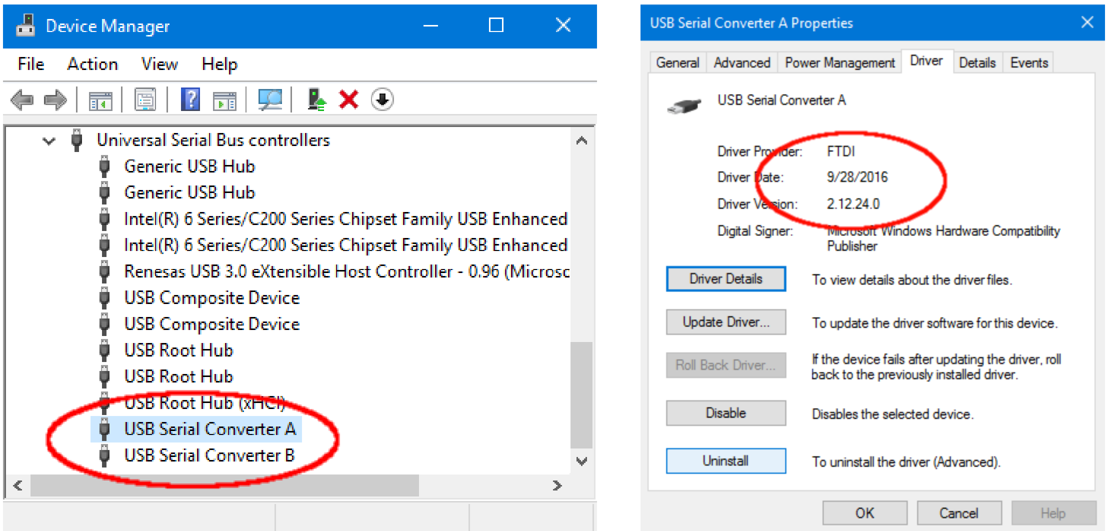
Define plot configurations, for example background, foreground and plot colors, and line width. This section is used by the LUMILOOP GUI only for saving of specific plot configurations.

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 LSPM 1.0/2.0 or 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 LSPM/CI-250 device as "USB Serial Converter A" and "USB Serial Converter B" as shown in Figure 29(a) and (b). Note that the device naming is generic and references neither LUMILOOP nor LSPM. However, this does not affect the proper operation of the power meter.



(a) Device Manager USB device

(b) Current FTDI USB driver version

Figure 29: *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 30.

It is strongly advised to observe the following recommendations:

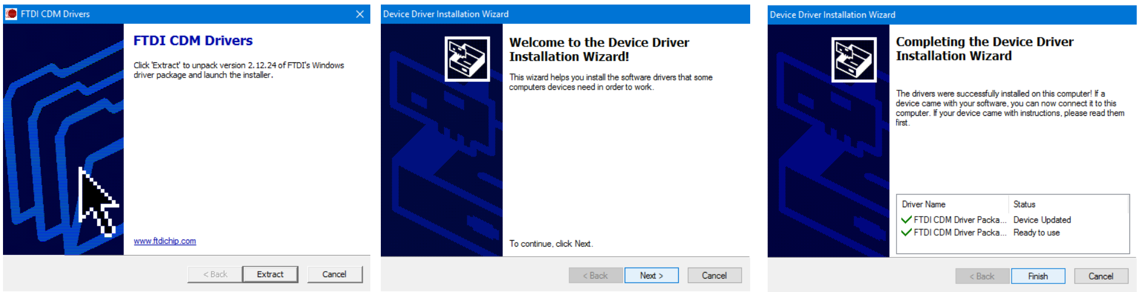


Figure 30: *Manual FTDI USB device driver installation*

- Plug the LSPM 1.0/2.0 or 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.

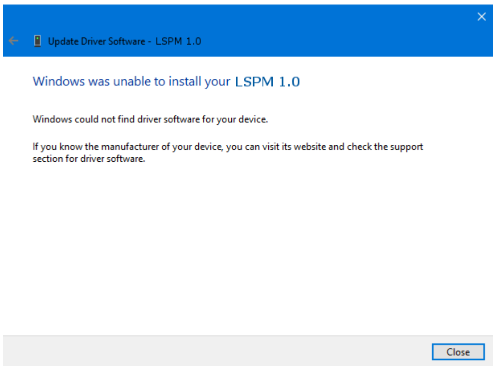
4.2.1 Troubleshooting USB Driver Installation

If no LSPM 1.0/2.0 or 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 31(a) will be displayed. In this case the Device Manager's "Other devices" section will give an output similar to Figure 31(b), listing the LSPM 1.0/2.0 or CI-250 device's USB end points as unknown devices.

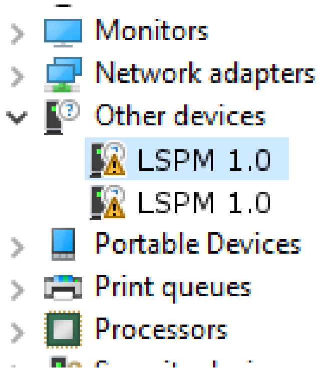
Make sure that you are using the most recent FTDI USB driver. The driver version at the time of writing is 2.12.28. Using out-of-date USB drivers may result in improper operation.

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 29(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 32, failing to do so will prevent driver updates.

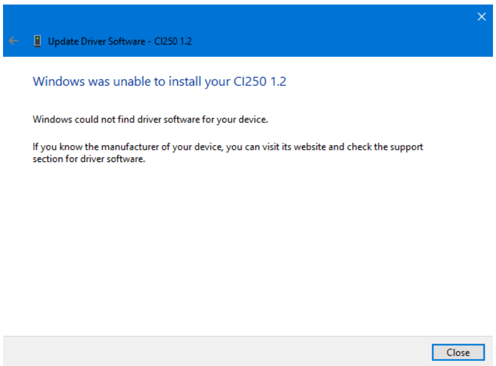
Make sure to repeat the uninstall process for all LSPM 1.0/2.0 or CI-250 devices using old FTDI USB driver versions. Note that the process must be executed for both "USB Serial Converter A" and "USB Serial Converter B" of every LSPM 1.0/2.0 or CI-250 device. Power-cycle each LSPM 1.0/2.0 or CI-250 device and repeat the installation procedure as described above in Section 4.2.



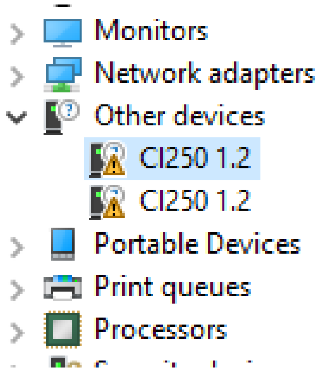
(a) Installation failure message for LSPM 1.0 device



(b) Device Manager output for LSPM 1.0 device



(c) Installation failure message for CI250 device



(d) Device Manager output for CI250 device

Figure 31: *USB device driver failure messages*

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 33. 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 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>
```

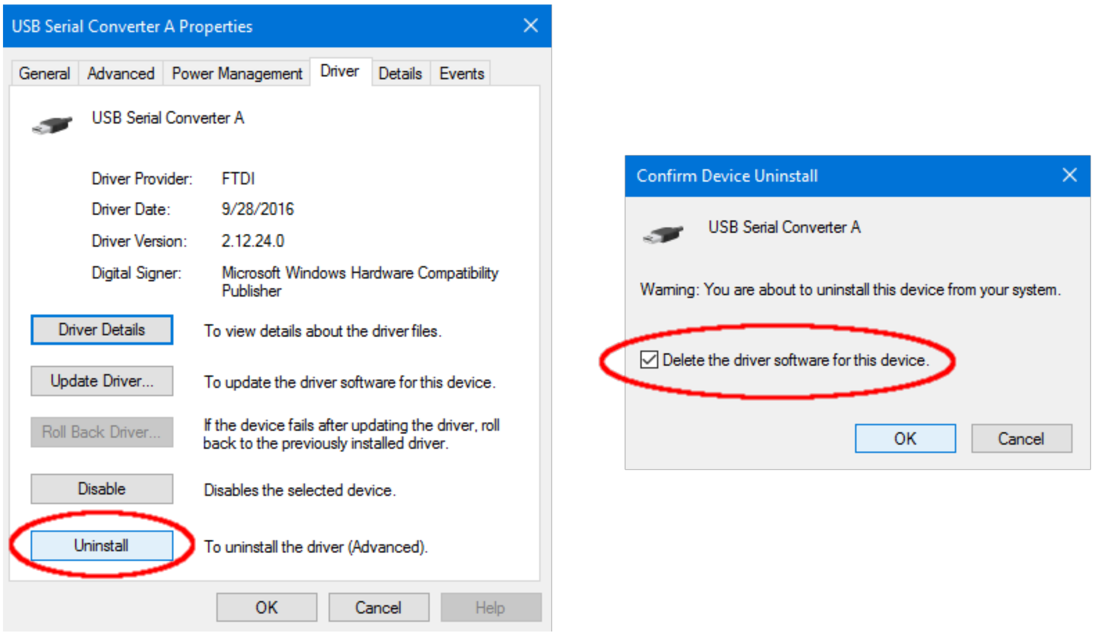


Figure 32: *Uninstalling the FTDI USB driver*

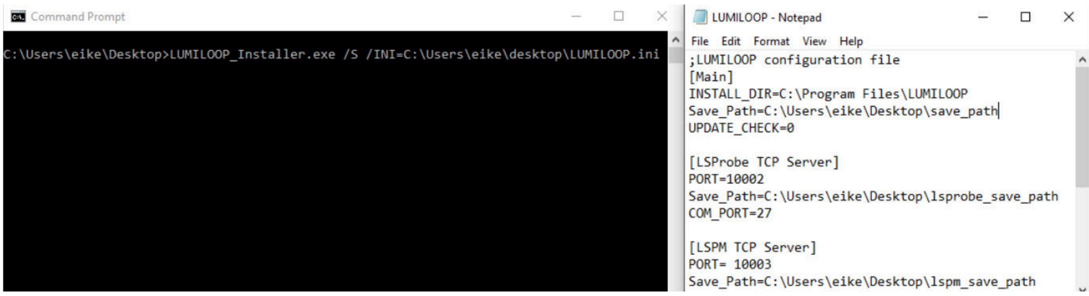


Figure 33: *Silent installation of the LUMILOOP software*

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 Power

5.1 Getting Ready to Measure

5.1.1 Making Optical Connections (LSPM 1.1 / 2.1)

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 power head being connected to it!**

Figure 34: *E2000 coupler of sacrificial optical cable assembly*

Sacrificial optical cables are supplied with each LSPM 1.1/2.1 . Always use the E2000 connectors shown in Figure 69 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 35. 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.

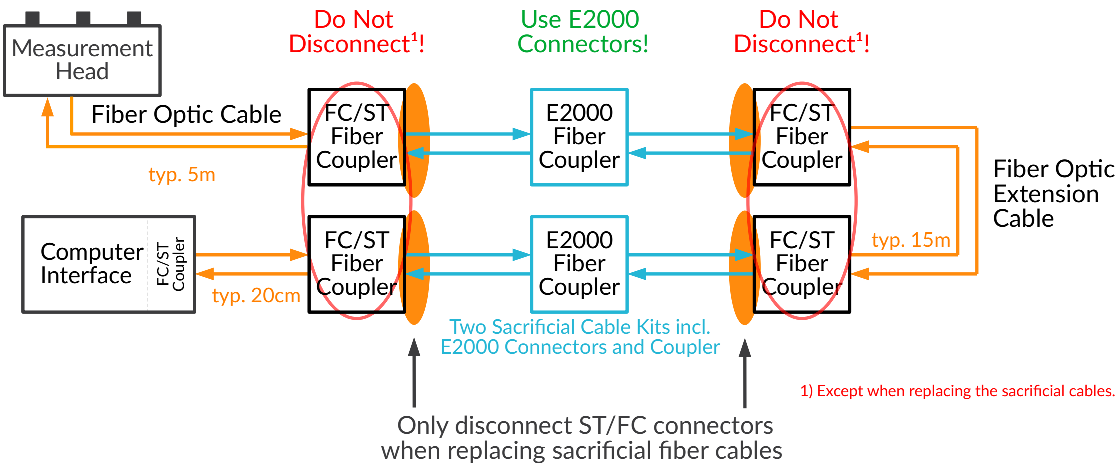


Figure 35: *Principle of sacrificial optical cable assembly*

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 71 for the correct alignment.

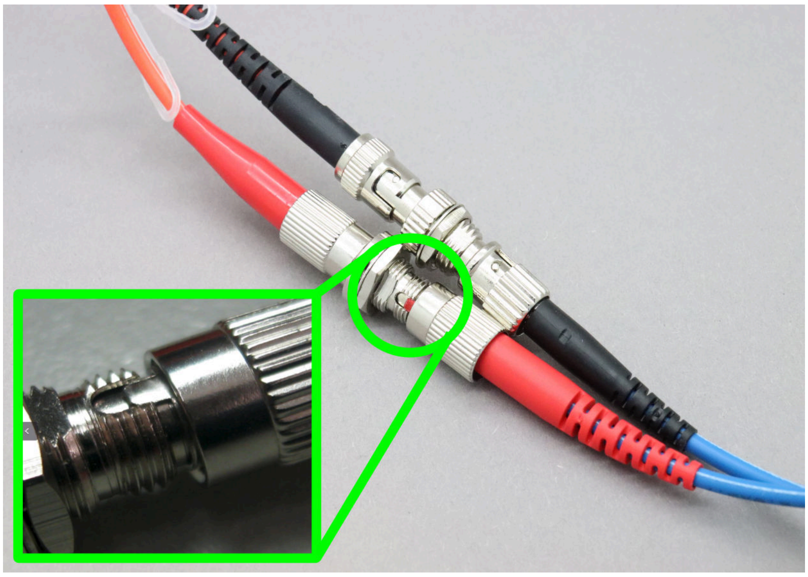


Figure 36: *FC fiber connector alignment*

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 LSPM system for the first time make the following electrical connections:

1. Connect the supplied mains adapter.
2. Connect the LSPM 1.0/2.0 or CI-250 device to the host computer using the supplied USB cable.

3. Optionally connect the LSPM 1.0/2.0 or CI-250 device to any trigger sources or sinks via the BNC trigger connector.

Switch on the LSPM 1.0/2.0 or CI-250 device setting the front panel switch to "1" and observe the green power LED starting to flash.

5.2 Power Meter 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 LSPM 1.0/2.0 devices and CI-250(+) Computer Interfaces, listing their serial numbers similar to Figure 37. 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 LSPM Power Meter and 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 LSPM 1.0/2.0 devices and CI-250(+) Computer Interfaces with their respective serial numbers and firmware revision numbers in the "LSPM 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 38).

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 37, it will display a command prompt indicating the serial number of the LSPM 1.0/2.0 or

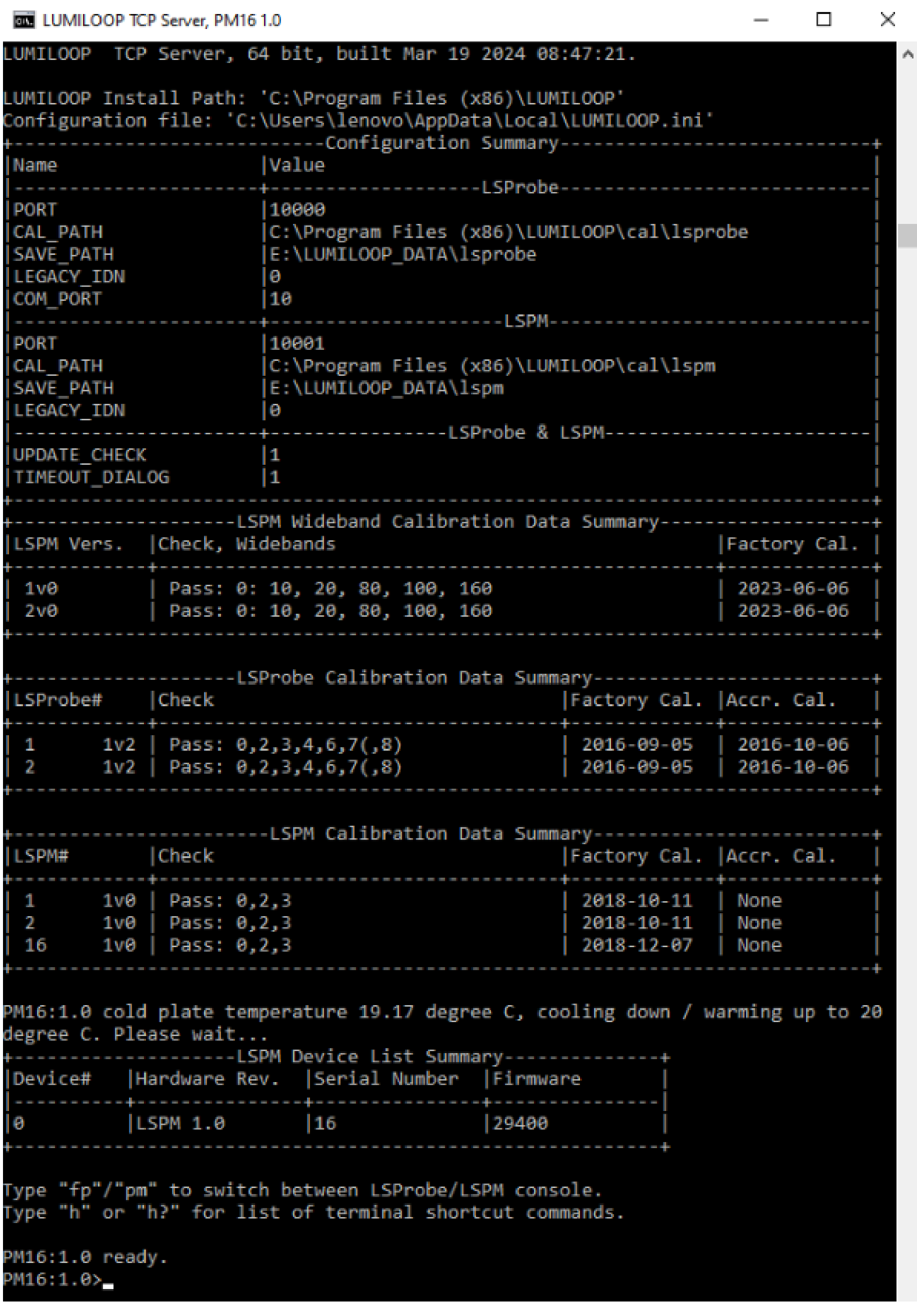


Figure 37: *LUMILOOP TCP Server terminal window*

serial numbers of the computer interface and power head which SCPI commands are exchanged with. The prompt will change when a different power meter or computer interface is selected or when an LSPM 1.1/2.1 Power Meter becomes operational. The same information can also be found in the title bar of the 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

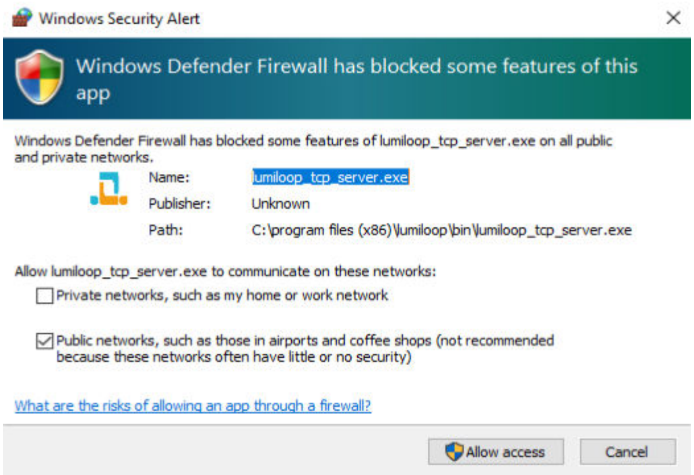


Figure 38: *Microsoft Windows Firewall requesting TCP port access permissions*

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 command »: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.

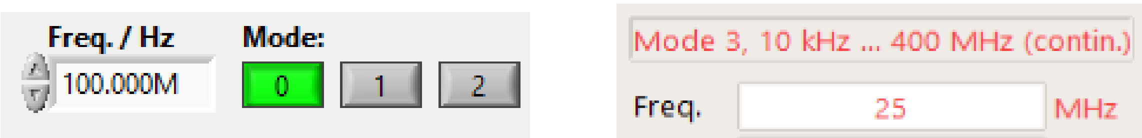
The prompt features a basic command history that can be accessed, using the up and down cursor keys. The command history also includes SCPI commands issued in previous TCP Server sessions.

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 p« can be used to query the power of all channels every 500 ms. The power of channel 1 can be polled every 100 ms by entering »l100 :meas:p?«. 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 41. Table Mode as shown in Figure 42 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 49 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 LSPM 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 power meter settings and measurement results, which is especially useful during third party EMC software integration and function testing.



(a) Match (b) Mismatch

Figure 39: *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 39 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 40, 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 41 shows the GUI upon start-up. For all connected devices of all

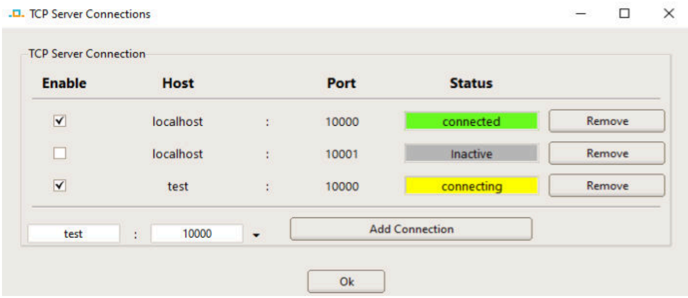


Figure 40: *Dialog for managing TCP Server Connections of the LUMILOOP GUI*

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.

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 "LSPM 1.1/2.1 CI# | PM#" field will display "?" instead of the power meter's serial number if the power meter connected to the computer interface is turned off. Additionally, the set operating mode, set frequency, set low-pass filter, the temperature of the LSPM 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.

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 43.

In LUMILOOP GUI Expert Mode, only a single device will be displayed at the same time. To change 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 41. 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 44. 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

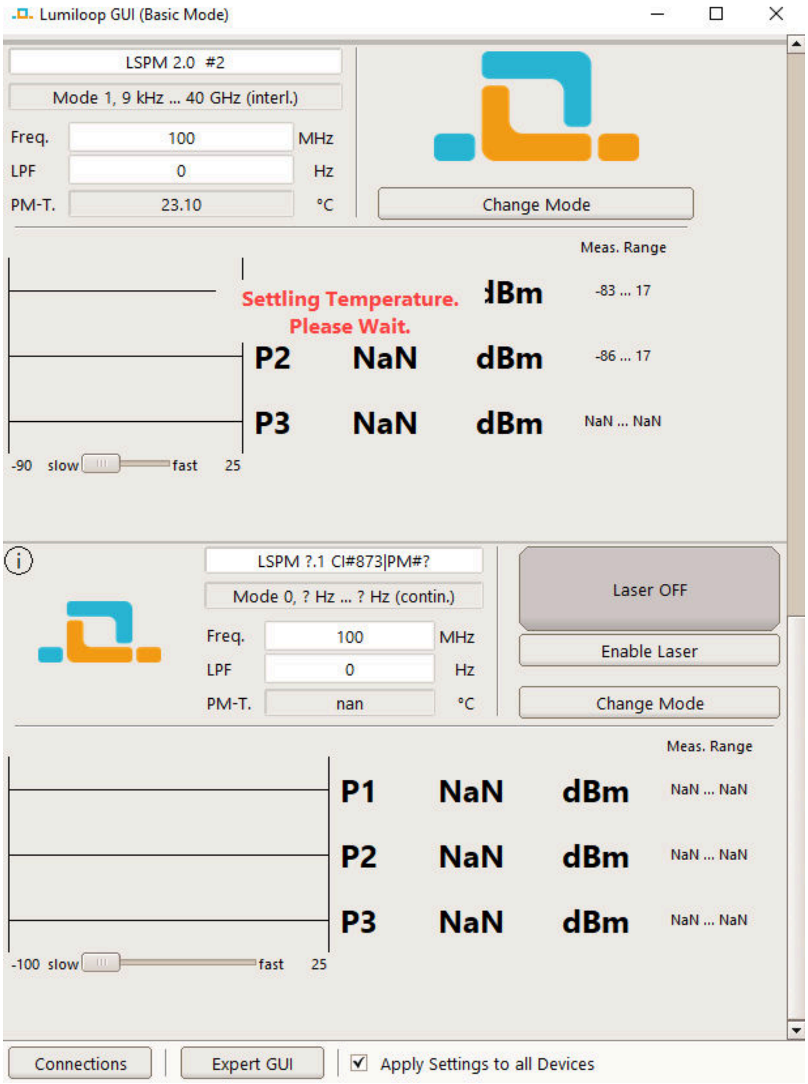


Figure 41: *LUMILOOP GUI upon startup in Basic Mode*

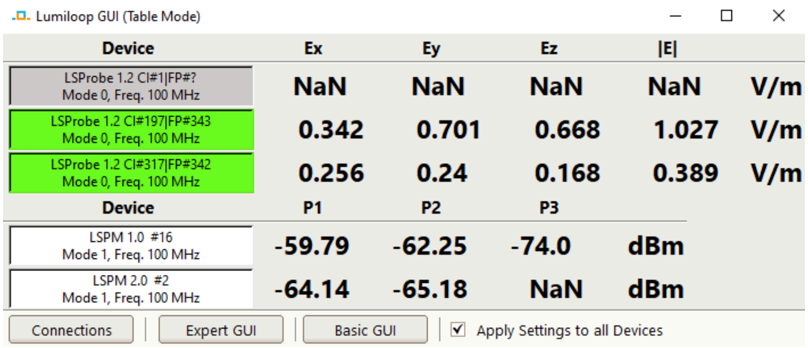
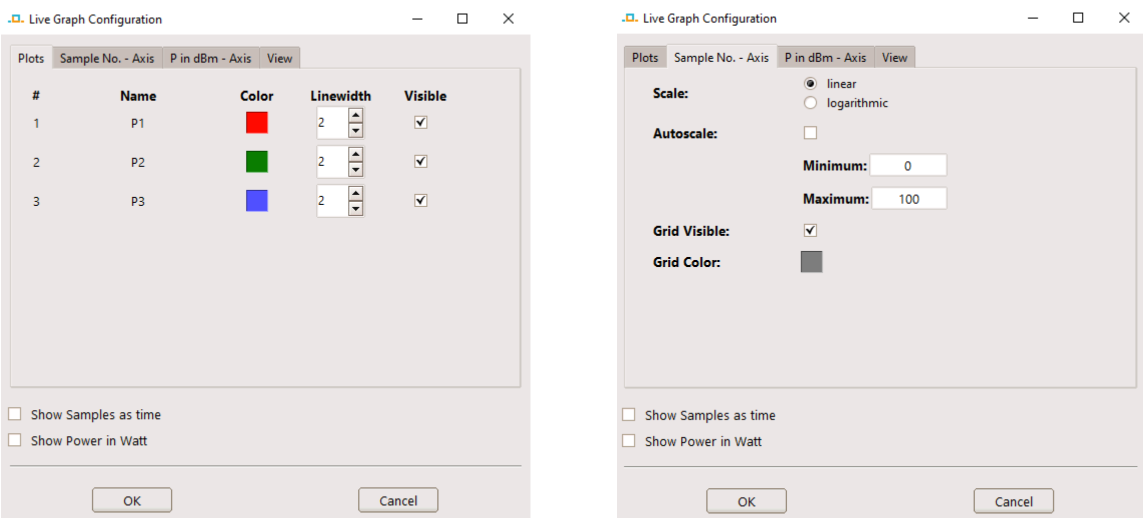


Figure 42: *LUMILOOP GUI in Table Mode*

Figure 43: *LUMILOOP GUI in Basic Mode resized to fit all connected device frames*

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

In general, for one- and two-channel power meters, "NaN" will be displayed for the unpopulated channels in the resective power value fields.

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 GUIfor LSPM 1.1/2.1 devices

Figure 45: *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 power meter 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 45).

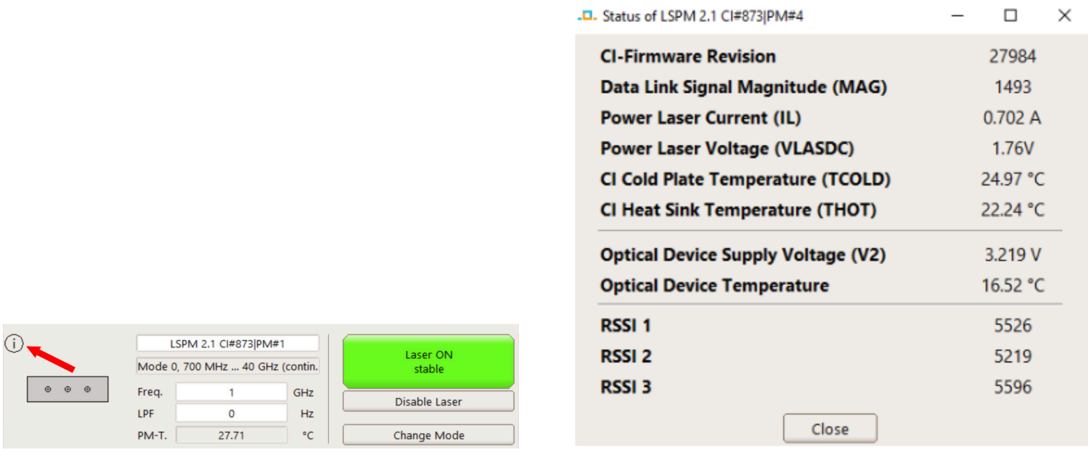
As soon as both the orange "Laser on" indicator and the blue "Data Link" indicator are continuously on Automatic Power Reduction is active and the laser connection is eye-safe. If any of the optical fibers gets interrupted, the supply laser will be switched off within one millisecond and the GUI will present the red indicator shown in Figure 45.

Clicking on the information icon in the top left corner next to the power head pictogram will open a subwindow as shown in Figure 78, 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 channel are displayed.

5.2.5 Mode Selection Using the GUI

For accurate power measurements the signal'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 power 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 power 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 power values. Below the low-pass filter field, the temperature of the power meter is shown.



(a) Laser link status icon (b) Laser link status window

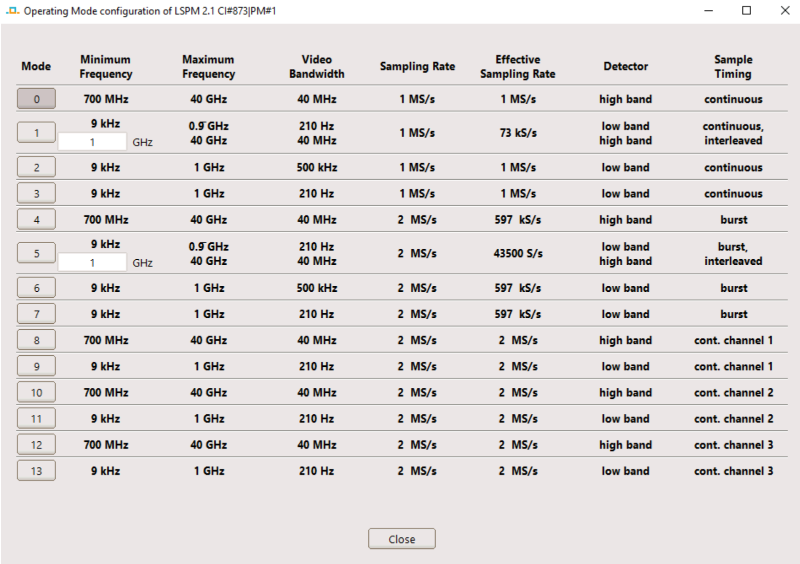
Figure 46: *LUMILOOP GUI laser link status icon & window*

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 47 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 LSPM 1.1/2.1),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 47. If the calibration data does not exists, "?" will be displayed in fields for the frequency range. For laser powered LSPM 1.1 or 2.1 Power Meter, the frequency range and video bandwidths columns will display "?" as long as the laser is not enabled. The depicted values are a device-specific version of the data shown in Table 1 to Table 4 on page 23 to page 26.

5.2.6 Enabling the Supply Laser and Mode Selection Using SCPI Commands

After establishing the TCP/IP connection, the SCPI command »:MEASure[:PMeter]:SERial? <MPMeter>« used with the MPMeter parameter set to zero lists all enumerated power meters. To access a specific LSPM(+) 1.x/2.x Power Meter, use the SCPI command »:MEASure[:PMeter]:SERial <Value>« with the LSPM version and serial number. In case of the laser powered LSPMs, the LSPM version and serial number is only known to the TCP Server if the measurement head is powered. To access the laser powered LSPM before turning on the measurement head, the corresponding CI-250(+) Computer Interface serial number in conjunction with the SCPI command »:SYSTem:CISerial <Value>« is used. To query all enumerated CI-250(+) Computer Interfaces with laser powered RF power meters connected, the SCPI command »:SYSTem:CISerial? [<MPMeter>]« with the MPMeter parameter set to zero is used. If only a single LSPM Power Meter or CI-250(+) Computer Interface is attached to the host computer, it will be selected automatically.

The desired operating mode of the selected power meter is set using »:SYSTem:MODe



Operating Mode configuration of LSPM 2.1 CI#873|PM#1

Mode	Minimum Frequency	Maximum Frequency	Video Bandwidth	Sampling Rate	Effective Sampling Rate	Detector	Sample Timing
0	700 MHz	40 GHz	40 MHz	1 MS/s	1 MS/s	high band	continuous
1	9 kHz 1 GHz	0.9 GHz 40 GHz	210 Hz 40 MHz	1 MS/s	73 kS/s	low band high band	continuous, interleaved
2	9 kHz	1 GHz	500 kHz	1 MS/s	1 MS/s	low band	continuous
3	9 kHz	1 GHz	210 Hz	1 MS/s	1 MS/s	low band	continuous
4	700 MHz	40 GHz	40 MHz	2 MS/s	597 kS/s	high band	burst
5	9 kHz 1 GHz	0.9 GHz 40 GHz	210 Hz 40 MHz	2 MS/s	43500 S/s	low band high band	burst, interleaved
6	9 kHz	1 GHz	500 kHz	2 MS/s	597 kS/s	low band	burst
7	9 kHz	1 GHz	210 Hz	2 MS/s	597 kS/s	low band	burst
8	700 MHz	40 GHz	40 MHz	2 MS/s	2 MS/s	high band	cont. channel 1
9	9 kHz	1 GHz	210 Hz	2 MS/s	2 MS/s	low band	cont. channel 1
10	700 MHz	40 GHz	40 MHz	2 MS/s	2 MS/s	high band	cont. channel 2
11	9 kHz	1 GHz	210 Hz	2 MS/s	2 MS/s	low band	cont. channel 2
12	700 MHz	40 GHz	40 MHz	2 MS/s	2 MS/s	high band	cont. channel 3
13	9 kHz	1 GHz	210 Hz	2 MS/s	2 MS/s	low band	cont. channel 3

Close

Figure 47: *LUMILOOP GUI Operating Mode configuration dialog*

<Mode>[,<MPMeter>]«. Refer to Table 1 up to Table 4 on page 23 to page 26 for a list of valid modes. Set the operating frequency in hertz using »:SYSTem:FREQuency <Frequency>[,<MPMeter>]«. 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? [<MPMeter>]« can be used to verify the frequency setting.

For the laser powered LSPMs, »:SYSTem:LASer:ENable <Value>[,<MPMeter>]« is used to enable the supply laser. During start-up the commands »:MEASure[:PMeter]:MODe? [<MPMeter>]« and »:SYSTem:LASer:TOut? [<MPMeter>]« 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 power head may take several tens of seconds to successfully set a mode. »:SYSTem:MODe <Mode>[,<MPMeter>]« 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 Power Measurements

While the LSPM is capable of exceptionally high speed measurements it is also able to perform high precision measurements of quasi-static electric fields. For continuous power measurements the TCP server receives all power values, applies calibration data and performs low-pass filtering if configured accordingly. The laser powered RF power meters also delivers channel 1, 2 and 3 acceleration data to the TCP Server. They are optionally low-pass filtered as well. The acceleration values indicate the orientation of the measurement head. Placing the measurement head with its feet on a surface parallel to the ground should give a reading of about positive 1 g, i.e., 9.81 m/s^2 on the channel 3.

5.3.1 Continuous Measurements Using the GUI

As depicted in Figure 48, the LUMILOOP GUI in Basic Mode displays the measured power values for up to three channels in the lower part of the frame. If a single or dual channel power meter is used, the GUI will show " Nan" for the unused channels. On the left half of the lower frame, a graphical representation of the measured power values is given via a bargraph. The orange bargraph represents the instantaneous power 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 power value is given, as well as the current measuring range of the device.

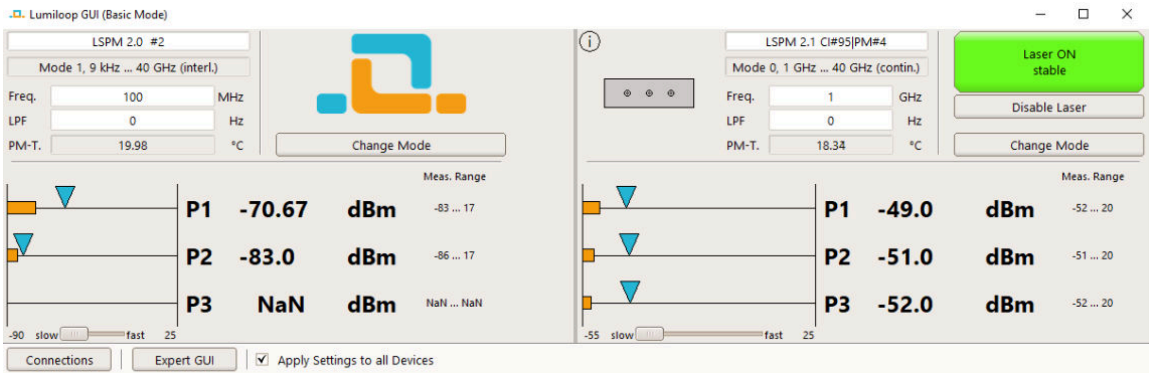


Figure 48: *LUMILOOP GUI Basic mode power measurements*

In the Expert Mode LUMILOOP GUI, continuous measurements are depicted in the "Live" tab as shown in Figure 49. Power and , in case of optically powered LSPM 1.1/2.1 devices,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 power values for the current operating mode, frequency and power meter temperature is displayed textually below each channel's power value. 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. For single and dual channel versions of the LSPM, "NaN" will be displayed for the unpopulated channels.

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 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. Representation of

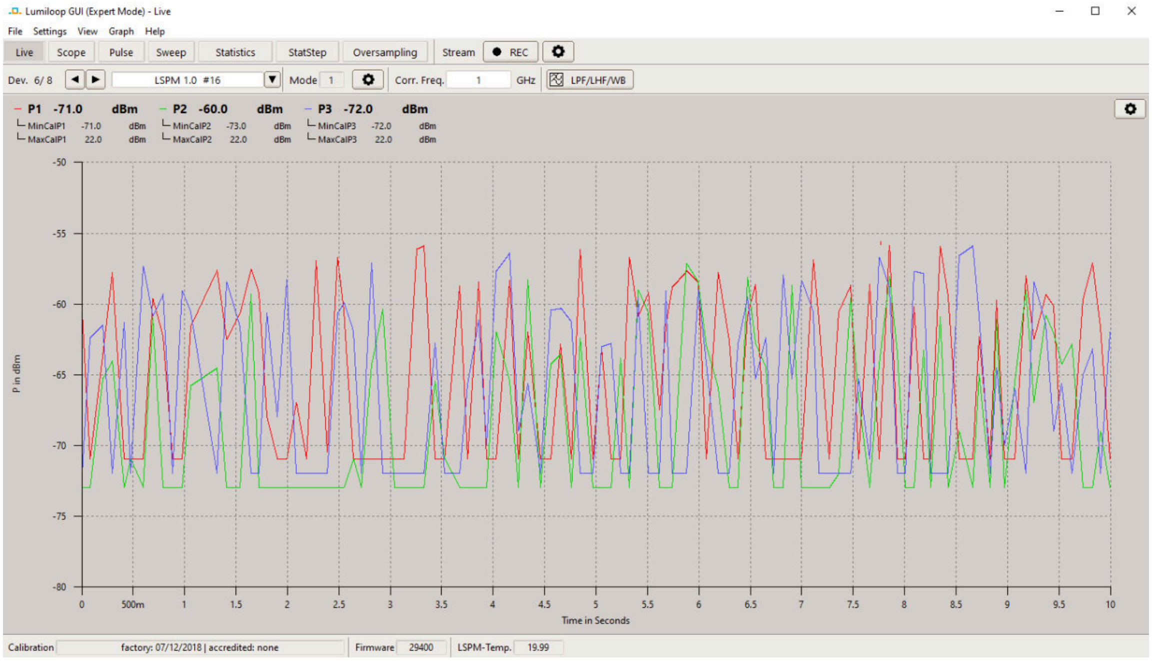


Figure 49: *LUMILOOP GUI Live view*

the power values on the y-axis can be switched from a logarithmic scale in dBm to a linear scale in watt via the "Show Power in Watt' check box. Both options 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, Sweep, Statistics, StatStepand 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 5.10 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 power meter identification string, a date and time string and a CSV file suffix will be appended to every newly created log file. See Section 12.1 on page 230 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/WB" button in the "Control" toolbar or the "Filter" entry of the "Settings" menu. The subdialog is shown in Figure 81. 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 power and acceleration values, for example 10 Hz. When changing the frequency the power 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 LSPM 1.1/2.1 also mode 5 can be set in the corresponding numeric in put field. For example, the transition frequency in Figure 81, the transition frequency is set to 750 MHz.

As described in Section 9, LSPM Power Meters are calibrated using CW signals. Most measurement scenarios in EMC testing uses unmodulated CW signals as well, but certain standards (e.g. ISO 11452-9:2021, Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy, Part 9: Portable transmitters) require modulated signals. For modulation bandwidths up to about the video bandwidth, the measurement error due to modulation is marginal. According to Table 1 up to Table 4, the highest videobandwidth and therefore lowest error for modulated signals is achieved in mode 0. For modulation bandwidths outside the detectors video bandwidth, additional correction factors are needed to compensate the measurement error due to modulation.

In the "Filter and LHF Configuration" dialog, these correction factors are set via the "Wideband Correction" drop-down menu. If "0 MHz" is selected, the wideband correction factors are disabled. Otherwise setting the appropriate modulation bandwidth applies the corresponding correction factors in the TCP-Server for all subsequent measurements. Currently, the correction factors for measurements according to ISO 11452-9:2021 are implemented, i.e 10/20/80/100/160 MHz AWGN bandwidth, 0.7 GHz to 6 GHz carrier frequency. Due to the higher video bandwidth in mode 0, the correction factors are only available in this mode and for frequencies within the frequency range of the correction factors. For mode or frequency settings outside the correction factors parameter, the "Wideband Correction" field is not displayed. New sets of correction factors can be created using the file format described in Section 12.4.3.

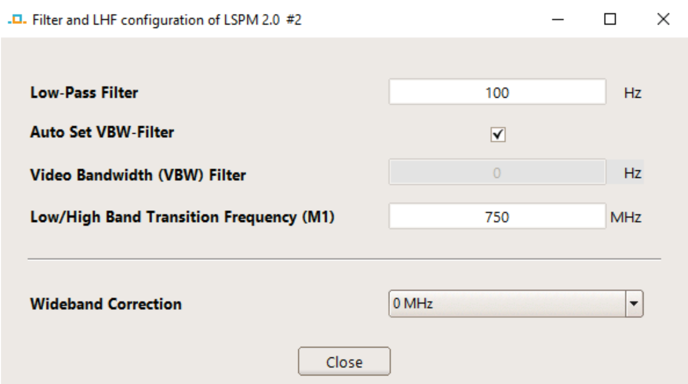


Figure 50: *LUMILOOP GUI Filter Configuration dialog*

The currently active device's factory and, if existing, accredited calibration date, the LSPM $1.0^{(+)}/2.0^{(+)}$ or CI-$250^{(+)}$ device's firmware, the power meter'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 power low-pass filter frequency is configured through »:MEASure[:PMeter]:LPFrequency <Frequency>[,<MPMeter>]«. A synchronized set of power valuescan be queried through the »:ALL« variant of »:MEASure[:Power]:P[1]/P2/P3/ALL? [<MPMeter>]«. This is the recommended method ensuring that the values have been acquired at the same time. Power values can also be queried individually through the »:P[1]/:P2/:P3«variants of the command.

For laser powered LSPMs, theacceleration low-pass filter frequency is configured through »:MEASure[:PMeter]:ACCeleration:LPFrequency <Frequency>[,<MPMeter>]«. Acceleration values can be queried through »:MEASure[:PMeter]:ACCeleration:1/2/3/ALL? [<MPMeter>]«.

5.4 Triggered Power Measurements

Triggered power measurements allow the user to take full advantage of the LSPM's exceptionally high-speed measurements. Waveform acquisition can be triggered by software or by hardware. The edge-sensitive hardware trigger signals originate from the LSPM 1.0$^{(+)}$/2.0$^{(+)}$ or CI-250$^{(+)}$ device's BNC/RJ45 connectors or the signal level with a set threshold for power 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 Power Waveform Acquisition Using the GUI

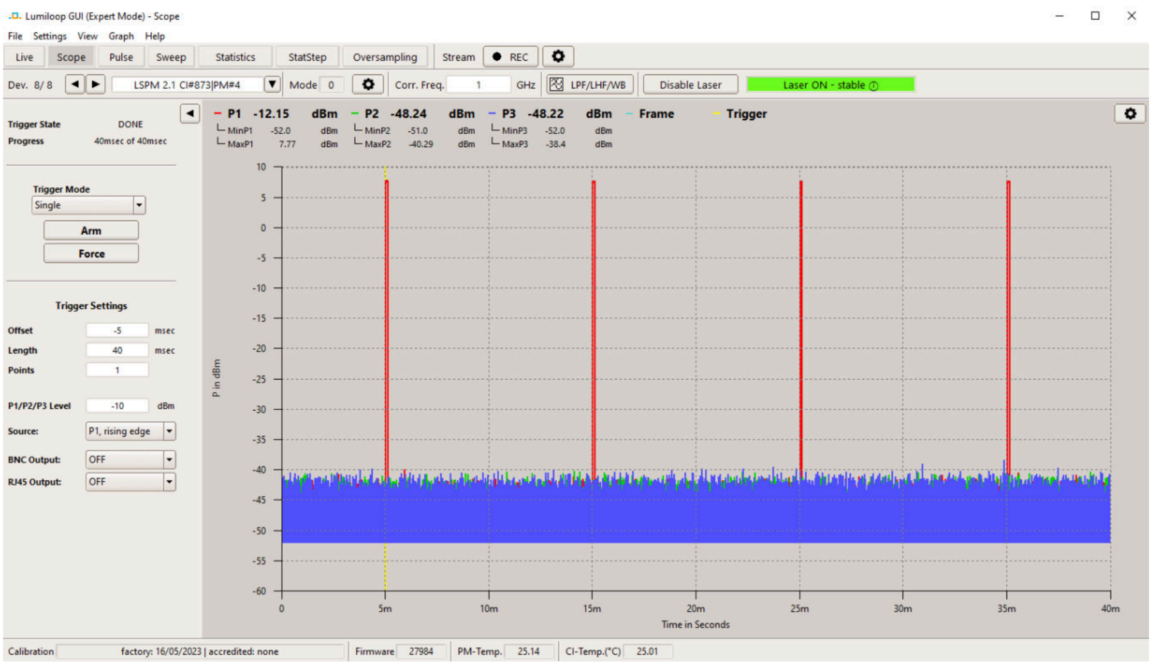


Figure 51: *LUMILOOP GUI, Scope tab*

Figure 51 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 channel 1, channel 2 and channel 3 power values 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, channel 1, channel 2, channel 3 power value or any of the channels' value triggering. For the power value triggering, the threshold value in dBm or Watt can be set via "P1/P2/P3 Level" . By changing "Trigger 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 4 on page 23 to page 26.

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, channel 1, channel 2, channel 3 or any of the channels' power value triggering. For the power value triggering the threshold value in dBm or Watt can be set via "P1/P2/P3 Level".

The "BNC Trigger Output" and "RJ45 Trigger Output" drop-down menus are used to enable trigger signal output via the LSPM 1.0$^{(+)}$/2.0$^{(+)}$ or 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 11.6.31.

5.4.2 Power Waveform Acquisition Using SCPI Commands

The state of the trigger system is queried using »:TRIGger:STATe? [<Timeout>,<MPMeter>]«. The configuration of triggered measurements must take place in IDLE state. Waveform query must take

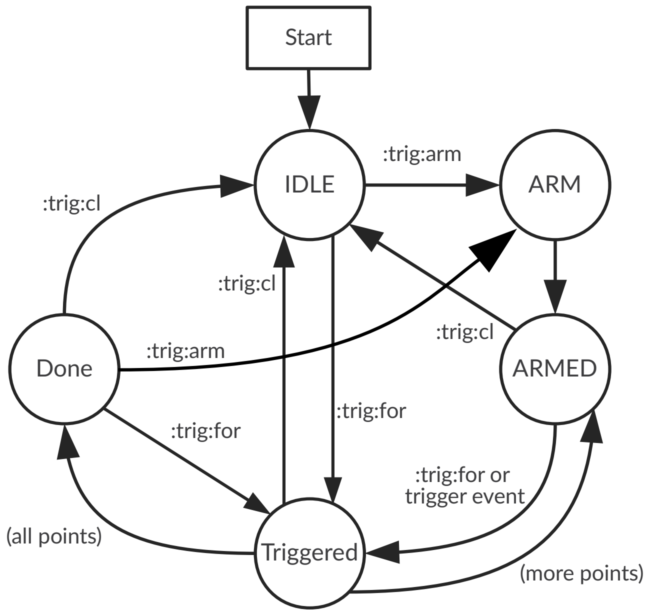


Figure 52: *Trigger system states and state transitions*

place when the trigger system is in DONE state. The SCPI commands »:TRIGger:CLear [<MPMeter>]«, »:TRIGger:ARM [<MPMeter>]« and »:TRIGger:FORce [<MPMeter>]« are used for directly manipulating the state of the trigger system. Figure 52 shows all valid trigger states and state transitions.

After receiving »:TRIGger:ARM [<MPMeter>]«, the trigger subsystem first transitions to the ARM state before entering the state ARMED, readying the LSPM 1.0$^{(+)}$/2.0$^{(+)}$ or CI-250$^{(+)}$ device for trigger event processing. Since trigger events will only be processed in state ARMED, the queries »:TRIGger:STATe? [<Timeout>,<MPMeter>]« or »:TRIGger:ARMed? [<Timeout>,<MPMeter>]« must be used to verify the state ARMED before generating trigger events. Similarly, the command »:TRIGger:DONE? [<Timeout>,<MPMeter>]« 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? [<MPMeter>]«, for progress of point trigger acquisition »:TRIGger:PTProgress? [<MPMeter>]«.

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

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

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

In DONE state the waveform values can be queried using »:TRIGger[:WAVeform][:Power]:P[1]/:P2/:P3/:ALL? [<MPMeter>]«. Averaged waveform values can be queried using »:TRIGger[:WAVeform][:Power]:ALL? [<MPMeter>]«. The »:TRIGger[:WAVeform][:Power]:BINary? [<MPMeter>]« command is available for fast and computationally efficient waveform readout in binary format.

5.4.3 Pulse Measurements Using the GUI

The LSPM is able to scan a previously recorded power waveform for pulses in order to find their positions, lengths, averaged power values and maximum power values. See Section 5.4.1 for details regarding triggered value acquisition. Pulses can be detected if they are at least 0.5 µs long and 0.5 µs apart. For the laser powered RF-powermeters in mode 0 and 2, the minimum pulse length is 1 µs and pulses need to be at least 1 µs apart for detection, due to lower sampling rate in these two modes. For conventional LSPM $1.0^{(+)}$/$2.0^{(+)}$ Power Meters pulse measurements in mode 1 below the crossover frequency and mode 3 are not recommended due to the small video bandwidth of the low-band detector. For LSPM 1.1/2.1 devices, pulse measurements in mode 3, as well as in mode 7 are not recommended due to the small video bandwidth of the low-band detector. 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 53.

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 power 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 power, the pulse's average value is defined as its largest sample value. For pulses containing at least three samples, the pulse's power is defined as the arithmetic mean of all but the first and last sample value of the pulse, Figure 54 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 55.

Pulse characteristics are presented independently for all channels of the power meter above the graph. The averaged values over all pulses' power values of the current waveform "AvgP", the applied

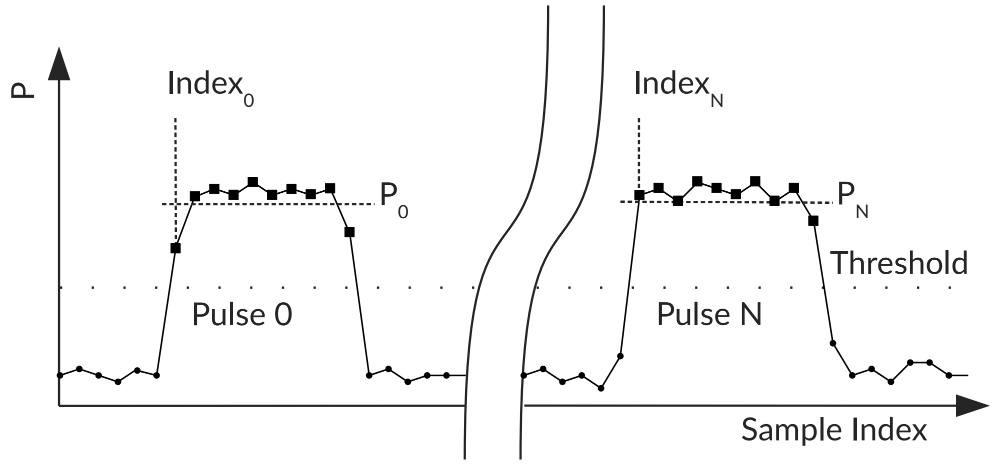


Figure 53: *Pulse detection when pulse trimming is disabled. All samples above the threshold are used for power calculation, leading to a lower average pulse power.*

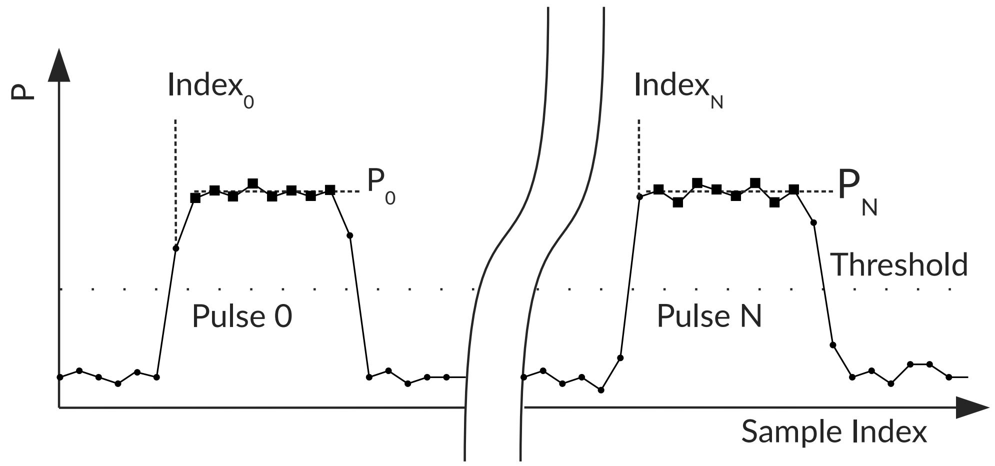


Figure 54: *Principle of pulse detection when pulse trimming is enabled*

threshold value for pulse detection “ThP” and the resulting number of pulses “CntP” are shown on top. The power of the pulse with the largest averaged power within the waveform is given in the “MaxP” field. “DutyP” states the ratio between the number of samples detected as pulses and the waveform's length.

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 channel. 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 (“P@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 power. The currently selected pulse will be highlighted in the graph via boxes, as depicted in Figure 55 for pulse number two. If no pulses are detected, the averaged power values will display “NaN” and number of detected pulses will display “0”. All other fields will be empty.

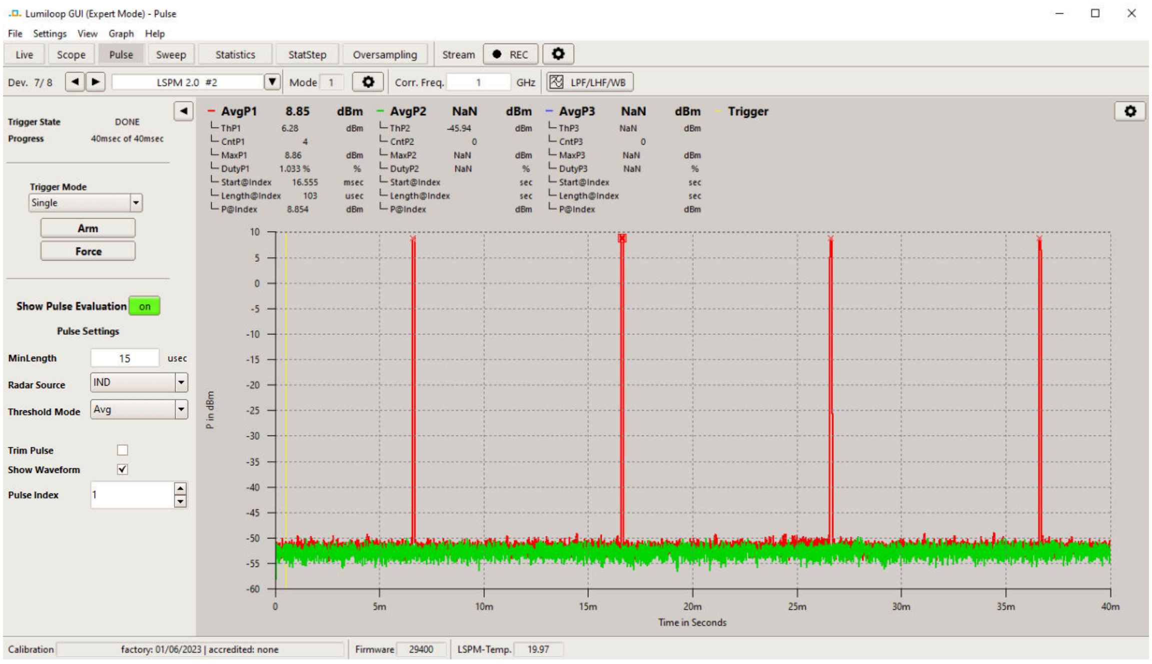


Figure 55: *LUMILOOP GUI, Pulse tab*

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 power waveform and with every change in the pulse evaluation source waveform, threshold value and trim setting.

The "MinLength" input field sets the minimum number of samples per pulse of the transmitter. All pulses that are shorter will be discarded, as shown in Figure 56.

The threshold value for all channels 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 power value and minimum power value in the waveform for each channel separately. Minimum and maximum power value are accessible via the statistics subsystem, see Section 5.6.

ABS
: Pulse detection will use the fixed power value in dBm or Watt 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 56 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, based on the minimum of the power value probability distribution which is located between the probabilities of the noise floor and the active transmitter's power level, as shown in Figure 56. 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 available threshold mode's entry field will become visible upon selecting the respective mode.

Figure 54 shows the relationship of power 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 "MinLength" setting, 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.

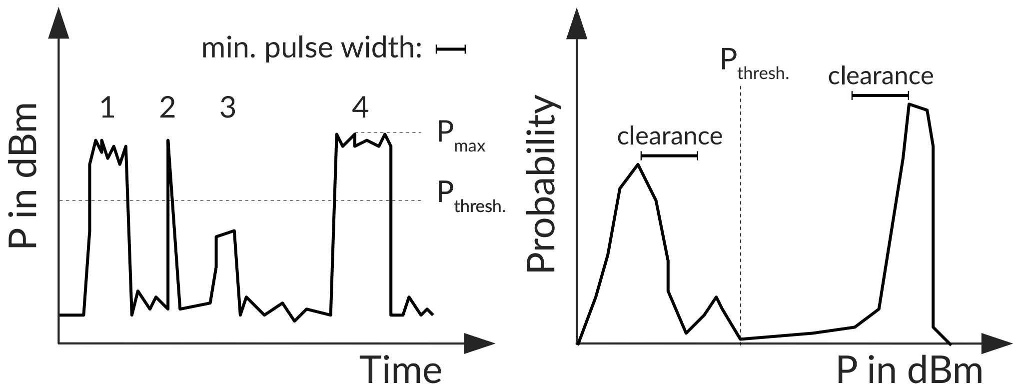


Figure 56: *Principle of pulsed power measurements' threshold calculation. Pulse 2 is omitted since it is too short. Pulse 3 is omitted since it is too low. Diagram on the right is the corresponding histogram.*

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>[,<MPMeter>]«. Configuration of the source waveform used for pulse evaluation is done via »[:TRIGger]:RADar:SOURce <Source>[,<MPMeter>]«. The pulse detection method is set using »[:TRIGger]:RADar:THMethod <Method>[<MPMeter>]«, allowing for minimum/maximum-based threshold calculation, absolute threshold setting, relative threshold setting and histogram-based threshold calculation. The latter are configured using the commands »[:TRIGger]:RADar:ATHold <Threshold>[<MPMeter>]«, »[:TRIGger]:RADar:RTHold <Threshold>[<MPMeter>]« and »[:TRIGger]:RADar:CLEARance <Clearance>[<MPMeter>]«. The applied threshold values can be queried using »[:TRIGger]:RADar:THold:P[1]/P2/P3/ALL? [<MPMeter>]«. Pulse evaluation can be performed multiple times using different threshold values or radar source waveforms.

The minimum pulse length is set by »[:TRIGger]:RADar:MINSamples <MinS>[<MPMeter>]«.

The number of detected pulses followed by triples of start sample index, pulse length in samples and maximum pulse power values can be obtained through the commands »[:TRIGger]:RADar:P[1]/P2/P3? [<MPMeter>]«. Individual properties can be queried using »[:TRIGger]:RADar:COUnt:P[1]/:P2/:P3/:ALL? [<MPMeter>]«, »[:TRIGger]:RADar:PULses:STArt:P[1]/:P2/:P3? [<MPMeter>]«, »[:TRIGger]:RADar:PULses:LENgth:P[1]/:P2/:P3? [<MPMeter>]« and »[:TRIGger]:RADar:PULses[:APOWer]:P[1]/:P2/:P3? [<MPMeter>]«. Averaged pulse power values can be queried using »[:TRIGger]:RADar:APOWer:P[1]/:P2/:P3/:ALL? [<MPMeter>]«. Results for the entire waveform can be queried using »[:TRIGger]:RADar:P[1]/P2/P3? [<MPMeter>]« for averaged pulse power values, »[:TRIGger]:RADar:COUnt:P[1]/:P2/:P3/:ALL? [<MPMeter>]« for the number of pulses, »[:TRIGger]:RADar:DUTY:P[1]/:P2/:P3/:ALL? [<MPMeter>]« for the duty cycle and »[:TRIGger]:RADar:MPOWer:P[1]/:P2/:P3/:ALL? [<MPMeter>]« for the power of the largest pulse. The »[:TRIGger]:RADar:BINary? <Wave>[,<MPMeter>]« command is available for fast and computationally efficient pulse detection readout in binary format.

5.4.5 Sweep Measurements Using the GUI

The LSPM is able to evaluate power 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 power waveform will have a different, constant frequency associated with it. Sweep measurements return the averaged power 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 LSPM, 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 power values via multiple discrete queries.

The sweep subsystem should be used in power meter modes 0, 2 and 3 for LSPM 1.0$^{(+)}$/2.0$^{(+)}$ Power Meters and 0, 2, 3, 8, 10, 12 for LSPM 1.1/2.1 Power Meter only. One or more sections of the waveform, which align with the sweep's steps, are analyzed independently, yielding a set of averaged power 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 57. 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 power 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

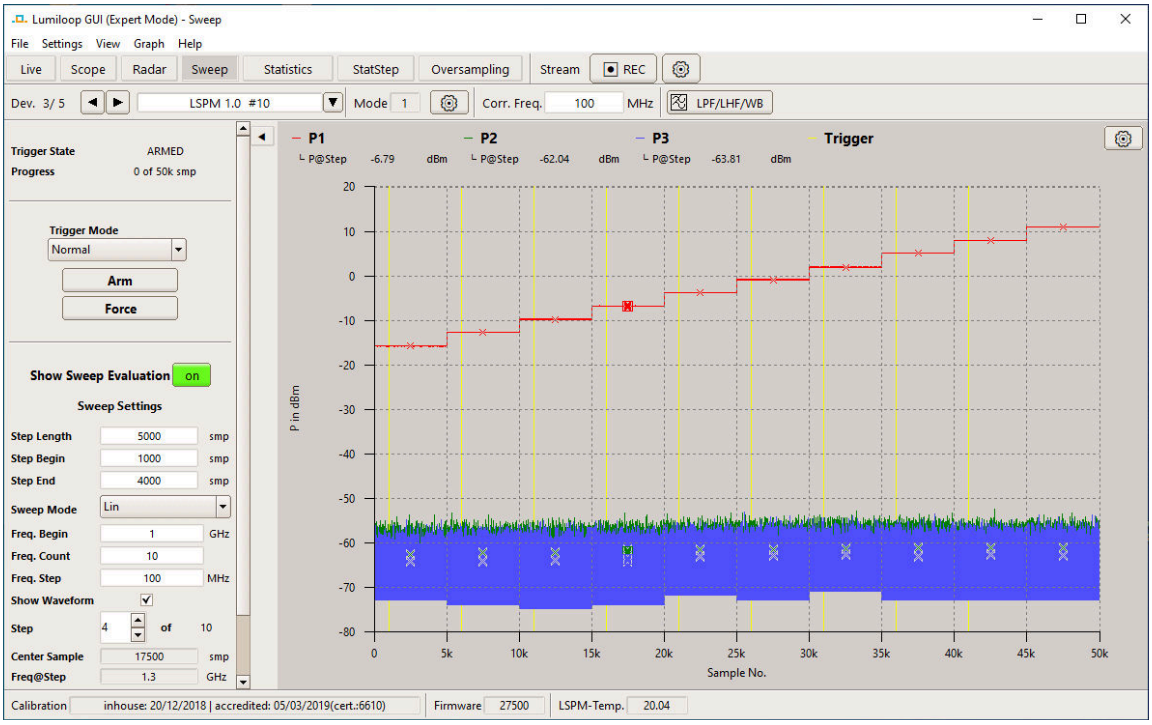


Figure 57: *LUMILOOP GUI, Sweep tab*

starts with the first sample of the power 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 power waveform is divided into as many sweep steps as will fit into the power 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 channel 1, 2 and 3 power 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>[,<MPMeter>]«, »[:TRIGger]:SWeep:TBegin <TBegin>[,<MPMeter>]« and »[:TRIGger]:SWeep:TEnd <TEnd>[,<MPMeter>]« are used. Use »[:TRIGger]:SWeep:ADDTimes <TStep>,<TBegin>,<TEnd>[,<MPMeter>]« to add additonal arbitrary sweep steps. Using one of the commands »[:TRIGger]:SWeep:TStep <TStep>[,<MPMeter>]«, »[:TRIGger]:SWeep:TBegin <TBegin>[,<MPMeter>]« or »[:TRIGger]:SWeep:TEnd <TEnd>[,<MPMeter>]« will shorten the set sweep step list to a single step. Alternatively use »[:TRIGger]:SWeep:CLEARTimes [<MPMeter>]« to delete all sweep steps except the first one. The sweep mode is set via »[:TRIGger]:SWeep:MODe <Mode>[,<MPMeter>]«, 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>[,<MPMeter>]«, »[:TRIGger]:SWeep:COUnt <Count>[,<MPMeter>]« and »[:TRIGger]:SWeep:STEP <Step>[,<MPMeter>]«. A list of arbitrary frequencies can be created incrementally via the »[:TRIGger]:SWeep:ARBAdd <Freq>[,<MPMeter>]« command. »[:TRIGger]:SWeep:ARBClear [<MPMeter>]« is used to clear the arbitrary frequency list. In any sweep mode, the command »[:TRIGger]:SWeep:LIST? [<MPMeter>]« returns the list of frequencies in accordance with the selected sweep mode and waveform length.

The command »[:TRIGger]:SWeep:IDX? [<MPMeter>]« returns the center sample indices of all sweep steps in the waveform. The averaged power and RSSI values for each step are queried using the commands »[:TRIGger]:SWeep[:Power]:P[1]?/:P2?/:P3?/[:ALL?] [<MPMeter>]« and »[:TRIGger]:SWeep:RSsi:P[1]/:P2/:P3/[:ALL]? [<MPMeter>]«. Frequency corrected trigger waveforms can be obtained using »[:TRIGger]:SWeep:WPower:P[1]/:P2/:P3/[:ALL]? [<MPMeter>]«. The »:TRIGger[:WAVeform][:Power]:BINary? [<MPMeter>]« command is available for fast and computationally efficient value 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 LSPM. For normal operating mode, the time resolution and therefore minimum pulse width and spacing is at least 0.5 µs. Via the oversampling feature the granularity can be improved down to 2 ns for LSPM $1.0^{(+)}/2.0^{(+)}$ and or 3.3ns for LSPM 1.1/2.1 devices 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 58.

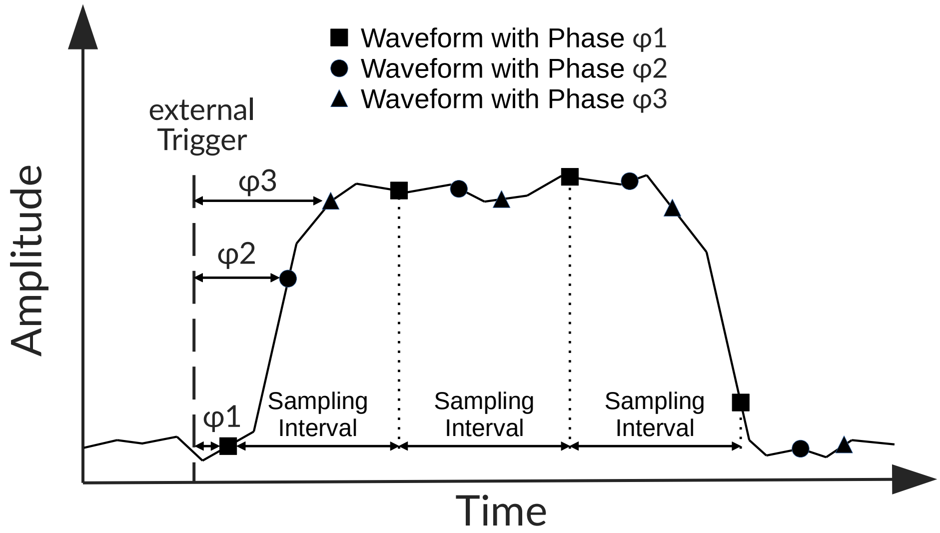


Figure 58: *Basic principle of oversampling feature*

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 LSPM $1.0^{(+)}/2.0^{(+)}$ or CI-$250^{(+)}$ device, see Section 3.3 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 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 59 for graphical depiction.

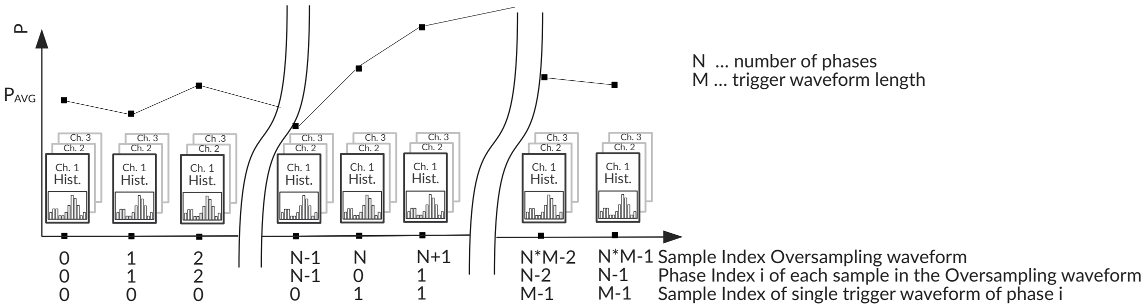


Figure 59: *Structure of Oversampling waveform*

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 60. 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 52. 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 60: *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 each power input waveform. The phase offset with the minimum sum is taken as the optimal phase offset.

Above the plot, power statistics of the oversampled waveform are displayed, namely the power average over the whole high resolution waveform, as well as its maximum and minimum recorded power value for each channel 1, 2 and 3.

5.5.2 Oversampling Using SCPI Commands

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

Using the »:TRIGger:OVERsampling:ENable <State>[,<MPMeter>]« SCPI command will enable the oversampling subsystem. To query the status of the oversampling subsystem, use »:TRIGger:OVERsampling:ENable? [<MPMeter>]«. 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 [<MPMeter>]« 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>,<MPMeter>]« command. After the measurement is finished, either by using »:TRIGger:OVERsampling:ENable <State>[,<MPMeter>]« 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? [<MPMeter>]« command. The percentage of phases satisfying the criteria is queried with the »:TRIGger:OVERsampling:PROgress? [<MPMeter>]« command. A detailed distribution of the number sub-waveforms per phase can be obtained using the »:TRIGger:OVERsampling:BINStatus? [<MPMeter>]« 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? [<MPMeter>]« For post processing of the sub-waveforms use the »:TRIGger:OVERsampling:MAXNoise <Value>[,<MPMeter>]« command, for adjusting the maximum distance between a sample and the average value in dB. With the »:TRIGger:OVERsampling:PHOffset <Offset>[,<MPMeter>]« command, the index of phase offset is set, a value between zero and the number of phases (»:TRIGger:OVERsampling:PHCount? [<MPMeter>]«) minus one. The current phase offset is queried with the »:TRIGger:OVERsampling:PHOffset? [<MPMeter>]« command and the auto phase offset detection is executed by using the »:TRIGger:OVERsampling:PHOffset:AUTO [<MPMeter>]«.

To obtain the results from the measurement, either the averaged power oversampled waveform or the histogram of the measurement can be queried by using the »:TRIGger:OVERsampling:P[1]/:P2/:P3/ALL? [<MPMeter>]« or »:TRIGger:OVERsampling:HISTogram:P1? [<MPMeter>]« command.

5.6 Power Statistics

Two types of power statistics are available for the LSPM, 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 power 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 power values of waveforms in memory. Almost all SCPI commands of the statistics subsystem apply to both continuously collected and triggered power values.

5.6.1 Continuous Power Statistics using the GUI

Statistics functions are controlled via the "Statistics" tab of the LUMILOOP GUI, see Figure 61. See Section 2.7 for an explanation of the operating principle.

All enumerated LSPM devices will be configured automatically as software controlled, independent units. In case of synchronized continuous power statistics, one master power meter or computer interface must be set, all other devices must be configured as statistics slaves. As explained in Section 3.4 synchronized continuous power statistics use the RJ45 socket of the LSPM 1.0$^{(+)}$/2.0$^{(+)}$ or CI-250$^{(+)}$ device for synchronized enabling of statistics collection and snapshot creation. For a single LSPM system the LSPM can be configured to either master or software controlled.

A power meter or 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"

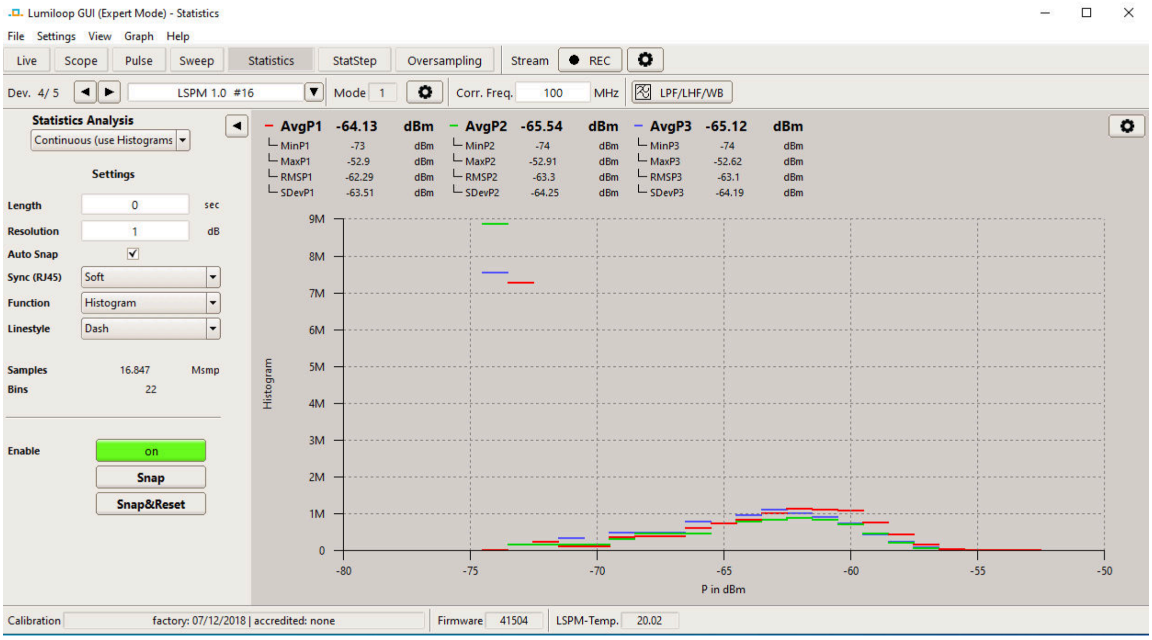


Figure 61: *LUMILOOP GUI, Statistics tab*

dialog as depicted in Figure 62 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.

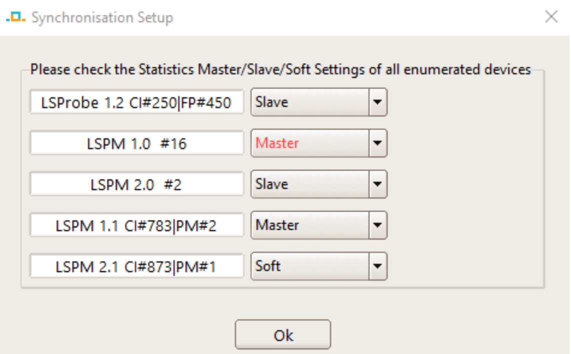


Figure 62: *LUMILOOP GUI, Statistics "Synchronization Setup" dialog*

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 power statistics collection via the statistics master power meter or 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 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 11.10 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 LSPM. The histogram-like statistics include arithmetic mean, minimum, maximum, root mean square and standard deviation for power values for channels 1, 2 and 3.

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

5.6.2 Continuous Power 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>« with the parameters “soft”, “slave” or “master”. The continuous statistics master power meter or computer interface must be set by first selecting it using »:SYSTem:SERial <Value>« in cases of traditional power meters LSPM 1.0$^{(+)}$/2.0$^{(+)}$ and »:SYSTem:CISerial <Value>« for laser powered LSPM 1.1/2.1 Power Meters, followed by setting its master status to “1” or “master” using »:STATistics:MAster <State>«. Statistics slave or software based statistics can be set for multiple devices at once using the MPMeter parameter as described in Section 11.1. The statistics synchronization status of any computer interface may be queried using »:STATistics:MAster? [<MPMeter>]«.

Continuous power statistics collection is started by issuing »:STATistics:ENable <State>[,<MPMeter>]« with the parameter "State" set to "1" for the statistics master power meter or computer interface or all software controlled devices. To set the maximum number of samples to be collected, use the »:STATistics:LENgth <Length>[,<MPMeter>]« 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>][,<MPMeter>]« or »:STATistics:ENable <State>[,<MPMeter>]« 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? [<MPMeter>]«. Using this query enables snapshot synchronization, since snapshot query and execution are inherently asynchronous for continuous power statistics. Enabling continuous statistics will reset the snapshot counter to zero. »:STATistics:SAMples? [<Triggered>][,<MPMeter>]« returns the number of samples used for the most recent statistics snapshot.

Scalar statistics values can be read using the commands described in Section 11.10.14 through 11.10.18. Histogram-like statistics values are returned by the commands described in Sections 11.10.20 through 11.10.23.

The resolution for histogram-like values is set using »:STATistics:RESolution <Resolution>[,<MPMeter>]«. The resulting number of bins, the offset of the bin with the smallest power value and the center power value of each bin can be queried via »:STATistics:HISTogram:SIZe? [<Triggered>][,<MPMeter>]«, »:STATistics:HISTogram:OFFset? [<Triggered>][,<MPMeter>]« and »:STATistics:Power? [<Triggered>][,<MPMeter>]« respectively. All statistics values are also available in binary format, see »:STATistics:BINary? [<Triggered>][,<MPMeter>]« 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 power statistics do not rely on the physical connections required for continuous synchronized power statistics. For triggered power 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 power statistics in the LUMILOOP GUI select "Triggered (use Waveforms)" from the "Statistics Analysis" drop-down list, this will enable additional controls for triggered power 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 power 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>][,<MPMeter>]«. 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 Power Step-Wise Statistics

Step-Wise Statistics allows for reduction of the LSPM's sampling rate by creating statistics over a user specified number of samples. The minimum. maximum and averaged power value for each step is computed for each power input. 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 63.

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 11.10.25. Enabling and disabling statistics collection is done via the scpi command 11.10.3 using the parameter "1" or "0". Refer to

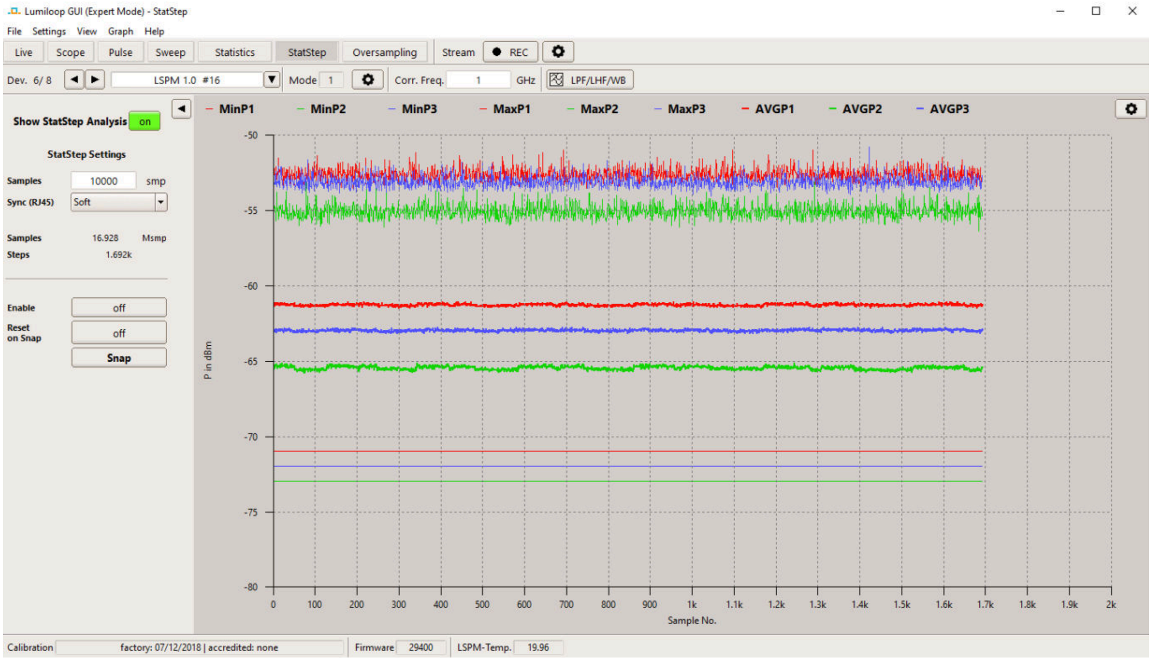


Figure 63: *LUMILOOP GUI, StatStep tab*

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 11.10.32 followed by a continuous snapshot command, e.g. 11.10.7 with the "Triggered" parameter set to zero.

Use 11.10.31 and 11.10.30 to query the processed number of samples or steps since last statistics collection enable or reset. 11.10.29 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 power value for channel 1, 2 and 3. Results are queried using 11.10.34. To disable output of certain statistics and/or channels use the command described in Sections 11.10.27. Therefore the command returns at max three times three values, at least a single value. The "greedy" parameter of the command 11.10.34 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>,<MPMeter>]« command is available for fast and computationally efficient step-wise value readout in binary format.

5.8 Stream Recording

The LSPM supports recording power values at the power meter'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 12.1.6. File names start with an arbitrary prefix string followed by the power meter'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 power data in a binary format in order to reduce both disk space and CPU load. The binary file format is detailed in Section 12.1.6. Binary stream files can be converted into CSV files using the "Bin2Csv" conversion tool described in Section 12.1.7.

Alternatively, the binary stream data can also be send to a user specified client connection. See Section 12.1.7 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 65. Set the synchronization i.e. "Master" or "Slave", status of the LSPM $1.0^{(+)}$/$2.0^{(+)}$ or CI-$250^{(+)}$ device using the "Master" drop-down list. Per default all power meter or 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 3.3 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 64 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.

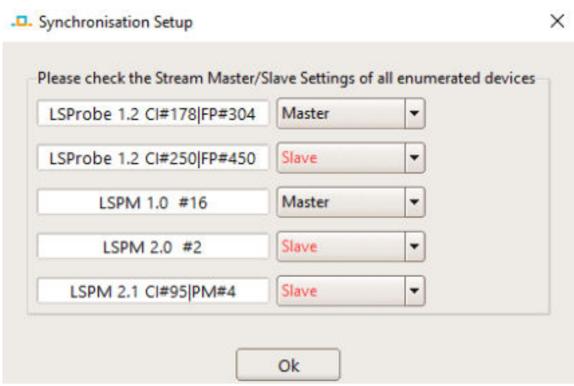


Figure 64: *LUMILOOP GUI, Stream "Synchronization Setup" dialog*

To record a specific number of power samples, set the "Length" numeric input field to this number. If set to zero, stream recording runs until manually disabled again. The number of power 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 65. 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.

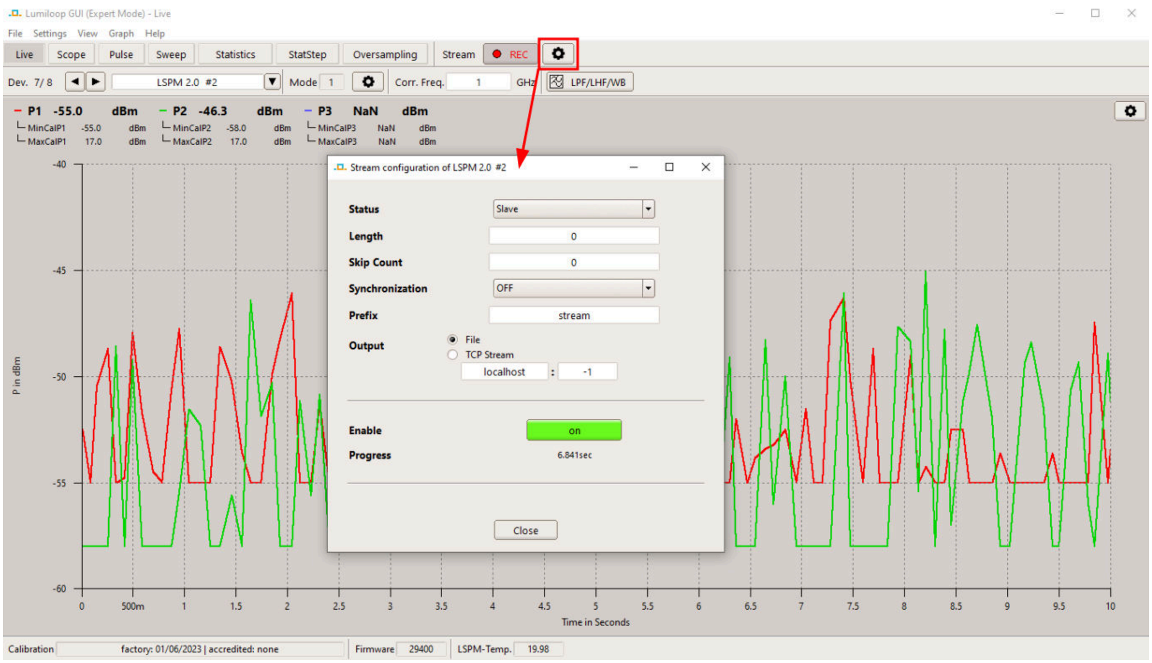


Figure 65: *LUMILOOP GUI and "Stream configuration" dialog of the current selected*

5.8.2 Stream Recording Using SCPI Commands

Stream synchronization can be configured using the »:STReam:SYNC <Sync>[,<MPMeter>]« SCPI command. When synchronization is disabled, the stream master LSPM 1.0$^{(+)}$/2.0$^{(+)}$ or CI-250$^{(+)}$ device can be changed by setting the former master LSPM 1.0$^{(+)}$/2.0$^{(+)}$ or CI-250$^{(+)}$ device to slave, selecting the new device and setting it to stream master using »:SYSTem:SERial <Value>« in cases of traditional power meters LSPM 1.0$^{(+)}$/2.0$^{(+)}$ or »:SYSTem:CISerial <Value>« for laser powered LSPM 1.1/2.1 Power Meters 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>[,<MPMeter>]« command. If set to a non-zero number stream recording will terminate automatically after reaching the maximum number of samples.

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

To change the output directory of the stream data use »:STReam:OUTput <OUT>[,<MPMeter>]«. 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>[,<MPMeter>]. The progress of stream recording can be monitored using the »:STReam:PROgress? [<MPMeter>]« command.

5.9 Shutting Down LUMILOOP TCP Server and LUMILOOP GUI

5.9.1 Shutting Down Using the LUMILOOP GUI

for LSPM 1.1/2.1 devices

Click on the "Disable Laser" button to disable the supply laser. if LSPM 1.1/2.1 devices are enumerated. 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.

5.9.2 Shutting Down Using SCPI Commands

The supply laser is turned off of LSPM 1.1/2.1 devices using the »:SYSTem:LASer:ENable <Value>[,<MPMeter>]« command with "0" as value. Terminate the TCP session and close the LUMILOOP TCP Server as described above.

5.10 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 66. 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", "Statistics", "Statstep" , "MProbe" 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 power meter 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 power meters 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 12.

Logging of RSSI values i.e., raw ADC sample values for channel 1, 2 and 3, can be enabled by selecting the "include RSSI" check box. The feature is available for "Live" and "Scope" log files.

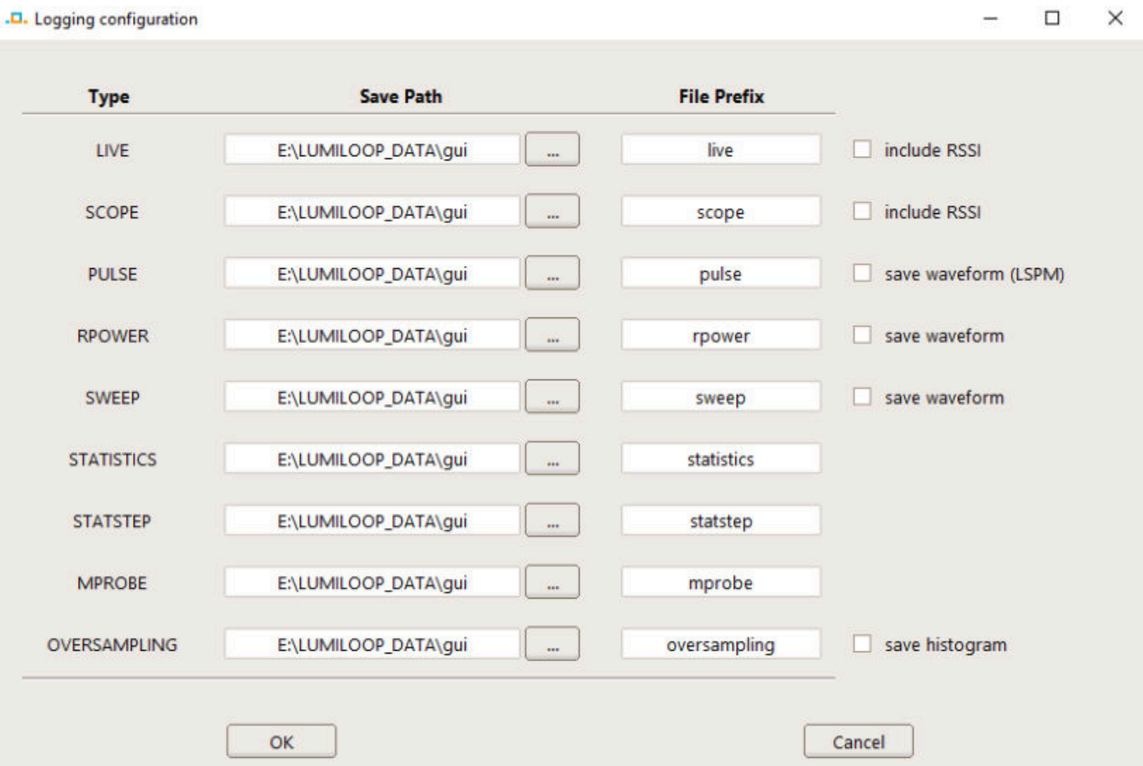


Figure 66: *LUMILOOP GUI, Data Logger tab*

5.11 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 12.1.1, 12.1.2 and 12.1.4. 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 12.1.8 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 68

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.

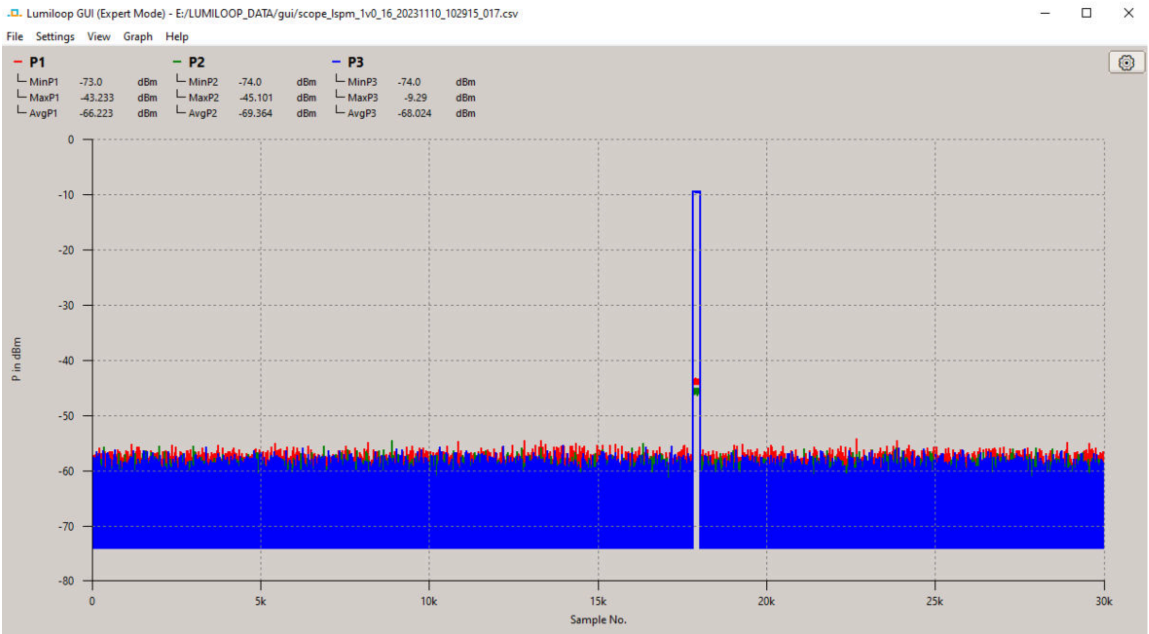
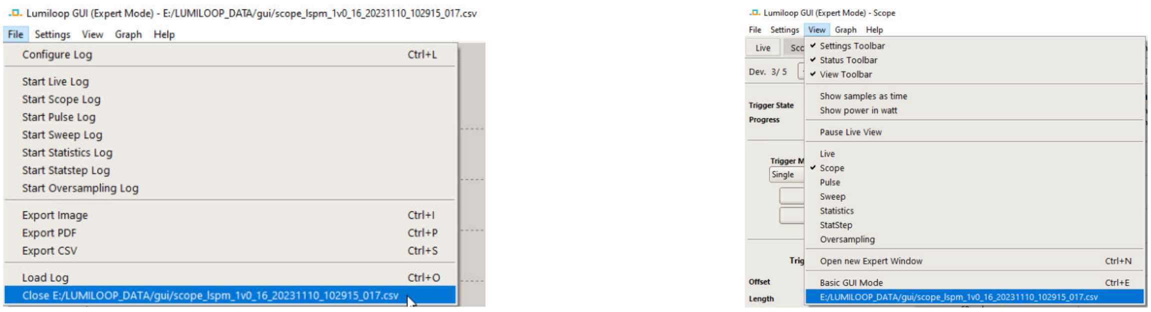


Figure 67: *LUMILOOP GUI, Data Load view*



(a) Reselect loaded file

(b) Close opened file

Figure 68: *Menu entries for loaded file*

6 Stand-Alone CI-250⁺ /, LSPM 1.0⁺, LSPM 2.0⁺

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 104 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 55 and Figure 40.

6.2 Getting ready to Measure

6.2.1 Making Optical Connections (LSPM 1.1+/2.1+)

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 power head being connected to it!**

Sacrificial optical cables are supplied with each LSPM 1.1/2.1 . Always use the E2000 connectors shown in Figure 69 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 69: *E2000 coupler of sacrificial optical cable assembly*

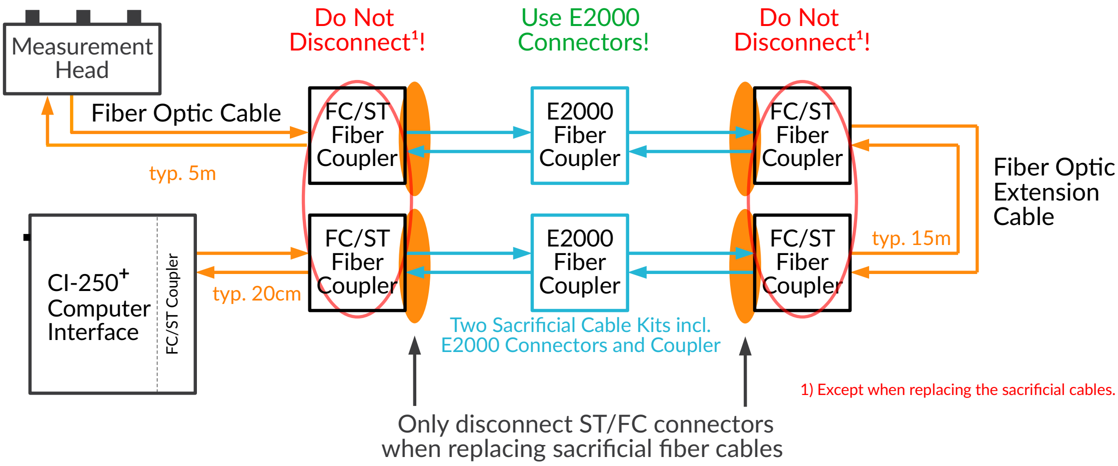


Figure 70: *Principle of sacrificial optical cable assembly*

The principle of the sacrificial cable assembly is explained in Figure 70. 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 71 for the correct alignment.

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

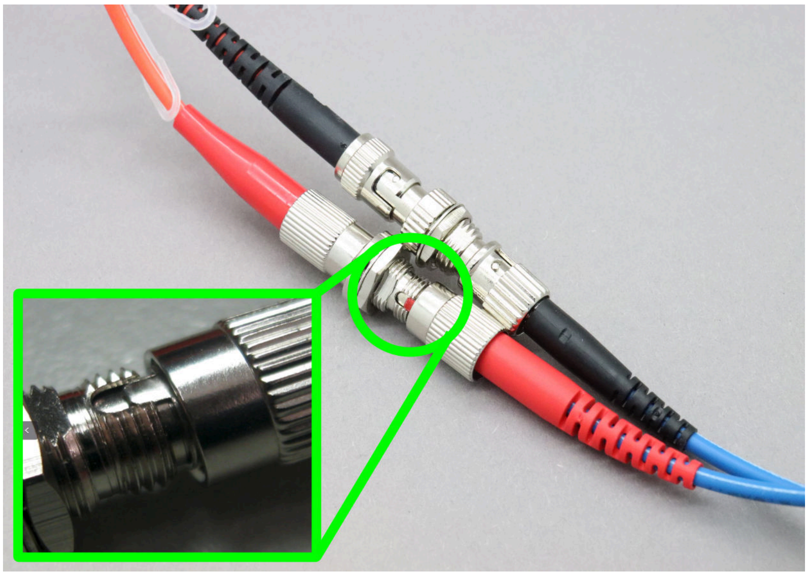


Figure 71: *FC fiber connector alignment*

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 72.

6.3 "+"Device GUI

6.3.1 General Notes on the "+"Device GUI

The "+"Device GUI, as depicted in Figure 82, is able to handle multiple USB devices. This includes the built-in LSPM Power Meter and additional, externally connected CI-250 Computer Interfaces and LSPM Power Meters. **+** Devices can also connect to remote LUMILOOP TCP Servers via the "TCP Server Connections" dialog, see Section 6.5.2 on page 101 for details. Only one device is displayed

Figure 72: **+** *Device after start up*

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 73. 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.

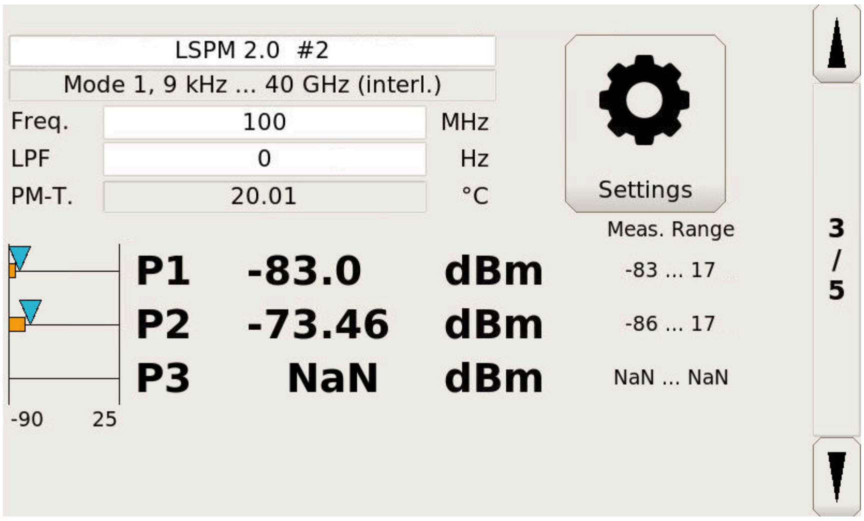


Figure 73: *"+"Device GUI appearance while managing multiple devices*

Press the middle button of the scrollbar to switch between "Basic" and "Table" mode. The "Table" mode, as shown in Figure 74, 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 setup. To disable this behaviour, click on "Apply Settings to all Devices" in the "Settings" dialog, as shown in Figure 83 (a).

For settings requiring numeric or text input, an on-screen keyboard is displayed in the appropriate

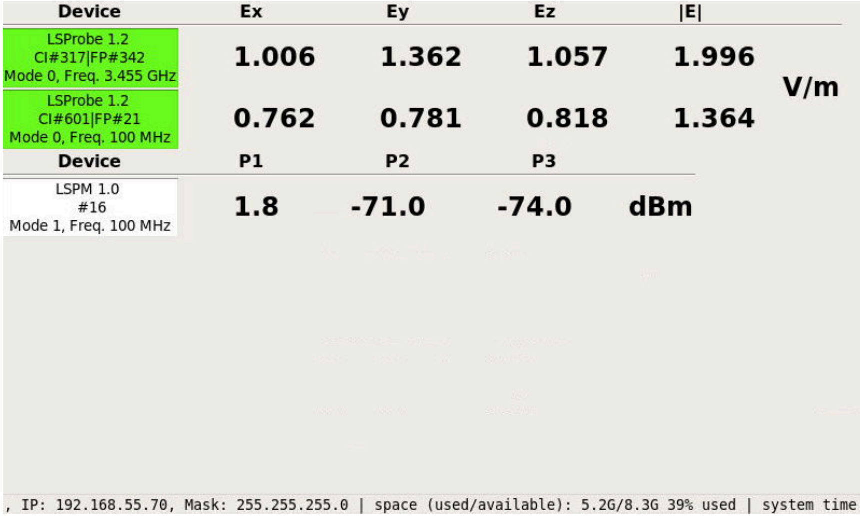
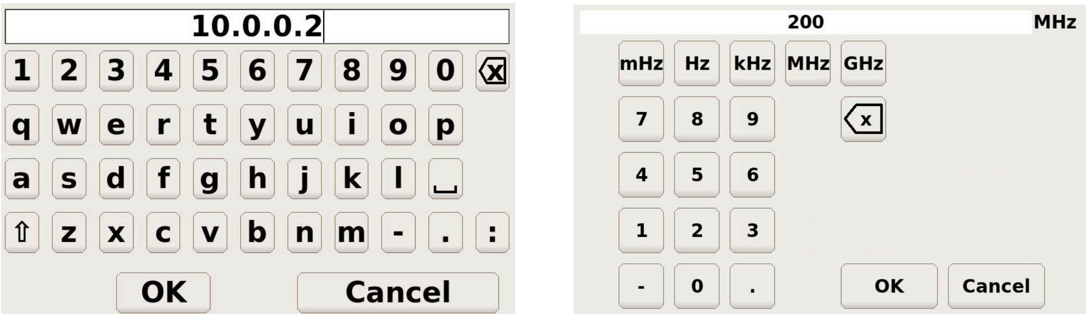


Figure 74: *"+"Device GUI table mode*

mode, as depicted in Figure 75.



(a) Generic appearance (b) Numeric appearance

Figure 75: *"+"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 (LSPM 1.1+/2.1+)

Clicking on the button labeled "Laser OFF" in the upper right corner of the screen activates the supply laser and sets the power meter 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. 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 77).

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

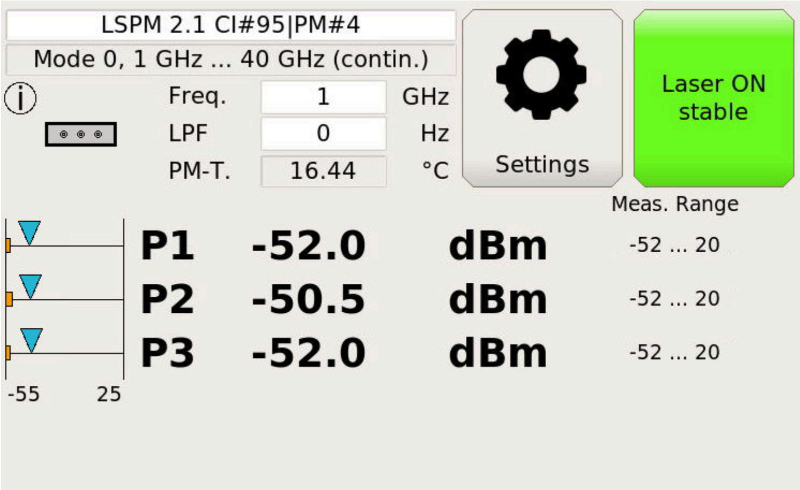


Figure 76: *"+"Device GUI with enabled laser*

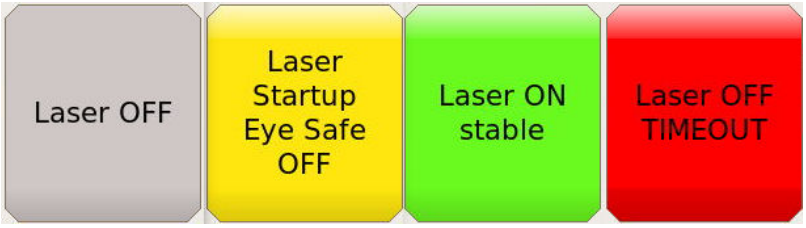


Figure 77: *"+"Device GUI laser indicator when off, during start-up, in safe operation and upon encountering a time-out error*

fibers gets interrupted, the supply laser will be switched off within ten milliseconds and the +GUI will present the red indicator shown in Figure 77.

Clicking on the image of the power head in the top left of the screen will open the dialog shown in Figure 78. It contains the status of the laser link, including temperatures and the operating conditions of optically powered devices.

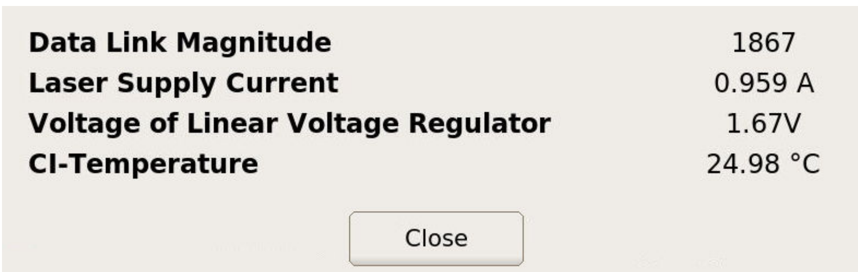


Figure 78: *"+"Device GUI Laser Link Status window*

6.3.3 Mode Selection Using the "+"Device GUI

For accurate power measurements, the signal'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 power 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.

To reduce the noise of the measured power 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 power 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 power meter is shown below the low-pass filter field in the main window.

To change the mode, open the dialog shown in Figure 79. It is opened via the "Mode" button in the "Settings" dialog shown in Figure 83.

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 , mode 5 is supported by LSPM 1.1/2.1 only, 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 79. Alternatively, press the "M1 Transition Freq." or "M1/M5 Transition Freq." for optically powered LSPM devices, button in the "Settings" dialog on the right side of the second button row, see Figure 83. If there is no calibration data, "?" will be displayed in the frequency range fields. For laser powered LSPM 1.1 or 2.1 Power Meters, the frequency range and video bandwidth columns will display "?" as well, as long as the laser is not enabled. The depicted values are a device-specific version of the values shown in Table 1 to Table 4 on page 23 to page 26.

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 80 will open. If accredited calibration data are available, its certificate string will be displayed.

As described in Section 9, LSPM Power Meters are calibrated using CW signals. Most measurement scenarios in EMC testing use unmodulated CW signals as well, but certain standards, e.g., ISO 11452-9:2021, Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy, Part 9: Portable transmitters, require modulated signals. For modulation bandwidths up to about the video bandwidth, the measurement error due to modulation is negligible. According to Table 1 through Table 4, the highest video bandwidth, and therefore lowest error for modulated signals, is achieved in mode 0. For modulation bandwidths beyond the

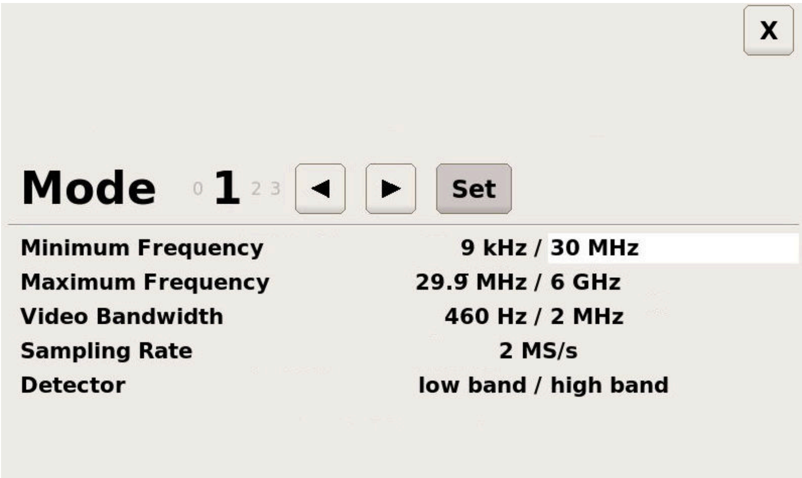


Figure 79: *"+"Device GUI Operating Mode configuration dialog*

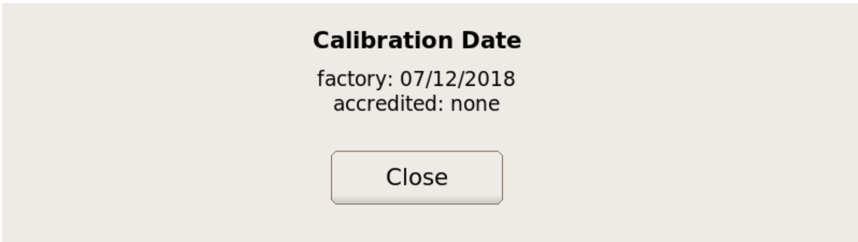


Figure 80: *"+"Device GUI Calibration dates dialog of current LSPM*

detectors' video bandwidth, additional correction factors are needed to compensate the measurement error due to modulation.

These correction factors can be configured In the "Wideband Correction" dialog, accessible from the "Settings" dialog. Selecting "0 MHz" disabled wideband correction. Otherwise, the TCP-Server will apply the appropriate correction factors for the given frequency. For LSPM 1.0 and 1.1 Power Meters correction factors for measurements according to ISO 11452-9:2021 are available for a bandwidth of 10, 20, 80, 100 and 160 MHz, for frequencies between 0.7 and 6 GHz, in mode 0. For different modes and frequencies outside this range, only "0 MHz" will be shown by the "Wideband Correction" dialog. Note that additional correction factors can be created by adding files according to the file format described in Section 12.4.3.

6.4 Continuous Power Measurements Using the +GUI

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

At the top of the "+"Device GUI the measurement device identification string, the current operating

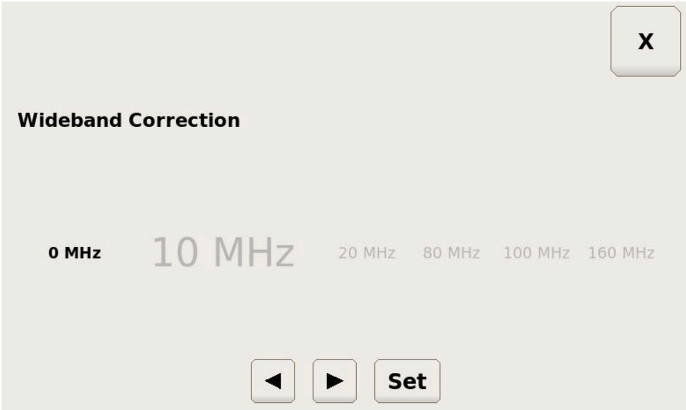
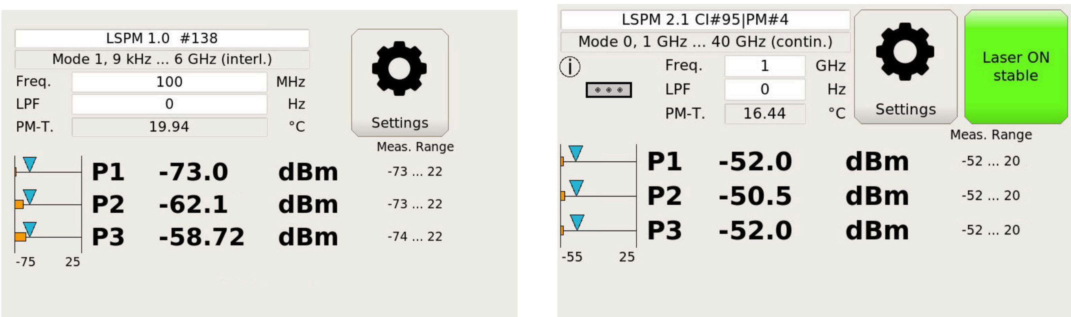


Figure 81: *"+"Device GUI Wideband Configuration dialog*

mode, the calibrated frequency range, the operating frequency, the low-pass filter setting and the power meter temperature are displayed. Upon clicking on the device identification string, a dialog containing the factory and accredited calibration date is shown, see Figure 80, "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.



(a) "+"Device GUI conventional power meter (b) "+"Device GUI optically supplied power meter

Figure 82: *"+"Device GUI LSPM devices connected*

As shown in Figure 82, the "+"Device GUI displays the measured power values for up to three channels in the lower half of the display. Single and dual channel power meters display " Nan" for unavailable channels. In the bottom left of the display, the measured values are shown as a bar graph. The orange bars represent the instantaneous power values, the blue triangles serve as peak markers with a built-in decay. A numerical representation of the instantaneous power 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

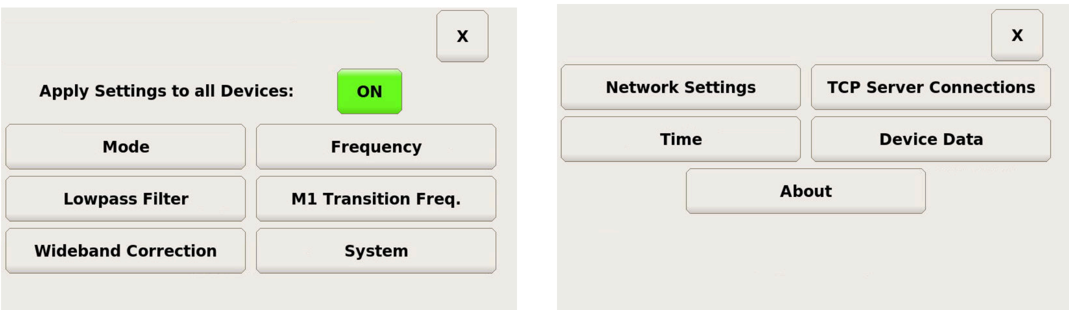
The "Settings" dialog is opened by pressing its button in the "+"Device GUI. It gives access to all LSPM settings, including operating mode, frequency and network configuration. The dialog will first open as depicted in Figure 83 (a), see Section 6.3.3 and 6.4 for details of the available settings. The 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 83 (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 84.

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



(a) Device Settings (b) System Settings

Figure 83: *"+"Device GUI "Settings" Dialog*

Figure 84: *"+"Device GUI About Dialog with Installer Revision*

6.5.1 Network Configuration

The "Network Configuration" dialog, shown in Figure 85, 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 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.

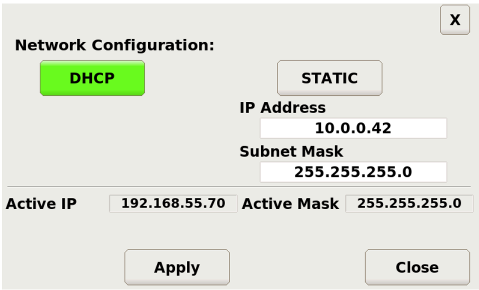


Figure 85: *"+"Device GUI Network Configuration Dialog*

6.5.2 TCP Server Client Connections

The dialog, shown in Figure 86, 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.

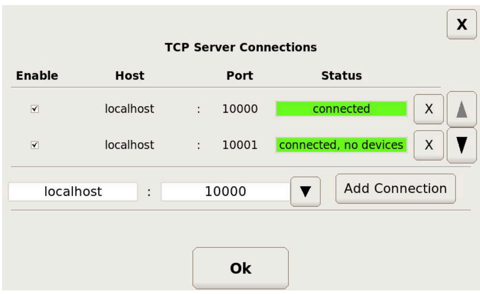


Figure 86: *"+"Device GUI Active TCP Server Client Connections Dialog*

6.5.3 System Time

System time can be set either manually or automatically using the network time protocol (NTP) as shown in Figure 87. 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 87: *"+"Device GUI System Time Setting Dialog*

6.6 Plus Device Manager

The Plus Device Manager is shown in Figure 88. 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 88: *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 88 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.

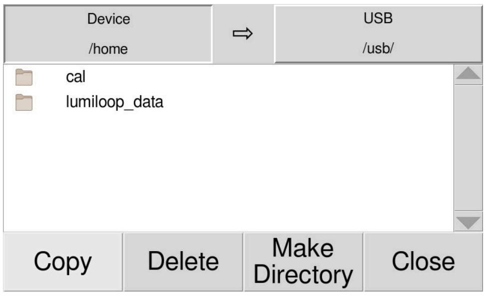


Figure 89: *USB Device Manager, Files Window*

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 90. 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.

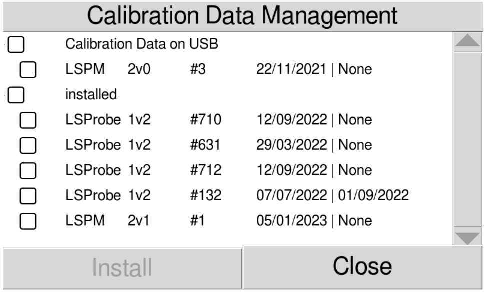


Figure 90: *USB Device Manager, Calibration Update Dialog*

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.

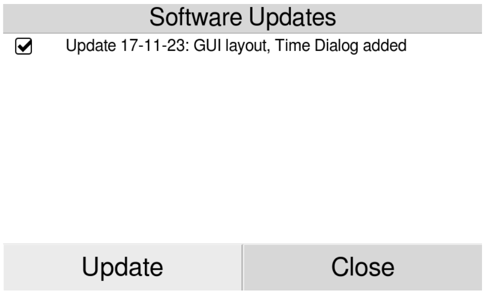


Figure 91: *USB Device Manager, Software Update Dialog*

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.

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 LSPM Power Meter in third party EMC test automation software. Third party support-files are installed in separate directories of the `lib` sub-directory of the LUMILOOP installation path.

Before running any third party EMC software follow the hardware setup instructions detailed in Section 5.1 on page 50 and start the LUMILOOP TCP Serveras described in Section 5.2.1 on page 52.

Starting the TCP server, setting the operating mode, enabling the laser in case of the LSPM 1.1 Power Meter or LSPM 2.1 Power Meter and starting third party software can be automated by the "LUMILOOP-Starscript.pl" Perl script in the `bin` sub-directory of the LUMILOOP installation path. "Strawberry Perl" has to be installed in order to use the start script. In Line 28 and 29 the paths for the LUMILOOP TCP Server and the third party software must be set appropriately. The measurement mode is defined in line 30, with a default value of "1". After closing the third party software, the TCP-Server will be terminated as well.

The LUMILOOP GUI is not required when using third party EMC software. For convenience, the GUI can be used for enabling the supply laser and setting the mode. 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 LSPM, e.g. version 1.x and version 2.x, please note the difference of the frequency ranges as described in Table 1 to Table 4.

7.1 Rohde & Schwarz – EMC32

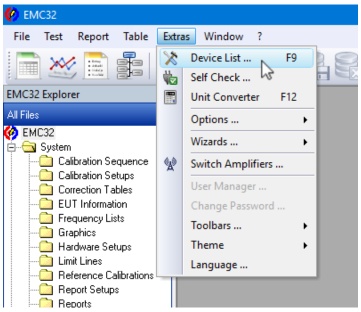
LUMILOOP recommends using the most recent version of the R&S EMC32 measurement software since EMC32 integration is always tested against the most recent EMC32 release. The LSPM Power Meter is supported by EMC32 version 10.3 and later.

Copy all device configuration files ending in `DeviceConfiguration` from the `EMC32-10.3` sub-directory of the LUMILOOP installation path's `lib` directory to the EMC32 program data path's `Configuration\Power Meters` sub-directoy, a typical location is `C:\ProgramData\EMC32\Configuration\Power Meters`.

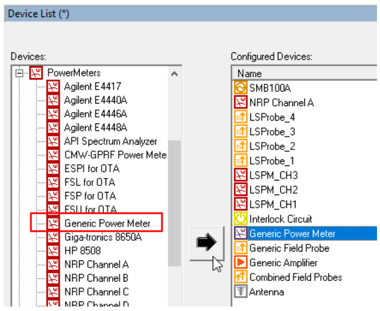
7.1.1 CW Measurement

To set up the LSPM Power Meter in EMC32 run the TCP server, then start EMC32.

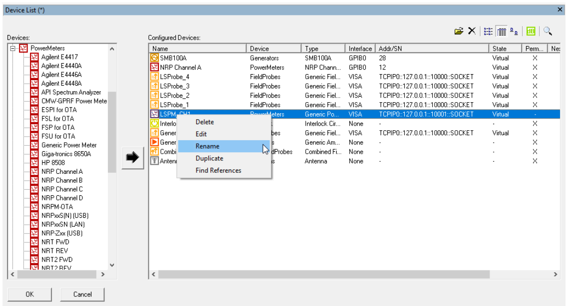
Open the EMC32 Device List via "Extras→Device List" in the menu bar as shown in Figure 92 (a). In the "Device List" window select "Generic Power Meter" from the "Devices:" list's "Power Meters" category and create a new "Configured Device" by clicking on the right-pointing arrow in the center as shown in Figure 92 (b). This will create a new entry named "Generic Power Meter". Optionally add a second and a third "Generic Power Meter" entry by clicking the right-pointing arrow an additionally one or two times. The first power meter will be used for channel 1 power value queries, the second for channel 2 and the third for channel 3. Rename the first "Generic Power Meter" entry to "LSPM_Ch1" and the optional second and third entries to either "LSPM_Ch2" or "LSPM_Ch3" via "right-click→Rename" as shown in Figure 92(c).



(a) Opening the Device List



(b) Adding Generic Power Meter(s)

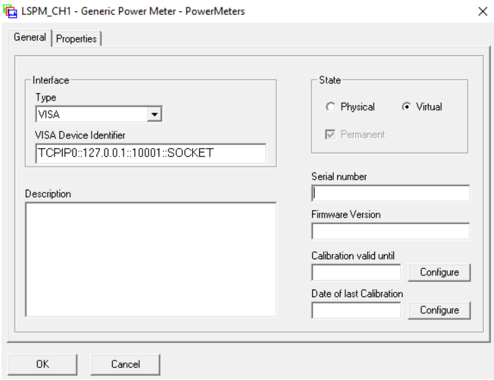


(c) Renaming Power Meters

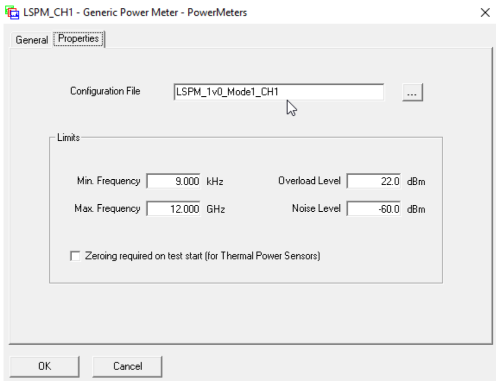
Figure 92: *Adding the LSPM Power Meter in EMC32*

Use "right-click→Edit" to open the Generic Power Meter's settings. In the "General" tab shown in Figure 93 (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 10001. Consequently, the default identifier string is "TCPIP0::127.0.0.1::10001::SOCKET". All other settings in the "General" tab are optional and may be left unchanged.

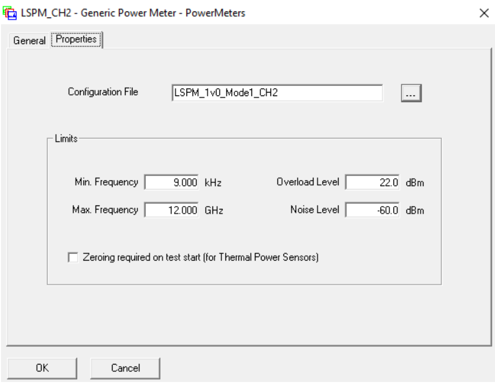
Select the "Properties" tab shown in Figure 93(b) through (d), edit all parameters as detailed in Table 6. Select the appropriate file for "Configuration File" located in `...\ProgramData\EMC32\Configuration\Power Meters`. The low pass filter value in the `.DeviceConfiguration` files can be adjusted by the user to accommodate longer or shorter settling times.



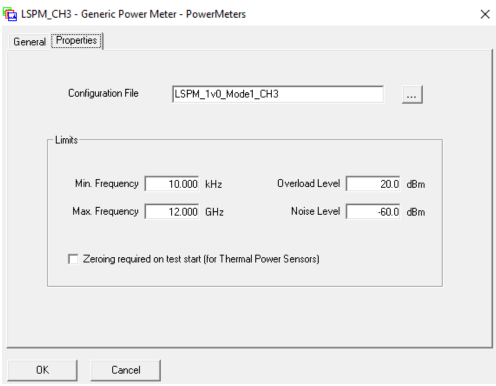
(a) General Settings



(b) Channel 1 Power Meter Properties



(c) Channel 2 Power Meter Properties



(d) Channel 3 Power Meter Properties

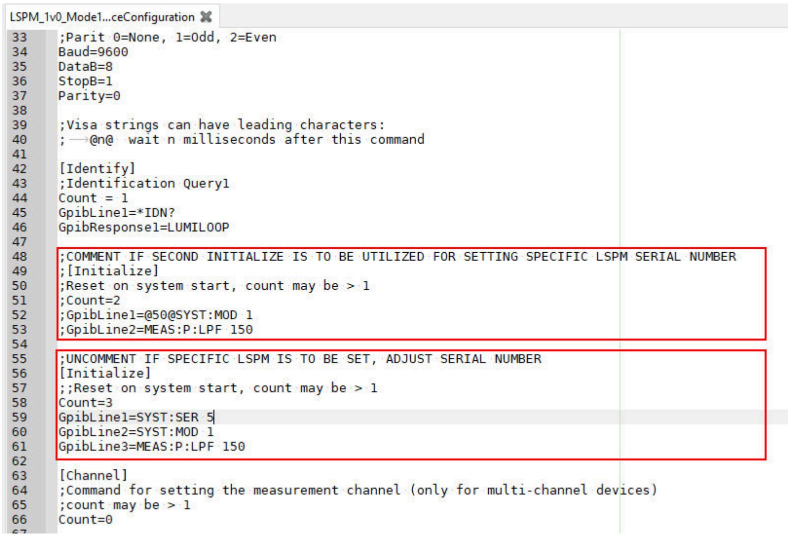
Figure 93: *Configuring LSPM Power Meters in EMC32*

Table 6: *EMC32 Property tab values for the LSPM Powermeter Channel 1*

Setting	**LPSM 1.0/1.1**	**LPSM 2.0/2.1**
Min. Frequency	9.000 kHz	9.000 kHz
Max. Frequency	12.000 GHz	40.000 GHz
Overload Level	22 dBm	15 dBm
Noise Level	-60 dBm	-60 dBm
Zeroing required on test start	unchecked	unchecked
Configuration File	LSPM_Mode1_CH1.DeviceConfiguration	LSPM_Mode1_CH1.DeviceConfiguration

To finish the setup restart EMC32 and open the EMC32 Device List via "Extras→Device List". Use "right-click→Edit" for the "LSPM" 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.

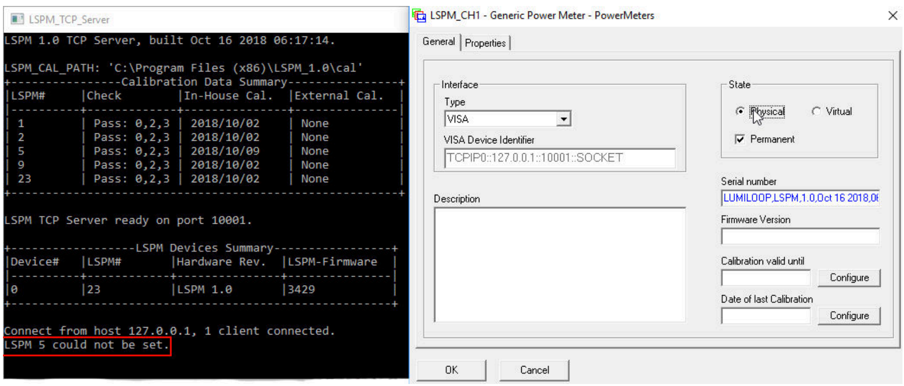
For multiple LSPM Power Meters, the configuration files have to be adapted so that a specific LSPM gets selected by a EMC32 client connection for communication. The first "[Initialize]" block encompassing line 49 to 53 has to be commented. The second "[Initialize]" block encompassing line 55 to 61 must not be commented out. An additional SCPI command is send to the LUMILOOP TCP Server setting the active power meter. The specific serial number is set in line 59. After changing "State" from "Virtual" to "Physical" check the TCP-Server window. If the setting of the active LSPM failed, an error message will be printed to the TCP server window, as depicted in Figure 94 (b). If



LSPM_1v0_Mode1...ceConfiguration

```
33 ;Parit 0=None, 1=Odd, 2=Even
34 Baud=9600
35 DataB=8
36 StopB=1
37 Parity=0
38
39 ;Visa strings can have leading characters:
40 ;    @n@  wait n milliseconds after this command
41
42 [Identify]
43 ;Identification Query1
44 Count = 1
45 GpibLine1=*IDN?
46 GpibResponse1=LUMILOOP
47
48 ;COMMENT IF SECOND INITIALIZE IS TO BE UTILIZED FOR SETTING SPECIFIC LSPM SERIAL NUMBER
49 ;[Initialize]
50 ;Reset on system start, count may be > 1
51 ;Count=2
52 ;GpibLine1=@50@SYST:MOD 1
53 ;GpibLine2=MEAS:P:LPF 150
54
55 ;UNCOMMENT IF SPECIFIC LSPM IS TO BE SET, ADJUST SERIAL NUMBER
56 [Initialize]
57 ;;Reset on system start, count may be > 1
58 Count=3
59 GpibLine1=SYST:SER 5
60 GpibLine2=SYST:MOD 1
61 GpibLine3=MEAS:P:LPF 150
62
63 [Channel]
64 ;Command for setting the measurement channel (only for multi-channel devices)
65 ;count may be > 1
66 Count=0
```

(a) Modification of LSPM_1v0_Mode1_CH1.Device-Configuration file



(b) Check LUMILOOP TCP Server for error messages

Figure 94: *Adapting LSPM device configuration files for selecting specific LSPM*

7.2 Nexio – BAT-EMC

The BAT-EMC software supports CW and pulsed power 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 "One-input Power Meter" equipment models listed in Table 7 by right-clicking on “One-input Power Meter” inside the “Equipment” tree structure as shown in Figure 95.

Table 7: *BAT-EMC equipment model files for CW and pulsed powers*

CW	Pulsed
LSPM_xv0_CW1.xml	LSPM_xv0_Pulse1.xml
LSPM_xv0_CW2.xml	LSPM_xv0_Pulse2.xml
LSPM_xv0_CW3.xml	LSPM_xv0_Pulse3.xml
LSPM_xv1_CW1.xml	LSPM_xv1_Pulse1.xml
LSPM_xv1_CW2.xml	LSPM_xv1_Pulse2.xml
LSPM_xv1_CW3.xml	LSPM_xv1_Pulse3.xml

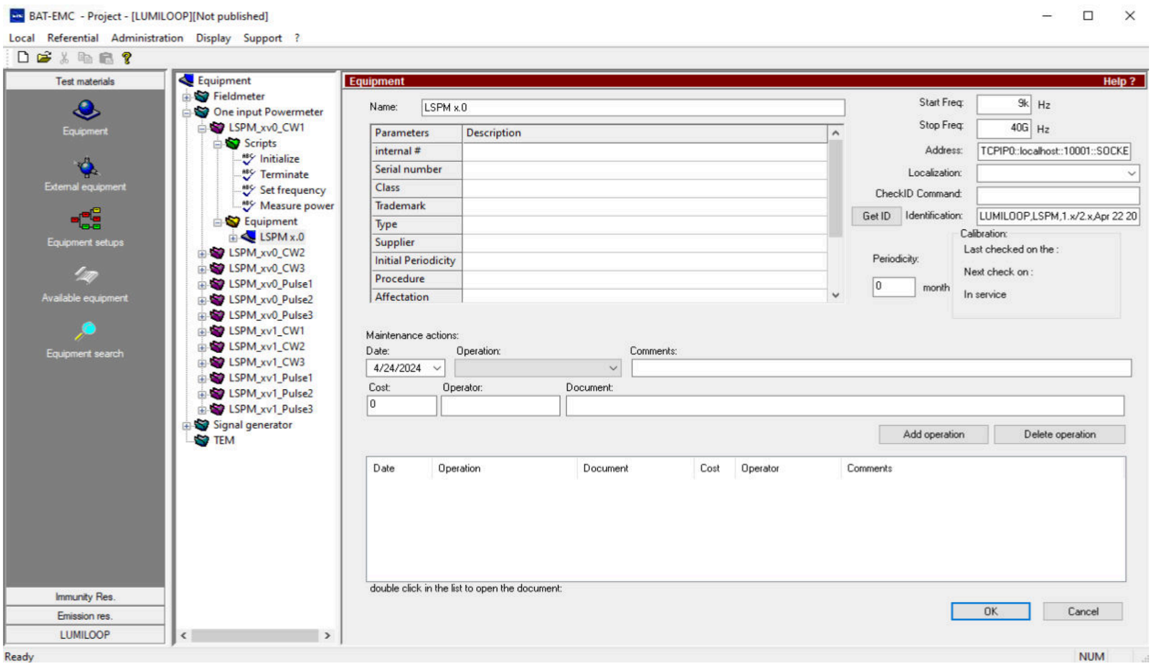


Figure 95: *BAT-EMC Equipment editor, network configuration*

If the IP address and/or the port number of the LSPM connection differ from the default values of localhost and port 10001, go to the “Equipment” subsection and change the “Address” input field appropriately, see also Figure 95.

BAT-EMC requires the LSPM Power Meter to be configured and, in case of optically powered LSPM 1.1 Power Meter or LSPM 2.1 Power Meter, with the laser enabled, before performing measurements. Before starting BAT-EMC, start the LUMILOOP TCP Server and optionally LUMILOOP GUI, enable the supply laser in case of LSPM 1.1/2.1 Power Meters and set the desired mode as described in Sections 5.2.1 through 5.2.6.

7.2.1 CW Power Measurements

The "One-input Power Meter" models "LSPM_xv0_CW1" and "LSPM_xv1_CW1" handle all communication including setting/checking the operating frequency as well as retrieving channel 1, channel 2 and channel 3 power values. The power meter returns the channel 1 power value and stores the power values of channel 2 and channel 3 in global variables named "PB" and "PC". The four "One-input Power Meter" models "LSPM_xv[0/1]_CW[2/3]" retrieve the global variables and return the respective channels' power values. When measuring channel 1, channel 2 and channel 3 power values, the "LSPM_xv[0/1]_CW1" Power Meter model must be called first.

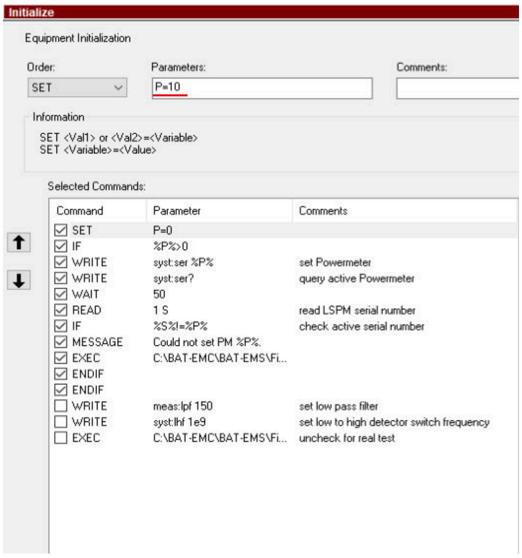
7.2.2 Pulsed Power Measurements

The "One-input Power Meter" model "LSPM_xv[0/1]_Pulse1" handles all communication including setting/checking the operating frequency as well as retrieving channel 1, channel 2 and channel 3 power values. Additionally, the "One-input Power Meter" model includes commands for trigger subsystem configuration, trigger detection and pulse property retrieval. The "One-input Power Meter" returns the channel 1 averaged pulse power value and, if enabled, queries and stores the power values of channel 2 and 3 using global variables named "PB" and "PC". The two "One-input Power Meter" models "LSPM_xv[0/1]_Pulse[2/3]" read these global variables and return the respective channels' averaged pulse power values. When measuring channel 1, channel 2 and channel 3 power values, the "LSPM_xv[0/1]_Pulse1" "One-input Power Meter" model must be called first.

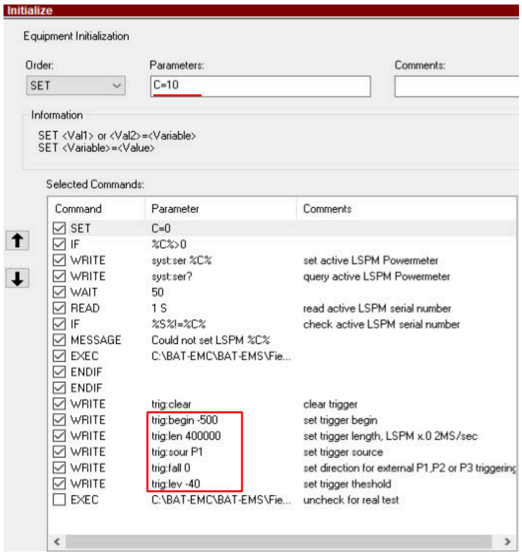
The trigger subsystem's configuration can be modified via the "One-input Power Meter" model's "Initialize" script, the relevant commands are shown inside the red frame in Figure 96 (b). See Section 5.4.2 for more information about the trigger subsystem's SCPI commands.

Figure 97 shows the "Measure level" script of the "LSPM_xv[0/1]_Pulse" "One-input Power Meter" 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 power values.

The default setting of the "LSPM_xv[0/1]_Pulse" "One-input Power Meter" model is suitable for the GMW-3097 standard. It will record a waveform of length 200 msec, i.e. 400,000 samples for LSPM x.0 and 200,000 samples for LSPM x.1 devices (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 power values for channel 1. The trigger source, trigger length and expected pulse count can be modified by editing the respective scripts. Pulse count checking can be disabled by setting the



(a) LSPM_xv[0/1]_CW1 Initalize script



(b) LSPM_xv[0/1]_Pulse1 Initalize script

Figure 96: *Configuring the Initialize scripts for LSPM x.0 CW and pulse measurements in BAT-EMC*

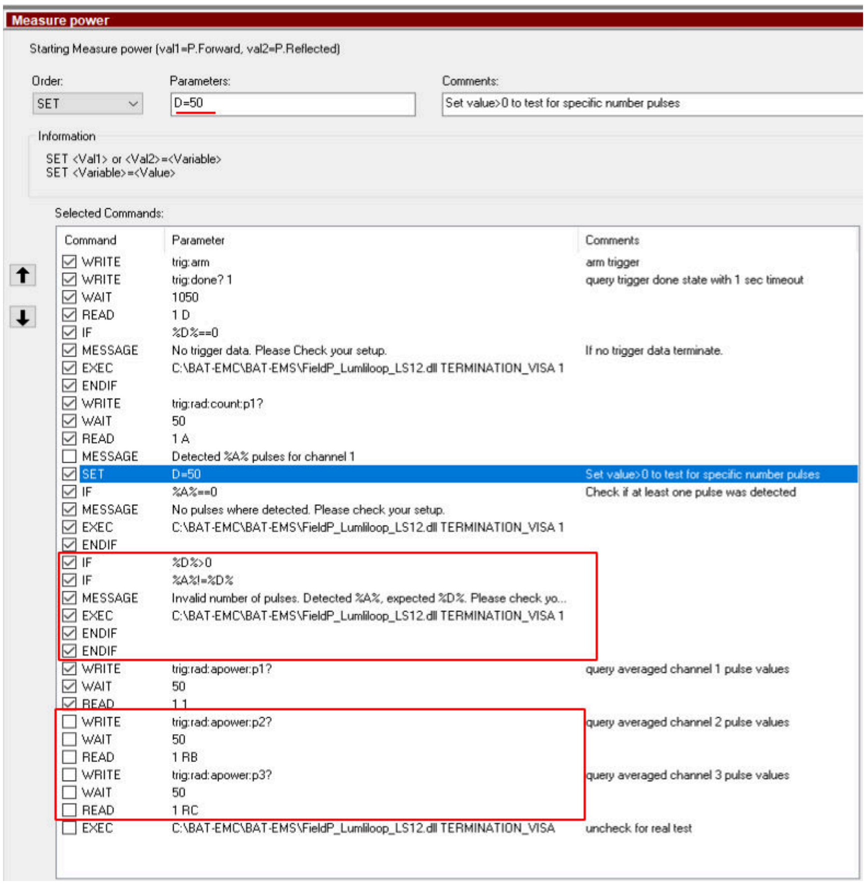


Figure 97: *Configuring the "Measure power" script for LSPM x.0 pulse measurements in BAT-EMC*

parameter "D" to "0". To additionally retrieve the averaged pulse power values for channel 2 and 3, check the boxes in the lower red frame in Figure 97.

If multiple LSPM Power Meters are attached to the host computer, the active power meter must be set. For LSPM x.0 devices, set the variable P in Figure 96(a) to a value other than zero. Doing so will enable the setting and verification In case of optically powered LSPM x.1 devices, set the variable C in Figure 96(b) to a value other than zero, where "C" stands for the Computer Inteface serial number. Doing so will enable the setting and verification of the traditional power meter's serial number and the computer interface's serial number for optically powered devices. The Figure 96(a) demonstrates setting the LSPM x.0 Power Meter's serial number to 10, the serial number must be changed to match the desired power meter's serial number. Figure 96(b) demonstrates setting the LSPM x.1 Power Meter's Computer Interface serial number to 10, the serial number must be changed to match the desired CI-250$^{(+)}$ Computer Interface's serial number. The variables are available for both CW and pulsed "One-input Power Meter" models.

For monitoring multiple power meters in parallel, create a copy of all "One-input Power Meter" models by right-clicking on the "One-input Power Meter" models and choosing "duplicate". Adjust all model names and power meter serial number variable settings appropriately.

7.3 AR – Emcware

LUMILOOP recommends using the most recent version of the AR emcware measurement software. An LSPM 1.0/2.0 Power Meter driver, supporting emcware 4.1 and above is included in the LUMILOOP installer.

Before using the LSPM Power Meter in emcware, copy `LSPM_xv0.dll` from the `lib` sub-directory of the LUMILOOP software installation directory into the `PM` sub-directory of the `Equipment Drivers` directory of the emcware installation path, i.e. `C:\emcware v4.1\Equipment Drivers\PM`. Moreover, run the LUMILOOP TCP Server and select the desired mode as described in Sections 5.2.1, and 5.2.5. Emcware will not change the power meter mode setting.

In order to add the LSPM 1.0/2.0 Power Meter to the equipment list, start emcware, open the "Equipment List Manager", select "Power Meter" and click the "New" button to bring up the configuration window as shown in Figure 98. The serial number of the connected LSPM 1.0/2.0 Power Meter can be taken from the LUMILOOP TCP Server window. The correct LSPM 1.0/2.0 Power Meter serial number must be stated, else emcware will abort with an error and error message "Device 'X' could not be set" will be printed to the LUMILOOP TCP Server window.

Select "LSPM_xv0.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 with the LSPM server listening to the default TCP port 10,001. Consequently, the default identifier string is "TCPIP0::127.0.0.1::10001::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 calibration factors.

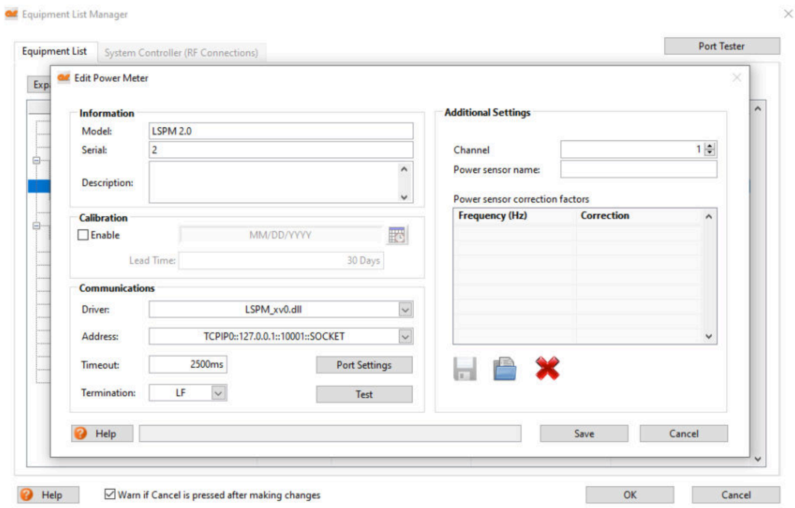


Figure 98: *Adding an LSPM 1.0 Power Meter in AR emcware*

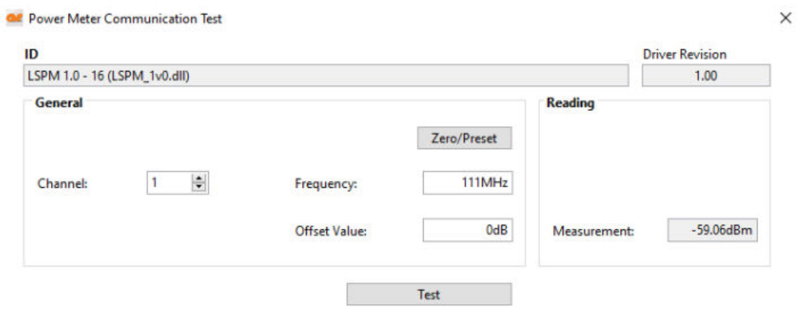


Figure 99: *Testing the LSPM 1.0 Power Meter in AR emcware*

Click on "Test" to verify that the power meter is working correctly as shown in Figure 99. This will open the window shown in Figure 99. Clicking "Test" will connect to the specified LUMILOOP TCP Server, set the correction frequency and read out the specified channel value.

7.4 TDK RF Solutions – Radiated Immunity Lab

7.5 ETS-Lindgren – TILE!

7.6 Rohde & Schwarz – ELEKTRA

7.7 TOYO - IM5CS

8 Virtual Power Meters

The LUMILOOP TCP Server is capable of instantiating virtual LSPM devices including the simulation of arbitrary power patterns.

Virtual power meters 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 power meters.

The following virtual power meter and, in case of virtual laser-powered rf power meters, computer interface properties can be configured:

- Computer interface serial number (LSPM 1.1/2.1 only),
- Computer interface supply laser state (LSPM 1.1/2.1 only),
- power meter version,
- power meter serial number,
- power meter temperature in °C and / or LSB (LSPM 1.1/2.1 only),
- power meter x-, y- and z-axis acceleration (LSPM 1.1/2.1 only) and
- power meter channel 1, 2 and 3 power value, see pattern description below.

Virtual computer interface serial numbers and power meter serial numbers must be unique, i.e., must not duplicate the serial numbers of any physical or virtual units. For optically powered power meters, the virtual power meter version and serial number must be configured before enabling the virtual supply laser. Power value patterns for channel 1, 2 and 3 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.

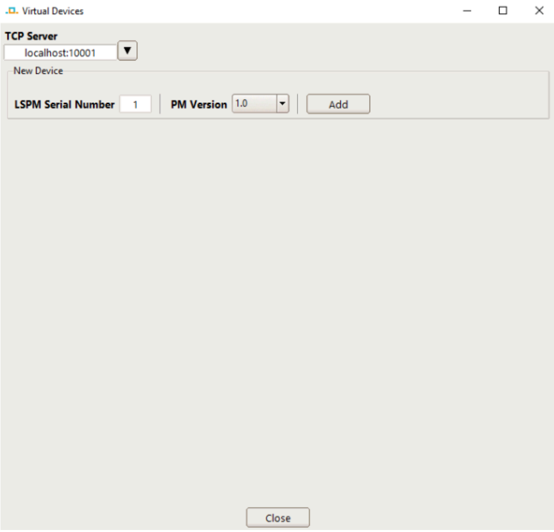
Pulse
: Generates periodically pulsed RSSI values whose OFF-value is zero and whose ON-value is configurable for each channel. The pattern's ON-time and period are configurable and apply to all channels.

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

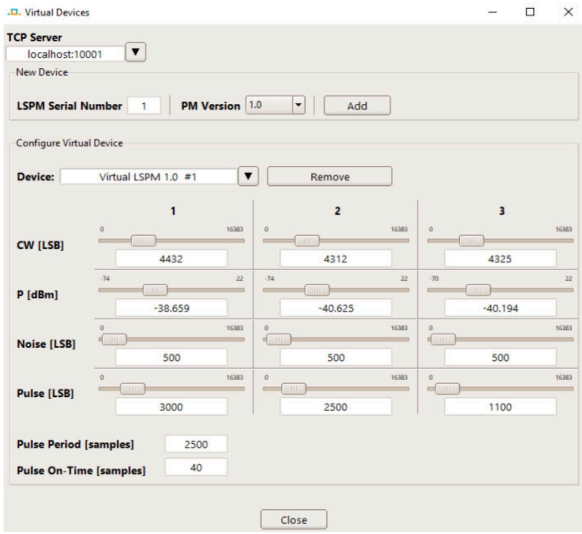
Virtual power meters support all operating modes. Triggering is supported with the exception of external trigger input and output. Virtual power meters support the collection of continuous statistics with the exception of synchronized continuous statistics. Note that a virtual statistics master power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

8.1 Controlling Virtual Power Meters Using the GUI

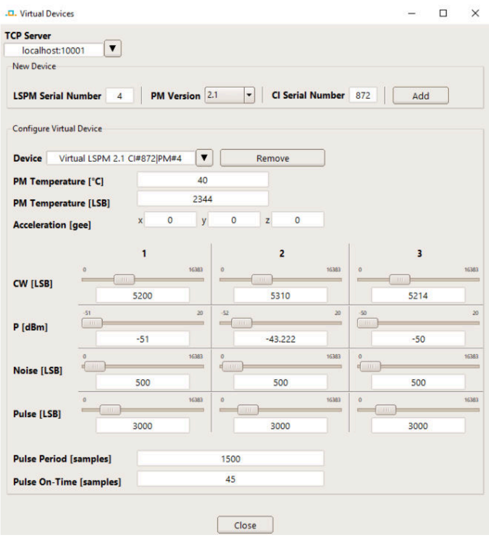
To open the "Virtual Devices" dialog go to "Expert Mode" of the LUMILOOP GUI and select the "Virtual Devices" item in the "Settings" menu. Alternatively press `Ctrl+M`. A dialog as depicted in Figure 100(a) will be opened.



(a) Virtual Devices Dialog



(b) Virtual Devices Dialog - LSPM 1.0



(c) Virtual Devices Dialog - LSPM 2.1

Figure 100: *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 power meter serial number, power meter version and, in case of optically powered LSPM 1.1 and 2.1 devices, 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 100(b) and (c) and show additional controls. The "Device" drop down menu lists all connected virtual LSPMs of the selected TCP Server client with their associated power meter's serial numbers and versions. Click the "Remove" button to disconnect the currently selected virtual device.

The selected virtual LSPM device can be configured using the controls in the frame below. Virtual power meter temperature in degree C, power meter temperature in LSB, acceleration(in case of optically powered LSPM 1.1 and 2.1 devices) and power pattern components are set using the controls inside the frame. Settings take effect as soon as they are entered. "PM Temperature [°C]" and "PM Temperature [LSB]" are interconnected, i.e. access the same base value. As soon as one value is adapted the other is automatically updated. "P [dBm]" controls are interconnected with the underlying "CW [LSB]" values and can only be used if the virtual power meter's laser is enabled (in case of laser-powered rf power meter). Power values are set to the nearest calibrated value for the current mode and frequency and temperature (LSPM 1.1/2.1 only) setting, i.e. changing frequency, mode or temperature setting will yield to different power values while the set RSSI values remain the same.

8.2 Controlling Virtual Power Meters Using SCPI Commands

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

empty
: An LSPM 1.0 of serial number 1 is added.

integer value X
: An LSPM 1.0 of serial number X is added.

device string "C:X.Y" or "C:XvY"
: An LSPM X.Y of serial number C is added in case of conventional power meters, else an LSPM X.Y of power meter serial number 1 and CI-250 serial number C is added.

device string "P:X.Y:C" or "P:XvY:C"
: An LSPM X.Y of serial number C is added in case of conventional power meters, else an LSPM X.Y of power meter serial number P and CI-250 serial number C is added.

»:VIRTual:CISerial?« lists the serial numbers of all virtual computer interfaces. »:VIRTual:SERial?« lists the serial numbers of all virtual power meters LSPM 1.0/2.0. The currently selected virtual device can be removed using »:VIRTual:DISConnect« The virtual power meter's serial number, version, temperature, supply voltage, acceleration values, in case of conventional power meter, and parametric power patterns are set/queried using the following SCPI commands:

- »:VIRTual:PMSerial <Value>« / »:VIRTual:PMSerial?«,
- »:VIRTual:PMVersion« / »:VIRTual:PMVersion?«,
- »:VIRTual:TEMPerature <Temperature>« / »:VIRTual:TEMPerature?« (LSPM 1.1/2.1 only),

- »:VIRTual:ACCeleration <ACCx>,<ACCy>,<ACCz>« / »:VIRTual:ACCeleration?« (LSPM 1.1/2.1 only),
- »:VIRTual:CW <RSSI1>,<RSSI2>,<RSSI3>« / »:VIRTual:CW?«,
- »:VIRTual:NOIse <NOISE1>,<NOISE2>,<NOISE3>« / »:VIRTual:NOIse?« and
- »:VIRTual:PULse [<RSSI1>],[<RSSI2>],[<RSSI3>],[<T>],[<Ton>]« / »:VIRTual:PULse?«.

Arbitrary power values are appended to the virtual power meter's list using »:VIRTual:LIST <RSSI1_1>,<RSSI2_1>,<RSSI3_1>[,...,<RSSI2_N>,<RSSI3_N>]« for arbitrary RSSI, »:VIRTual:PLIST <P1_1>,<P2_1>,<P3_1>[,...,<P1_N>,<P2_N>,<P3_N>]« for arbitrary power 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.

9 Power-Meter Calibration

The LSPM Power Meter uses data from factory and, optionally, accredited calibration for calculating accurate power values based on the ADC values generated by each of the power meter's channels, see Figure 8 on page 21 of the LSPM Manual for a principle block diagram of the power meter. The data is stored in factory calibration files and correction factor files.

9.1 Factory Calibration

Factory calibration records the digitized output voltage of both logarithmic RF detector circuits covering all channels, frequencies, signal levels and relevant modes. For optically powered models the ambient temperature is recorded as well. The resulting linearity and frequency compensation files, whose format is detailed in Section 12.4.1 of the LSPM Manual, contain the relationship between detector input power and returned ADC value. The LUMILOOP TCP Server interpolates between these data points to obtain stable, highly linear measurement results for each channel.

Tables 8 and 9 list the default factory calibration frequencies for LSPM 1.0/1.1 and 2.0/2.1. Calibration RF power is set in 1 dB steps, covering each detector from its noise floor to saturation.

Table 8: *LSPM 1.0/1.1 Power Meter default factory calibration frequencies, revision 2022-1*

Mode	Calibration Frequency Steps
2, 3	9 kHz, 15 kHz, 20 kHz to 100 kHz in 20 kHz steps, 400 kHz, 700 kHz, 1 MHz, 4 MHz, 7 MHz, 10 MHz to 385 MHz in 25 MHz steps, 400 MHz
0, 4	30 MHz, 40 MHz, 50 MHz, 60 MHz, 80 MHz, 100 MHz, 200 MHz, 300 MHz, 600 MHz, 900 MHz, 1.00 GHz to 4.25 GHz in 250 MHz steps 4.5 GHz to 8.2 GHz in 100 MHz steps

All LSPM power meters are factory calibrated in modes 0 and 3. LSPM 2.0 power meters are calibrated in mode 2 as well. LSPM 1.1 and 2.1 power meters are calibrated in modes 2 and 4 as well.

9.2 Accredited Calibration

Factory calibration is not accredited. Therefore, LSPM Power Meters supports the inclusion of accredited calibration factors.

Correction factor files of accredited calibration, whose format is detailed in Section 12.4.2 of the LSPM User's Manual, contain correction factors in decibel for a fixed calibration power and number of frequencies. Typically, calibration is performed at 0 dBm. If required, accredited calibration can be performed at multiple calibration power levels.

Table 9: *LSPM 2.0/2.1 Power Meter default factory calibration frequencies, revision 2023-1*

Mode	Calibration Frequency Steps
2, 3	9 kHz, 20 kHz, 30 kHz to 90 kHz in 20 kHz Steps, 100 kHz to 900 kHz in 200 kHz Steps, 1 MHz to 9 MHz in 2 MHz Steps, 10 MHz, 20 MHz, 30 MHz, 50 MHz, 70 MHz, 90 MHz 100 MHz, 120 MHz, 150 MHz, 180 MHz, 220 MHz, 270 MHz, 330 MHz, 390 MHz, 470 MHz, 560 MHz, 680 MHz, 820 MHz, 940 MHz, 1 GHz
0, 4	700 MHz, 800 MHz, 900 MHz, 1 GHz to 9.7GHz in 300 MHz Steps, 10 GHz to 14.95 GHz in 150 MHz steps 15.0 GHz to 35 GHz in 150 MHz steps 26.5 GHz, 37,55 GHz, 35.0 GHz to 40 GHz in 100 MHz steps

Accredited calibration of LSPM Power Meters has to be performed separately in mode 0 and 3, covering all frequencies of each mode. The displayed power values for frequencies covered by both detectors may differ. Thus, this frequency range must be calibrated both mode 0 and 3. Other modes may be calibrated if desired. Accredited calibration cannot be performed beyond the frequency range established by factory calibration.

9.2.1 SCPI-Commands for Calibration

At the beginning of a calibration session, the LSPM power meter should be reset to its default state. This is achieved by executing the SCPI command »`*RST`« or by (re-)starting the TCP-Server or the **+** Device.

(Re-)Calibration is always performed relative to the power meter's factory calibration data. Consequently, accredited correction factors must not be enabled as they would result in erroneous correction factors. Correction factors are disabled via the SCPI command »`:CALibration:CORRfactor 0`«. The automated calibration procedure should verify that accredited correction factors are disabled, both before and after the accredited calibration by executing the SCPI command »`:CALibration:CORRfactor?`«.

Using the LSPM Power Meter calibration logging feature during calibration is strongly recommended. It ensures correct operation of the LSPM Power Meter and efficient technical support in case of issues, by saving all measurement values and settings to a log file. Use the SCPI command »`:CALibration:LOGging 1`« to enable logging. Note that the TCP connection must not be closed during the calibration procedure, as this would interrupt logging.

Set the low-pass filter to 100 Hz, using the SCPI command »:MEASure:LPFrequency 100«. This helps reducing influence of detector noise on the measurement result. At 100 Hz, the required minimum dwell time is 50 ms between measurements.

For LSPM 1.1/2.1, the laser supply must be turned on prior to measurement. To enable the laser, use the SCPI command »:SYSTem:LASer:ENable <Value>«. Setting Value to 1 turns the laser on, using a value of 0 turns it off. Turning on the power laser and changing modes takes several seconds and might fail in case of an issue with the optical connection. Therefore, the SCPI commands »:SYSTem:RDY?« and »:SYSTem:LASer:TOut?« must be executed repeatedly until a value of 1 is returned for the former command and no timeout is returned for the latter command, before continuing with the calibration procedure.

For conventional LPSM(+) power meters, readiness must be verified by executing the SCPI command »:SYSTem:RDY?« to ensure that the required operating temperature has been reached. Depending on the ambient temperature, the warm-up or cool-down may take several minutes.

After inital start-up, a warm-up time of 15 minutes is recommended, for maximum accuracy.

The LSPM operating frequency must be set via the SCPI command »:SYSTem:FREQuency <Frequency>« for every frequency step. After letting the low-pass filter settle for at least the dwell time mentioned above, the SCPI command »:MEASure:P[1/2/3]?« is used to read the indicated power value of channel 1, 2 or 3.

Table 10 summarizes the commands needed for accredited calibration of LSPM Power Meters. Please refer to Section 11 of the LSPM User's Manual for details of all SCPI commands.

9.2.2 Calibration Parameters

It is recommended to use the calibration frequencies detailed in Tables 8 and 9 for accredited power calibration. While LSPM 2.0/2.1 are factory calibrated up to 40 GHz, they may be calibrated in an accredited fashion up to 26.5 GHz only, due to limited performance at higher frequencies.

If the factory calibrated frequency range does not match the accredited calibrated frequency range, the latter will be used to determine the usable frequency range.

Older devices may have deviating factory calibration frequencies and cover a smaller frequency range. These devices should be accredited calibrated using the calibration frequencies identical to the factory calibration frequencies. The LUMILOOP TCP Server will interpolate correction factors as needed if accredited calibration is performed at frequencies not covered by the factory calibration. The following commands can be used the query the factory calibration frequency range for the current mode:

- :CALibration:CORRfactor 0
- :SYSTem:FREQuency:MINimum?
- :SYSTem:FREQuency:MAXimum?

If the power meter needs to be calibrated over a wider range of frequencies, please contact LUMILOOP (calibration@lumiloop.de).

Correction factor file names generally take the format `AvBsnX_P_mM.csv`, where `AvB` denotes the LSPM variant, e.g., 1.0, or 2.1, `P` denotes the nominal calibration power and `M` denotes the mode of the power meter. For example, `2v0sn1_0_m0.csv` and `2v0sn1_0_m3.csv` are the calibration files for LSPM 2.0 Power Meter serial number 1, at 0 dBm in mode 0 and mode 3. The CalImport tool will generate files adhering to this file format.

For older LSPM 1.0 Power Meters, the file format may take either the format `snX.csv` or `snX_S.csv`, where `S` denotes an arbitrary string, for distinguishing different reference power values and power-meter modes. These files can be used with the most recent version of the LUMILOOP TCP Server, but lack the explicit mode specification and do thus not support multi-level calibration. The LUMILOOP TCP Server will parse the contents of all files matching this file name pattern and ignore the arbitrary string `S`.

9.3 Linearity and Reflection Measurement

In addition to measuring the frequency response of the LSPM power meter, accredited calibration usually includes a measurement of the input reflection factor and a linearity test as well.

For measuring the frequency response and reflexion factors, a power level of 0 dBm is recommend. For linearity testing, both detectors need to be tested individually. In mode 3, for the low-band detector, a test frequency of 50 MHz is recommended. In mode 0, for the high-band detector, a test frequency of 2 GHz is recommended. Make sure to execute the commands in Table 10 before starting linearity measurements.

The input reflection factor must be measured in both mode 0 and mode 3. Using the same frequencies as the frequency response measurement is recommended. The power meter needs to be turned on and be operating in the desired mode before measurements.

9.3.1 Measurement and Meta Data

To generate the correction factors for the LUMILOOP TCP Server, $P_{disp}(f)$, the indicated power level, $P_{cal}(f)$, the calibrated power level, both in dBm and, optionally, $CF(f)$, the correction factor in dB are required for each frequency in the calibration certificate. The mode that each measurement was conducted in has to be indicated as well, either by giving separate tables for each mode or by using an additional mode column in the table. Additionally, the measurement data must be provided in a machine-readable format. CSV format is preferred, see Section 12.3 for the specification of the format. Correction factors are calculated using the equation:

$$\frac{CF}{dB} = \frac{P_{disp}}{dBm} - \frac{P_{cal}}{dBm}.$$

The calibration certificate must state the factory calibration date of the LSPM Power Meter. This is necessary because accredited calibration is performed relative to a specific factory calibration (see Section 9.1). The factory calibration date can be retrieved by using the SCPI command »:CALibration:DATE?« which returns two dates, the factory calibration date and the accredited calibration date in a standard ISO format (YYYY-MM-DD).

9.3.2 Log Files

To ensure that LSPM Power Meters work correctly during calibration, and enable easier support in case of issues, log files can be created automatically during calibration. They record measurement results, including raw ADC values, the operating mode and other status data. Logging is enabled as mentioned in Table 10, by issuing the SCPI command »:CALibration:LOGging 1«. The LUMILOOP TCP Server will add a line to the log file when a »:MEASure:P[1]/P2/P3/ALL?« SCPI command is received. Log files are stored in the directory defined by the `SAVE_PATH` setting in the `LUMILOOP.ini` configuration file. A specification of the file format can be found in Section 12.2 of the LSPM User's Manual.

When an LSPM$^{(+)}$ 1.x/2.x Power Meter is calibrated, log files need to be transferred from the LSPM$^{(+)}$ 1.x/2.x Power Meter to the computer doing the data import by using a USB thumb drive connected to one of its USB ports. See Section 6.6.1 of the LSPM User's Manual for a detailed description of the data transfer procedure.

9.3.3 Calibration Data Import

As shown in Figure 101, 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.

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 12.3 on page 242. 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 12.4.2 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.

Import the calibration data using the following steps:

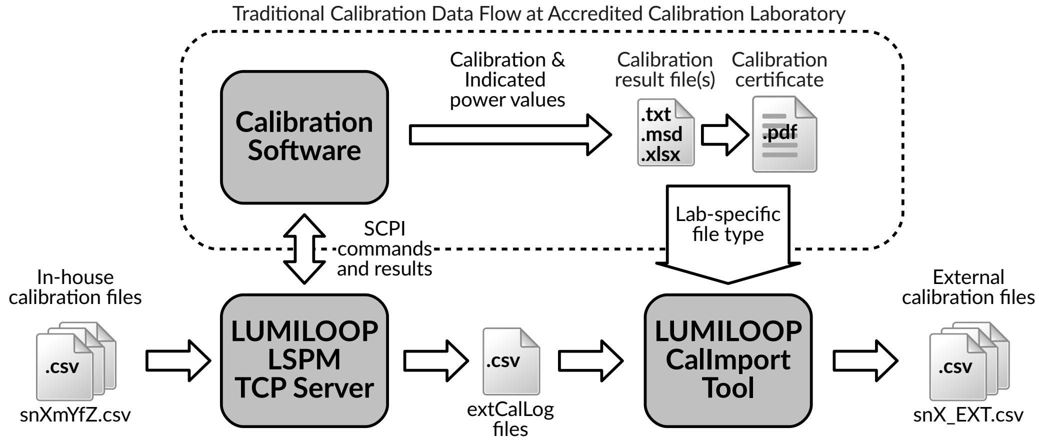


Figure 101: *Enhanced calibration data flow*

1. Run CalImport as shown in Figure 102.
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.

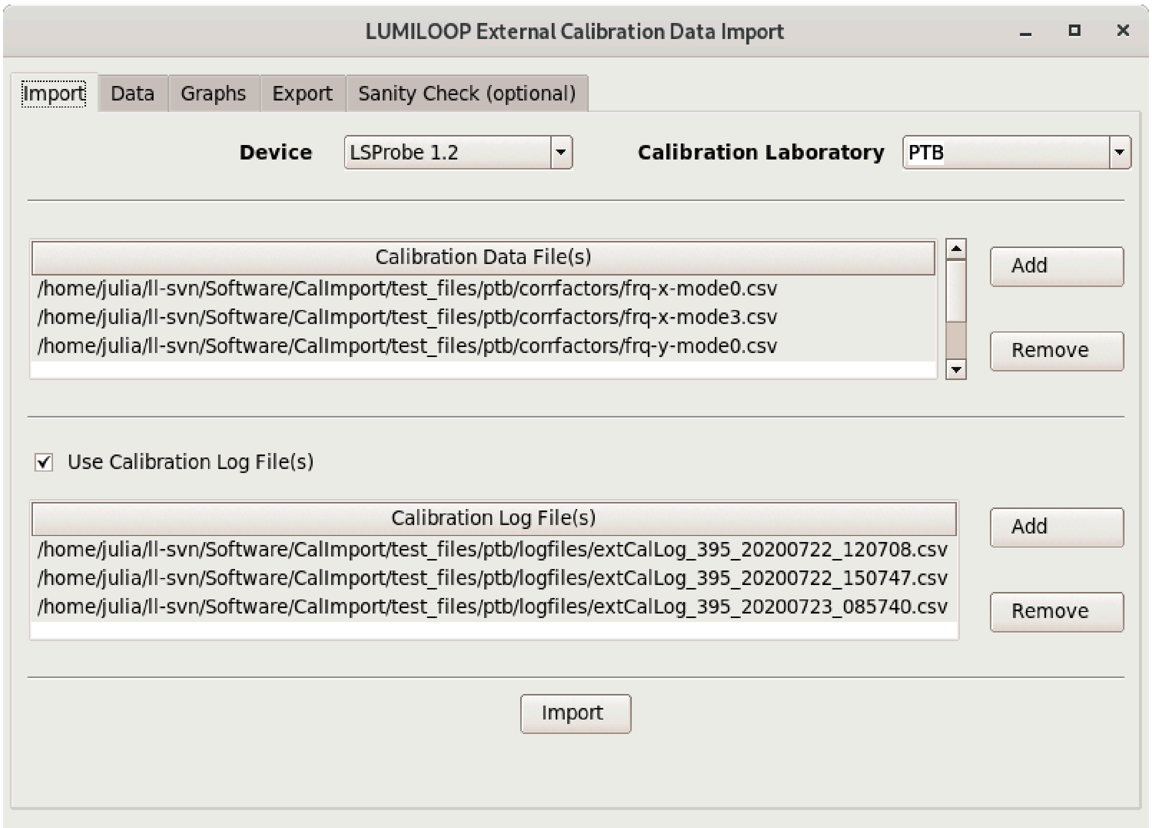


Figure 102: *Using the calibration data import tool CalImport*

Table 10: *LSPM Power Meter calibration procedure summary.*

SCPI Command	Description
`*RST`	Reset TCP-Server (once per calibration session)
`:CALibration:CORRfactor 0`	Disable correction factors
`:CALibration:CORRfactor?`	Verify that correction factors are disabled
`:CALibration:LOGging 1`	Enable calibration logging
`:MEASure:LPFrequency 100`	Set low-pass filter to 100 Hz
`:SYSTem:MODe <Mode>`	Set mode to 0 or 3
`:SYSTem:LASer:ENable 1`	Enable laser supply, LSPM 1.1/2.1 only
`:SYSTem:RDY?`	Wait readiness of LSPM, execute multiple times together with command below
`:SYSTem:LASer:TOut?`	Check for laser timeout, LSPM 1.1/2.1 only
`:CALibration:DATE?`	Read factory calibration date
	Before first measurement, wait 15 min for warm-up
`:SYSTem:FREQuency <Frequency>`	Set measurement frequency
	Wait for minimum dwell time of 50 ms before every measurement
`:MEASure:P[1/2/3]?`	Measure displayed power value for channel 1, 2 or 3
	Repeat previous two steps for all frequencies, power levels and channels, go to the mode setting step above after changing the LSPM mode
`:CALibration:CORRfactor?`	Verify that correction factors are still disabled
`:SYSTem:LASer:ENable 0`	Disable laser supply, LSPM 1.1/2.1 only

10 SCPI Communication Basics

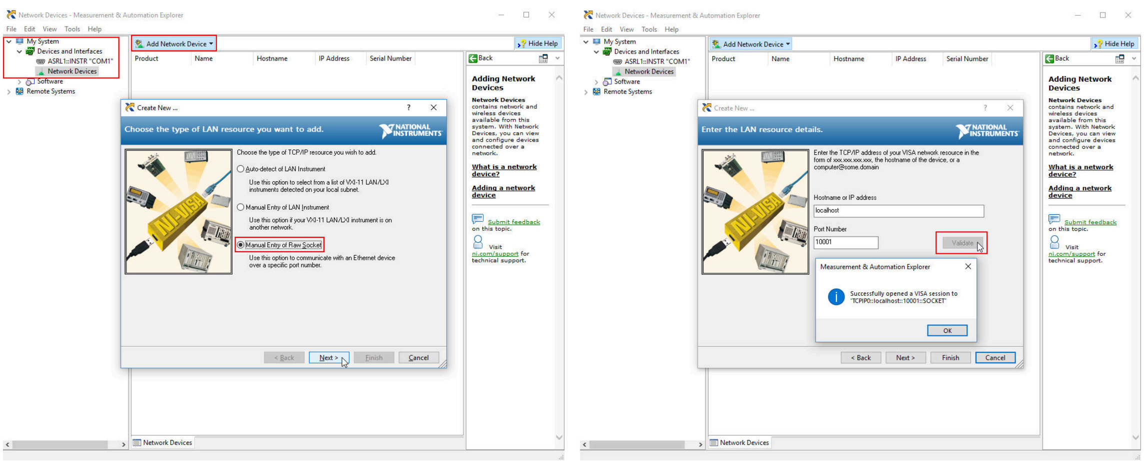
The LUMILOOP TCP Server provides a convenient text command-based interface to power meter measurement data, it supports up to 32 concurrent TCP/IP client connections. All commands sent to the TCP server are ASCII text commands which terminated by a newline (\n), carriage return (\r) or semicolon (;) 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 11 for further details.

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

10.1 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 103(a), select "Manual Entry of Raw Socket" and click "Next". As shown in Figure 103(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.



(a) (b)

Figure 103: *Connection to LUMILOOP TCP Server through NI MAX*

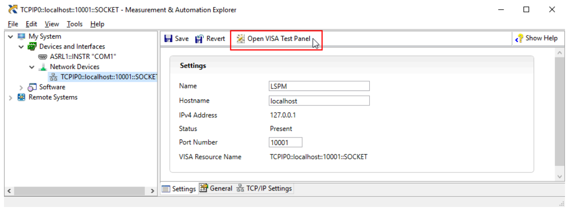
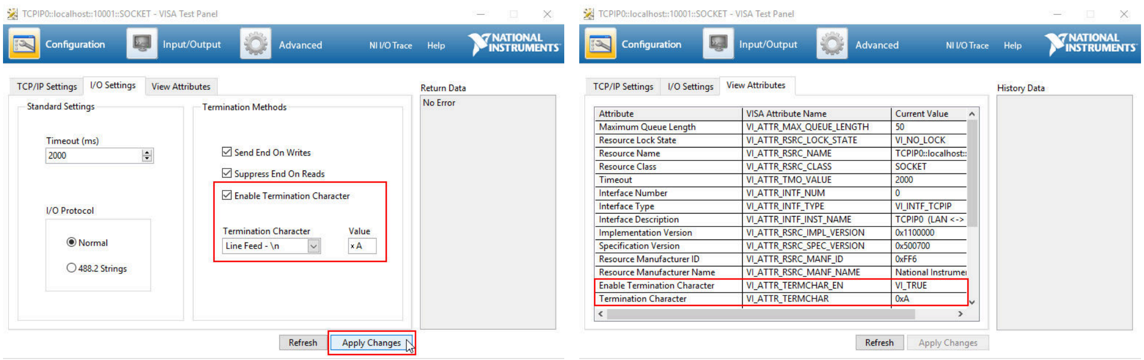


Figure 104: *Starting NI VISA Test Panel*

Right-click on the newly created network device and select "OPEN VISA Test Panel" as shown in Figure 104. 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 105(a). This step needs to be repeated for every NI VISA Input/Output debug session. The "View Attributes" tab in Figure 105(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.



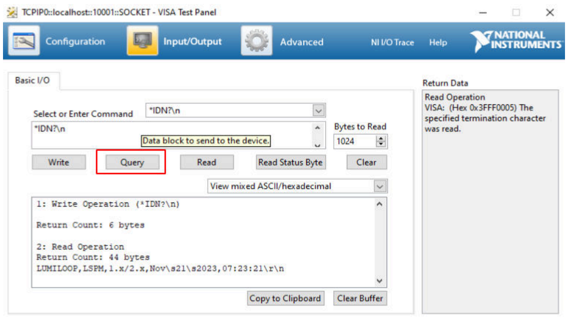
(a) (b)

Figure 105: *Configuring VISA TCP/IP socket parameters*

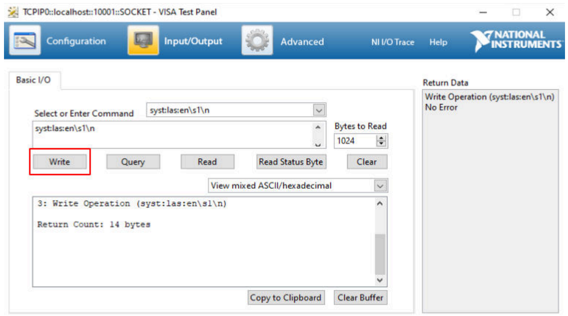
Click on "Input/Output" to start testing NI VISA communication. Clicking "Query" will retrieve the identification string using the "*idn?\n" command, see Figure 106(a). As shown in Figure 106(b) the laser is enabled by entering and writing the "syst:las:en 1" command for laser-powered rf power meters. As shown in Figure 106(c), the frequency is set to a specific value by entering and writing the "syst:freq 1e9\n" command. After the power meter is operational, set the command "meas:p:all?"and click "Query" to obtain three power values. Make sure no errors are produced at any time.

10.2 Raw TCP socket communication using PuTTY

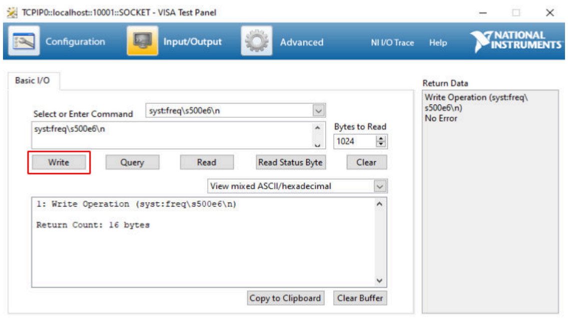
Run PuTTY and enter the host name or IP address and the TCP port number. Set "Connection type" to "Raw" as shown in Figure 107(a). Optionally, save the session configuration for later use. Click "Open" to start the terminal session. Figure 107(b) shows the terminal window. Enter commands and press Return when done. Query commands will generate one reply line each. Multiple commands



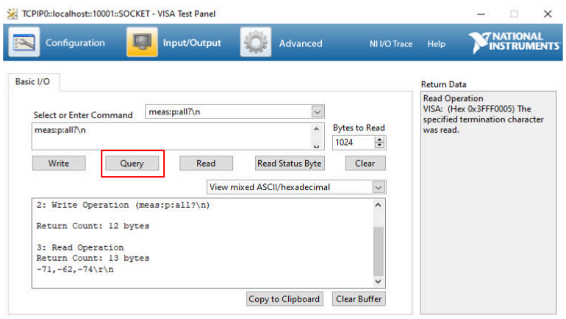
(a) Identification string query



(b) Enabling the supply laser



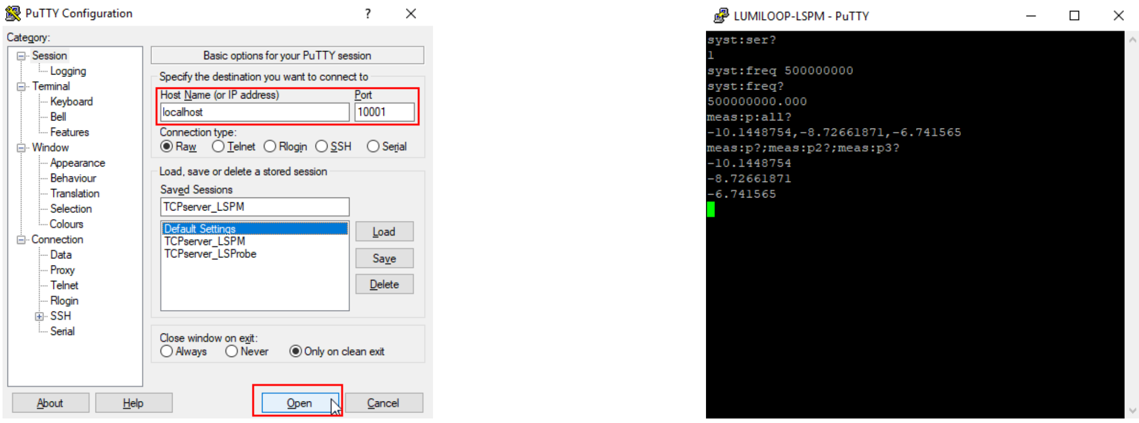
(c) Setting the frequency



(d) power value query

Figure 106: *Testing NI VISA LUMILOOP TCP Server writes and queries*

may be sent in rapid succession by separating them by semicolons.



(a) Session settings

(b) LUMILOOP TCP Server session

Figure 107: *Using PuTTY*

11 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., <>.

11.1 Multi-Power Meter Behavior

Most SCPI commands support the optional MPMeter parameter determining the Multi-Power Meter behavior of the respective command. The following MPMeter parameters are available:

empty

: If the MPMeter parameter is omitted the command will only be executed for the presently active power meter.

0

: If the MPMeter parameter is set to zero the command is executed for all enumerated power meters. Power meters will be enumerated and displayed sorted by their serial numbers starting with the smallest value.

N

: If the MPMeter parameter is set to a number N that is greater than zero the command will be executed for all power meters of the specified LSPM 1.0 Multi-Power Meter setup. LSPM Multi-Power Meter Systems are defined using the :MPMeter:SERial <MPMeter>,<SN1>[,<SN2>,...,<SNN>] SCPI command, the identifier N can be any positive, non-zero integer value. Use :MPMeter:SERial? <MPMeter> to query the LSPM Multi-Power Meter System.

When any SCPI command is executed for more than one power meter, i.e., the MPMeter parameter refers to multiple power meters, the command behaves as if executed for each power meter of the specified LSPM Multi-Power Meter System successively. The order of execution is the same as the serial numbers returned by »:MPMeter:SERial? <MPMeter>«. All output will be joined on a single line by replacing line breaks between the output of different power meters 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.

11.2 Generic Commands

11.2.1 *CLS

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

11.2.2 *ESE <ESR>

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

Parameters:
Integer value for event status register.

11.2.3 *ESE?

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

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

11.2.4 *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.

11.2.5 *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,LSPM,1.x/2.x,Sep 2 2023,08:07:06".

11.2.6 *OPC

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

11.2.7 *OPC?

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

Return value:
Always 1.

11.2.8 *RST

Reset LSPM TCP server. This will close all previously opened power meters, rescan the USB hardware and open all detected power meters. This will perform a power-on reset of all power meters.

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

11.2.9 *SRE <int>

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

Parameter:
Integer value of service request enable register.

11.2.10 *SRE?

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

Return value:
Always 0.

11.2.11 *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.

11.2.12 *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.

11.2.13 *WAI

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

11.3 :SYSTem Commands

11.3.1 :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.

11.3.2 :SYSTem:WAIT <Sec>

Pause processing of LSP SCPI commands for Sec seconds.

11.3.3 :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".”

11.3.4 :SYSTem:ERRor:COUNt?

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

Return value:

Number of values in error queue.

11.3.5 :SYSTem:AUTOCONnect <State>

Enable/disable polling for new power meters.

Parameter:

Setting State to 1 activates polling for new power meters, 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.

11.3.6 :SYSTem:AUTOCONnect?

Query status of new device polling.

Return value:

The command returns an unsigned integer value containing the status of polling for new power meters. If disabled, the command returns 0, if enabled 1.

11.3.7 :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.

11.3.8 :SYSTem:SERial <Value>

Select active LSPM by LSPM serial number.

Parameter:
One serial number out of the list returned by :MEASure[:PMeter]:SERial? <MPMeter> with the MPMeter parameter set to 0 or string stating the serial number and version string separated by a ":", e.g. "3:2.0" for setting the active device to LSPM 2.0 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.

11.3.9 :SYSTem:SERial? [<MPMeter>]

Query serial number of one or multiple conventional power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
Unsigned integer-valued serial number of selected conventional power meter. If the selected device is optically powered, the command will return NAN.

11.3.10 :SYSTem:CISerial <Value>

Select active CI-250 Computer Interface by serial number.

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

11.3.11 :SYSTem:CISerial? [<MPMeter>]

Query serial number of one or multiple CI-250$^{(+)}$ Computer Interfaces .

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

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

11.3.12 :SYSTem:COUnt?

Query number of enumerated LSPM devices.

Return value:
Unsigned integer-valued number of enumerated power meters.

11.3.13 :SYSTem:MAKer? [<MPMeter>]

Query maker identification string of one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

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

11.3.14 :SYSTem:DEVice? [<MPMeter>]

Query identification string of one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
Name string of the device, e.g., "LSPM".

11.3.15 :SYSTem:VERSion? [<MPMeter>]

Query device version string of one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
Version string of the device, e.g., "1.0'. If the version string is unknown, e.g. optically powered devices with turned off laser, "?.?" is returned.

11.3.16 :SYSTem:FVERSion? [<MPMeter>]

Query device version as a float number of one or multiple power meters.

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
: Float valued version of the device, e.g., 1.0. If the device version is unknown 0.0 is returned.

11.3.17 :SYSTem:REVision? [<MPMeter>]

Query firmware revision of one or multiple power meters.

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

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

11.3.18 :SYSTem:FWUPdate?

Query firmware revision provided by TCP server.

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

11.3.19 :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
: Not implemented.

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 power meter polling

Bit 15, Value 32768, String “FW”
: Information about firmware programming

Bit 16, Value 65536, String “LUT”
: Information about processing of Power look-up-tables

Bit 17, Value 131072, String “STRLUT”
: Information about processing of look-up-tables for stream saving

Bit 18, Value 262144
: Not implemented.

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
: Not implemented

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".

11.3.20 :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.

11.3.21 :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.

11.3.22 :SYSTem:LASer:ENable <Value>[,<MPMeter>]

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 MPMeter is described in Section 11.1.

11.3.23 :SYSTem:LASer:ENable? [<MPMeter>]

Query status of supply laser of one or multiple CI-250(+) Computer Interfaces.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

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 conventional power meters.

11.3.24 :SYSTem:LASer:RDY? [<MPMeter>]

Query laser ready status of one or multiple CI-250(+) Computer Interfaces.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

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 conventional power meters.

11.3.25 :SYSTem:LASer:TOut? [<MPMeter>]

Query laser timeout status of one or multiple CI-250(+) Computer Interfaces.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

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 conventional power meters.

11.3.26 :SYSTem:MODe <Mode>[,<MPMeter>]

Set operating mode of one or multiple power meters.

Parameters:

The unsigned integer parameter Mode specifies the power meter operating mode as described in Table 1 on page 23 for LSPM 1.0 devices, Table 2 on page 23 for LSPM 2.0 devices, Table 3 on page 26 for LSPM 1.1 devices and Table 3 on page 26 for LSPM 2.1 devices. Valid values are 0, 1, 2 and 3 for conventional power meters, 0, 1, 2, 3, 4, 8, 10 and 12 for laser-powered rf power meters.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.3.27 :SYSTem:MODe? [<MPMeter>]

Query operating mode of one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

An unsigned integer mode value as described in Table 1 , Table 2, Table 3, Table 4 will be returned.

11.3.28 :SYSTem:FREQuency <Frequency>[,<MPMeter>]

Set frequency for frequency-compensated operation of one or multiple power meters.

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>[,<MPMeter>]« all power value queries will return NAN.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1. E.g., ":syst:freq 1e9,0" will set the compensation frequency to 1 GHz for all enumerated power meters, »:syst:freq 2e9« will set the compensation frequency to 2 GHz for the currently selected power meter.

11.3.29 :SYSTem:FREQuency? [<MPMeter>]

Query frequency for frequency-compensated operation of one or multiple power meters.

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
: A floating-point value rounded to three decimal places indicating the set compensation frequency will be returned.

11.3.30 :SYSTem:FREQuency:MINimum? [<MPMeter>]

Query minimum calibrated frequency for frequency-compensated operation of one or multiple power meters.

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
: A floating-point value indicating the minimum calibrated compensation frequency of the current mode will be returned. NAN will be returned if calibration data is missing or the laser-powered rf power meters is turned off.

11.3.31 :SYSTem:FREQuency:MAXimum? [<MPMeter>]

Query maximum calibrated frequency for frequency-compensated operation of one or multiple power meters.

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
: A floating-point value indicating the maximum calibrated compensation frequency of the current mode will be returned. NAN will be returned if calibration data is missing or the laser-powered rf power meters is turned off.

11.3.32 :SYSTem:LHFrequency <Frequency>[,<MPMeter>]

Set transition frequency for interleaved Modes 1 and 5 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 MPMeter is described in Section 11.1.

11.3.33 :SYSTem:LHFrequency? [<MPMeter>]

Query transition frequency for interleaved Modes 1 and 5 between low-band and high-band detector for one or multiple power meters.

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

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.

11.3.34 :SYSTem:SSKip <Skip>[,<MPMeter>]

Set sample skip count for reduced USB data rate for one or multiple conventional power meters.

Parameters:
: The first unsigned byte-valued parameter Skip (0 ... 255) sets the number number of samples to skip upon reading one sample (for each channel). This reduces the USB data rate to 2,000,000/(Skip+1) samples per second. The TCP server sets the sample skip rate automatically upon detection of a USB FIFO overflow due to a slow USB link, additionally, adding an error to the error queue.

: The second, optional unsigned integer parameter MPMeter is described in Section 11.1. The command will be ignored for all laser-powered rf power meters

11.3.35 :SYSTem:SSKip? [<MPMeter>]

Query sample skip count of one or multiple conventional power meters.

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
: An unsigned integer value indicating the currently active sample skip rate of the USB communication. NAN will be returned for all laser-powered rf power meters.

11.3.36 :SYSTem:RDY? [<MPMeter>]

Query ready status of one or multiple power meters.

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
An unsigned integer value of 1 indicates that the system is ready to operate, a value of 0 indicates that the temperature is currently cooling down / warming up for conventional power meters, rep. that the laser is not yet stable for laser-powered rf power meters.

11.3.37 :SYSTem:SRAte? [<MPMeter>]

Query current sampling rate of one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
An unsigned integer value indicating the current sampling rate of the power meter resulting from the set mode value that can be queried via »:MEASure[:PMeter]:MODe? [<MPMeter>] for laser-powered rf power meters, the skip counter value that can be queried via »:SYSTem:SSKip? [<MPMeter>]« for conventional power meters.

11.3.38 :SYSTem:ESRAte? [<MPMeter>]

Query current effective sampling rate of one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
An unsigned integer value indicating the current sampling rate of the power meter resulting from the set mode value that can be queried via »:MEASure[:PMeter]:MODe? [<MPMeter>] for laser-powered rf power meters, the skip counter value that can be queried via »:SYSTem:SSKip? [<MPMeter>]« for conventional power meters.

11.3.39 :SYSTem:CHANnels? [<MPMeter>]

Query number of channels of one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
An unsigned integer value indicating the number of operating channels. NAN will be returned if no valid calibration data is loaded or if the laser-powered rf power meters is turned off.

11.4 :CALibration Commands

11.4.1 :CALibration:DATA:LIST? [<Serno>]

Query available calibration data sets for single device.

Parameter:

An integer valued serial number or string "SN:X.Y" denoting the serial number and version of a power meter.

Return values:

A list of string valued names of the available calibration data sets is returned with "default" denoting the standard calibration data. If no calibration data is available for the currently active device or given Serno, "undefined" will be returned.

11.4.2 :CALibration:DATA:SELect <NAME>

Set active calibration data set.

Parameter:

A string returned by "" defining the calibration data set to be loaded.«.

11.4.3 :CALibration:DATA:SELect? [<MPMeter>]

Query name of current calibration data set for one or multiple power meters.

Return values:

A string indicating the name of the active calibration data set, 'default' is returned for the standard calibration data set.

11.4.4 :CALibration:WB:LIST? [<Serno>,

Query list of calibrated wideband values of single device and mode.

Parameters:

The first optional integer valued serial number or string "SN:X.Y" denoting the serial number and version of a power meter. The second optional integer parameter denotes the mode.If the parameter Mode is set the parameter Serno is mandatory. If the parameters are omitted, the active device and its operating mode are used.

Return values:

A list of floating-point values indicating the calibrated widebands.

11.4.5 :CALibration:WB <Wideband>[,<MPMeter>]

Set wideband value for interpolation for one or multiple power meters. Default value is zero.

Parameters:
    The first floating-point value Wideband sets the wideband value used for interpolation, Wideband must be included in lsit returned by »:CALibration:WB:LIST? [<Serno>,«. The second optional unsigned integer parameter MPMeter is described in Section 11.1.

11.4.6 :CALibration:WB? [<MPMeter>]

Query set wideband value for one or multiple power meters.

Parameters:
    The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
    A floating-point value indicating the set wideband.

11.4.7 :CALibration:WB:APPlied? [<MPMeter>]

Query application of set wideband for currently set mode and frequency for one or multiple power meters.

Parameters:
    The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
    0 if wideband data is not applicated, 1 if set wideband is valid and applied during interpolation for currently set mode and frequency.

11.4.8 :CALibration:LOGging <Value>

Enable or disable logging of status information when receiving measurement commands from current TCP session.

Parameter:
    Enable logging of LSPM information for the current TCP session by setting Value to 1, disable logging by setting Value to 0.

    When status logging is enabled, »:MEASure[:Power]:P[1]/P2/P3/ALL? [<MPMeter>]« SCPI queries will log one line to the calibration log.

    See Section 12.2 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 power meter.

11.4.9 :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.

11.4.10 :CALibration:LOGging:GLObal <Value>

Enable or disable logging of status information when receiving measurement commands from any TCP session.

Parameter:

Enable global logging of LSPM information for all TCP session by setting Value to 1, disable logging by setting Value to 0.

When status logging is enabled, »:MEASure[:Power]:P[1]/P2/P3/ALL? [<MPMeter>]« SCPI queries will log one line to the calibration log.

See Section 12.2 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 power meter.

11.4.11 :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.

11.4.12 :CALibration:AIGNore? [<MPMeter>]

Query ignoring of excluded frequencies due to aliasing effects for certain modes and frequencies for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

An unsigned integer value or NAN will be returned. If aliasing effects are being ignored the command returns 1, otherwise 0 will be returned. NAN will be returned if no power meter is connected.

11.4.13 :CALibration:CORRfactor <Value>[,<MPMeter>]

Enable or disable application of correction factors of accredited calibration of one or multiple power meters. After start-up the application of correction factors of accredited calibration is enabled.

The old syntax »:CALibration:EXTernal <Value>[,<MPMeter>]« remains supported.

Parameters:

Enable application of correction factors of accredited calibration by setting Value to 1, disable application by setting Value to 0.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.4.14 :CALibration:CORRfactor? [<MPMeter>]

Query application of correction factors of accredited calibration of one or multiple power meters.

The old syntax »:CALibration:EXTernal? [<MPMeter>]« remains supported.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

An unsigned integer value or NAN will be returned. If correction factores are being applied the command returns 1, otherwise 0 will be returned. NAN will be returned if no power meter is connected.

11.4.15 :CALibration:CERTificate? [<MPMeter>]

Query accredited calibration certificate string of one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

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, no power meter is connected or there is no valid accredited calibration data "undefined" will be returned.

11.4.16 :CALibration:TStamp? [<MPMeter>]

Query factory and accredited calibration time stamps of one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

A pair of unsigned integer values indicating the time stamp of factory calibration and accredited calibration will be returned. Time stamps are expressed as the number of seconds since Jan 1 1904 00:00:00. NAN will be returned if no power meter is connected 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>[,<MPMeter>]«.

11.4.17 :CALibration:DATe? [<MPMeter>]

Query factory and accredited calibration dates of one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

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 laser-powered rf power meter 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>[,<MPMeter>]«.

11.5 :MEASure Commands

11.5.1 :MEASure[:PMeter]:TCold:TARget? [<MPMeter>]

Query the target common cold plate temperature of the power sensors for one or multiple conventional power meters. Temperature is controlled at 20 °C by a Peltier cooler for temperature-independent sensor operation or 32 °C for new hardware revisions.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:

The command returns the float-valued cold plate temperature in °C. NAN will be returned for laser-powered rf power meters.

11.5.2 :MEASure[:PMeter]:TCold? [<MPMeter>]

Query the common cold plate temperature of the power sensors for one or multiple conventional power meters or CI-250$^{(+)}$ Computer Interfaces for laser-powered rf power meters. Temperature is controlled at 20 °C by a Peltier cooler for temperature-independent sensor operation.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns the float-valued cold plate temperature in °C.

11.5.3 :MEASure[:PMeter]:THot? [<MPMeter>]

Query the hot side temperature of the cold plate's Peltier cooler for one or multiple conventional power meters or CI-250(+) Computer Interfaces for laser-powered rf power meters. The temperature is measured at the power meter's tubular heat sink.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns the float-valued laser heat sink temperature in °C.

11.5.4 :MEASure[:PMeter]:VPeltier? [<MPMeter>]

Query Peltier cooler voltage for one or multiple conventional power meters or. CI-250(+) Computer Interfaces for laser-powered rf power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns the float-valued Peltier cooler voltage in volt.

11.5.5 :MEASure[:PMeter]:IPeltier? [<MPMeter>]

Query Peltier cooler current for one or multiple conventional power meters or CI-250(+) Computer Interfaces for laser-powered rf power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
The command returns the float-valued Peltier cooler current in ampere.

11.5.6 :MEASure:CInterface:VSWLaser? [<MPMeter>]

Query switching supply voltage for laser supply for one or multiple CI-250(+) Computer Interfaces.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

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. NAN will be returned for conventional power meters.

11.5.7 :MEASure:CInterface:VLINLaser? [<MPMeter>]

Query linear regulator voltage for laser supply for one or multiple CI-250$^{(+)}$ Computer Interfaces.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
The command returns the float-valued voltage value of linear voltage regulator in volt. This voltage is the laser's supply voltage. NAN will be returned for conventional power meters.

11.5.8 :MEASure:CInterface:ILaser? [<MPMeter>]

Query laser supply current for one or multiple CI-250$^{(+)}$ Computer Interfaces.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
The command returns the float-valued laser supply current in ampere. NAN will be returned for conventional power meters.

11.5.9 :MEASure:CInterface:MAGnitude? [<MPMeter>]

Query magnitude of optical receiver received signal strength for one or multiple CI-250$^{(+)}$ Computer Interfaces.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
The command returns an unsigned integer valued magnitude of the data link receiver in arbitrary units. NAN will be returned for conventional power meters.

11.5.10 :MEASure[:PMeter]:VERsion? [<MPMeter>]

Query version string of one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
Version string of the power meter, e.g., "1.2" or "2.0". NAN will be returned if the laser-powered rf power meter is off.

11.5.11 :MEASure[:PMeter]:FWVERsion? [<MPMeter>]

Query firmware version of one or multiple laser-powered rf power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
Integer valued firmware version of the laser-powered rf power meter, e.g., 5 for LSPM 1.1 devices. NAN will be returned if the laser-powered rf power meter is off or for conventional power meter.

11.5.12 :MEASure[:PMeter]:ICapable? [<MPMeter>]

Query interleaved mode capability of one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
The commands returns an integer value of 1, if the power meter supports operation in mode 1 for conventional power meters, and 1,5 for laser-powered rf power meters. If zero is returned,cinterleaved modes are not available. All current power meters variants support interleaved modes, e.g. 1 will always be returned. NAN will be returned if the laser-powered rf power meter is turned off.

11.5.13 :MEASure[:PMeter]:TIMer? [<MPMeter>]

Query power meter activity timer for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:

The command returns the unsigned integer value approximating the power meter's operating time in seconds. The counter runs over after reaching 4095. NAN will be returned for conventional power meters or if the laser-powered rf power meter is off or in start-up.

11.5.14 :MEASure[:PMeter]:SERial <Value>

Select active power meter by serial number.

The old syntax »:SYStem:SERial« remains supported.

Parameter:

One serial number out of the list returned by :MEASure[:PMeter]:SERial? <MPMeter> with the MPMeter parameter set to 0o r string stating the serial number and revision string separated by a ":", e.g. "3:2.0" for setting the active device LSPM 2.0 of serial number 3. In case of enumerated devices with the same serial number but different revisions, e.g. LSPM 1.0 #3 and LSPM 1.1 #3 the string containing the serial number and revision has to be given.

11.5.15 :MEASure[:PMeter]:SERial? <MPMeter>

Query power meter serial number for one or multiple devices. The old syntax »:SYStem:SERial? [<MPMeter>]« remains supported.

Parameters:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

The command returns the unsigned integer value giving the power meter's serial number. NAN will be returned if the laser-powered rf power meter is off or in start-up.

11.5.16 :MEASure[:PMeter]:REVision? [<MPMeter>]

Query laser-powered rf power meter firmware revision of one or multiple laser-powered rf power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

An unsigned integer value indicating the laser-powered rf power meter's firmware's revision number is returned. NAN will be returned for conventional power meters, or if the laser-powered rf power meter is off or in start-up.

11.5.17 :MEASure[:PMeter]:MODe? [<MPMeter>]

Query power meter mode for one or multiple power meters. remains supported.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns an unsigned integer value giving the power meter's operating mode. Valid modes are 0, 1, 2, 3 for conventional power meters and 0, 1, 2, 3, 4, 8, 10, 12 for laser-powered rf power meters. NAN will be returned if the laser-powered rf power meter is off or in start-up.

11.5.18 :MEASure[:PMeter]:TEMPerature? [<MPMeter>]

Query power meters internal temperature for one or multiple laser-powered rf power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns the power meters temperature in °C. This temperature is approximately 5 °C above the power meter's ambient temperature. NAN will be returned for conventional power meters. If the laser-powered rf power meter is off or in start-up, returned values are nonsensical.

11.5.19 :MEASure[:PMeter]:ATEMPerature? [<MPMeter>]

Query low-pass filtered laser-powered rf power meter internal temperature for one or multiple laser-powered rf power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns a low-pass filtered value as described in »:MEASure[:PMeter]:TEMPerature? [<MPMeter>]«. A 10 Hz first oder low-pass filter is used. NAN will be returned for conventional power meters or if the laser-powered rf power meter is off or in start-up.

11.5.20 :MEASure[:PMeter]:ADCTemperature? [<MPMeter>]

Query laser-powered rf power meter internal temperature in LSB for one or multiple laser-powered rf power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns the ADC power meter's temperature in LSB. -1 will be returned if the laser-powered rf power meter is off or in start-up. NAN will be returned for conventional power meters.

11.5.21 :MEASure[:PMeter]:VOLTage? [<MPMeter>]

Query laser-powered rf power meter supply voltage for one or multiple laser-powered rf power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns the float-valued laser-powered rf power meter supply voltage value in Volts. The last measured value will be returned if the laser-powered rf power meter is off or in start-up. NAN will be returned for conventional power meters.

11.5.22 :MEASure[:PMeter]:RDY? [<MPMeter>]

Query ready state for query of measruement data.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns the unsigned integer value indicating that calibration data was found and, in case of conventional power meters the settling temperature was reached, respectively for laser-powered rf power meters that the laser is in ready state.

11.5.23 :MEASure[:Power]:P[1]/P2/P3/ALL? [<MPMeter>]

Query power value for one or multiple power meters.

Return result for one of:

:P[1]?/:P2?/:P3?
Channel 1, 2 or 3 power value

:ALL?
all three results above as a list.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
The command returns a float-valued power value in dBm. Values are low-pass filtered as described in »:MEASure[:PMeter]:LPFrequency <Frequency>[,<MPMeter>]«. -100 will be returned if the power sensor of the respective channel is not present. If ALL values are queried, a list of three values is returned. NAN will be returned if there is no valid calibration data or if the laser-powered rf power meter is off or in start-up.

11.5.24 :MEASure[:Power]:MIN P[1]/P2/P3/ALL? [<MPMeter>]

Query minimum value power range for one or multiple power meters.

Return result for one of:

:P[1]?/:P2?/:P3?
Channel 1, 2 or 3 power value

:ALL?
all three results above as a list.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns a float-valued minimum calibrated power value in dBm. The value is determined using the calibration data for a given frequency and mode. -100 will be returned if the power sensor of the respective channel is not present. If ALL values are queried, a list of three values is returned. NAN will be returned if there is no valid calibration data or if the laser-powered rf power meter is off or in start-up.

11.5.25 :MEASure[:Power]:MAX P[1]/P2/P3/ALL? [<MPMeter>]

Query maximum value power range for one or multiple power meters.

See »:MEASure[:Power]:MIN P[1]/P2/P3/ALL? [<MPMeter>]« for a description of parameter and return values.

11.5.26 :MEASure[:PMeter]:LPFrequency <Frequency>[,<MPMeter>]

Set power low-pass filter -3 dB cut-off frequency for one or multiple power meters.

Parameter:
Float value specifying the -3 dB cut-off frequency for the first order power low-pass filter in

hertz. The filter is applied to calibrated and uncalibrated power values. Setting the value to 0 Hz disables low-pass filtering.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.5.27 :MEASure[:PMeter]:LPFrequency? [<MPMeter>]

Query power low-pass filter -3 dB cut-off frequency for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:

The command returns a float value specifying the -3 dB cut-off frequency for the first order power low-pass filter in hertz. A value to 0 indicates that low-pass filtering is disabled.

11.5.28 :MEASure[:PMeter]:AUTOVBW <State>[,<MPMeter>]

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 in Mode 2 for the LSPM 1.0$^{(+)}$ Power Meter below 500 kHz, for the LSPM 2.0$^{(+)}$ Power Meter below 800 kHz and for the LSPM 1.1/2.1 Power Meter below 400 kHz. If the parameter State is set to 0 the bandwidth set by the SCPI command »:MEASure[:PMeter]:VBW <Frequency>[,<MPMeter>]« will be used.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.5.29 :MEASure[:PMeter]:AUTOVBW? [<MPMeter>]

Query state automatic, frequency-dependent setting of the software-defined video bandwidth

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:

If automatic software-defined video bandwidth setting is enabled, the command returns 1, otherwise the command returns 0.

11.5.30 :MEASure[:PMeter]:VBW <Frequency>[,<MPMeter>]

Set software-defined video bandwidth

Parameters:

The float-valued parameter Frequency sets 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 MPMeter is described in Section 11.1.

11.5.31 :MEASure[:PMeter]:VBW? [<MPMeter>]

Query software-defined video bandwidth

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

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.

11.5.32 :MEASure[:PMeter]:ACCeleration:1/2/3/ALL? [<MPMeter>]

Query laser-powered rf power meter acceleration value for one or multiple laser-powered rf power meters.

Return result for one of:

:1?/:2?/:3?

1-, 2- or 3-axis acceleration value,

:ALL?

all three results above as a list.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

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 a channel is pointing straight up, minus one g will be returned if a channel is pointing straight down. If ALL values are queried, a list of three values is returned. NAN will be returned for conventional power meters or if the laser-powered rf power meter is off or in start-up.

11.5.33 :MEASure[:PMeter]:ACCeleration:LPFrequency <Frequency>[,<MPMeter>]

Set acceleration low-pass filter -3 dB cut-off frequency for one or multiple laser-powered rf power meters. The command will be ignored for conventional power meters.

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 MPMeter is described in Section 11.1.

11.5.34 :MEASure[:PMeter]:ACCeleration:LPFrequency? [<MPMeter>]

Query acceleration low-pass filter -3 dB cut-off frequency for one or multiple laser-powered rf power meters.

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

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. NAN will be returned for conventional power meters.

11.5.35 :MEASure:RSsi:P[1]/P2/P3/ALL? [<MPMeter>]

Query RSSI value for one or multiple power meters.

Return result for one of:

:P[1]?/:P2?/:P3?
: Channel 1, 2 or 3 power value

:ALL?
: all three results above as a list.

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
: The command returns an unsigned integer value representing the uncalibrated 14 bit ADC value the RSSI chip, i.e., received signal strength indicator, used to detect the power. The value is low-pass filtered using the low-pass filter as described in :MEASure[:PMeter]:LPFrequency <Frequency>[,<MPMeter>]. 0 will be returned if the power sensor of the respective channel is not present. If ALL values are queried, a list of three values is returned. NAN will be returned if the laser-powered rf power meter is off or in start-up.

11.6 :TRIGger Commands

11.6.1 :TRIGger:BEGin <Index>[,<MPMeter>]

Set index of first sample of power waveform for one or multiple power meters.

Parameters:

The first parameter is the integer-valued position of the beginning of the power 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 MPMeter is described in Section 11.1.

11.6.2 :TRIGger:BEGin? [<MPMeter>]

Query index of first sample of power waveform for one or multiple power meters. The command is only accepted if trigger state »:TRIGger:STATe? [<Timeout>,<MPMeter>]« is IDLE, set via »:TRIGger:CLear [<MPMeter>]«.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:

The command returns an integer-valued position of the beginning of the power waveform relative to the position of the trigger, corresponds to the first parameter of »:TRIGger:BEGin <Index>[,<MPMeter>]«.

11.6.3 :TRIGger:LENgth <Length>[,<MPMeter>]

Set length of the power waveform per trigger point for one or multiple power meters. The command is only accepted if trigger state »:TRIGger:STATe? [<Timeout>,<MPMeter>]« is IDLE, set via »:TRIGger:CLear [<MPMeter>]«.

Parameters:

The unsigned integer-valued parameter of the command specifies the length of a power waveform per trigger point. E.g., »:trig:len 100« will record 100 samples starting at the sample index specified by :TRIGger:BEGin <Index>[,<MPMeter>].

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.6.4 :TRIGger:LENgth? [<MPMeter>]

Query number of samples per trigger point in power waveform for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns an unsigned integer-valued length of the power waveform per trigger point, corresponding to the length set by »:TRIGger:LENgth <Length>[,<MPMeter>]«.

11.6.5 :TRIGger:POINts <Points>[,<MPMeter>]

Set number of the trigger points for one or multiple power meters. The command is only accepted if trigger state »:TRIGger:STATe? [<Timeout>,<MPMeter>]« is IDLE, set via »:TRIGger:CLear [<MPMeter>]«.

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>[,<MPMeter>]«.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.6.6 :TRIGger:POINts? [<MPMeter>]

Query number of the trigger points for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns the unsigned integer-valued number of trigger points, corresponding to the value set by »:TRIGger:POINts <Points>[,<MPMeter>]«.

11.6.7 :TRIGger:FLENght? [<MPMeter>]

Query full number of samples in complete power waveform for all trigger points, for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns the unsigned integer-valued full length of the power 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? [<MPMeter>]« multiplied by the number of trigger points returned by »:TRIGger:POINts? [<MPMeter>]«.

11.6.8 :TRIGger:PROgress? [<MPMeter>]

Query progress of waveform acquisition for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns the unsigned integer-valued number of samples that have been recorded to the power waveform buffer. Upon reaching the trigger state DONE the return value equals the number returned by »:TRIGger:FLENght? [<MPMeter>]«.

11.6.9 :TRIGger:PTProgress? [<MPMeter>]

Query progress of point trigger acquisition for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

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? [<MPMeter>]«.

11.6.10 :TRIGger:PTTimes? [<MPMeter>]

Query point trigger sample offsets for a full waveform for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

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., an LSPM 1.0 power meter 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, 2000 and 4000, 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.

11.6.11 :TRIGger:EVCNT? <Samples>[,<MPMeter>]

Query the number of hardware-detected trigger events for one or multiple power meters 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 MPMeter is described in Section 11.1.

Return value:

An integer-valued number of hardware-detected trigger events is returned.

11.6.12 :TRIGger:STATe? [<Timeout>,<MPMeter>]

Query the state of the trigger system for one or multiple power meters.

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 MPMeter is described in Section 11.1. 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 52 on page 67 for reference.

11.6.13 :TRIGger:CLear [<MPMeter>]

Clear trigger, the trigger system will change state from any other trigger state to IDLE for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

11.6.14 :TRIGger:ARM [<MPMeter>]

Arm trigger, the trigger system will change state to ARMED if in IDLE or DONE state for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

11.6.15 :TRIGger:ARMed? [<Timeout>,<MPMeter>]

Query if the trigger system is in state ARMED for one or multiple power meters.

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 MPMeter is described in Section 11.1. 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.

11.6.16 :TRIGger:FORce [<MPMeter>]

Force trigger, the trigger system will change state to TRIGGERED independent of the trigger source set by »:TRIGger:SOURce <Source>[,<MPMeter>]« for one or multiple power meters. This command is used for software triggering.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

11.6.17 :TRIGger:DONE? [<Timeout>,<MPMeter>]

Query if the trigger system is in state DONE for one or multiple power meters.

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 MPMeter is described in Section 11.1. 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.

11.6.18 :TRIGger:COUnt? [<MPMeter>]

Query number of detected trigger events for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:

An integer-valued number of trigger events recorded is returned.

11.6.19 :TRIGger:SOURce <Source>[,<MPMeter>]

Set trigger source for triggered operation for one or multiple power meters.

Parameter:

String parameter without quotes specifying the trigger source. Valid values are SOFT, EXT, EXT2, P1, P2 and P3. When set to SOFT triggering must occur by means of the »:TRIGger:FORce [<MPMeter>]« command. When set to EXT triggering uses the external trigger input configured by »:TRIGger:INVert <0/1>[,<MPMeter>]«, »:TRIGger:SYNC <0/1>[,<MPMeter>]« and »:TRIGger:OUTput <0/1>[,<MPMeter>]«. EXT refers to the trigger signal of the BNC connector. EXT2 refers to the trigger signal of the "Ext1" RJ45 socket of the respective power meter and is configured by »:TRIGger:BPINVert <0/1>[,<MPMeter>]«, »:TRIGger:BPSYNC <0/1>[,<MPMeter>]« and »:TRIGger:BPOUTput <0/1>[,<MPMeter>]«.

When set to either P1, P2 or P3 value of the selected channel is used for triggering, »:TRIGger:LEVel <Level>[,<MPMeter>]« and »:TRIGger:FALLing <0/1>[,<MPMeter>]« are used for configuration. For laser-powered rf power meters field triggering is not supported for operating modes 1 and 5.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.6.20 :TRIGger:SOURce? [<MPMeter>]

Query trigger source for triggered operation for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:

The command returns a string value without quotes specifying the trigger source, see »:TRIGger:SOURce <Source>[,<MPMeter>]« for more details.

11.6.21 :TRIGger:LEVel <Level>[,<MPMeter>]

Set the trigger power level for P1, P2 and P3 triggering for one or multiple power meters.

Parameter:

Float parameter specifying the power level in dBm. Triggering occurs when the power value crosses the set power level.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.6.22 :TRIGger:LEVel? [<MPMeter>]

Query the trigger power level for P1, P2 and P3 triggering for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

The command returns the trigger level as a float-valued power value in dBm.

11.6.23 :TRIGger:FALLing <0/1>[,<MPMeter>]

Set the direction for external, P1, P2 and P3 triggering for one or multiple power meters.

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 MPMeter is described in Section 11.1.

11.6.24 :TRIGger:FALLing? [<MPMeter>]

Query the direction for external, P1, P2 and P3 triggering for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:

The command returns the boolean value giving the trigger edge direction, see »:TRIGger:FALLing <0/1>[,<MPMeter>]« for details.

11.6.25 :TRIGger:RELay <0/1>[,<MPMeter>]

Enable or disable the output of a received hardware trigger signal via the conventional power meter's or laser-powered rf power meters CI-250$^{(+)}$ Computer Interface's BNC connector or RJ45 connector to the RJ45 connector or BNC connector for one or multiple power meters.

Parameters:

Boolean value of either 0 or 1. If set to 0 trigger relay is disabled and the 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 MPMeter is described in Section 11.1.

11.6.26 :TRIGger:RELay? [<MPMeter>]

Query status of trigger relay for one or multiple power meters.

Parameter:
  The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
  The command returns a boolean value giving the state of the trigger relay setting, see »:TRIGger:RELay <0/1>[,<MPMeter>]« for details.

11.6.27 :TRIGger:OUTput <0/1>[,<MPMeter>]

Enable or disable the output of a trigger signal via the conventional power meter's or laser-powered rf power meters CI-250(+) Computer Interface's BNC connector for one or multiple power meters.

Parameters:
  Boolean value of either 0 or 1. If set to 0 trigger output is disabled and the power meter's BNC connector can be used for trigger input. If set to 1 trigger output is enabled and the power meter's BNC connector cannot be used for trigger input.

  The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.6.28 :TRIGger:OUTput? [<MPMeter>]

Query status of trigger output for one or multiple power meters.

Parameter:
  The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
  The command returns a boolean value giving the state of the power meters BNC trigger connector, see »:TRIGger:OUTput <0/1>[,<MPMeter>]« for details.

11.6.29 :TRIGger:INVert <0/1>[,<MPMeter>]

Set the polarity for trigger output via the conventional power meter's or laser-powered rf power meters CI-250(+) Computer Interface's BNC trigger connector for one or multiple power meters.

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 MPMeter is described in Section 11.1.

11.6.30 :TRIGger:INVert? [<MPMeter>]

Query the polarity for trigger output via the power meter's BNC trigger connector for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns a boolean value of either 0 or 1. See »:TRIGger:INVert <0/1>[,<MPMeter>]« for details.

11.6.31 :TRIGger:SYNC <0/1>[,<MPMeter>]

Enable or disable synchronization trigger output using the power meter's BNC trigger connector for one or multiple power meters. This function is useful for synchronizing signal generators or transmitters with the power meter.

Parameters:
Boolean value of either 0 or 1. If set to 0 and external trigger output is enabled, the output trigger signal described for »:TRIGger:OUTput <0/1>[,<MPMeter>]« and »:TRIGger:INVert <0/1>[,<MPMeter>]«. If set to 1 and trigger output is enabled, a logic pulse will be generated synchronously with power value acquisition. For conventional power meters, a 250 ns long pulse will be generated once every 500 ns. For laser-powered rf power meters the following applies: In mode 0, 2 and 3 a 1 µs long pulse will be generated once every 2 µs. In mode 4 a 1 µs long pulse is generated for the first value of a burst frame. In mode 8, 10 and 12 a 250 ns long pulse will be generated once every 500 ns. Mode 1 and 5 only a subset of sample values is made available by TCP server.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.6.32 :TRIGger:SYNC? [<MPMeter>]

Query synchronization trigger output for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns a boolean value of either 0 or 1. See »:TRIGger:SYNC <0/1>[,<MPMeter>]« for details.

11.6.33 :TRIGger:BPOUTput <0/1>[,<MPMeter>]

Enable or disable the output of a trigger signal via the power meter's upper RJ45 connector for one or multiple power meters. See »:TRIGger:OUTput <0/1>[,<MPMeter>]« for parameters.

11.6.34 :TRIGger:BPOUTput? [<MPMeter>]

Query status of trigger output via the power meter's upper RJ45 connector for one or multiple power meters. See »:TRIGger:OUTput? [<MPMeter>]« for parameter and return value.

11.6.35 :TRIGger:BPINVert <0/1>[,<MPMeter>]

Set the polarity for trigger output via the power meter's upper RJ45 connector for one or multiple power meters. See »:TRIGger:INVert <0/1>[,<MPMeter>]« for parameters.

11.6.36 :TRIGger:BPINVert? [<MPMeter>]

Query the polarity for trigger output via the power meter's upper RJ45 connector for one or multiple power meters. See »:TRIGger:INVert? [<MPMeter>]« for parameter and return value.

11.6.37 :TRIGger:BPSYNC <0/1>[,<MPMeter>]

Enable or disable synchronization trigger output via the power meter's upper RJ45 connector for one or multiple power meters. See »:TRIGger:SYNC <0/1>[,<MPMeter>]« for parameters.

11.6.38 :TRIGger:BPSYNC? [<MPMeter>]

Query the configuration of the synchronization trigger output via the power meter's upper RJ45 connector for one or multiple power meters. See »:TRIGger:SYNC? [<MPMeter>]« for parameter and return value.

11.6.39 :TRIGger:OVERsampling:ENable <State>[,<MPMeter>]

Enable or disable high resolution waveform acquisition for one or multiple power meters.

Parameters:

Setting State to 1 activates high resolution waveform acquisition, setting State to 0 disables oversampled high resolution waveform acquisition for one or multiple power meters. 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>[,<MPMeter>]« with parameter "0", »:TRIGger:SOURce <Source>[,<MPMeter>]« with Parameter "EXT" and »:TRIGger:ARM [<MPMeter>]«. A dedicated signal source has to be connected to the LSPM 1.0/2.0 or CI-250 device's BNC connector for synchronization purposes. For each sample of the sub-waveform length N set by »:TRIGger:LENgth <Length>[,<MPMeter>]«, 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 76 for further details.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.6.40 :TRIGger:OVERsampling:ENable? [<MPMeter>]

Query status of high resolution waveform acquisition for one or multiple power meters. During oversampling enabled state all commands for changing the trigger state and trigger settings are disabled.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

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>[,<MPMeter>]« with parameter "0" or if at least one of the termination criterion »:TRIGger:OVERsampling:BINCnt <Value>[,<MPMeter>]« resp. »:TRIGger:OVERsampling:WAVCnt <Value>[,<MPMeter>]« was configured and subsequently reached.

11.6.41 :TRIGger:OVERsampling:RESet [<MPMeter>]

Reset high resolution waveform acquisition for one or multiple power meters. All recorded data will be cleared and the progress set to 0, same as if issuing »:TRIGger:OVERsampling:ENable <State>[,<MPMeter>]« first with parameter "0" and then "1".

Parameters:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

11.6.42 :TRIGger:OVERsampling:BINCnt <Value>[,<MPMeter>]

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 power meters.

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 MPMeter is described in Section 11.1.

11.6.43 :TRIGger:OVERsampling:BINCnt? [<MPMeter>]

Query minimum number of required number of sub-waveforms for each phase for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

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>[,<MPMeter>]«.

11.6.44 :TRIGger:OVERsampling:WAVCnt <Value>[,<MPMeter>]

Set termination criterion of number of sub-waveforms overall independet on their respective phases, forming the high resolution waveform for one or multiple power meters.

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 MPMeter is described in Section 11.1.

11.6.45 :TRIGger:OVERsampling:WAVCnt? [<MPMeter>]

Query number of required sub-waveforms for the high resolution waveform for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

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>[,<MPMeter>]«.

11.6.46 :TRIGger:OVERsampling:PHOffset:AUTO [<MPMeter>]

Automatically compute phase offset for current high resolution waveform for one or multiple power meters. 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 MPMeter is described in Section 11.1.

11.6.47 :TRIGger:OVERsampling:PHOffset <Offset>[,<MPMeter>]

Set phase offset manually for current high resolution waveform for one or multiple power meters.

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? [<MP-Meter>]«.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.6.48 :TRIGger:OVERsampling:PHOffset? [<MPMeter>]

Query phase offset of current high resolution waveform for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

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>[,<MPMeter>]« or computed by »:TRIG-ger:OVERsampling:PHOffset:AUTO [<MPMeter>]«.

11.6.49 :TRIGger:OVERsampling:MAXNoise <Value>[,<MPMeter>]

Set confidence interval for each sample histogram of the high resolution waveform for one or multiple power meters.

Parameters:
The floating point valued parameter <Value> specifies the maximum noise parameter for average computation of the power value for each sample histogram of the current high resolution waveform.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.6.50 :TRIGger:OVERsampling:MAXNoise? [<MPMeter>]

Query maximum noise for average computation for each sample histogram of the high resolution waveform for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

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>[,<MPMeter>]«.

11.6.51 :TRIGger:OVERsampling:PHCount? [<MPMeter>]

Query number of phases for current high resolution waveform for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

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.

11.6.52 :TRIGger:OVERsampling:BINStatus? [<MPMeter>]

Query number of recorded sub-waveforms for each phase bin for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

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? [<MPMeter>]«. 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.

11.6.53 :TRIGger:OVERsampling:PROgress? [<MPMeter>]

Query acquisition of high resolution waveform progress on a range between zero and one for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

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 citerias »:TRIGger:OVERsampling:BINCnt <Value>[,<MPMeter>]« resp. »:TRIGger:OVERsampling:WAVCnt <Value>[,<MPMeter>]« was set and met or if both termination criterias are set to zero, for each phase at least one waveform was recorded.

11.6.54 :TRIGger:OVERsampling:WAVProgress? [<MPMeter>]

Query number of recorded sub-waveforms forming the high resolution waveform for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns the unsigned integer-valued number of recorded sub-waveforms that form the high resolution waveform.

11.6.55 :TRIGger:OVERsampling:P[1]/:P2/:P3/ALL? [<MPMeter>]

Query high resolution power waveform for one or multiple power meters.

Return result for one of:

:1?/:2?/:3?
channel 1, channel 2 or channel 3 power values.

:ALL?
channel 1, channel 2 and channel 3 power values.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
The command returns a comma-separated list of float-valued power waveform values in dBm. Power 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>[,<MPMeter>]«. For phase samples missing a recorded sub-waveform, NAN is returned for all samples belonging to this phase. The sequence of the power values is in accordance with the phase offset returned by »:TRIGger:OVERsampling:PHOffset? [<MPMeter>]« NAN will be returned if the laser-powered rf power meter is off, in start-up, if there is no valid calibration or high resolution waveform data.

11.6.56 :TRIGger:OVERsampling:HISTogram:P1? [<MPMeter>]

Query histogram data for each sample of the high resolution waveform for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

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? [<MPMeter>]«. The second single precision float-valued value denotes the power value in dBm 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 power values falling into the stated power bin of the sample index.

NAN will be returned if the laser-powered rf power meter is off, in start-up, if there is no valid calibration or high resolution waveform data.

11.7 :TRIGger[:WAVeform] Commands

11.7.1 :TRIGger[:WAVeform][:Power]:P[1]/:P2/:P3/:ALL? [<MPMeter>]

Query power values of power waveform channel 1, 2 or 3 for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
The command returns a comma-separated list of float-valued channel 1, 2 or 3 power values of the power waveform in dBm. -100 will be returned if the power sensor of the respective channel is not present. NAN will be returned if there is no valid calibration data, if the trigger system state is not equal to DONE or if the laser-powered rf power meter is off or in start-up.

11.7.2 :TRIGger[:WAVeform][:Power]:ALL? [<MPMeter>]

Query channel 1, 2 and 3 power values averaged over the present power waveform for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

The command returns a comma-separated list of three float values giving the arithmetic mean of channel 1, 2 and 3 power, in this order. -100 will be returned if the power sensor of the respective channel is not present. NAN will be returned if there is no valid calibration data or if the trigger system state is not equal to DONE or if the laser-powered rf power meter is off or in start-up.

11.7.3 :TRIGger[:WAVeform]:RSsi:P[1]/:P2/:P3? [<MPMeter>]

Query channel RSSI values of a waveform of channel 1, 2 or 3 for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

The command returns a list of unsigned integer values representing the uncalibrated 14 bit ADC value acquired by the channel 1, 2 or 3 RSSI chip, i.e., received signal strength indicator, used to detect the power level. 0 will be returned if the power sensor of the respective channel is not present. NAN will be returned if the trigger system state is not equal to DONE or if the laser-powered rf power meter is off or in start-up.

11.7.4 :TRIGger[:WAVeform]:FRame? [<MPMeter>]

Query frame indicator values of power waveform for one or multiple laser-powered rf power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

The command returns a comma-separated list of integer values indicating the burst frame index inside a power waveform. Valid values are 0 and 1. In mode 0, 2, 3, 8, 10 and 12 the transition from 0 to 1 or vice versa indicates the acquisition of new LF sample values, there is no gap between power values or RSSI values. In mode 1, and 4, the transition from 0 to 1 or vice versa indicates the beginning of a burst frame and thus a gap between power or RSSI values. NAN will be returned for conventional power meters, if the laser-powered rf power meter is off, in start-up or if the trigger system state is not equal to DONE.

11.7.5 :TRIGger[:WAVeform]:ACCeleration:1/2/3? [<MPMeter>]

Query acceleration waveform values for one or multiple laser-powered rf power meters. Using :1?/:2?/:3?, return acceleration for either channel 1, 2 or 3.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

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 a power waveform. A value of one g will be returned if the channel is pointing straight up, minus one g will be returned if the channel is pointing straight down. Since the sampling rate of acceleration values is 1.3 kHz and asynchronous to power strength sampling the number of samples is much smaller than »:TRIGger[:WAVeform][:Power]:P[1]/:P2/:P3/:ALL? [<MPMeter>]« and can vary by one value for a constant power waveform length. NAN will be returned for conventional power meters, if the laser-powered rf power meter is off, in start-up or if the trigger system state is not equal to DONE.

11.7.6 :TRIGger[:WAVeform]:TEMPerature? [<MPMeter>]

Query power meter's internal temperature values for one or multiple laser-powered rf power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

The command returns a comma-separated list of float-valued temperature values in °C within a waveform. See »:TRIGger[:WAVeform]:ACCeleration:1/2/3? [<MPMeter>]« for further details about the return value format.

11.7.7 :TRIGger[:WAVeform]:VOLTage? [<MPMeter>]

Query power meter's supply voltage values of a waveform for one or multiple laser-powered rf power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

The command returns a comma-separated list of float-valued voltage values in volt within a waveform. See »:TRIGger[:WAVeform]:ACCeleration:1/2/3? [<MPMeter>]« for further details about the return value format.

11.7.8 :TRIGger[:WAVeform][:Power]:BINary? [<MPMeter>]

Query channel 1, channel 2 and channel 3 power values of power waveform in binary format for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

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 power meter P a chunk of binary data will be sent. All values are encoded in little endian format. Data is ordered as follows:

power meter number
: 32 bit unsigned integer value giving the serial number of the power meter. If the laser-powered rf power meter is off or in start-up the power meter serial number, power meter version and sample count is set to zero and the binary data block ends.

CI number
: 32 bit signed integer value giving the serial number of the Computer Interface corresponding for laser-powered rf power meters. In case of conventional power meter, the CI serial number is set to minus one.

power meter version
: 32 bit single-precision, floating-point value giving the version of the corresponding power meter.

sample count
: 32 bit unsigned integer value giving the number of samples S in the waveform of the corresponding power meter. 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 is set to zero and the binary data block ends.

waveform count
: 32 bit unsigned integer value giving the number of the following waveform sets. If the power meter P is laser-powered, seven waveforms (channel 1 power, channel 2 power, channel 3 power, frame indicator, channel 1 RSSI, channel 2 RSSI, channel 3 RSSI) are returned, else six (without frame indicator).

channel 1 power
: S 32 bit single-precision, floating-point values giving a list of channel 1 power values in dBm of the power waveform, see »:TRIGger[:WAVeform][:Power]:P[1]/:P2/:P3/:ALL? [<MPMeter>]«.

channel 2 power
: S 32 bit single-precision, floating-point values giving a list of channel 2 power values in dBm of the power waveform, see »:TRIGger[:WAVeform][:Power]:P[1]/:P2/:P3/:ALL? [<MPMeter>]«.

channel 3 power
: S 32 bit single-precision, floating-point values giving a list of channel 3 power values in dBm of the power waveform, see »:TRIGger[:WAVeform][:Power]:P[1]/:P2/:P3/:ALL? [<MPMeter>]«.

frame indicator, LSPM X.1 only
: S 32 bit single-precision, floating-point values giving a list of laser-powered LSPM frame indicator values as described in »:TRIGger[:WAVeform]:FRame? [<MPMeter>]«, only returned for version LSPM X.1, i.e. if CI number is not set to minus one.

channel 1 RSSI
: S 32 bit unsigned integer values, giving a list of channel 1 RSSI values in LSB of the waveform, see »:TRIGger[:WAVeform]:RSsi:P[1]/:P2/:P3? [<MPMeter>]«.

channel 2 RSSI
: S 32 bit unsigned integer values, giving a list of channel 2 RSSI values in LSB of the waveform, see »:TRIGger[:WAVeform]:RSsi:P[1]/:P2/:P3? [<MPMeter>]«.

channel 3 RSSI
: S 32 bit unsigned integer values, giving a list of channel 3 RSSI values in LSB of the waveform, see »:TRIGger[:WAVeform]:RSsi:P[1]/:P2/:P3? [<MPMeter>]«.

11.7.9 :TRIGger[:WAVeform][:Power]:BINWait? [<Timeout>,<MPMeter>]

Convenience command combining »:TRIGger:DONE? [<Timeout>,<MPMeter>]« and »:TRIGger[:WAVeform][:Power]:BINary? [<MPMeter>]«. The command will wait for the trigger system to reach the DONE state for at most Timeout seconds. When the state DONE is reached, Timeout is set to 0, or when the Timeout is reached »:TRIGger[:WAVeform][:Power]:BINary? [<MPMeter>]« is executed. If the trigger system is in the DONE state the trigger system will be be cleared and armed automatically.

This command is most useful for rapid and efficient waveform value polling.

11.7.10 :TRIGger[:WAVeform][:Power]:BINReduced? [<MPMeter>]

Query channel 1, channel 2 and channel 3 power values in binary format for one or multiple power meters.

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
: See »:TRIGger[:WAVeform][:Power]:BINary? [<MPMeter>]« for a description of the command's return values. RSSI and frame indicator waveforms are not returned.

11.8 [:TRIGger]:RADar, Commands

11.8.1 [:TRIGger]:RADar:TRIM <State>[,<MPMeter>]

Enable/disable pulse trimming for one or multiple power meters.

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 optional second unsigned integer parameter MPMeter is described in Section 11.1.

11.8.2 [:TRIGger]:RADar:TRIM? [<MPMeter>]

Query state of pulse trimming for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:

An unsigned integer value indicating state of pulse trimming, see »[:TRIGger]:RADar:TRIM <State>[,<MPMeter>]«.

11.8.3 [:TRIGger]:RADar:MINTime <MinT>[<MPMeter>]

Set minimum required pulse duration in seconds for one or multiple power meters.

Parameter:

The mandatory floating-point value MinT sets the minimum duration of a pulse in seconds. Shorter pulses will be discarded.

The optional unsigned integer parameter MPMeter is described in Section 11.1.

11.8.4 [:TRIGger]:RADar:MINTime? [<MPMeter>]

Query minimum required pulse duration in seconds for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:

A floating-point value indicating minimum pulse duration in seconds.

11.8.5 [:TRIGger]:RADar:MINSamples <MinS>[<MPMeter>]

Set minimum required pulse duration in samples for one or multiple power meters.

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 MPMeter is described in Section 11.1.

11.8.6 [:TRIGger]:RADar:MINSamples? [<MPMeter>]

Query minimum required pulse duration in samples for one or multiple power meters.

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
: An unsigned integer value indicating minimum required pulse duration expressed in samples.

11.8.7 [:TRIGger]:RADar:SOURce <Source>[,<MPMeter>]

Set pulse evaluation source waveform for one or multiple power meters.

Parameter:
: The string parameter **Source**, without quotes, specifies the waveform master for pulse evaluation. Valid values are IND (default), P1, P2 and P3. When set to IND, channel 1, channel 2 and channel 3 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 MPMeter is described in Section 11.1.

11.8.8 [:TRIGger]:RADar:SOURce? [<MPMeter>]

Query pulse evaluation source waveform for one or multiple power meters.

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
: The command returns a string value without quotes specifying the pulse evaluation source, see »[:TRIGger]:RADar:SOURce <Source>[,<MPMeter>]« for more details.

11.8.9 [:TRIGger]:RADar:THMethod <Method>[<MPMeter>]

Set the method for setting the pulse threshold for one or multiple power meters.

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 power value and minimum power 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:ATHold <Threshold>[<MPMeter>]« is used.

REL, relative threshold

When set to REL, the threshold set by the SCPI command »[:TRIGger]:RADar:RTHold <Threshold>[<MPMeter>]« 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]:RADar:CLEARance <Clearance>[<MPMeter>]« to either probability peak.

The optional second unsigned integer parameter MPMeter is described in Section 11.1.

11.8.10 [:TRIGger]:RADar:THMethod? [<MPMeter>]

Query the method for setting the pulse threshold for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

A string value indicating the set pulse threshold method, see »[:TRIGger]:RADar:THMethod <Method>[<MPMeter>]« for details.

11.8.11 [:TRIGger]:RADar:ATHold <Threshold>[<MPMeter>]

Set the absolute threshold for pulse detection for one or multiple power meters.

Parameter:

The mandatory floating-point value Threshold sets the threshold for detecting pulses in dBm. The optional second unsigned integer parameter MPMeter is described in Section 11.1.

11.8.12 [:TRIGger]:RADar:ATHold? [<MPMeter>]

Query the absolute threshold for pulse detection for one or multiple power meters.

Parameter:

The optional second unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

A floating-point value indicating the absolue pulse detection threshold in dBm.

11.8.13 [:TRIGger]:RADar:RTHold <Threshold>[<MPMeter>]

Set the relative threshold for pulse detection for one or multiple power meters.

Parameter:

The mandatory floating-point 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 detection threshold 10 dB below the highest power value in the waveform.

The optional second unsigned integer parameter MPMeter is described in Section 11.1.

11.8.14 [:TRIGger]:RADar:RTHold? [<MPMeter>]

Query the relative threshold for pulse detection for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

A floating-point value indicating the pulse detection threshold expressed in dB relative to the maximum power value found in the waveform, see »[:TRIGger]:RADar:RTHold <Threshold>[<MPMeter>]« for details.

11.8.15 [:TRIGger]:RADar:CLEARance <Clearance>[<MPMeter>]

Set the clearance of smallest probability in the distribution to its neighboring probability peaks for one or multiple power meters.

Parameter:

The mandatory floating-point value Clearance sets the clearance for automatic pulse threshold setting in dB. The default value is 6 dB, see »[:TRIGger]:RADar:THMethod <Method>[<MPMeter>]« for details.

11.8.16 [:TRIGger]:RADar:CLEARance? [<MPMeter>]

Query the clearance of smallest probability in the distribution to its neighboring probability peaks for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

A floating-point value indicating the minimum clearence of the smallest probability in the distribution relative to its neighboring probability peaks.

11.8.17 [:TRIGger]:RADar:THold:P[1]/P2/P3/ALL? [<MPMeter>]

Query threshold value for pulse detection for one or multiple power meters, via :P[1]?/:P2?/:P3? return results for channel 1, 2 or 3, via :ALL? return results for channel 1, 2 and 3.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:

A floating-point value indicating the respective channel's pulse detection threshold in dBm. With the ALL variant, return list of three values. NAN will be returned, if there is no valid threshold value.

11.8.18 [:TRIGger]:RADar:P[1]/P2/P3? [<MPMeter>]

Query number of pulses, pulse positions, pulse lengths and averaged pulse power for channel 1, 2 or 3 power waveform for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

The command returns a comma-separated list of values, starting with an unsigned integer value giving the number of detected pulses, followed by index/length/power value triples giving the sample position, length in samples and power value of each radar 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 power value of the respective pulse. The number of pulses will be returned as zero and no index/length/power value triple be returned if no pulses could be detected, there is no valid calibration data or the trigger system is not in the DONE state

11.8.19 [:TRIGger]:RADar:APOWer:P[1]/:P2/:P3/:ALL? [<MPMeter>]

Query average power of all pulses found in the waveform for one or multiple power meters, via :P[1]?/:P2?/:P3? return results for channel 1, 2 or 3, via :ALL? return results for channel 1, 2 and 3.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
A floating-point value indicating the arithmetic mean of all power values in the waveform of the respective channel which exceed the set threshold value and minimum pulse length. Using the ALL variant, return a list of all three values. NAN will be returned if no pulses could be detected, there is no valid calibration data or the trigger system is not in the DONE state

11.8.20 [:TRIGger]:RADar:MPOWer:P[1]/:P2/:P3/:ALL? [<MPMeter>]

Query power of pulse with the highest averaged power for one or multiple power meters, via :P[1]?/:P2?/:P3? return results for channel 1, 2 or 3, via :ALL? return results for channel 1, 2 and 3.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
A floating-point value indicating the arithmetic mean of all power values of the largest pulse in the waveform for the respective channel. Using the ALL variant, return a list of all three values. NAN will be returned if there is no valid calibration data or the trigger system state is not equal to DONE.

11.8.21 [:TRIGger]:RADar:COUnt:P[1]/:P2/:P3/:ALL? [<MPMeter>]

Query number of detected channel 1, 2, 3 or all channels' power pulses in the present power waveform for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

The command returns an unsigned integer value giving the number of detected pulses for the respective channel or a list of three integer values for all channels. NAN will be returned if there is no valid calibration data or the trigger system state is not equal to DONE.

11.8.22 [:TRIGger]:RADar:PULses:STArt:P[1]/:P2/:P3? [<MPMeter>]

Query start of all pulses found in the waveform for one or multiple power meters. via :P[1]?/:P2?/:P3? return results for for channel 1, 2 or 3.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

The command returns a list of integer values indicating the start of the respective channel's pulses expressed in samples relative to the beginning of the waveform. NAN will be returned if no pulses are detected.

11.8.23 [:TRIGger]:RADar:PULses:LENgth:P[1]/:P2/:P3? [<MPMeter>]

Query length of all pulses found in the waveform for one or multiple power meters, via :P[1]?/:P2?/:P3? return results for for channel 1, 2 or 3.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

The command returns a list of integer values indicating the length of the respective axis' pulses expressed as samples. NAN will be returned if no pulses are detected.

11.8.24 [:TRIGger]:RADar:PULses[:APOWer]:P[1]/:P2/:P3? [<MPMeter>]

Query average power of all pulses found in the waveform for one or multiple power meters, via :P[1]?/:P2?/:P3? return results for for channel 1, 2 or 3.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

The command returns a list of single-precision, floating-point values giving the arithmetic mean of each pulse's power. NAN will be returned if no pulses are detected.

11.8.25 [:TRIGger]:RADar:DUTY:P[1]/:P2/:P3/:ALL? [<MPMeter>]

Query duty cycle of power values for one or multiple power meters, via :P[1]?/:P2?/:P3? return results for channel 1, 2 or 3, via :ALL? return results for channel 1, 2 and 3.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:

A double-point value indicating the ratio of the number of the respective channel's samples, which exceed the set threshold value and minimum pulse length, and the total number of samples in the waveform. Return a list of three values if the ALL variant is used.

11.8.26 [:TRIGger]:RADar:BINary? <Wave>[,<MPMeter>]

Query details of all channels' pulses found in the waveform in binary format for one or multiple power meters.

Parameter:

The first mandatory integer-valued parameter Wave controls the output of sweep corrected power waveform values. If set to 1 waveform output is enabled, if set to 0 waveform is disabled.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

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 power meter P a chunk of binary data will be sent. All values are encoded in little endian format. If the power meter P is not defined the serial number, 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, in case of conventional power meters the serial number of the corresponding LSPM, in case of laser-powered rf power meters the corresponding CI-250$^{(+)}$ Computer Interface serial number.

OPD serial number

32 bit signed integer value giving the serial number of the power head in case of laser-powered rf power meters. In case of conventional power meter, the OPD serial number is set to minus one.

power meter version

32 bit single-precision, floating-point value giving the version of the corresponding power meter.

sample count

32 bit unsigned integer value giving the number of samples in the waveform of the corresponding power meter.

minimum pulse duration

32 bit unsigned integer value giving the minimum pulse duration in samples used for pulse detection, see »[:TRIGger]:RADar:MINSamples? [<MPMeter>]«.

moving average filter

32 bit unsigned integer value giving the number of samples used for calculating a moving average for pulse detection, static set to 1.

channel 1 threshold value

32 bit single-precision, floating-point value giving the channel 1 threshold value for pulse detection, see »[:TRIGger]:RADar:THold:P[1]/P2/P3/ALL? [<MPMeter>]«. 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.

channel 2 threshold value

See description of channel 1 threshold value above.

channel 3 threshold value

See description of channel 1 threshold value above.

channel 1 averaged power

32 bit single-precision, floating-point value giving the arithmetic mean of all power values of the waveform which belong to pulses, see »[:TRIGger]:RADar:P[1]/P2/P3? [<MPMeter>]«. 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.

channel 2 averaged power

See description of channel 1 averaged power above.

channel 3 averaged power

See description of channel 1 averaged power above.

channel 1 maximum pulse power

32 bit single-precision, floating-point value giving the arithmetic mean of the power of the largest channel 1 pulse in the waveform, see »[:TRIGger]:RADar:MPOWer:P[1]/:P2/:P3/:ALL? [<MPMeter>]«. 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.

channel 2 maximum pulse

See description of channel 1 maximum pulse power above.

channel 3 maximum pulse

See description of channel 1 maximum pulse power above.

channel 1 duty cycle
: 32 bit single-precision, floating-point value giving the duty cycle of channel 1 power values, see »[:TRIGger]:RADar:DUTY:P[1]/:P2/:P3/:ALL? [<MPMeter>]«. 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.

channel 2 duty cycle
: See description of channel 1 duty cycle above.

channel 3 duty cycle
: See description of channel 1 duty cycle above.

channel 1 pulse count, P1
: 32 bit unsigned integer value giving the number of detected channel 1 radar power pulses P1, see »[:TRIGger]:RADar:COUnt:P[1]/:P2/:P3/:ALL? [<MPMeter>]«. If there is no valid calibration data, if the trigger system state is not equal to DONE or if there are no channel 1 radar pulses detected above the set threshold R1 is set to zero.

channel 2 pulse count, P2
: See description of channel 1 pulse count above.

channel 3 pulse count, P3
: See description of channel 1 pulse count above.

channel 1 pulse start indexes
: P1 32 bit unsigned integer values giving a list of start indexes of all channel 1 pulses expressed as samples relative to the beginning of the waveform, see »[:TRIGger]:RADar:PULses:STArt:P[1]/:P2/:P3? [<MPMeter>]«.

channel 1 pulse lengths
: P1 32 bit unsigned integer values giving a list of sample counts of all channel 1 pulses expressed as samples, see »[:TRIGger]:RADar:PULses:LENgth:P[1]/:P2/:P3? [<MPMeter>]«.

channel 1 pulse powers arithmetic mean
: P1 32 bit single-precision, floating-point values giving a list of the arithmetic mean values of the channel 1 power values belonging to each pulse, see »[:TRIGger]:RADar:PULses[:APOWer]:P[1]/:P2/:P3? [<MPMeter>]«.

channel 2 pulse start indexes
: P2 32 bit unsigned integer values, as described for channel 1 pulse start indexes above.

channel 2 pulse lengths
: P2 32 bit unsigned integer values, as described for channel 1 pulse lengths above.

channel 2 pulse powers arithmetic mean
: P2 32 bit single-precision, floating-point values, as described for channel 1 pulse powers arithmetic mean above.

channel 3 pulse start indexes
: P3 32 bit unsigned integer values, as described for channel 1 pulse start indexes above.

channel 3 pulse lengths
: P3 32 bit unsigned integer values, as described for channel 1 pulse lengths above.

channel 3 pulse powers arithmetic mean
: P3 32 bit single-precision, floating-point values, as described for channel 1 pulse powers arithmetic mean above.

waveform sample count
: 32 bit unsigned integer value S giving the number of samples for waveform output of the corresponding power meter. If waveform output is disabled, this value is set to zero.

channel 1 power waveform
: S 32 bit single-precision, floating-point values giving a list of channel 1 power values in dBm of the power waveform.

channel 2 power waveform
: S 32 bit single-precision, floating-point values as described for channel 1 power waveform above.

channel 3 power waveform
: S 32 bit single-precision, floating-point values as described for channel 1 power waveform above.

11.9 [:TRIGger]:SWeep, Commands

11.9.1 [:TRIGger]:SWeep:TStep <TStep>[,<MPMeter>]

Set number of samples per sweep step for one or multiple power meters.

Parameters:
: The unsigned, integer-valued parameter of the command specifies the number of samples per sweep step within the power 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 MPMeter is described in Section 11.1.

11.9.2 [:TRIGger]:SWeep:TStep? [<MPMeter>]

Query number of samples per sweep step for one or multiple power meters.

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

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>[,<MPMeter>]«, the default

value is 1000 samples. If executed for multiple power meters the command returns a list of values for each power meter of the respective list.

11.9.3 [:TRIGger]:SWeep:TCNT? [<MPMeter>]

Query number of sweep step for present power waveform for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns the unsigned integer-valued number of sweep steps for the present power waveform, corresponding to the length of the full waveform queried via »:TRIGger:FLENght? [<MPMeter>]« divided by the sweep step length set via »[:TRIGger]:SWeep:TStep <TStep>[,<MPMeter>]«. If executed for multiple LSPM Power Meters the command returns a list of values for each power meter of the respective list.

11.9.4 [:TRIGger]:SWeep:TBegin <TBegin>[,<MPMeter>]

Set the index of the first sample of the averaged portion of each sweep step for one or multiple power meters.

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 MPMeter is described in Section 11.1.

11.9.5 [:TRIGger]:SWeep:TBegin? [<MPMeter>]

Query the index of the first sample of the averaged portion of each sweep step for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

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>[,<MPMeter>]«, the default value is 500. If executed for multiple power meters the command returns a list of indexes for each power meter of the respective list.

11.9.6 [:TRIGger]:SWeep:TEnd <TEnd>[,<MPMeter>]

Set the index of the last sample of the averaged portion of each sweep step for one or multiple power meters.

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 MPMeter is described in Section 11.1.

11.9.7 [:TRIGger]:SWeep:TEnd? [<MPMeter>]

Query the index of the last sample of the averaged portion of each sweep step for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

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>[,<MPMeter>]«, the default value is 899. If executed for multiple power meters the command returns a list of indexes for each power meter of the respective list.

11.9.8 [:TRIGger]:SWeep:ADDTimes <TStep>,<TBegin>,<TEnd>[,<MPMeter>]

Append single sweep step to the list of sweep steps for one or multiple power meters.

Parameters:
The first unsigned, non-zero integer-valued parameter of the command specifies the number of samples for the next sweep step within the power 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 MPMeter is described in Section 11.1.

11.9.9 [:TRIGger]:SWeep:CLEARTimes [<MPMeter>]

Reduce list of sweep steps to first step for or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

11.9.10 [:TRIGger]:SWeep:TIMes? [<MPMeter>]

Query list of sweep steps for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
The command returns the unsigned integer-valued number of sweep steps configured.

11.9.11 [:TRIGger]:SWeep:ATCNT? [<MPMeter>]

Query number of arbitrary sweep steps for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
The command returns the unsigned integer-valued number of sweep steps configured.

11.9.12 [:TRIGger]:SWeep:MODe <Mode>[,<MPMeter>]

Set frequency sweep mode for power waveform evaluation for one or multiple power meters.

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>[,<MPMeter>]«, »[:TRIGger]:SWeep:STEP <Step>[,<MPMeter>]« and »[:TRIGger]:SWeep:COUnt <Count>[,<MPMeter>]«. 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>[,<MPMeter>]«.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.9.13 [:TRIGger]:SWeep:MODe? [<MPMeter>]

Query frequency sweep mode for power waveform evaluation for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns a string value without quotes specifying the sweep mode, see »[:TRIGger]:SWeep:MODe <Mode>[,<MPMeter>]« for more details. If executed for multiple power meters the command returns a list of modes of all power meters of the respective list.

11.9.14 [:TRIGger]:SWeep:BEGin <Freq>[,<MPMeter>]

Set frequency of first sweep step for linear and logarithmic frequency sweeps for one or multiple power meters.

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 MPMeter is described in Section 11.1.

11.9.15 [:TRIGger]:SWeep:BEGin? [<MPMeter>]

Query frequency of first sweep step for linear and logarithmic frequency sweeps for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns the double-precision, floating-point valued frequency of the first sweep step in hertz for linear and logarithmic frequency sweeps, corresponding to the value set by »[:TRIGger]:SWeep:BEGin <Freq>[,<MPMeter>]«. The default value is 100 MHz. If executed for multiple power meters the command returns a list of floating-point values indicating the frequency of the first sweep step for each power meters.

11.9.16 [:TRIGger]:SWeep:COUnt <Count>[,<MPMeter>]

Set number of frequency steps for linear and logarithmic frequency sweeps for one or multiple power meters.

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 MPMeter is described in Section 11.1.

11.9.17 [:TRIGger]:SWeep:COUnt? [<MPMeter>]

Query number of frequency steps for linear and logarithmic frequency sweeps for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:

The command returns the unsigned integer-valued number of frequency steps set via »[:TRIGger]:SWeep:COUnt <Count>[,<MPMeter>]«. The default is 10 steps. If the sweep mode is set to neither LIN nor LOG, NAN will be returned. If executed for multiple power meters the command returns a list of unsigned integer-valued number of frequency steps for each power meters.

11.9.18 [:TRIGger]:SWeep:STEP <Step>[,<MPMeter>]

Set the incremental frequency step for linear and logarithmic frequency sweeps for one or multiple power meters.

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 MPMeter is described in Section 11.1.

11.9.19 [:TRIGger]:SWeep:STEP? [<MPMeter>]

Query the incremental frequency step for linear and logarithmic frequency sweeps for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:

The command returns the double-precision, floating-point valued linear frequency increment in hertz with up to three decimal places, or factor from one sweep step to the next by »[:TRIGger]:SWeep:STEP <Step>[,<MPMeter>]«, the default value is 1.1. If the sweep mode is set to neither LIN nor LOG, NAN will be returned. If executed for multiple power meters the command returns a list of floating-point valued numbers for each power meter.

11.9.20 [:TRIGger]:SWeep:ARBAdd <Freq>[,<MPMeter>]

Append single frequency to the list of arbitrary sweep frequencies for one or multiple power meters.

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 MPMeter is described in Section 11.1.

11.9.21 [:TRIGger]:SWeep:ARBClear [<MPMeter>]

Clear the list of arbitrary sweep frequencies for one or multiple power meters.

Parameters:
  The optional unsigned integer parameter MPMeter is described in Section 11.1.

11.9.22 [:TRIGger]:SWeep:ARBitrary? [<MPMeter>]

Query the arbitrary list of frequencies used for the sweep evaluation in LIST mode of a power waveform for one or multiple power meters.

Parameters:
  The optional unsigned integer parameter MPMeter is described in Section 11.1.

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>[,<MPMeter>]«. If the number of arbitrary list frequencies is zero the query will return NAN. If executed for multiple power meters the command returns a list of frequencies for each power meter.

11.9.23 [:TRIGger]:SWeep:LIST? [<MPMeter>]

Query the list of frequencies used for the sweep evaluation of a power waveform for one or multiple power meters.

Parameters:
  The optional unsigned integer parameter MPMeter is described in Section 11.1.

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? [<MPMeter>]« and »[:TRIGger]:SWeep:TStep <TStep>[,<MPMeter>]«. 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. 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 power meters the command returns a list of frequencies for each power meter.

11.9.24 [:TRIGger]:SWeep:IDX? [<MPMeter>]

Query the center indices of the averaged portions of each sweep step for one or multiple power meters.

Parameters:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
The command returns a comma separated, integer-valued list of index values of the power 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>[,<MPMeter>]« and »[:TRIGger]:SWeep:TEnd <TEnd>[,<MPMeter>]«. The index is especially useful for overlaying power waveforms and averaged sweep values. If executed for multiple power meters the command returns a list of indices for each power meter.

11.9.25 [:TRIGger]:SWeep[:Power]:P[1]?/:P2?/:P3?/[:ALL?] [<MPMeter>]

Query averaged channel power value for each sweep step of the power waveform for one or multiple power meters, for one of:

:P[1]?/:P2?/:P3?
averaged channel 1, 2 or 3 power for all sweep steps

:ALL?
averaged channel 1, 2 and 3 power for all sweep steps

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
The command returns a comma-separated list of float-valued averaged channel 1, 2 or 3 power values for each sweep step of the power waveform in dBm. If ALL values are queried, a multiple of three values is returned, consisting of the averaged channel 1, 2 and 3 power values for each sweep step. NAN will be returned 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.

11.9.26 [:TRIGger]:SWeep:RSsi:P[1]/:P2/:P3/[:ALL]? [<MPMeter>]

Query averaged channel RSSI value for each sweep step of the power waveform for one or multiple power meters, for one of:

:P[1]?/:P2?/:P3?
averaged channel 1, 2 or 3 RSSI value for all sweep steps

:ALL?
: averaged channel 1, 2 and 3 RSSI values for all sweep steps

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
: The command returns a comma-separated list of integer-valued averaged channel 1, 2 or 3 RSSI values for each sweep step of the power waveform in LSB. If ALL values are queried, a multiple of three values is returned, consisting of the averaged channel 1, 2 and 3 RSSI values for each sweep step. NAN will be returned if the trigger system's state is not equal to DONE or if or if there are no valid sweep frequencies.

11.9.27 [:TRIGger]:SWeep:WPower:P[1]/:P2/:P3/[:ALL]? [<MPMeter>]

Query power values of frequency corrected power waveform using the configured sweep frequencies for one or multiple power meters.

Return results for one of:

:P[1]?/:P2?/:P3?
: channel 1, 2 or 3 power waveform values

:ALL?
: channel 1, 2 and 3 power waveform values

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return values:
: The command returns a list of float-valued channel 1, 2 or 3 power values of the sweep frequency corrected power waveform in dBm. If ALL values are queried, a multiple of three values is returned, consisting of the channel 1, 2 and 3 power values for each sample in the waveform. NAN will be returned if there is no valid calibration data, if the trigger system state is not the state DONE or if there are no valid sweep frequencies.

11.9.28 [:TRIGger]:SWeep:BINary?

Query averaged and unaveraged sweep corrected channel 1, 2 and 3 power values, and center indices of averaged sweep values in binary format for one or multiple power meters.

Parameters:
: The first mandatory integer-valued parameter Wave controls the output of sweep corrected power waveform values. If set to 1 waveform output is enabled, if set to 0 waveform is disabled.

: The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

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 power meter a chunk of binary data will be sent. All values are encoded in little endian format. If the power meter is not defined the power meter serial number, version and sweep step count are set to zero and the binary data block ends. Data are ordered as follows:

power meter number
: 32 bit unsigned integer value giving the serial number of the corresponding power meter.

CI number
: 32 bit signed integer value giving the serial number of the Computer Interface corresponding for laser-powered rf power meters. In case of conventional power meter, the CI serial number is set to minus one.

power meter version
: 32 bit single-precision, floating-point value giving the version of the corresponding power meter.

sweep step count
: 32 bit unsigned integer value giving the number of sweep steps S1 in the power waveform of the corresponding power meter. 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 power waveform of the corresponding power meter.

index
: S1 32 bit unsigned integer values giving a list of center index values for the averaged portion of each sweep step of the power waveform as described in »[:TRIGger]:SWeep:IDX? [<MPMeter>]«.

Frequencies
: S1 64 bit double-precision, floating-point values giving a list of the sweep frequency values for the averaged portion of each sweep step of the power waveform as described in »[:TRIGger]:SWeep:LIST? [<MPMeter>]«.

channel 1 averaged power
: S1 32 bit single-precision, floating-point values giving a list of averaged channel 1 power values in dBm of each sweep step within the power waveform, see »[:TRIGger]:SWeep[:Power]:P[1]?/:P2?/:P3?/[:ALL?] [<MPMeter>]«.

channel 2 averaged power
: S1 32 bit single-precision, floating-point values giving a list of averaged channel 2

power values in dBm of each sweep step within the power waveform, see »[:TRIGger]:SWeep[:Power]:P[1]?/:P2?/:P3?/[:ALL?] [<MPMeter>]«.

channel 3 averaged power
: S1 32 bit single-precision, floating-point values giving a list of averaged channel 3 power values in dBm of each sweep step within the power waveform, see »[:TRIGger]:SWeep[:Power]:P[1]?/:P2?/:P3?/[:ALL?] [<MPMeter>]«.

channel 1 power waveform
: S2 32 bit single-precision, floating-point values giving a list of sweep frequency corrected channel 1 power values in dBm, see »[:TRIGger]:SWeep:WPower:P[1]/:P2/:P3/[:ALL]? [<MPMeter>]«.

channel 2 power waveform
: S2 32 bit single-precision, floating-point values giving a list of sweep frequency corrected channel 2 power values in dBm, see »[:TRIGger]:SWeep:WPower:P[1]/:P2/:P3/[:ALL]? [<MPMeter>]x.

channel 3 power waveform
: S2 32 bit single-precision, floating-point values giving a list of sweep frequency corrected channel 3 power values in dBm, see »[:TRIGger]:SWeep:WPower:P[1]/:P2/:P3/[:ALL]? [<MPMeter>]«.

11.10 :STATistics Commands

11.10.1 :STATistics:MAster <State>

Set currently selected power meter to be the master or a slave power meter for continuous statistics collection. The active power meter is set using »:SYSTem:SERial <Value>«. By default the first enumerated power meter automatically becomes the continuous statistics master power meter.

Parameter:
: Setting State to 1 makes the current power meter the master of the continuous statistics subsystem. A State of 0 makes the power meter a slave of the continuous statistics subsystem, i.e., continuous statistics will be controlled by a different power meter.

11.10.2 :STATistics:MAster? [<MPMeter>]

Query statistics subsystem master/slave status of the currently active power meter. By default the first enumerated power meter automatically becomes the continuous statistics master power meter.

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
: The command returns an unsigned integer value containing the master/slave status of the currently active power meter. Slaves return 0, the master returns 1.

11.10.3 :STATistics:ENable <State>[,<MPMeter>]

Enable or disable statistics acquisition for statistics subsystem master power meter. This command is only effective for power meters configured as the statistics subsystem master power meter, see »:STATistics:MAster <State>«. Enabling statistics acquisition resets the snapshot counter queried via »:STATistics:COUnt? [<MPMeter>]«.

Parameters:

Setting State to 1 activates statistics acquisition, setting State to 0 disables statistics acquisition for one or multiple power meters. 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>][,<MPMeter>]« and stop statistics collection, see also »:STATistics:SNAPshot [<Triggered>][,<MPMeter>]«.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.10.4 :STATistics:ENable? [<MPMeter>]

Query status of statistics acquisition for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

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, see »:STATistics:MAster <State>« and »:STATistics:ENable <State>[,<MPMeter>]«. All statistics subsystem slave power meters are controlled by the statistics master power meter, their return value is thus always be identical to the master power meter if connected correctly.

11.10.5 :STATistics:LENgth <Length>[,<MPMeter>]

Set number of samples to be used for continuous statistics acquisition for one or multiple power meters. 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? [<MPMeter>]« command.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.10.6 :STATistics:LENgth? [<MPMeter>]

Query number of statistics samples to be recorded for statistics acquisition for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

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>[,<MPMeter>]« command. A value of zero indicates indefinite statistics acquisition.

11.10.7 :STATistics:SNAPshot [<Triggered>][,<MPMeter>]

Create a snapshot of either continuously collected statistics, or of waveforms recorded by the trigger subsystem for one or multiple power meters.

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 power meter configured as the statistics subsystem master, see »:STATistics:MAster <State>«. Additionally, statistics acquisition must be enabled using »:STATistics:ENable <State>[,<MPMeter>]« 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 power meter or multiple power meters at a time, see the description of the second parameter below.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1. If the parameter MPMeter is set the parameter Triggered is mandatory. For continuous statistics only power meters configured as the statistics master power meter will output a snapshot trigger signal.

11.10.8 :STATistics:COUnt? [<MPMeter>]

Return continuous statistics snapshot counter for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns an unsigned integer value giving the number of snapshots taken for the selected power meter since the last enabling of statistics acquisition.

11.10.9 :STATistics:RESolution <Resolution>[,<MPMeter>]

Set resolution for histograms and distribution functions for one or multiple power meters.

Parameters:

The float-valued parameter Resolution specifies the power value 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 0 dBm. The smallest permissible value for Resolution is 0.005 dB.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.10.10 :STATistics:RESolution? [<MPMeter>]

Query resolution in dB for histograms and distribution functions for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:

The command returns a float value giving the power resolution in dB for all statistics query commands returning histograms and distribution functions.

11.10.11 :STATistics:HISTogram:SIZe? [<Triggered>][,<MPMeter>]

Query number of bins for histograms and distribution functions for one or multiple power meters.

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 MPMeter is described in Section 11.1. If the parameter MPMeter 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>[,<MPMeter>]«. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

11.10.12 :STATistics:HISTogram:OFFset? [<Triggered>][,<MPMeter>]

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 0 dBm, for one or multiple power meters.

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 MPMeter is described in Section 11.1. If the parameter MPMeter is set the parameter Triggered is mandatory.

Return value:

The command returns an integer value for the presently set resolution, see »:STATistics:RESolution <Resolution>[,<MPMeter>]«. E.g., when the resolution is set to 1 dB, a return value of -20 indicates that the first bin of the histogram covers -20 dBm ±0.5 dB. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

11.10.13 :STATistics:SAMples? [<Triggered>][,<MPMeter>]

Query number of sample values used for statistics acquisition for one or multiple power meters.

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>[,<MPMeter>]«.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1. If the parameter MPMeter 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.

11.10.14 :STATistics:MINimum:P[1]/:P2/:P3/[:ALL]? [<Triggered>][,<MPMeter>]

Query minimum power of the most recent statistics snapshot or triggered waveform for one or multiple power meters.

Return results for one of:

:P[1]?/:P2?/:P3?
: channel 1, 2 or 3 power waveform values

:ALL?
: channel 1, 2 and 3 power waveform values as a list

Parameters:
: If no parameter is provided or if Triggered is set to 0 the channel 1 minimum power for the most recently created statistics snapshot based on continuous statistics acquisition is returned. If the parameter Triggered is set to 1 the channel 1 minimum power of the most recently created statistics snapshot based on triggered waveforms is returned.

: The second, optional unsigned integer parameter MPMeter is described in Section 11.1. If the parameter MPMeter is set the parameter Triggered is mandatory.

Return value:
: The command returns a float-valued channel 1 minimum power in dBm. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

11.10.15 :STATistics:MAXimum:P[1]/:P2/:P3/[:ALL]? [<Triggered>][,<MPMeter>]

Query maximum power of the most recent statistics snapshot or triggered waveform for one or multiple power meters, see »:STATistics:MINimum:P[1]/:P2/:P3/[:ALL]? [<Triggered>][,<MPMeter>]« for description of parameters and return values.

11.10.16 :STATistics:MEAN:P[1]/:P2/:P3/[:ALL]? [<Triggered>][,<MPMeter>]

Query arithmetic mean power of the most recent statistics snapshot or triggered waveform for one or multiple power meters, see »:STATistics:MINimum:P[1]/:P2/:P3/[:ALL]? [<Triggered>][,<MPMeter>]« for description of parameters and return values.

11.10.17 :STATistics:RMS:P[1]/:P2/:P3/[:ALL]? [<Triggered>][,<MPMeter>]

Query root mean square power of the most recent statistics snapshot or triggered waveform for one or multiple power meters, see »:STATistics:MINimum:P[1]/:P2/:P3/[:ALL]? [<Triggered>][,<MPMeter>]« for description of parameters and return values.

11.10.18 :STATistics:SDEViation:P[1]/:P2/:P3/[:ALL]? [<Triggered>][,<MPMeter>]

Query standard deviation power of the most recent statistics snapshot or triggered waveform for one or multiple power meters, see »:STATistics:MINimum:P[1]/:P2/:P3/[:ALL]? [<Triggered>][,<MPMeter>]« for description of parameters and return values.

11.10.19 :STATistics:Power? [<Triggered>][,<MPMeter>]

Query center power value of bins used by histograms and distribution functions for one or multiple power meters.

Parameters:

If no parameter is provided or if Triggered is set to 0 the center power values 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 power values of the most recently created statistics snapshot based on triggered waveforms are returned.

The second, optional unsigned integer parameter MPMeter is describe in Section 11.1. If the parameter MPMeter is set the parameter Triggered is mandatory.

Return values:

The command returns a comma-separated list of float-valued power values in dBm. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

11.10.20 :STATistics:HISTogram:P[1]/:P2/:P3? [<Triggered>][,<MPMeter>]

Query channel 1, 2 or 3 histogram for one or multiple power meters.

Parameters:

If no parameter is provided or if Triggered is set to 0 the channel 1 histogram for the most recently created statistics snapshot based on continuous statistics acquisition is returned. If the parameter Triggered is set to 1 the channel 1 histogram of the most recently created statistics snapshot based on triggered waveforms is returned.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1. If the parameter MPMeter 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 power value falling into the associated power value bins returned by »:STATistics:Power? [<Triggered>][,<MPMeter>]«. The bin size is specified by »:STATistics:RESolution <Resolution>[,<MPMeter>]«. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

11.10.21 :STATistics:P[1]/:P2/:P3DF:P? [<Triggered>][,<MPMeter>]

Query channel 1, 2 or 3 discrete relative probability distribution of the most recent statistics snapshot or triggered waveform for one or multiple power meters.

Parameters:

See »:STATistics:HISTogram:P[1]/:P2/:P3? [<Triggered>][,<MPMeter>]« parameter description for details.

Return values:

The command returns a list of float-valued discrete relative probabilities of channel 1, 2 or 3 power values. Each value is associated with a power value bin returned by »:STATistics:Power? [<Triggered>][,<MPMeter>]«. NAN will be returned if there is no valid statistics snapshot data or triggered waveform data.

11.10.22 :STATistics:CDF:P[1]/:P2/:P3? [<Triggered>][,<MPMeter>]

Query channel 1, 2 or 3 discrete cumulative probability distribution of the most recent statistics snapshot or triggered waveform for one or multiple power meters, see »:STATistics:P[1]/:P2/:P3DF:P? [<Triggered>][,<MPMeter>]« for description of parameters and return values.

11.10.23 :STATistics:CCDF:P[1]/:P2/:P3? [<Triggered>][,<MPMeter>]

Query channel 1, 2 or 3 discrete complementary cumulative probability distribution of the most recent statistics snapshot or triggered waveform for one or multiple power meters, see »:STATistics:P[1]/:P2/:P3DF:P? [<Triggered>][,<MPMeter>]« for description of parameters and return values.

11.10.24 :STATistics:BINary? [<Triggered>][,<MPMeter>]

Query all statistical values of the most recent statistics snapshot or triggered waveform in binary format for one or multiple power meters. This command can be used to reduce communications overhead when polling statistical values via software.

Parameters:

See »:STATistics:MINimum:P[1]/:P2/:P3/[:ALL]? [<Triggered>][,<MPMeter>]« 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 power meter P a chunk of binary data will be sent. All values are encoded in little endian format. Data are ordered as follows:

power meter serial number

32 bit unsigned integer value giving the serial number of the corresponding power meter. If the power meter P is not defined the power meter serial number, version and bin count are set to zero and the binary data block ends.

CI number
: 32 bit signed integer value giving the serial number of the Computer Interface corresponding for laser-powered rf power meters. In case of conventional power meter, the CI serial number is set to minus one.

power meter version
: 32 bit single-precision, floating-point value giving the version of the corresponding power meter.

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, as described in »:STATistics:HISTogram:SIZe? [<Triggered>][,<MPMeter>]«. 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.

channels
: Four bytes specifying the number of active channells. Only for this numer statistics and histogram data will be returned.

histogram offset
: 32 bit signed integer value as described in »:STATistics:HISTogram:OFFset? [<Triggered>][,<MPMeter>]«.

sample count
: 64 bit unsigned integer value as described in »:STATistics:SAMples? [<Triggered>][,<MPMeter>]«.

resolution
: 32 bit single-precision, floating-point value as described in »:STATistics:RESolution? [<MPMeter>]«.

minimum
: Channels 32 bit single-precision, floating-point values as described in »:STATistics:MINimum:P[1]/:P2/:P3/[:ALL]? [<Triggered>][,<MPMeter>]«.

maximum
: Channels 32 bit single-precision, floating-point values as described in »:STATistics:MAXimum:P[1]/:P2/:P3/[:ALL]? [<Triggered>][,<MPMeter>]«.

arithmetic mean
: Channels 32 bit single-precision, floating-point values as described in »:STATistics:MEAN:P[1]/:P2/:P3/[:ALL]? [<Triggered>][,<MPMeter>]«.

root mean square
: Channels 32 bit single-precision, floating-point values as described in »:STATistics:RMS:P[1]/:P2/:P3/[:ALL]? [<Triggered>][,<MPMeter>]«.

standard deviation
: Channels 32 bit single-precision, floating-point values as described in »:STATistics:SDEViation:P[1]/:P2/:P3/[:ALL]? [<Triggered>][,<MPMeter>]«.

bins
: N 32 bit single-precision, floating-point values as described in »:STATistics:Power? [<Triggered>][,<MPMeter>]«.

histogram, channel 1
: N 64 bit unsigned integer values as described in »:STATistics:HISTogram:P[1]/:P2/:P3? [<Triggered>][,<MPMeter>]«.

histogram, channel 2
: N 64 bit unsigned integer values as described in »:STATistics:HISTogram:P[1]/:P2/:P3? [<Triggered>][,<MPMeter>]«.

histogram, channel 3
: N 64 bit unsigned integer values as described in »:STATistics:HISTogram:P[1]/:P2/:P3? [<Triggered>][,<MPMeter>]«.

relative probability, channel 1
: N 32 bit single-precision, floating-point values as described in »:STATistics:P[1]/:P2/:P3DF:P? [<Triggered>][,<MPMeter>]«.

relative probability, channel 2
: N 32 bit single-precision, floating-point values as described in »:STATistics:P[1]/:P2/:P3DF:P? [<Triggered>][,<MPMeter>]«, only if channels greater one.

relative probability, channel 3
: N 32 bit single-precision, floating-point values as described in »:STATistics:P[1]/:P2/:P3DF:P? [<Triggered>][,<MPMeter>]«, only if channels greater two.

relative cumulative probability, channel 1
: N 32 bit single-precision, floating-point values as described in »:STATistics:CDF:P[1]/:P2/:P3? [<Triggered>][,<MPMeter>]«.

relative cumulative probability, channel 2
: N 32 bit single-precision, floating-point values as described in »:STATistics:CDF:P[1]/:P2/:P3? [<Triggered>][,<MPMeter>]«, only if channels greater one.

relative cumulative probability, channel 3
: N 32 bit single-precision, floating-point values as described in »:STATistics:CDF:P[1]/:P2/:P3? [<Triggered>][,<MPMeter>]«, only if channels greater two.

relative complementary cumulative probability, channel 1
: N 32 bit single-precision, floating-point values as described in »:STATistics:CCDF:P[1]/:P2/:P3? [<Triggered>][,<MPMeter>]«.

relative complementary cumulative probability, channel 2
: N 32 bit single-precision, floating-point values as described in »:STATistics:CCDF:P[1]/:P2/:P3? [<Triggered>][,<MPMeter>]«, only if channels greater one.

relative complementary cumulative probability, channel 3
: N 32 bit single-precision, floating-point values as described in »:STATistics:CCDF:P[1]/:P2/:P3? [<Triggered>][,<MPMeter>]«, only if channels greater two.

11.10.25 :STATistics:STEPwise:SAMPles <Samples>[,<MPMeter>]

Set number of samples to reduce the sampling rate for one or multiple power meters.

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 MPMeter is described in Section 11.1.

11.10.26 :STATistics:STEPwise:SAMPles? [<MPMeter>]

Query sampling rate decimation for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

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>[,<MPMeter>]«.

11.10.27 :STATistics:STEPwise:P1 <State>[,<MPMeter>]:P1

Enable/disable output of respective values via »:STATistics:STEPwise:VALues? [<Greedy>,<MPMeter>]« for one or multiple power meters.

Parameters:

Setting State to 1 activate, setting State to 0 disables the respective output:

:P1/:P2/:P3

Enable/disable output of channel 1, channel 2 or channel 3 values

:MINimum

Enable/disable output of minimum value for channel 1, channel 2 and channel 3 values.

:MAXimum

Enable/disable output of maximum value for channel 1, channel 2 and channel 3 values.

:MEAN

Enable/disable output of averaged value for channel 1, channel 2 and channel 3 values.

The second optional unsigned integer parameter MPMeter is described in Section 11.1.

11.10.28 :STATistics:STEPwise:P1? [<MPMeter>]:P1

Query output of respective values via »:STATistics:STEPwise:VALues? [<Greedy>,<MPMeter>]« for one or multiple power meters.

Return result for one of:

:X/:Y/:Z
: output status of channel 1, channel 2 or channel 3 values

:MINimum
: output status of minimum value for channel 1, channel 2 and channel 3 values.

:MAXimum
: output status of maximum value for channel 1, channel 2 and channel 3 values.

:MEAN
: output status of averaged value for channel 1, channel 2 and channel 3 values.

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
: The command returns an unsigned integer value containing the status of the output of the respective values via »:STATistics:STEPwise:VALues? [<Greedy>,<MPMeter>]«. A value of 1 is returned when the respective values are returned, 0 is returned if output is disabled.

11.10.29 :STATistics:STEPwise:COUNt? [<MPMeter>]

Query number of overall stat-stepwise samples since start of continuous statistic or reset of stat-stepwise sampling for one or multiple power meters.

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

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.

11.10.30 :STATistics:STEPwise:CCOUNt? [<MPMeter>]

Query number of available samples in step-wise statistics fifo for one or multiple power meters.

Parameter:
: The optional unsigned integer parameter MPMeter is described in Section 11.1.

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.

11.10.31 :STATistics:STEPwise:SCOUNt? [<MPMeter>]

Query number of overall samples since start of continuous statistic or reset of stat-stepwise sampling for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

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.

11.10.32 :STATistics:STEPwise:SNAPRESet <State>[,<MPMeter>]

Enable or disable reset of step-wise statistics on next statistic snapshot signal for one or multiple power meters.

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>][,<MPMeter>]« 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 MPMeter systems in a synchronzied fashion. The second optional unsigned integer parameter MPMeter is described in Section 11.1.

11.10.33 :STATistics:STEPwise:SNAPRESet? [<MPMeter>]

Query state of step-wise statistics reset on next receiving of a statistics snapshot signal for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

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.

11.10.34 :STATistics:STEPwise:VALues? [<Greedy>,<MPMeter>]

Query all available values in step-wise statistics fifo in accordance with set values of interest via »:STATistics:STEPwise:P1 <State>[,<MPMeter>]:P1« for one or multiple power meters.

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>,<MPMeter>]« 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 MPMeter is described in Section 11.1.

Return Values: For each step-wise value, the minimum, the maximum and the arithmetic mean (in this order) of channel 1, channel 2 and channel 3 will be returned. This results in the command returning »:STATistics:STEPwise:CCOUNt? [<MPMeter>]« multiples of at a max of 9 float-valued, comma-separated values. If a return value is diabled via »:STATistics:STEPwise:P1 <State>[,<MPMeter>]:P1«, fewer values are returned.

Measurements are returned in the following order:

- minimum channel 1 power value if return of channel 1 value and minimum is enabled via »:STATistics:STEPwise:P1 <State>[,<MPMeter>]:P1«
- maximum channel 1 power value if return of channel 1 value and maximum is enabled via »:STATistics:STEPwise:P1 <State>[,<MPMeter>]:P1«
- averaged channel 1 power value if return of channel 1 value and mean is enabled via »:STATistics:STEPwise:P1 <State>[,<MPMeter>]:P1«
- minimum channel 2 power value if return of channel 2 value and minimum is enabled via »:STATistics:STEPwise:P1 <State>[,<MPMeter>]:P1«
- maximum channel 2 power value if return of channel 2s value and maximum is enabled via »:STATistics:STEPwise:P1 <State>[,<MPMeter>]:P1«
- averaged channel 2 power value if return of channel 2 value and mean is enabled via »:STATistics:STEPwise:P1 <State>[,<MPMeter>]:P1«
- minimum channel 3 power value if return of channel 3 value and minimum is enabled via »:STATistics:STEPwise:P1 <State>[,<MPMeter>]:P1«
- maximum channel 3 power value if return of channel 3 value and maximum is enabled via »:STATistics:STEPwise:P1 <State>[,<MPMeter>]:P1«
- averaged channel 3 power value if return of channel 3 value and mean is enabled via »:STATistics:STEPwise:P1 <State>[,<MPMeter>]:P1«

11.10.35 :STATistics:STEPwise:BINary? [<Greedy>,<MPMeter>]

Query all current statist step values in binary format for one or multiple power meters. This command can be used to reduce communications overhead when polling step-wise statistics values.

Parameters:

See »:STATistics:STEPwise:VALues? [<Greedy>,<MPMeter>]« 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 power meter P a chunk of binary data will be sent. All values are encoded in little endian format. Data are ordered as follows:

power meter number
: 32 bit unsigned integer value giving the serial number of the power meter. If the laser-powered rf power meter is off or in start-up the power meter serial number, power meter version and sample count is set to zero and the binary data block ends.

CI number
: 32 bit signed integer value giving the serial number of the Computer Interface corresponding for laser-powered rf power meters. In case of conventional power meter, the CI serial number is set to minus one.

power meter version
: 32 bit single-precision, floating-point value giving the version of the corresponding power meter.

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.

channel no
: 32 bit unsigned integer value giving the number M of the active axes.

minimum, channel 1
: N 32 bit single-precision, floating-point values giving the minimum step-wise channel 1 power values in dbm.

minimum, channel 2
: N 32 bit single-precision, floating-point values giving the minimum step-wise channel 2 power values in dbm, skipped in case of 1 channel power meter.

minimum, channel 3
: N 32 bit single-precision, floating-point values giving the minimum step-wise channel 3 power values in dbm, skipped in case of 1 or 2 channel power meter.

maximum, channel 1
: N 32 bit single-precision, floating-point values giving the maximum step-wise channel 1 power values in dbm

maximum, channel 2
: N 32 bit single-precision, floating-point values giving the maximum step-wise channel 2 power values in dbm, skipped in case of 1 channel power meter.

maximum, channel 3
: N 32 bit single-precision, floating-point values giving the maximum step-wise channel 3 power values in dbm, skipped in case of 1 or 2 channel power meter.

average, channel 1
: N 32 bit single-precision, floating-point values giving the averaged step-wise channel 1 power values in dbm.

average, channel 2
: N 32 bit single-precision, floating-point values giving the averaged step-wise channel 2 power values in dbm, skipped in case of 1 channel power meter.

average, channel 3
: N 32 bit single-precision, floating-point values giving the averaged step-wise channel 3 power values in dbm, skipped in case of 1 or 2 channel power meter.

11.11 :MPMeter Commands

11.11.1 :MPMeter:SERial <MPMeter>,<SN1>[,<SN2>,...,<SNN>]

Define a LSPM Multi-Power Meter System by specifying one or multiple LSPM Power Meter serial numbers.

Parameters:

The first unsigned integer parameter MPMeter sets the LSPM Multi-Power Meter System number for a LSPM Multi-Power Meter System setup. MPMeter must be greater that zero. MPMeter does not specify the number of power meters in a LSPM Multi-Power Meter System.

The following unsigned integer parameters SN1 through SNN specify the LSPM Power Meter serial numbers of a LSPM Multi-Power Meter System setup. Individual power meters may be referenced multiple times by one or more LSPM Multi-Power Meter Systems. power meter serial numbers must be set to one of the enumerated power meters that can be queried via »:SYSTem:SERial? [<MPMeter>]«, unknown power meter serial numbers will cause empty output of multi power meter commands.

11.11.2 :MPMeter:SERial? <MPMeter>

Query power meter serial number(s) for LSPM Multi-Power Meter Systems. This command is an alias of »:SYSTem:SERial? [<MPMeter>]« when the latter is used with the same MPMeter parameter.

Parameters:

The unsigned integer parameter MPMeter specifies LSPM Multi-Power Meter System number defined either automatically, as for setup number 0, or via »:MPMeter:SERial <MPMeter>,<SN1>[,<SN2>,...,<SNN>]« for setup numbers greater than zero.

Return values:

Comma-separated list of unsigned integers indicating the LSPM Power Meter serial numbers for the LSPM Multi-Power Meter System specified by the parameter MPMeter. NAN will be returned instead of the power meter serial number if the specified LSPM Multi-Power Meter System does not exist. NAN will be returned if the specified LSPM Multi-Power Meter System has not been configured.

11.11.3 :MPMeter:CISerial <MPMeter>,<Ci1>[,<Ci2>,...,<CiN>]

Define a LSPM Multi-Power Meter System by specifying one or multiple CI-250$^{(+)}$ Computer Interface serial numbers. The old syntax »:MPMeter:SETCi <MPMeter>,<Ci1>[,<Ci2>,...,<CiN>]« remains supported.

Parameters:

The first unsigned integer parameter MPMeter sets the MPMeter system number for a LSPM Multi-Power Meter System setup. MPMeter must be greater that zero. MPMeter does not specify the number of power meters in the MPMeter system.

The following unsigned integer parameters Ci1 through CiN specify the CI-250$^{(+)}$ Computer Interface serial numbers of a LSPM Multi-Power Meter System setup. Individual CI-250$^{(+)}$ Computer Interfaces may be referenced multiple times by one or more LSPM Multi-Power Meter System. CI-250$^{(+)}$ Computer Interface serial numbers must be set to one of the enumerated CI-250$^{(+)}$ Computer Interfaces queried via »:SYSTem:CISerial? [<MPMeter>]« unknown CI-250$^{(+)}$ Computer Interface serial numbers will cause the command to fail. The command does not depend on the state of the laser-powered rf power meter. Specifically, the supply laser(s) need not be enabled for the command to produce a valid setup.

11.11.4 :MPMeter:CISerial? <MPMeter>

Query CI-250$^{(+)}$ Computer Interface serial number(s) for LSPM Multi-Power Meter System systems. This command is an alias of »:SYSTem:CISerial? [<MPMeter>]« when used with an MPMeter parameter. The old syntax »:MPMeter:GETCi? <MPMeter>« remains supported.

Parameters:

The unsigned integer parameter MPMeter specifies the LSPM Multi-Power Meter System number defined either automatically for setup number 0, or via »:MPMeter:SERial <MPMeter>,<SN1>[,<SN2>,...,<SNN>]« or »:MPMeter:CISerial <MPMeter>,<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 LSPM Multi-Power Meter System specified by the parameter MPMeter. NAN will be returned instead of the CI-250$^{(+)}$ Computer Interface serial number if the specified LSPM Multi-Power Meter System has not been configured. The output of the command does not depend on the state of the laser-powered rf power meter. Specifically, the supply laser(s) need not be enabled for the command to return a valid result.

11.11.5 :MPMeter:SETS?

Query list of defined Multi Powermeter systems.

Return values:

Comma-separated list of unsigned integers designating all user-defined LSPM Multi-Power Meter Systems, i.e. excluding "0". NAN is returned if there are no user-defined Multipowermeter systems.

11.12 :VIRTual Power Meter Commands

11.12.1 :VIRTual:SERial?

Query serial numbers of connected virtual conventional power meters.

Return values:

Unsigned integer-valued comma-separated list of all connected virtual conventional power meter serial numbers. If no virtual conventional power meters are connected the command will return NAN.

11.12.2 :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.

11.12.3 :VIRTual:CONnect [<SER>]

Connect a new virtual power meter.

Parameter:

The optional unsigned integer parameter power meter specifies the serial number of the virtual conventional power meter 1.0. If omitted the default serial number is set to 1 and default version to 1.0. Alternatively, a string stating the power meter serial number, the power meter revision and, in case of laser-powered rf power meters devices, the computer interface serial number separated by a ":" can be given. E.g. "12:2.0" will have the same effect as using the folloing three commands with the respective parameters: »:VIRTual:CONnect [<SER>] 3«, »:VIRTual:PMVersion 1.1« and »:VIRTual:PMSerial <Value> 567«.

11.12.4 :VIRTual:DISConnect

Disconnect currently active power meter if it is a virtual power meter.

11.12.5 :VIRTual:PMSerial <Value>

Set virtual laser-powered rf power meter serial number for currently selected virtual computer interface.

Parameter:

The optional unsigned integer parameter Value sets the desired virtual power meter serial number. The default value is 1.0. The power meter serial number can only be set when the laser supply of the virtual laser-powered rf power meter is off.

11.12.6 :VIRTual:PMSerial?

Query power meter serial number for currently selected virtual computer interface.

Return value:

The command returns the unsigned integer value giving the virtual power meter's serial number. NAN is returned if the virtual power meter is off, in start-up or if the currently active computer interface is not virtual.

11.12.7 :VIRTual:PMRevision <Value>

Set virtual power meter revision for currently selected virtual computer interface.

Parameter:

The unsigned integer parameter Value sets the desired virtual power meter revision 0, 1, 2 or 3. The default value is 2. The power meter revision number can only be set when the laser supply of the virtual power meter is off.

11.12.8 :VIRTual:PMRevision?

Query virtual power meter revision number for currently selected virtual computer interface.

Return value:
: The command returns the unsigned integer valued virtual power meter's revision number. NAN is returned if the currently active computer interface is not virtual.

11.12.9 :VIRTual:PMVersion

Set virtual power meter version for currently selected virtual computer interface.

Parameter:
: The float parameter Value sets the desired virtual power meter version 1.2 or 2.0. The default value is 1.2. The power meter version number can only be set when the laser supply of the virtual power meter is off.

11.12.10 :VIRTual:PMVersion?

Query power meter serial number for currently selected virtual computer interface.

Return value:
: The command returns the virtual power meter's version string. NAN is returned if the currently active computer interface is not virtual.

11.12.11 :VIRTual:TEMPerature <Temperature>

Set optical power meter internal temperature for the currently selected virtual computer interface.

Parameter:
: The float-valued temperature in °C sets the internal temperature of the virtual optical power meter. The default is 40 °C.

11.12.12 :VIRTual:TEMPerature?

Query optical power meter internal temperature of the currently selected virtual computer interface.

Return value:
: The command returns the virtual power meter's temperature in °C. NAN is returned if the active device is not virtual or an laser-powered LSPM.

11.12.13 :VIRTual:ADCTemperature <Temperature>

Set power meter 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 optical power meter. The default is 2344.0 LSB.

11.12.14 :VIRTual:ADCTemperature?

Query power meter internal temperature of the currently selected virtual computer interface.

Return value:
The command returns the virtual power meter's the ADC temperature in LSB. NAN is returned if the active computer interface is not virtual or an laser-powered LSPM.

11.12.15 :VIRTual:VOLTage <Voltage>

Set power meter supply voltage for the currently selected virtual computer interface.

Parameter:
The float-valued voltage in V sets the supply voltage of the virtual power meter. The default is 2.1 V.

11.12.16 :VIRTual:VOLTage?

Query virtual power meter supply voltage.

Return value:
The command returns the float-valued virtual power meter supply voltage value in V. NAN will be returned if the active computer interface is not virtual.

11.12.17 :VIRTual:ACCeleration <ACCx>,<ACCy>,<ACCz>

Set the x-, y- and z-axis acceleration values for the currently selected virtual power meter.

Parameters:
The three float-valued parameters set the acceleration values in g, i.e., multiples of 9.81 m/s^2, for the virtual power meter. The default values are 0.

11.12.18 :VIRTual:ACCeleration?

Query the x-, y- and z-axis acceleration values for the currently selected virtual power meter.

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 m/s^2. NAN will be returned if the active computer interface is not virtual.

11.12.19 :VIRTual:CW <RSSI1>,<RSSI2>,<RSSI3>

Set channel 1, 2 and 3 CW RSSI values of the currently selected virtual power meter.

Parameters:
: The three unsigned integer parameters for the channel 1, 2 and 3 RSSI values set the signal strength indicated by the virtual power meter's ADCs. The default values are 0.

11.12.20 :VIRTual:CW?

Query channel 1, 2 and 3 RSSI values of the currently selected virtual power meter.

Return values:
: The command returns a comma-separated list of three unsigned integer values giving the channel 1, 2 and 3 RSSI values. NAN will be returned if the active power meter is not virtual.

11.12.21 :VIRTual:POWer <P1>,<P2>,<P3>

Set channel 1, 2 and 3 Power values of the currently selected virtual power meter.

Parameters:
: The three unsigned integer parameters for the channel 1, 2 and 3 RSSI values set the signal strength indicated by the virtual power meter's ADCs. The default values are 0.

11.12.22 :VIRTual:POWer?

Query channel 1, 2 and 3 Power values of the currently selected virtual power meter.

Return values:
: The command returns a comma-separated list of three float values giving the channel 1, 2 and 3 power value in dBm. NAN will be returned if the active power meter is not virtual or no calibration data is available.

11.12.23 :VIRTual:NOIse <NOISE1>,<NOISE2>,<NOISE3>

Set the added noise amplitude of the currently selected virtual power meter.

Parameters:
The three unsigned integer parameters for channel 1, 2 and 3 NOISE set the maximum added RSSI value noise amplitude. 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.

11.12.24 :VIRTual:NOIse?

Query channel 1, 2 and 3 noise amplitude of the currently selected virtual power meter.

Return values:
The command returns a comma-separated list of three unsigned integer values giving the maximum amplitude of added channel 1, channel 2 and channel 3 noise in LSB. NAN will be returned if the active power meter is not virtual.

11.12.25 :VIRTual:PULse [<RSSI1>],[<RSSI2>],[<RSSI3>],[<T>],[<Ton>]

Set the parameters of the virtual pulse signal for currently selected virtual power meter.

Parameters:

RSSI1
: unsigned integer value setting the channel 1 RSSI pulse value

RSSI2
: unsigned integer value setting the channel 2 RSSI pulse value

RSSI3
: unsigned integer value setting the channel 3 RSSI pulse value

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

11.12.26 :VIRTual:PULse?

Query the pulse parameters of the currently selected virtual power meter.

Return values:

The command returns a comma-separated list of five unsigned integer values as described in the parameter's description of »:VIRTual:PULse [<RSSI1>],[<RSSI2>],[<RSSI3>],[<T>],[<Ton>]«. NAN will be returned if the active power meter is not virtual.

11.12.27 :VIRTual:PLIST <P1_1>,<P2_1>,<P3_1>[,...,<P1_N>,<P2_N>,<P3_N>]

Append sets of channel 1, channel 2 and channel 3 power values to list of the currently selected virtual power meter.

Parameters:

Multiples of three float-valued power values, specifying channel 1, 2 and 3 power values. The command accepts up to tree times 256 values. The power values are converted to RSSI values using the currently set mode and frequency. RSSI values will not be adjusted when mode or frequency are changed. Power values exceeding the calibrated signal range will be limited to the maximum or minimum calibrated value.

11.12.28 :VIRTual:PLIST?

Query the list of arbitrary power values of the currently selected virtual power meter.

Return values:

The command returns a comma separated, floating-point valued list of all channel 1, 2, and 3 power values of the arbitrary power meter value list. NAN will be returned if the active power meter is not virtual or if the list is empty.

11.12.29 :VIRTual:LIST <RSSI1_1>,<RSSI2_1>,<RSSI3_1>[,...,<RSSI2_N>,<RSSI3_N>]

Append sets of channel 1, 2 and 3 RSSI values to list of the currently selected virtual power meter.

Parameters:

Multiples of three integer-valued RSSI, specifying the channel 1, channel 2 and channel 3 RSSI values. The command accepts up to tree times 256 values.

11.12.30 :VIRTual:LIST?

Query the list of arbitrary RSSI values the currently selected virtual power meter.

Return values:

The command returns a comma separated, unsigned integer list of all channel 1, 2 and 3 RSSI values of the arbitrary power value list. NAN will be returned if the active power meter is not virtual or the list is empty.

11.12.31 :VIRTual:LCNt?

Query number of samples in arbitrary power value list of the currently selected virtual power meter.

Return value:
Unsigned integer-valued number of power samples in arbitrary power value list. NAN will be returned if the active power meter is not virtual.

11.12.32 :VIRTual:LCLear

Clear arbitrary power value list of the currently selected virtual power meter.

11.13 :STReam Recording Commands

11.13.1 :STReam:MAster <State>

Set currently selected power meter to be the master or a slave power meter for stream recording.

Parameter:
Setting State to 1 makes the current power meter the master during stream recording. A State of 0 makes the power meter a slave during stream recording, i.e., stream synchronization will controlled by a different power meter.

11.13.2 :STReam:MAster? [<MPMeter>]

Query master/slave status of the currently active power meter during.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns an unsigned integer value giving the stream recording master/slave status of the currently active power meter. Slaves return 0, the master returns 1.

11.13.3 :STReam:LENgth <Length>[,<MPMeter>]

Set number of samples to be recorded during stream recording for one or multiple power meters. 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 <State>[,<MPMeter>]« command.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.13.4 :STReam:LENgth? [<MPMeter>]

Query number of stream samples to be recorded for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns the unsigned integer-valued number of samples to be streamed as specified using the »:STReam:LENgth <Length>[,<MPMeter>]« command. A value of zero indicates indefinite streaming. If executed for multiple power meters the command returns a list of unsigned integer-valued lengths of the number of streaming samples for each power meter of the list specified by the MPMeter parameter.

11.13.5 :STReam:OUTput <OUT>[,<MPMeter>]

Set output of stream recording to file or to specific host and port setting for one or multiple power meters.

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? [<MPMeter>]«.This is the default. A string parameter with quotes specifying the host and port, separated by a ":" will print 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 MPMeter is described in Section 11.1.

11.13.6 :STReam:OUTput? [<MPMeter>]

Query output of stream data for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns a string value containing the stream output direction, e.g. "FILE" or "HOST:PORT".

11.13.7 :STReam:ENable <State>[,<MPMeter>]

Enable or disable stream recording for one or multiple power meters.

Parameters:

Setting State to 1 activates stream recording, creating a new stream file for each addressed power meter. Setting State to 0 disables stream recording and closes the associated stream file(s). See Section 12.1.6 for details about the stream file format.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.13.8 :STReam:ENable? [<MPMeter>]

Query status of stream recording for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

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.

11.13.9 :STReam:PROgress? [<MPMeter>]

Query number of samples in current stream recording for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:

The command returns an unsigned 64 bit integer value giving the number of samples that have been recorded for the selected power meter since the start of stream recording.

11.13.10 :STReam:SKIp <SkipCnt>[,<MPMeter>]

Set number of stream samples to be skipped for one or multiple power meters. 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 MPMeter is described in Section 11.1.

11.13.11 :STReam:SKIp? [<MPMeter>]

Query number of stream samples to be skipped for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

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>[,<MPMeter>]«. If executed for multiple power meters the command returns a list of unsigned integer-valued numbers for values to skip for each power meter of the respective list.

11.13.12 :STReam:PREfix <String>[,<MPMeter>]

Set file prefix for stream recording for one or multiple power meters. The parameter can only be set when stream recording is disabled.

Parameters:
String parameter with quotes specifying the stream log file prefix. The 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. See Section 12.1.6 for a detailed description of stream file naming conventions and the stream file format.

The second, optional unsigned integer parameter MPMeter is described in Section 11.1.

11.13.13 :STReam:PREfix? [<MPMeter>]

Query file prefix for stream recording for one or multiple power meters.

Parameter:
The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:
The command returns a string value without quotes specifying the set stream log file prefix, see »:STReam:PREfix <String>[,<MPMeter>]« for more details. If executed for multiple power meters the command returns a list of string values containing the value for each power meter of the respective list.

11.13.14 :STReam:SYNC <Sync>[,<MPMeter>]

Set synchronization source for stream recording for one or multiple power meters.

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>[,<MPMeter>]« command. When set to EXT the power meter's BNC connector will be used to synchronize stream recording slaves with the stream recording master. When set to EXT2 the power meter'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 MPMeter is described in Section 11.1.

11.13.15 :STReam:SYNC? [<MPMeter>]

Query synchronization source for stream recording for one or multiple power meters.

Parameter:

The optional unsigned integer parameter MPMeter is described in Section 11.1.

Return value:

The command returns a string value without quotes specifying the set stream synchronization source, see »:STReam:SYNC <Sync>[,<MPMeter>]« for more details. If executed for multiple power meters the command returns a list of string values containing the value for each power meter of the respective list.

12 File Formats

Except for streaming files, see Section 12.1.6, 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 12.3, 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.

12.1 LUMILOOP GUI Log Files

The filename of all LSPM LUMILOOP GUI log files, formatted as "PREFIX lspm_XvY_N_YYYYMMDD_hhmmss_SSS", consists of an adjustable file prefix "PREFIX", the device type "lspm", the LSPM 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 power meter 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 108. 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 power meter 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.

12.1.1 Live Data Logger

The file format for all live log files contains at least 7 columns for conventional power meters and 13 columns for laser-powered rf power meters 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 power meter are present one log file will be created for every power meter.

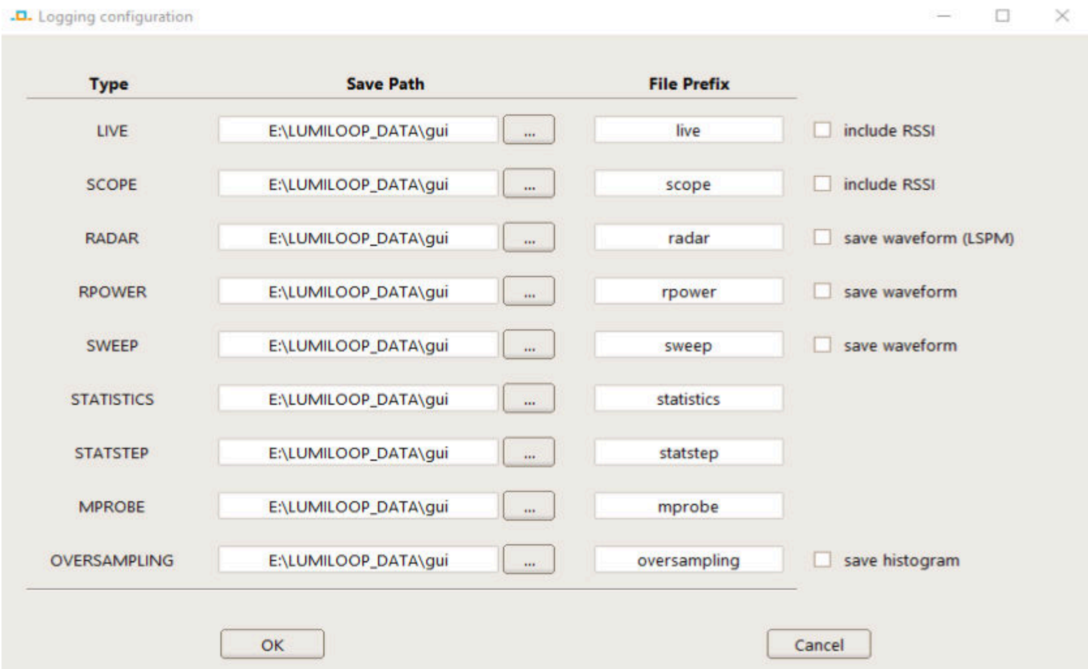


Figure 108: *LUMILOOP GUI "Configure Log" Dialog*

If a log file is created using the GUI's "Quick Save" button all presently displayed values of the active power meter will be saved to a newly created file.

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 Tables 1 to 4, page 23 to page 26
3	f	Hz	Compensation frequency
4	P1	dBm	Channel 1 power
5	P2	dBm	Channel 2 power
6	P3	dBm	Channel 3 power
7	fLpP	Hz	Power value low pass filter frequency
8	RSSI1	LSB	Channel 1 RSSI value, optional
9	RSSI2	LSB	Channel 2 RSSI value, optional
10	RSSI3	LSB	Channel 3 RSSI value, optional

Example of basic log file:

```
#t ⊣Mode ⊣f⊣P1 ⊣P2 ⊣P3 ⊣fLpP ⊣RSSI1⊣RSSI2⊣RSSI3↵
3606197249.102 ⊣1⊣100000000⊣-42.45547⊣-41.116783 ⊣-41.568943 ⊣0⊣↙
    6074 ⊣6074 ⊣6074↵
3606197249.245 ⊣1⊣100000000⊣-38.207194 ⊣-36.87114⊣-37.288121 ⊣0⊣↙
    6702 ⊣6702 ⊣6702↵
```


12.1.2 Power Scope Data Logger

The file format for all field scope log files contains at least five columns described with their column headers and unit values in the table below.

Column	Header	Unit	Description
4	P2	dBm	Channel 2 power
5	P3	dBm	Channel 3 power
6	RSSI1	LSB	Channel 1 RSSI value, optional
7	RSSI2	LSB	Channel 2 RSSI value, optional
8	RSSI3	LSB	Channel 3 RSSI value, optional

Example of field scope log file:

```
#Mode␉f␉P1 ␉P2 ␉P3 ␉RSSI1␉RSSI2␉RSSI3␉f␉P1 ␉P2 ␉P3
1␉100000000␉-82.007195 ␉-83.007195 ␉-75.007301 ␉30 ␉30 ␉30 ␉
   100000000␉-82.007195 ␉-83.007195 ␉-75.007301
1␉100000000␉-82.007195 ␉-83.007195 ␉-75.007301 ␉1030 ␉1030 ␉1030 ␉
   200000000␉-82.007195 ␉-83.007195 ␉-75.007301
```

12.1.3 Radar Data Logger

The file format for all radar log files contains at least 21 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 channels. For every pulse a triple of columns consisting of the sample index of the start of the pulse, of the length of the pulse in samples and maximum power value for the pulse will be added to the radar log file. First, N1 value pairs for the channel 1 values will be added, followed by N2 and N3 value pairs for the other channels' values. The pulse counts N1, N2 and N3 are given in columns 11 through 13.

Continuous logging will create a new line in the log file for every newly recorded set of waveforms. If more than one power meter are present one log file will be created for every power meter.

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 Tables 1 to 4, page 23 to page 26
3	f	Hz	Compensation frequency
4	Samp		Number of samples in waveforms evaluated for radar measurements
5	minS		Set minimum required pulse duration in samples for radar measurements
6	Th P1	dBm	Threshold value for power pulse detection for channel 1
7	Th P2	dBm	Threshold value for power pulse detection for channel 2

Column	Header	Unit	Description
8	Th P3	dBm	Threshold value for power pulse detection for channel 3
9	Avg P1	dBm	Arithmetic mean of all pulses' channel 1 averaged pulse power values
10	Avg P2	dBm	Arithmetic mean of all pulses' channel 2 averaged pulse power values
11	Avg P3	dBm	Arithmetic mean of all pulses' channel 3 averaged pulse power values
12	Max P1	dBm	Power of pulse with the highest averaged power of all channel 1 pulses
13	MAx P2	dBm	Power of pulse with the highest averaged power of all channel 2 pulses
14	Max P3	dBm	Power of pulse with the highest averaged power of all channel 3 pulses
15	Duty P1		Duy cycle of channel 1 power values
16	Duty P2		Duy cycle of channel 2 power values
17	Duty P3		Duy cycle of channel 3 power values
18	CNT1		Number of pulses detected for channel 1
19	CNT2		Number of pulses detected for channel 2
20	CNT3		Number of pulses detected for channel 3
21...	IDX1N		Sample index of N^{th} channel 1 pulse
22...	Len1N		N^{th} channel 1 pulse's length in samples
23...	P1N	dBm	N^{th} channel 1 pulse's maximum power value
21...	IDX2N		Sample index of N^{th} channel 2 pulse
22...	Len1N		N^{th} channel 2 pulse's length in samples
23...	P2N	dBm	N^{th} channel 2 pulse's maximum power value
21...	IDX3N		Sample index of N^{th} channel 3 pulse
22...	Len1N		N^{th} channel 3 pulse's length in samples
23...	P3N	dBm	N^{th} channel 3 pulse's maximum power value

Example of radar log file:

```
#t ⊣Mode ⊣f in Hz⊣Samp ⊣minS ⊣Th P1 in dBm ⊣Th P2 in dBm ⊣Th P3 in ↙
    dBm ⊣Avg P1 in dBm⊣Avg P2 in dBm⊣Avg P3 in dBm⊣Max P1 in dBm⊣↙
    Max P2 in dBm⊣Max P3 in dBm⊣Duty P1⊣Duty P2⊣Duty P3⊣CNT1 ⊣CNT2↙
     ⊣CNT3 ⊣IDX1N⊣Len1N⊣P1N in dBm ⊣IDX2N⊣Len2N⊣P2N in dBm ⊣IDX3N⊣↙
    Len3N⊣P3N in dBm↵
3686018740.515 ⊣1⊣100000000⊣2000 ⊣1⊣-5.822069⊣-13.437619 ⊣↙
    -13.163526 ⊣-3.990641⊣-11.685132 ⊣-11.351974 ⊣-3.916312⊣↙
```

```
    -11.432185 ⊣-11.341158 ⊣0.025⊣0.025⊣0.025⊣2⊣2⊣2⊣892⊣25 ⊣↙
    -4.066264⊣1892 ⊣25 ⊣-3.916312⊣892⊣25 ⊣-11.953728 ⊣1892 ⊣25 ⊣↙
    -11.432185 ⊣892⊣25 ⊣-11.362818 ⊣1892 ⊣25 ⊣-11.341158⏎
3686018824.093 ⊣1⊣100000000⊣2000 ⊣1⊣-25⊣-25⊣-25⊣-4.010297⊣-11.81766↙
    ⊣-11.410587 ⊣-3.973205⊣-11.771922 ⊣-11.294949 ⊣0.025⊣0.025⊣↙
    0.025⊣2⊣2⊣2⊣947⊣25 ⊣-3.973205⊣1947 ⊣25 ⊣-4.047709⊣947⊣25 ⊣↙
    -11.771922 ⊣1947 ⊣25 ⊣-11.863885 ⊣947⊣25 ⊣-11.529389 ⊣1947 ⊣25↙
     ⊣-11.294949⏎
```

12.1.4 Sweep Data Logger

The file format for all sweep log files contains at least six 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 power meter are present one log file will be created for every power meter.

If a log file is created using the GUI's "Quick Save" button all presently displayed values of the active power meter will be saved to a newly created file.

Column	Header	Unit	Description
1	Mode		Measurement mode, see Tables 1 to 4, page 23 to page 26
2	f	Hz	Compensation frequency
3	Index		Center sample index
4	P1	dBm	Averaged channel 1 power
5	P2	dBm	Averaged channel 2 power
6	P3	dBm	Averaged channel 3 power
7	RSSI1	LSB	Averaged raw channel 1 RSSI value, optional
8	RSSI2	LSB	Averaged raw channel 2 RSSI value, optional
9	RSSI3	LSB	Averaged raw channel 3 RSSI value, optional

Example of sweep log file:

```
#Mode⊣f⊣Index⊣P1 ⊣P2 ⊣P3 ⊣RSSI1⊣RSSI2⊣RSSI3⏎⊣
1⊣100000000⊣699⊣-52.943813 ⊣-45.659973 ⊣-49.853455 ⊣4561 ⊣5422 ⊣↙
    4896⏎ ⊣
1⊣450000000⊣1699 ⊣-52.845222 ⊣-45.333584 ⊣-49.958347 ⊣4575 ⊣5469 ⊣↙
    4881⏎ ⊣
```

If the "Save freq. corr. waveforms" checkbox in the "Log"-tab is enabled, an additional sweep log file is saved, containing the sweep frequency corrected waveform values of the current waveform. The file format for all sweep waveform log files contains five columns described with their column headers and unit values in the table below. A power waveform log file will only be created

Continuous logging will create a new log file for every newly recorded set of waveforms. If more than one power meter is present one log file will be created for each power meter.

If a log file is created using the GUI's "Quick Save" button all presently displayed values of the active power meter will be saved to a newly created file.

Column	Header	Unit	Description
1	Mode		Measurement mode, see Tables 1 to 4, page 23 to page 26
2	fSweep	Hz	Compensation frequency
3	P1	dBm	Channel 1 power for sweep
4	P2	dBm	Channel 2 power for sweep
5	P3	dBm	Channel 3 power for sweep

```
#Mode⇥fSweep ⇥P1 ⇥P2 ⇥P3↵
1⇥100000000⇥-31.042856 ⇥-35.417912 ⇥-35.820896↵
1⇥100000000⇥-31.957144 ⇥-37.623077 ⇥-34.283581↵
```

12.1.5 Statistics Data Logger

The file format for all statistics log files contains at least 26 columns described with their column headers and unit values in the table below. The number of columns is dependent on the number of power value bins in the recorded histogram, there is at least one bin in the histogram. For every bin three columns consisting of the number of channel 1, 2 and 3 samples detected for the corresponding bin will be added to the radar log file. The number of bins is specified in column number 23.

Continuous logging will add a new line to the log file for every newly recorded statistics snapshot. If more than one power meter are present, one log file will be created for every power meter.

If a log file is created using the GUI's "Quick Save" button all presently displayed values of the active power meter will be saved to a newly created file.

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 Tables 1 to 4, page 23 to page 26
3	f	Hz	Compensation frequency

Column	Header	Unit	Description
4	Type		Statistics type, 0 for continuous statistics, 1 for triggered statistics
5	MIN1	dBm	Channel 1 power minimum
6	MIN2	dBm	Channel 2 power minimum
7	MIN3	dBm	Channel 3 power minimum
8	MAX1	dBm	Channel 1 power maximum
9	MAX2	dBm	Channel 2 power maximum
10	MAX3	dBm	Channel 3 power maximum
11	MEAN1	dBm	Channel 1 power arithmetic mean
12	MEAN2	dBm	Channel 2 power arithmetic mean
13	MEAN3	dBm	Channel 3 power arithmetic mean
14	RMS1	dBm	Channel 1 power root mean square
15	RMS2	dBm	Channel 2 power root mean square
16	RMS3	dBm	Channel 3 power root mean square
17	SDEV1	dBm	Channel 1 power standard deviation
18	SDEV2	dBm	Channel 2 power standard deviation
19	SDEV3	dBm	Channel 3 power standard deviation
20	Samp		Number of samples used for statistics evaluation
21	Res	dB	Power resolution for histogram output
22	Offs	dBm	Power offset of minimum bin in histogram
23	Bins		Number of bins in power value histogram
24...	CNT1N		Bins number of channel 1 power values from first up to Nth bin of histogram
24+N...	CNT2N		Bins number of channel 2 power values from first up to Nth bin of histogram
24+2*N...	CNT3N		Bins number of channel 3 power values from first up to Nth bin of histogram

Example of statistics log file:

```
#t ⊣Mode ⊣f⊣Type ⊣MIN1 ⊣MIN2 ⊣MIN3 ⊣MAX1 ⊣MAX2 ⊣MAX3 ⊣MEAN1⊣MEAN2⊣↙
   MEAN3⊣RMS1 ⊣RMS2 ⊣RMS3 ⊣SDEV1⊣SDEV2⊣SDEV3⊣Samp ⊣Res⊣Offs ⊣Bins↙
    ⊣CNT1N⊣CNT2N⊣CNT3N⏎
3606271892.999 ⊣1⊣100000000⊣0⊣-82.004997 ⊣-83.004997 ⊣-75.004997 ⊣↙
   10.995 ⊣10.995 ⊣10.995 ⊣-30.340851 ⊣-29.428646 ⊣-28.592386 ⊣↙
   44.246136⊣43.74614 ⊣41.94656 ⊣32.204865⊣32.367878⊣30.691845⊣↙
```

```
    22726830 ⊣5⊣-17⊣20 ⊣0⊣3406472⊣122056 ⊣330106 ⊣678243 ⊣914033 ⊣↙
    962578 ⊣1002801⊣1000027⊣1024993⊣1015284⊣1015284⊣1018058⊣1001650↙
    ⊣1014628⊣975764 ⊣1029706⊣981996 ⊣927903 ⊣4305248⊣3190100⊣37449⊣↙
    119282 ⊣313462 ⊣654664 ⊣891841 ⊣952869 ⊣994479 ⊣991705 ⊣1020832↙
    ⊣1011123⊣1009736⊣1020832⊣1004223⊣1014628⊣970212 ⊣1020180⊣979244↙
     ⊣919581 ⊣4610388⊣0⊣0⊣3453630⊣325945 ⊣651890 ⊣890454 ⊣951482 ⊣↙
    984770 ⊣980609 ⊣1013897⊣1002801⊣1008349⊣1015284⊣995946 ⊣1006300↙
    ⊣959108 ⊣1013236⊣975061 ⊣911259 ⊣4586809⏎
3606271976.273 ⊣1⊣100000000⊣0⊣-82.004997 ⊣-83.004997 ⊣-75.004997 ⊣↙
    10.995 ⊣10.995 ⊣10.995 ⊣-30.341587 ⊣-29.429396 ⊣-28.593102 ⊣↙
    44.246834⊣43.746834⊣41.947224⊣32.205132⊣32.368137⊣30.692085⊣↙
    26576572 ⊣20 ⊣-4 ⊣6⊣4273970⊣3806834⊣4734618⊣4716471⊣4345745⊣↙
    4698934⊣4058244⊣3722490⊣4705422⊣4721137⊣4362165⊣5007114⊣4191248↙
    ⊣3716002⊣4668116⊣4685486⊣4357266⊣4958454⏎
```

12.1.6 Stream Files in Binary Format

The naming convention "PREFIX_PMSN_TYPE_CISN_YYYYMMDD_hhmmss.bin" and "PREFIX_PMSN__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',

PMSN
: Power meter serial number, e.g. PM23.

TYPE
: Power meter type, e.g. 2v1 for LSPM 2.1 Power Meter.

CISN
: CI-250 serial number, only for LSPM 1.1/2.1, otherwise omitted, e.g. CI762.

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 power values for all channels, 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 as from which on the new look-up table is valid. 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	Power meter serial number, 16 bit, little endian, unsigned integer
Optical PM	10	1	Optical power meter present yes/no?, 8 bit, little endian, unsigned integer
Mode	11	1	Power meter mode, 8 bit, little endian, unsigned integer
Frequency	12	8	Power meter frequency in hertz, 64 bit, double-precision, little-endian floating-point value
Temperature	20	4	Power meter 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
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 an arbitrary number of power value blocks. Each block contains synchronous channel 1, 2 and 3 power values and a frame information byte 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, 8 bit unsigned integer
CH1 power	4	Channel 1 power value in dBm, 32 bit single-precision, little-endian floating-point value
CH2 power	4	Channel 2 power value in dBm, 32 bit single-precision, little-endian floating-point value
CH3 power	4	Channel 3 power value in dBm, 32 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 channel number of the device (1-3 channels for LSPM, 3 channels/axis for LSProbe). Bit 0/LSB is the frame indicator. For the continuous modes (mode 0-3 for all LSPMs & mode 8-13 for LPSM 1.1/2.1), 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 for LPSM 1.1/2.1), the frame indicator change its value when a new burst frame is received.

12.1.7 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, optional
2	f	Hz	Compensation frequency, optional
3	P1	dBm	Channel 1 power
4	P2	dBm	Channel 2 power
5	P3	dBm	Channel 3 power
6	T	°C	Power meter cold plate temperature, optional
7	Skip		Skip count used during stream recording, 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 power stream files, redundant parameters will be ignored silently:

-h
: display usage information and quit program,

-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.

12.1.8 GUI load file format

The file format for files that can be viewed with the LUMILOOP GUI contains at least 1 column. Either power values for channel 1, 2 or 3 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 "p1", "p2" or "p3". Units have to be in 'dBm". All other columns will be ignored. Multiple data sets for the same channel must be clearly distinguishable via their column header, e.g. "P1_pm1" and "P1_pm2".

Example of file:

```
#P1_pm1 in dBm	P2_pm1 in dBm	P3_pm2 in dBm	P1_pm2 in dBm	P2_pm2 in dBm	P3_pm2 in dBm
-15.8		-60.0		-60.0		12.6			0.5			-35.7
-16.9		-60.0		-60.0		15.6			-60.0		-38.9
```

12.2 extCalLog TCP-Server Logger

For each TCP/IP connection with the exception of the LUMILOOP GUI, the SCPI command :CALibration:LOGging <Value> enables/ disable logging of power meter status information and power values every time a »:MEASure[:Power]:P[1]/P2/P3/ALL? [<MPMeter>]« SCPI query is sent by a client which previously set its log flag set to 1.

For conventional power meters LSPM 1.0$^{(+)}$/2.0$^{(+)}$ the CSV file format for all calibration log files contains sixteen columns described by their column headers and unit values in the table below.

Column	Header	Unit	Description
1	RSSI1	LSB	Channel 1 RSSI value
2	RSSI2	LSB	Channel 2 RSSI value
3	RSSI3	LSB	Channel 3 RSSI value
4	T	°C	Power meter cold plate temperature
5	f	Hz	Compensation frequency
6	P1	dBm	Channel 1 power
7	P2	dBm	Channel 2 power
8	P3	dBm	Channel 3 power
9	Serno LSPM		Power meter serial number

Column	Header	Unit	Description
10	Mode		Measurement mode, see Tables 1 to 4, page 23 to page 26
11	FW LSPM		LSPM 1.0 FPGA firmware version
12	Server Built date		LUMILOOP TCP Server built date formatted as YYYYMMDD
13	t	s	Timestamp expressed as a float number of seconds since 1904/01/01 00:00:00 UTC
14	cal:corr		Correction factors enabled state, see :CALibration:CORRfactor <Value>[,<MPMeter>]
15	fLpP	Hz	Power value low pass filter frequency
16	123a		Inidcator which SCPI query prompted logging of actual line

Example of extCalLog file:

```
#RSSIx ⊣RSSIy⊣RSSIz⊣T⊣f⊣P1 ⊣P2 ⊣P3 ⊣SerNo LSPM ⊣Mode ⊣FW LSPM⊣↙
   Server Built date⊣t⊣cal:ext⊣fLpP ⊣123a⏎
```

For optically powered power meters LSPM 1.1/2.1 the CSV file format for all calibration log files contains twenty columns described by their column headers and unit values in the table below.

Column	Header	Unit	Description
1	RSSI1	LSB	Channel 1 RSSI value
2	RSSI2	LSB	Channel 2 RSSI value
3	RSSI3	LSB	Channel 3 RSSI value
4	T	°C	Temperature inside the power head
5	f	Hz	Compensation frequency
6	P1	dBm	Channel 1 power
7	P2	dBm	Channel 2 power
8	P3	dBm	Channel 3 power
9	Serno CI		CI-250[+] Computer Interface serial number
10	Serno MP		power head serial number
11	Mode		Measurement mode, see Tables 1 to 4, page 23 to page 26
12	FW CI		CI250 FPGA firmware version
13	Server Built date		LUMILOOP TCP Server built date formatted as YYYYMMDD
14	cal:corr		Correction factors enabled state, see :CALibration:CORRfactor <Value>[,<MPMeter>]
15	fLpP	Hz	Power value low pass filter frequency

Column	Header	Unit	Description
16	ACCx	g	X-axis acceleration in multiples of 9.81 m/s^2
17	ACCy	g	Y-axis acceleration in multiples of 9.81 m/s^2
18	ACCz	g	Z-axis acceleration in multiples of 9.81 m/s^2
19	123a		Inidcator which SCPI query prompted logging of actual line

Example of extCalLog file:

```
#RSSI1  RSSI2   RSSI3   T   f   P1  P2  P3  SerNo CI    SerNo PM
      Mode     FW CI    Server built date    cal:corr    fLPP     ACC1
       ACC2     ACC3     123a
```

12.3 Generic Calibration Result Files

To simplify the conversion of calibration results into corrections factors for the use in the LUMILOOP TCP Server, a generic calibration result file is described below.

Generic calibration result files are CSV files that use the formatting conventions outlined in Section 12 of the LSPM User's Manual. They employ a subset of the CSV file format standard, with neither quotation marks nor escape characters. Every generic calibration result file begins with a metadata header. Metadata lines start with a »#« comment character, followed by key-value pair strings, separated by a »:« colon character. Additional whitespace characters at the start or the end of lines will be ignored.

The calibration data part of the generic calibration result file begins with the first line that does not start with a comment character. The first such line is the table head, starting with the word »`Mode`«. It describes the values in the lines below.

12.3.1 Metadata Section

The following metadata keys in the table below are pre-defined. Additional metadata keys may be added but will be ignored by the CalImport tool, just as the keys marked as unused. Keys are case sensitive and must match the spelling in the table below. If a key consists of more than one word, they are separated by single spaces.

Metadata Key	Used	Description
Certificate Identifier	yes	Unique identifier for the calibration certificate
Date of Calibration	yes	Last day of the calibration (local time) in the format YYYY-MM-DD
Calibration Laboratory	yes	Short form name of the calibration laboratory (e.g., NPL, PTB, etc.)
Manufacturer	yes	Manufacturer of the device, here LUMILOOP
Type	yes	The full Type or name of the device, as indicated on the type plate or in the corresponding documents (e.g., LSPM 1.0/1.1/2.0/2.1)
Serial Number	yes	Serial number of calibrated device
Nominal Power	yes	Nominal power value in dBm used for calibration as a floating point number, rounded to the nearest multiple of 0.01 dBm
Date of Factory Calibration	yes	Date of factory calibration, formerly "Date of Manufacturer Calibration", in the format YYYY-MM-DD
Ambient Temperature	no	Ambient temperature in °C as a floating point number
Ambient Humidity	no	Relative ambient humidity as a floating point number in %
Customer	no	Name of customer
Order Number	no	Number of order by customer
Date of Certificate	no	Date of calibration certificate approval (local time) in the format YYYY-MM-DD
Approved by	no	Person who has approved the calibration certificate
Description	no	Description of the calibration, e.g., used to distinguish calibrations for different purposes
Accredited by	no	Name of accreditation body and identifier thereof

12.3.2 Data Section

The data section contains a maximum of eight entries per line depending on the number of calibrated LSPM channels, as shown in the table below. Values occupy the column defined by the table head. Columns for channel 2 and 3 need only be added if they were calibrated. All values must exactly match the ones given in the calibration certificate.

Column	Header	Description
1	Mode	Power meter mode, as queried by »`:SYSTem:MODe?`«, only modes 0 and 3 are supported by CalImport
2	Frequency/Hz	Calibration frequency, as queried by »`:SYSTem:FREQuency?`«
3	P_1,cal/dBm	Channel 1 calibration power applied by the calibration setup
4	P_1,disp/dBm	Displayed channel 1 power, as queried by »`:MEASure:P1?`«
5	P_2,cal/dBm	Channel 2 calibration power applied by the calibration setup
6	P_2,disp/dBm	Displayed channel 2 power, as queried by »`:MEASure:P2?`«
7	P_3,cal/dBm	Channel 3 calibration power applied by the calibration setup
8	P_3,disp/dBm	Displayed channel 1 power, as queried by »`:MEASure:P3?`«

12.3.3 Ensuring Data Integrity

To ensure data integrity, and guard against inadvertent alteration of calibration data fines, an additional metadata line with the key »`#Hash`« may be provided as the last line.

The value must contain »`sha256`« to indicate the hash algorithm, followed by »`:`« and the hash encoded as hexadecimal string. The hash is calculated from all bytes in the preceding lines, including the line break characters. The hashing algorithm must be SHA-256 and all line breaks must be `LF`/(`0x0A`).

12.3.4 Generic Calibration Result File Example

```
#Certificate Identifier: PI:20210707:abc
#Date of Calibration: 2021-06-28
#Date of Factory Calibration: 2021-03-14
#Calibration Laboratory: Circlelab
#Object: power meter
#Manufacturer: LUMILOOP
#Type: LSPM 1.0
#Serial Number: 42
#Nominal Power: 0 dBm
#Customer: Powertesters, 01001 Musterhausen, GERMANY
#Date of Certificate: 2021-06-28
#Description: Pulse measurements
Mode	Frequency/Hz	P_1,cal/dBm	P_1,disp/dBm	P_2,cal/dBm	P_2,disp/dBm	P_3,cal/dBm	P_3,disp/dBm
3	10000	0.01	0.50	0.05	0.31	0.01	0.24
3	200000000	0.00	0.03	0.01	0.07	0.02	0.13
```

```
#Hash: sha256:edf7143e305cf66637e15ad1d988f9dd56d00949330b19a
    c8cc762b51fba9acd
```

12.3.5 Generation of Generic Calibration Result Files Using Spread-Sheet Program

While not recommended, generic calibration result files can be generated using a spread-sheet program, e.g., LibreOffice Calc or Microsoft Excel.

Arrange all data as shown in the table below and export it as a CSV file using tabulators as column separators, a point as decimal separator and no quotation marks for string values.

	A	B	C	…
01	#Certificate Identifier:	PI:20210707:abc		
02	#Date of Calibration:	2021-06-28		
03	#Calibration Laboratory:	Circlelab		
⋮	⋮	⋮		
20	Mode	Frequency/Hz	P_1,cal/dBm	…
21	0	9000	0.01	…
⋮	⋮	⋮	⋮	⋮

12.4 Calibration Files

Each LSPM Power Meter comes with a detailed set of factory calibration files used for linearity compensation, frequency compensation and absolute power value calibration. Optionally, an correction factors files of accredited power calibration can be added. Calibration files are stored in one directory per power meter, directory names consist of »sn« followed by the decimally coded power meter serial number without leading zeros. Calibration directories are stored in the directory specified via the `CAL_PATH` setting of the configuration file `LSPM_1.0.ini`. The CSV file conventions detailed in section 12 apply to all calibration files.

Calibration data folders can also be stored in the form of ZIP files consisting of »sn« followed by the decimally coded power meter serial number and the extension ».zip«. `LSPM_CAL_PATH` must not contain both a ZIP file and a directory for the same serial number.

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.

12.4.1 Factory Linearity and Frequency Compensation Files

One factory linearity and frequency file, or short LF file, exists for every factory calibrated frequency and power meter mode. LF file names consist of »sn« followed by the decimally coded power meter serial number, »m« followed by the decimally coded mode number, »f« followed by the decimally coded frequency value in hertz, followed by ».csv«.

The first line of LF files starts with a hash mark character (»#«) and gives context information for the LF 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		Power meter serial number as decimally coded integer value
2		Measurement mode, see Tables 1 to 4, page 23 to page 26
3	Hz	Measurement frequency
5		Time stamp of calibration for given frequency and mode
6		Checksum for rest of file as described in Section 12.4

The following lines of LF files have the following contents:

Column	Unit	Description
1	dBm	Power level used for given mode and frequency given in the first line of the file
2	LSB	Channel 1 RSSI value for given frequency, mode and power value in first column
3	LSB	Channel 2 RSSI value for given frequency, mode and power value in first column
4	LSB	Channel 3 RSSI value for given frequency, mode and power value in first column

Calibration files for power meters equipped with less than three channels contain an RSSI constant value of zero for all power levels for the unavailable power detectors.

12.4.2 Accredited Power Calibration Files

At least one accredited power calibration file, or short AP file, exists for every accredited calibrated LSPM Power Meter. 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 power meter is multi-level calibrated then there exists a file for every combination of mode and power level.

An AP file contains correction factors expressed in Decibels, the correction factor will be applied to the base power value derived from the supplied internal calibration data. A value greater than zero will make the displayed power value larger, values smaller than zero lower the displayed power value.

The AP file name consists of four parts: »sn« followed by the decimally coded LSProbe E-Field Probe serial number, the nominal calibration power of the calibration in dBm (but without the unit), »m« followed by the mode and the file name extension ».csv«. All parts (except the file name extension) are separated with an underscore (e.g. »sn55_0_m0.csv«).

For older TCP Servers or if the calibration is done without considering the different modes only one AP file exists. The name of this file consists of »sn« followed by the decimally coded LSPM Power Meter serial number (e.g. »sn55.csv«), and 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 AP files).

The first three lines of an AP file start with a hash mark character (»#«) and give context information for the AP file and the calibration conditions, 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		Power meter serial number as decimally coded integer value
2		Maximum time stamp during calibration
3		Checksum for rest of file as described in Section 12.4

The second line of the AP file contains a calibration certificate string/identifier that extends to the end of the second line. Normally the calibration certificate string is prefixed with the (short) name of the calibration laboratory.

The third line of the AP file contains two columns. The first column gives the power meter operating mode which the AP applies to, the second column gives the nominal calibration power (in dBm without the unit), supporting multilevel calibration. (Both values as given by the file name).

The subsequent lines of an AP file have the following contents:

Column	Unit	Description
1	Hz	Frequency for accredited power calibration
2	dB	Channel 1 correction factor for the given frequency
3	dB	Channel 2 correction factor for the given frequency
4	dB	Channel 3 correction factor for the given frequency

12.4.3 Wideband Correction Files

The wideband correction factors (WCF) are used for compensating measurement error introduce through modulation of the test signal, as described in Section 5.3.1. Wideband correction factors are type specific with one set of typical correction factors being valid for all individual power meters of an LSPM model. They also apply to all aviable channels of the power meter equally. They are stored in the same location as the regular calibration data, with the folder being named by the device type followed by the suffix »wb«, e.g. »1v1wb« for the LSPM 1.1 Power Meters. Within the wideband correction factor folder, the files containing the correction factors are namend in a similar manner as the factory linearity and frequency files. WCF file names consist of the device type, e.g. »1.0« for a LPSM 1.0 followed by the »wbm« identifier, followed by the decimally coded mode number, »f« followed by the decimally coded carrier frequency value in hertz, followed by ».csv«.

The first line of WCF files starts with a hash mark character (»#«) and gives context information for the specific 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		Measurement mode,
2	Hz	Measurement frequency
3...n	MHz	Modulation bandwidth 1 ... n
n+1		Maximum time stamp during calibration
n+2		Checksum for rest of file as described in Section 12.4

The following lines of WCF files have the following contents:

Column	Unit	Description
1	dBm	Power level used for given mode and frequency given in the first line of the file
1+n	dB	Correction factor for modulation bandwidth n at given measured power level

13 Specifications

Table 28: *LSPM Power Meter specifications*

Frequency Range Low Band High Band	 9 kHz ... 400 MHz 30 MHz ... 6 GHz (usable up to 12 GHz)
Analog Rise Time Low Band (Video BW 500 Hz) Low Band (Video BW 1 MHz) High Band (Video BW 3 MHz)	 1.9 ms 770 ns 330 ns
Minimum Pulse Width	500 ns
VSWR	<1.2:1
Sampling Rate	2 MSamples/s
Measurement Range & Dynamic Range Low Band High Band up to 4 GHz High Band 4 ... 6 GHz High Band 6 ... 12 GHz	 <-60 dBm ... >20 dBm (>80 dB) <-70 dBm ... >20 dBm (>90 dB) <-50 dBm ... >20 dBm (>70 dB) <0 dBm ... >20 dBm (>20 dB)
Amplitude Accuracy*	0.1 dB
Linearity Error	0.15 dB
Temperature Stability	0.1 dB
Power Resolution	<0.1 dB (see plot below)
Channel Isolation	>50 dB
Damage Level	>30 dBm
PC Interface	USB 2.0
Application Software	LUMILOOP TCP Server, LUMILOOP GUI, CalImport
Trigger Voltage	5 V
Trigger Connector	BNC
Input Voltage	5 V ±5 %
Input Current	<3 A
Ambient Temperature	10 ... 40 °C
Dimensions (W × D × H)	165 × 142 × 61 mm^3
Certifications	CE

*) At 0 dBm, CW, accredited Calibration at Ametek CTS Europe GmbH.

13.0.1 Typical Dynamic Range

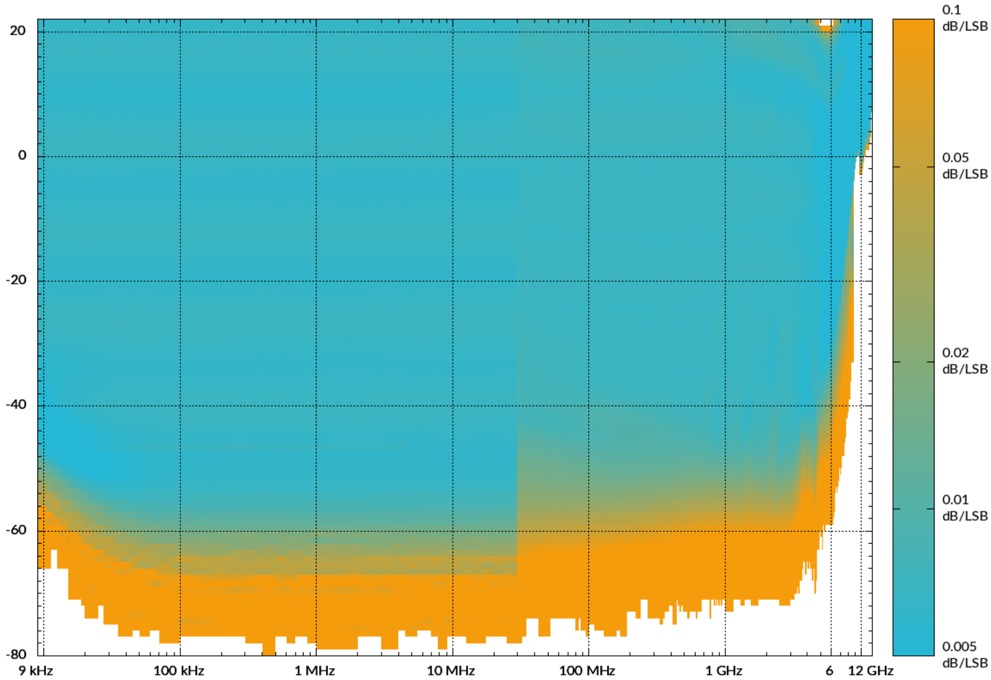


Figure 109: *Typical dynamic range, low and high band*

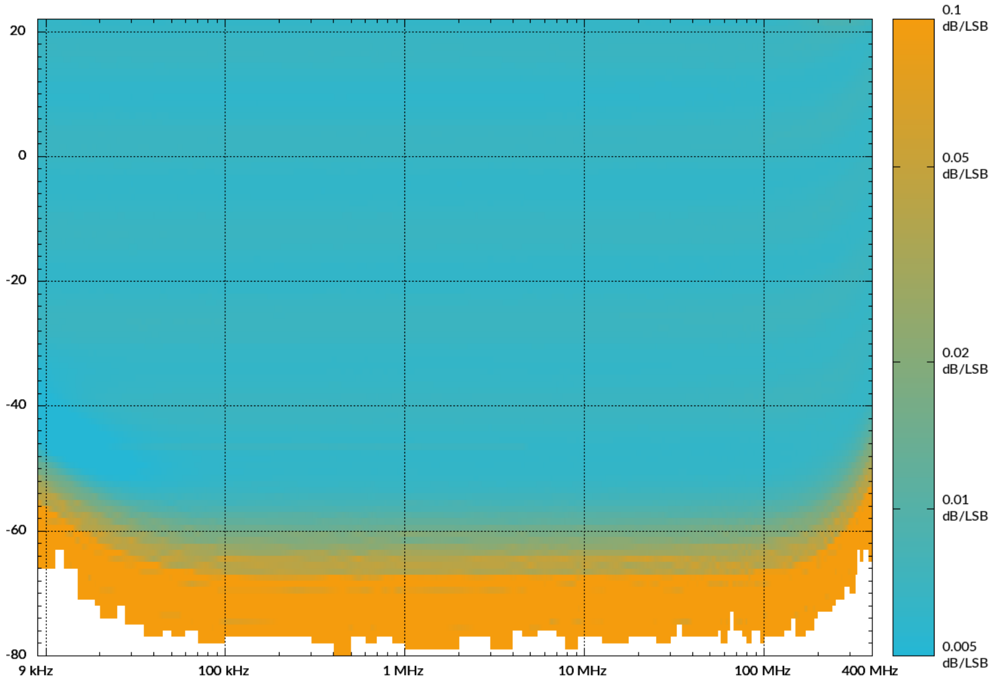


Figure 110: *Typical dynamic range, low band*

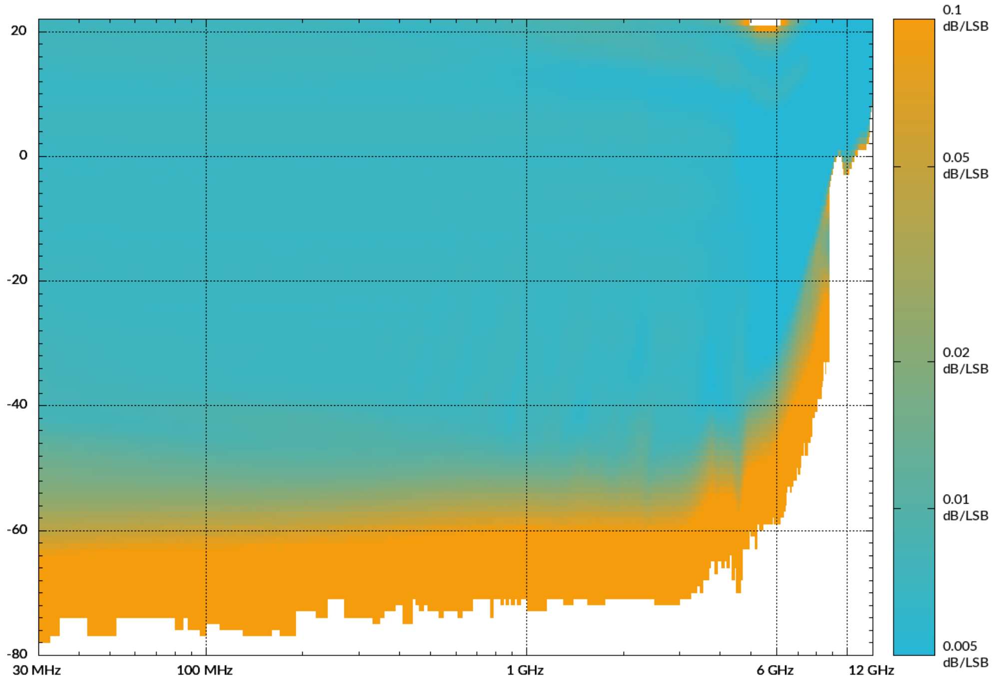


Figure 111: *Typical dynamic range, high band*

14 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:	LSPM Power Meters
Model / Part Numbers:	2011, 2012, 2013, 2021, 2022, 2023, 2101, 2102, 2103, 2104, 2105, 2106, 2107, 2108, 2109 2111, 2112, 2113, 2114, 2115, 2116, 2117, 2118, 2119, 3023, 3025, 3028, 3029
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, Technical Director

This declaration attests the compliance with the stated directives. It does not imply any assurance of characteristics.

16 Revision History

2018/10/16

- Initial release.

2018/11/27

- Update of dynamic range plots.
- Fix spelling.
- Expected format of correction factor files by TCP-Server fixed.
- LUMILOOP GUI indicates accredited calibration enabled/disabled state via date string.

2020/11/24

- 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.
- Bug fix: use average of power values instead of RSSI value average for all averaging queries.
- 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: »trig:arm« race condition fixed by handshake flag in CI and modified trigger state transitions.
- Bug fix: fix monotonous range error for snXmYfZ.csv calibration file parsing.
- Bug fix: do not re-use old LUT for new waveforms.
- Bug fix: return correct number of commas for more that 64k return values.
- Firmware fix: prevent self-triggering on external trigger polarity change.
- Command line prompt with history and shortcuts added for TCP server.
- Loop command for all SCPI commands added for TCP server.
- »[:TRIGger]:RADar:BINary? <Wave>[,<MPMeter>]« added.
- Stricter sanity checks for all calibration data files.
- Support multi-level and multi-mode correction factor data using snX_Y.csv files.
- »:SYSTem:WAIT <Sec>« added to wait for a number of milliseconds.
- »:SYSTem:AUTOCONnect <State>« added to reduce interference with other FTDI USB devices.
- CI polling intervall set to 1 s, only call CreateDeviceInfoList() if number of connected USB devices has changed.
- »:TRIGger:POINts <Points>[,<MPMeter>]« added for point triggering.
- Simplify SCPI syntax for MEAS and TRIG subsystems.
- »[:TRIGger]:RADar:MINSamples <MinS>[<MPMeter>]«, »[:TRIGger]:RADar:MINTime <MinT>[<MPMeter>]«, »[:TRIGger]:RADar:THMethod <Method>[<MPMeter>]«, »[:TRIGger]:RADar:THold:P[1]/P2/P3/ALL? [<MPMeter>]«, »[:TRIGger]:RADar:MAVG <Count>[,<MPMeter>]« (obsolet), »[:TRIGger]:RADar:MPOWer:P[1]/:P2/:P3/:ALL?

[<MPMeter>]«, »[:TRIGger]:RADar:DUTY:P[1]/:P2/:P3/:ALL? [<MPMeter>]«, »[:TRIGger]:RADar:WPower:P[1]/:P2/:P3/:ALL? [<MPMeter>]« (obsolete) added to radar pulse subsystem.
- »[:TRIGger]:RADar:P[1]/P2/P3? [<MPMeter>]«, »[:TRIGger]:RADar:PULses:STArt:P[1]/:P2/:P3? [<MPMeter>]«, »[:TRIGger]:RADar:PULses:LENgth:P[1]/:P2/:P3? [<MPMeter>]« added for individual pulse queries.
- »[:TRIGger]:RADar:TRIM <State>[,<MPMeter>]« to control behavior at pulses' edges.
- »[:TRIGger]:SWeep:ARBitrary? [<MPMeter>]« added.
- Ask for confirmation before closing TCP server due to error.
- »:SYSTem:ERRor[:NEXT]?« and »:SYSTem:ERRor:COUNt?« extended for detailed error messages.
- »:MEASure[:PMeter]:VBW <Frequency>[,<MPMeter>]« added to support low frequency operation with high video bandwidth detector and software-based video bandwidth setting.
- Extend operating frequency range for mode 2 to low frequencies, add forbidden frequency range to avoid aliasing..
- »:SYSTem:DFLags?« added for textual debug flag setting and query.
- Create separate waveform log files for sweep waveforms in GUI.
- Display pulse average values in GUI's waveform.
- 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:FLENght? [<MPMeter>]« added for query of waveform length, including all trigger points.
- »:TRIGger:PTTimes? [<MPMeter>]« added to query trigger timing.
- »[:TRIGger]:SWeep:TCNT? [<MPMeter>]« added to query number of sweep steps that fit into waveform.
- Bin2CSV: LSPM streaming file support added.
- New streaming files with separate LUT and data files, also supported by Bin2CSV.
- Stricter sanity checks for pulse modulation of virtual probes added.
- Added reduced data rate mode for slow USB connections.

2024/07/18

- Bug fix: LPF greater 0 and change of mode only channel 1 was reset
- 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 change: wait for Hardware lock of correct mode before parsing of new SCPI command allowed
- Temperatur muss stabil sein ehe Werte geliefert werden, sonst NAN
- Frequenz wird nur noch beim Modus-Wechsel an Grenzen angepasst, sonst bei nicht ein-

halten der kalibirerten Grenzen NAN zurück gegeben

- Single LUMILOOP TCP Server for all LSProbe and LSPM devices
- 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 conventional power meter LSPM 2.0 and optically powered power meters LSPM 1.1 and 2.1
- 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" shortcut SCPI command for overview list of calibration data with key elements
- trigger system ADC value queries »:TRIGger[:WAVeform]:ACCeleration:1/2/3? [<MPMeter>]«, »:TRIGger[:WAVeform]:TEMPerature? [<MPMeter>]«, »:TRIGger[:WAVeform]:VOLTage? [<MPMeter>]« with MProbe parameter: for each probe same number of values will be returned, if value is not occupied empty string will be returned
- new Python based LUMILOOP-GUI for simultanous LSPM and LSProbe handling and visualization of log files
- »:SYSTem:LHFrequency <Frequency>[,<MPMeter>]«, »:SYSTem:LHFrequency? [<MPMeter>]« added for setting and query of crossover frequency of low to high band detector in Mode 1 and 5
- 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 wideband calibration data
- improved temperature handling of conventional power meters, new 32 degrees
- streaming power value binary logging
- added streaming to client connection
- added support for wideband correction data
- added support for arbitrary sweep steps
- added support for silent installation

2025/05/13

- Bug fix: adjusted allowed modes for LSPM xv1, disabled Mode 5, 6, 7, 9, 11, 13 (burst mode and single channel high sampling rate modes for low-band detector)
- Bug fix: LSPM xv1 sampling rate for low-band detector to 500 kSamples/second reduced (Mode 2, 3)
- Bug fix: segmentation fault in some cases of USB communication problem, USB Fifo Over-

flow

- 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
- added »[:TRIGger]:RADar:SOURce <Source>[,<MPMeter>]« and »[:TRIGger]:RADar:SOURce? [<MPMeter>]« for setting and query of radar source
- removed moving average waveform filtering in radar subsystem

2025/08/15

- Bug fix: +Devices: flush file operation(s)
- Bug fix: +Devices: +device management dialog: handle zip calibration files
- Bug fix: Description of SCPI command "[:TRIGger]:RADar:TRIM?" revised
- Bug fix: Chapter "Power-Meter Calibration" revised
- Bug fix: LSPM Power Meter calibration procedure summary revised
- Paragraph "Generic Calibration Result files" outsourced as own subchapter for external reference
- added: Subchapter "Linearity and Reflection Measurement" added to chapter "Power-Meter Calibration"
- 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>[,<MPMeter>]« and »:STATistics:LENgth? [<MPMeter>]« 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