

Fibotec Fiberoptics GmbH
Herpfer Str. 40
98617 Meiningen
Germany
Tel. +49 3693 8813-200
Fax. +49 3693 8813-201
www.fibotec.com



Instruction Manual

Optical Fiber Fault Locator Module

(Version 3.0 Apr. 2012)

Safety precautions

This manual contains a description of controls, adjustments and procedures for normal operation of the Fault Locator Module. The Fault Locator should only be operated by qualified personnel who reviewed this manual before installing and applying the module.

CAUTION: Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.

LASER SAFETY: This product contains laser diodes of class 1M. To ensure continued safety, do not remove any covers or attempt to gain access to the inside of the product.



Contents

Introduction

1. Installation

2. Functional description

- 2.1 Optical time domain reflectometry
- 2.2 Building-blocks of the Fault Locator Module
- 2.3 Fault Locator Module measurement process
- 2.4 Specifics of correlation OTDR measurement data

3. Programming, serial interface commands

- 3.1 Command structure
- 3.2 Basic Operation
- 3.3 Advanced Operation
- 3.4 Functional list of commands
- 3.5 Alphabetical list of commands
- 3.6 Error messages

4. Measurement examples

5. Technical specifications

- 5.1 General
- 5.2 Remark

Introduction

This manual describes the principle, the communications interface and the operation of the Optical Fiber Fault Locator Module. The communications interface is designed to work with a simple serial ASCII terminal or any PC with a serial or USB port and terminal software on the basis of sending and receiving ASCII commands. All operational features of the module described in this manual are accessible in this way.

Additional software for graphically presenting measurement results or a graphical user interface for the Fault Locator Module is available separately and is not described in this manual.

1. Installation

- Depending on the version the module is integrated into a slide-in unit for 19" cabinet use or requires an external power supply of usually 5Vdc supply voltage.
- The optical output power is limited to 3dBm, according to laser class 1M.
- Serial Interface initial settings: 115200 baud, 8N1, no handshake
- RS232-ports or USB-ports with USBtoRS232-converters can be used, respectively.

2. Functional description

The Optical Fiber Fault Locator Module (hereafter referenced as **FL**) is a Correlation Optical Time-Domain Reflectometer (COTDR) for online-monitoring the transmission quality of optical fiber networks. Pulse sequences are sent down the fiber and back-reflected signals are detected and analyzed by strength and distance. Reflective and absorptive discontinuities can be identified at a spatial resolution up to 1.25m (80MHz version). Such discontinuities are caused by connectors, breaks and many other types of flaws in the fiber material, which contribute to a reduced optical transmission quality of the fiber network.

2.1 Optical time domain reflectometry

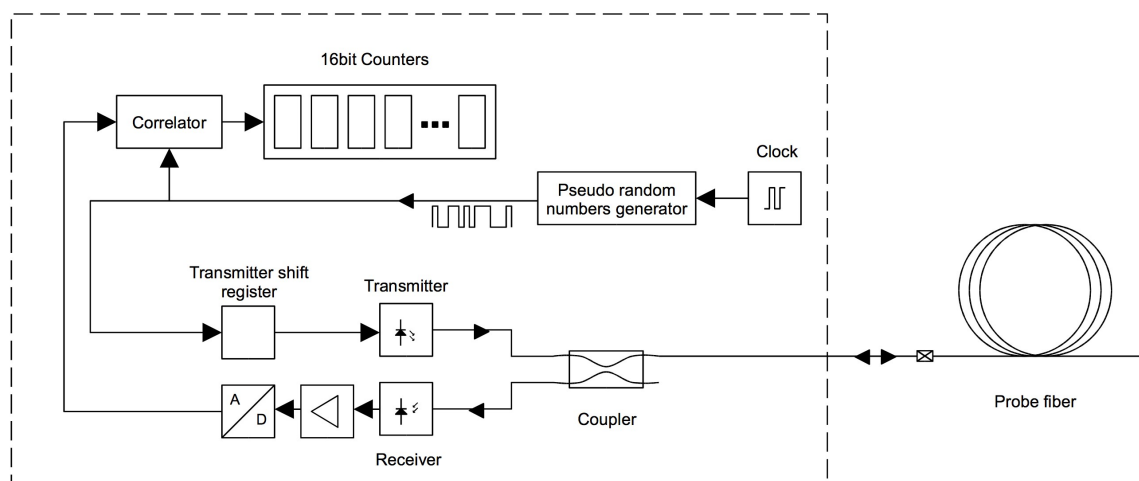
In a standard optical time-domain reflectometer (OTDR) high-energy pulses of nsec duration are sent down the fiber. Measuring the time delay between the emitted pulse and detected back-reflexes and knowing the speed of light in the fiber (i.e. the refractive index of the fiber) allows for a calculation of the distance of the reflective discontinuities down the fiber. Absorptive discontinuities can be monitored as well, provided that they affect the detectable Rayleigh backscatter signal.

The FL is based on the principle of correlation OTDR (COTDR). Here a continuous stream of low-power pulses at a cycle-frequency of kHz to several MHz is sent down the fiber. The pulse stream comprises of digital pseudo-random numbers, number "0" corresponds to a low laser power level and number "1" corresponds to a high laser power level. The back-reflected stream of pulses is digitized and correlated with a time-delayed version of the transmitted digital pseudo random number stream. A high degree of correlation at specific delays allows for a calculation of the distance of the reflective discontinuities down the fiber, if the speed of light (i.e. the refractive index) in the fiber is known.

The advantage of correlation OTDR compared to standard OTDR lies in a better signal-to-noise factor when integrating the reflected signal over a fixed amount of time. Additionally there is no need for a high-power pulsed laser source, so the reflectometer can be operated at laser safety class 1M at any desired wavelength, including CWDM and DWDM channel wavelengths.

2.2 Building blocks of the Fault Locator Module

Figure 1 shows the building blocks of the FL:



A digital pseudo random numbers generator sends a continuous stream of states "0" and "1" at a user-selectable clock rate (kHz to MHz). The states modulate the power of a laser diode (transmitter) which is connected to the fiber network (probe) via a 50%/50% directional coupler. Reflections from the fiber enter the same coupler. A digital correlator is responsible for delaying the emitted data stream and correlating it with the digitized reflected signal stream. The result is fed into 256 up/down counters of 16 bit length (15 bit plus sign). Each counter integrates the correlation of the stream at one cycle additional time delay. For example counter 5 shows signal correlation, if the reflected data stream from the fiber correlates to the transmitted data stream sent 5 cycles ago. This corresponds to reflective events within $4.5 \cdot (\text{cycle time}/2) / c$ and $5.5 \cdot (\text{cycle time}/2) / c$ meters down the fiber, with c =speed of light in the fiber. The resolution equals cycle-time divided by a factor of two, because the light has to travel down the fiber to the reflective event, and then back again to the FL. If several events in several counters are detected, the numbers in the counters directly relate to the strengths of the reflective events.

Reflection signals don't get lost, if the network is measured at low spatial resolution, i.e. at low cycle-time. If a resolution of e.g. 160 meters is chosen, all events within each 160 meters slot are integrated in the corresponding counter. Then a particular slot can be chosen by pre-delaying the transmitted data stream with the transmitter shift register. After the resolution has been increased, it can be checked, how many different events are hidden within the previous 160 meters slot. The previous slot can be checked again at higher resolution, and so on.

2.3 Fault Locator Module measurement process

The FL integrates the correlation values in the 256 up/down counters until a counter reaches the value \$FFFF or \$0000. This event is called "overflow", because it prevents the counter from overflowing. Now the user needs to read-out all counter values, to reset the counters (value \$8000) and to start integration again.

The counter values are signed (value \$8000 corresponds to zero), because the noise can generate negative correlation values during integration. With a perfectly absorbing probe connected to the FL, all counter values will be equally distributed around value \$8000 during a measurement.

In theory infinite low reflective events can be detected, only limited by the time the user is willed to wait for an overflow to occur or by stopping integration manually. Even with a perfectly absorbing probe connected to the FL the overflow will occur sometime due to a random walk of a counter from \$8000 to \$FFFF or \$0000.

A-priori there is no information available about the absolute strength of the reflective event causing the overflow. Nonetheless, different signals in different counters can be linearly related in strength to each other. Absolute reflection strength numbers can be generated, if one of the signals in the counters is a signal from a reflection reference introduced along the fiber network.

If a strong reflection dominates others and causes an overflow before the weaker reflections can build up in the counters, the corresponding counter can be disabled. In this case the strongest of the remaining reflections will cause an overflow. By continuing this process of disabling counters several times with several reflection signals it is possible to measure events of lower and lower signal strength and to take advantage of the high sensitivity of the measurement principle.

2.4 Specifics of correlation OTDR measurement data

Two effects are limiting the high sensitivity of the correlation OTDR measurement principle in practice. One effect is caused by the finite amplification bandwidth of the optical-to-electrical interface behind the optical receiver. The other effect results from electrical crosstalk in the correlator and in the counting unit.

Any deviation from infinite bandwidth in the electronics behind the optical receiver results in a characteristic high-pass filter like deformation of the correlation signal. As a consequence ringing structures behind large reflective peaks and extended regions of negative counter values are observable at low resolution. Even with dc-coupled amplifiers bandwidth limitations are present, caused by automatic gain control or automatic offset correction feedback loops in the kHz or Hz range in the amplifier ICs.

Even minor electrical crosstalk is manifesting itself in the up/down counters as reflective "ghosts" of positive or negative sign. Such ghosts eventually become visible when taking a large number of averages of measurement data to minimize noise. They are easy to identify, because they are sticking to their corresponding counters, independent of the resolution chosen.

3. Programming, serial interface commands

The Fault Locator Module is controlled by a RS-232 serial interface. Any serial ASCII terminal or any PC with a serial port and terminal software can be used to operate the FL. All operational features of the module described in this manual are accessible in this way. It is possible to use an USB to RS232 converter to connect the FL to a computer lacking a serial port.

3.1 Command structure

The FL is controlled by sending simple commands based on the ASCII character set. Except for one set of commands all responses of the FL are based on the ASCII character set. Several commands produce no response at all. In case of misspelling a command or in case of sending an unknown command, an error message ("Sorry?") is the response.

Every command is represented either by a single word, two words separated by a space or one word and a number separated by a space. Do not omit the space. All letters of a word are lowercase letters. Numbers are hexadecimal and either two digits (\$00-\$FF) or four digits (\$0000-\$FFFF) in length and either upper or lowercase letters. Do not omit leading zeroes, i.e. type "000A" instead of "A".

A colon at the beginning of a new line indicates, that the FL is ready to receive a command. Commands are accepted by the FL after sending the carriage return key (ASCII code \$0D). In response the FL produces a new line on the terminal by sending the three codes carriage return (\$0D), line feed (\$0A) and colon (\$3A). If the command produces response, additional characters follow.

Most of the commands are used to modify internal registers or status flags of the FL. There are no commands to read-out the state of these registers or flags. Values can only be changed but not extracted from the FL. The user or the external software is responsible for keeping its own record of recently sent commands to evaluate the current status of the FL.

3.2 Basic operation

3.2.1 Serial connection to the FL

After power-on reset the FL adjusts its serial interface parameters to 115200 baud and 8N1. Assure that the terminal software uses the same parameters. The FL will send a "hello message" including the version number of its firmware. Receiving the hello message confirms that the reset was successful and that serial communication works well. Change the serial baud rate by typing **baud XX** with XX = baud rate factor to 9600 in hexadecimal. E.g. sending **baud 04** increases the baud rate to 38400. The maximum baud rate depends on the type and length of cable used.

3.2.2 Preparation for measurement

General knowledge about working with an OTDR (optical time-domain reflectometer) is recommended, especially if the FL is used for the first time without the help of an external data visualization software. If the FL seems to produce just noise as output, carefully check the parameter settings and the connection to the optical fiber or network under test. If the FL is poorly connected to the optical fiber any choice of parameters will result in a void measurement. If a strong reflection at the first counter dominates the measurement, check for a poorly cleaned connector directly behind the FL.

The optical connector of the FL should not only remain free from solid particles (dust, dirt) but also free from transparent greasy films like fingerprints. Such films can cause very high reflections and will blind the FL. It is recommended to periodically clean the connector end face with alcohol, acetone, etc. Using a standard reel tape connector cleaner (like a Cletop cassette) might not be sufficient!

3.2.3 Measurement procedure

After power-on reset the FL will immediately start correlating and modifying the 256 up/down counters from their initial values \$8000. You can check individual counter values by the command **rch XXXX** with XXXX = channel number \$0000 to \$01FF. The response is a hexadecimal number in the range \$0000 to \$FFFF. Successive channels can be viewed by sending **rchn XXXX** with XXXX = the highest channel, e.g. **rchn 0110** sends 17 lines of hexadecimal numbers, the values of the counters \$0010 down to \$0000. If an external software is used to communicate with the FL, the command **rchnb XXXX** can be used to receive the counter values in binary format. The advantage of binary format is the reduced time for read-out of the FL counters. To allow for checking the integrity of the counter values received over the serial line the commands **rchnb XXXX** and **rchnbc XXXX** are available. All five commands rch, rchn, rchnb, rchnbc and rchnbc can be sent to the FL any time without interfering with its correlation process.

If one of the counters experiences an overflow (values \$0000 or \$FFFF encountered) the FL stops correlation. The state of the FL (running or halted) can be tested by the command **readovfl**. Response \$01 reads as running and response \$00 reads as overflow occurred and the correlation is halted. Reading counter values via the five **rch...** commands is always possible independent of the state of the FL being halted or running.

Counter values are initialized to \$8000 and the FL correlating is restarted by the command **preload** (The commands **resfac** and **txcntfw/txcntres** affect the FL similarly). To get an immediate information as soon as a counter overflow is experienced, the FL can be set to a state of "sending asynchronous messages is permitted". After power-on reset sending asynchronous messages is not permitted, i.e. the FL is only sending messages or data as a direct response to a command. The command **amsg on** permits the FL to send messages at any time. This allows the FL to send the word "ovfl" immediately in case of a counter overflow is experienced. The successive and timeconsuming use of the command **readovfl** becomes obsolete this way.

The horizontal resolution slot of each up/down counter directly corresponds to the frequency of the clock generating the pseudo random numbers. The maximum clock rate of current FL versions is 100 MHz. Assuming a fiber refractive index of $n=1.5$ the cycle time of $1/100\text{MHz} = 10 \text{ nsec}$ leads to a resolution slot of approx. 1.0 meters for each counter. The resolution is half the length of a cycle, because the light has to travel down the fiber to the reflective event, and then back again to the FL. The clock frequency can be reduced by a

factor. This is achieved by the command **resfac XX** with XX = 00 to FF. The resolution calculates as follows:

$$res_{hor}[m] = \frac{2 \cdot resfac \cdot c_0}{2 \cdot n \cdot 100.000.000s^{-1}} \quad \text{Exc.: resfac 00} \quad res_{hor}[m] = \frac{c_0}{2 \cdot n \cdot 100.000.000s^{-1}}$$

C₀ = speed of light in vacuum (299792458m/s)
n = refractive index of fiber (glass typ. 1,48)

Please see the table below for examples.

resfac XX	resolution [m] @ n=1.48
\$00	1.01
\$01	2.03
\$02	4.05
\$03	6.08
:	:
\$FE	514,5
\$FF	516,5

To get an overview of the complete probe fiber network, type eg. **resfac 31** and thus measure the network at approx. 100 meters resolution. Keep in mind that the exact resolution value depends on the fiber refractive index.

The start of the first resolution slot resp. counter can be shifted in relation to the beginning of the fiber attached to the FL. This allows the measurement of selected portions of the fiber at high resolution. The commands **txcntfw XXXX** and **txcntres** are used to shift the starting point along the fiber. The value \$XXXX gives the shift in resolution slots and it is possible to send the command several times to allow for shifts larger than \$FFFF slots. (See the subsequent specifications section for the maximum number of shifts allowed for the specific FL used.) If a segment 20 km down the fiber should be measured at 10 meters resolution, choose **resfac 05** and **txcntfw 076C**. The FL now starts correlating signals 1900 slots of 10m resolution behind the beginning of the fiber. Command **txcntres** resets the shift to zero. It is important to keep in mind that the actual starting point in meters automatically changes, if the resolution is modified via the **resfac** command after using the **txcntfw** command.

A typical start of a measurement session looks like this:

```
:hello ; test of the serial interface
:resfac 31 ; 100m horizontal resolution
:amsg on ; permit asynchronous messages

:cnt on ; start correlation and wait for async message"ovfl"
:rchnb 00FF ; -> "overflow" experienced, thus read the correlation result
:cnt on
:rchnb 00FF ; etc.
```

In case of the external software can't handle async messages, the session looks like this:

```
:hello                ; test of the serial interface
:resfac 31            ; 100m horizontal resolution

:cnt on              ; start correlation
:readovfl            ; periodically check for FL correlation finished
:01
:readovfl
:00
...
:rchnb 00FF          ; -> "ovfl" experienced, thus read the correlation result

:cnt on
:readovfl
:01
:readovfl
:01
:readovfl
:00
:rchnb 00FF          ; etc.
```

Because internal states can only be changed but not extracted from the FL via the commands described, external software is responsible for setting-up the FL into its own requested default state after start-up. The following list of commands is an example for such an initialization:

```
:echo on
:resfac 31
:txcntres
:chonn 0000
:amsg off
:setpow FF
```

3.3 Advanced operation

3.3.1 Measurement time and measurement dynamics

If a strongly absorbing fiber is attached to the FL, it might take quite a long time (several to tens of seconds) before a counter overflow is experienced. During this time the actual status of the counters can be checked any time by using the command set **rchxxx**. There is no implicit necessity to wait for an overflow to read measurement results. If the counter values are extracted and a new measurement is started consecutively after a fixed amount of time (e.g. 3 seconds), the corresponding readings can be processed and averaged exactly like a measurement achieved after an overflow event.

If a strong reflection dominates the measurement, the corresponding counter can be disabled from producing an overflow via the command **choff XXXX** with XXXX = counter number. Now smaller reflections are enabled to grow during the correlation in different counters to produce overflow. The subsequent overflow counter can be disabled again, and so on. Finally the command **chonn 0000** can be used to quickly enable all counters again for normal operation of the FL.

The transmitter laser power can be adjusted by the command **setpow XX** with XX = \$00 to \$FF. The value \$00 reduces the power to a minimum. The scale is a logarithmic one. On behalf of a minimum correlation time it seems correct to choose maximum laser power. However, this procedure increases the risk of blinding the A/D-converter behind the optical receiver with a strong reflective event somewhere along the fiber. This risk is hard to assess, especially because the blinding reflection might be located behind the actual measurement range and so is invisible to the user. The strange observation of Rayleigh backscattering signal becoming smaller if the laser power is increased is a clear signature for FL blinding by an invisible peak. The same holds, if due to a strong reflex a counter is disabled, but after this the remaining channels are still not gaining more correlation signal. In both cases reduce the laser power value.

3.4 Functional list of commands

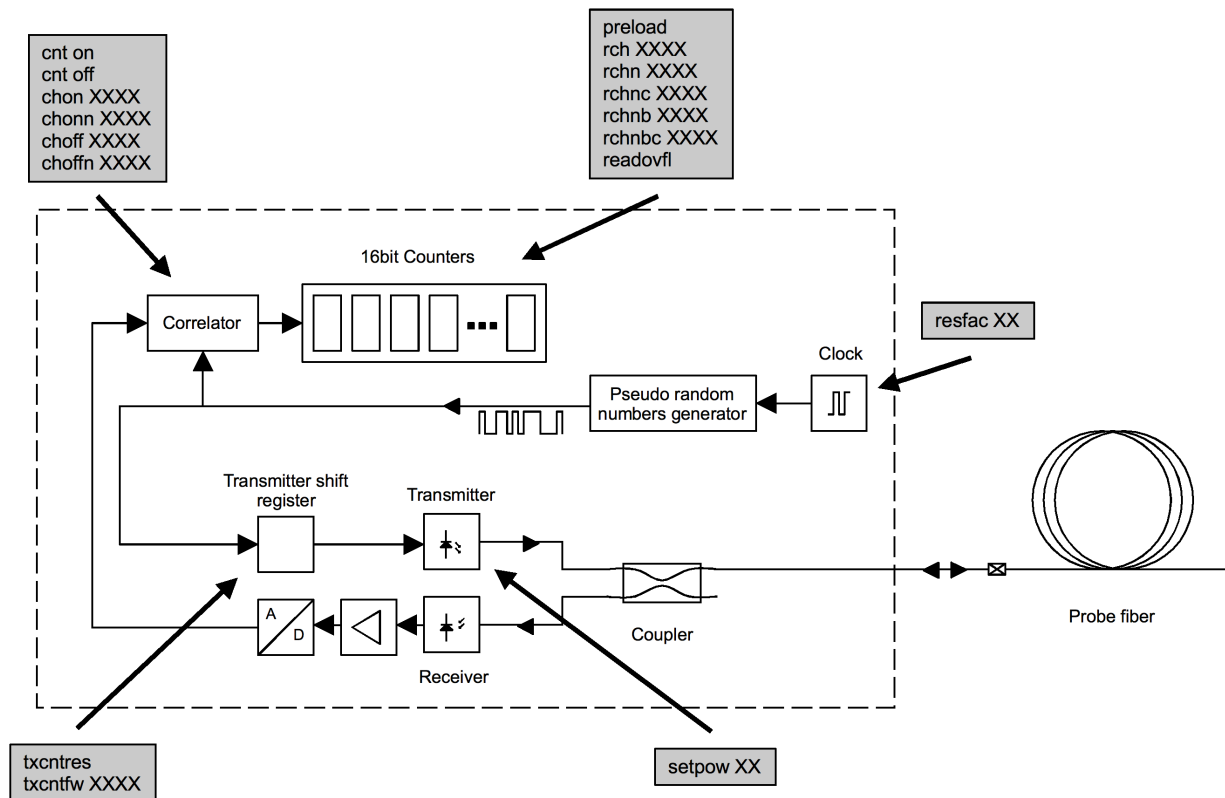


Figure 2: Functional building blocks of the Fault Locator Module and its commands for controlling the functional units

Correlator:

cnt on	Enable correlation and run up/down counters
cnt off	Stop correlation and stop up/down counters
chon XXXX	Enable counter \$XXXX
chonn XXXX	Enable counters \$XXXX to \$01FF
choff XXXX	Disable counter \$XXXX (fixed value \$8000)
choffn XXXX	Disable counters \$XXXX to \$01FF (fixed value \$8000)
setmaxcnt XXXXXXXX	Set correlation time in 10ns steps
corrtime	Displays correlation time of last measurement in 10ns steps (Format \$XXXXXXXX)

Up/down counters:

preload	Preload all counters with value \$8000 and start correlation
rch XXXX	Display value of counter \$XXXX
rchn XXXX	Display values of counters \$XXXX to \$0000
rchnc XXXX	Display values of counters \$XXXX to \$0000 with checksum
rchnb XXXX	Display values of counters \$XXXX to \$0000 in binary format
rchnbc XXXX	Display values of counters \$XXXX to \$0000 in binary format with checksum
readovfl	Show overflow status (00 = overflow experienced)

Transmitter shift register:

txcntfw XXXX	Forward transmitter shift register \$XXXX clock cycles
txcntres	Reset transmitter shift register to zero clock cycles

Random number generator clock:

resfac XX	set horizontal resolution
-----------	---------------------------

Transmitter power control:

setpow XX	Set transmitter power level to \$XX
-----------	-------------------------------------

Serial interface:

hello	Display firmware version number
baud XXXX	Change baud rate to \$XXXX
echo on	Echo input characters
echo off	No echo of input characters
amsg on	Permit asynchronous output messages
amsg off	Prohibit asynchronous output messages

General commands:

help	Display list of commands
sernb	Display FL's serial number
chnumb	Display number of channels -1
mfrequ	Display maximum clock rate [MHz]

3.5 Alphabetical list of commands

Every command is represented either by a single word, two words separated by a space or one word and a number separated by a space. Do not omit the space. All letters of a word are lowercase letters. Numbers are hexadecimal and either two digits (\$00-\$FF) or four digits (\$0000-\$FFFF) in length and either upper or lowercase letters. Do not omit leading zeroes, i.e. type "000A" instead of "A". Commands are accepted by the FL after sending \$0D. This is indicated by sending a new line.

The field "response" relates to output sent via the serial interface. Several commands produce no output, nonetheless the corresponding changes in the FL hardware are initiated.

The term "default" relates to the corresponding function enabled after power-up reset. Every line sent by the FL is terminated by the three bytes \$0D, \$0A, \$3A.

Command: **amsg off** (default)

Function:

Prohibit asynchronous message output via the serial interface. This might be the necessary state for an external communications software, if it cannot handle the FL sending messages at times other than directly after a command.

Response: none

Command: **amsg on**

Function:

Permit asynchronous message output via the serial interface. Get immediate information about FL hardware conditions via the serial interface.

Response:

Error messages or "ovfl", if one of the up/down counters experiences an overflow (\$0000 or \$FFFF).

Command: **baud XX** (default XXXX = \$0C)

Function:

Change the baud rate to \$XXXX baud. Typical values are

9600 baud	\$01 (min)
19200 baud	\$02
57600 baud	\$06
115200 baud	\$0C (def)
230400 baud	\$18 (max)

Hence that FL with USB interface do not use the baud command

Response: none

Command: **chnumb**

Function:

Display FL's number of channels -1.

Response:

A line with hex number YYYY.

Command: **choff XXXX**

Function:

Disable up/down counter \$XXXX from counting. The value becomes fixed at \$8000.

Response: none

Command: **choffn XXXX**

Function:

Disable up/down counters \$XXXX to \$00FF from counting. The values become fixed at \$8000.

Response: none

Command: **chon XXXX**

Function:

Enable up/down counter \$XXXX for correlation.

Response: none

Command: **chonn XXXX**

Function:

Enable up/down counters \$XXXX to \$00FF for correlation.

Response: none

Command: **cnt off**

Function:

Stop correlation manually and stop up/down counters from changing its values.

Response: none

Command: **cnt on** (default)

Function:

Reset counters and start correlation. This command starts correlation. It also resets the corrttime value to zero.

Response: "ovfl", if amsg on is enabled and overflow condition is experienced.

Command: **corrtime**

Function:

Read the correlation time of the last measurement in 10ns units. Correlation time can be set with the *setmaxcnt* command.

Response:

A line with hex number XXXXXXXX. Example: 000F4240 = 1.000.000 * 10ns = 10ms

Command: **echo off**

Function:

Stop echoing input characters via the serial interface.

Response: none

Command: **echo on** (default)

Function:

Echo input characters via the serial interface.

Response: none

Command: **hello**

Function:

"Hello message": displays the firmware version number

Response:

Several lines of ASCII character text.

Command: **help**

Function:

Display a list of commands.

Response:

Several lines of ASCII character text.

Command: **ledon XX**

Function:

Enable external LED number \$XX. Numbering starts from \$00; maximum number of LEDs available depends on FL model.

Response: none

Command: **mfrequ**

Function:

Display FL's maximum clock rate in units of MHz.

Response:

A line with hex number YY.

Command: **preload**

Function:

Preloads all up/down counters with value \$8000 and starts correlation. For restarting measurement better use 'cnt on' command.

Response:

"ovfl", if amsg on is enabled and overflow condition is experienced.

Command: **rch XXXX**

Function:

Display value of up/down counter \$XXXX. Correlation and counting is not affected by this command.

Response:

A line with hex value YYYY.

Command: **rchn XXXX**

Function:

Display values of up/down counters \$XXXX to \$0000. Correlation and counting is not affected by this command.

Response:

XXXX+1 lines with hex values YYYY.

Command: **rchnb XXXX**

Function:

Display values of up/down counters \$XXXX to \$0000. Correlation and counting is not affected by this command. Same as **rchn XXXX** except for binary data output: each hex value YYYY is represented by a pair of 8bit bytes instead of two pairs of 7bit ASCII characters.

Response:

One line with $2*(XXXX+1)$ bytes of 8bit binary data (no pairs of 7bit ASCII characters). Do not use this command if working on an ASCII terminal, since generic output might be produced.

Command: **rchnbc XXXX**

Function:

Display values of up/down counters \$XXXX to \$0000 plus a checksum of all values. Correlation and counting is not affected by this command. Same as **rchnc XXXX** except for binary data output: each hex value YYYY is represented by a pair of 8bit bytes instead of two pairs of 7bit ASCII characters. Finally a pair of 8bit bytes representing the checksum \$ZZZ is sent. The checksum is the sum of all displayed counter values modulo \$10000.

Response:

One line with $2 \cdot (XXXX+2)$ bytes of 8bit binary data (no pairs of 7bit ASCII characters). Do not use this command if working on an ASCII terminal, since generic output might be produced.

Command: **rchnc XXXX**

Function:

Display values of up/down counters \$XXXX to \$0000 plus a checksum of all values. Correlation and counting is not affected by this command. The checksum \$ZZZ is the sum of all displayed counter values modulo \$10000.

Response:

XXXX+1 lines with hex counter values YYYY and one line with checksum value ZZZ.

Command: **readovfl**

Function:

Show overflow status of the up/down counters. 00 = overflow experienced. 01 = FL still correlating. If external software allows for async messages, better enable the 'amsg on' status and wait for the FL to signalize an "ovfl".

Response:

A line with hex number 00 or 01.

Command: **resfac XX** (default XX = FF)

Function:

Divide PRBS frequency to lower rates for lower resolution. The corresponding horizontal resolution is depending on the fiber refractive index.

$$res_{hor}[m] = \frac{2 \cdot resfac \cdot c_0}{2 \cdot n \cdot 100.000.000s^{-1}} \quad \text{Exc.: resfac 00} \quad res_{hor}[m] = \frac{c_0}{2 \cdot n \cdot 100.000.000s^{-1}}$$

Response: none

Command: **setmaxcnt XXXXXXXX**

Function:

Set maximum correlation time in 10ns units. For normalizing the vertical axis it is useful to use the same correlation time for different measurements. The correlation will always stop after this time if there is no overflow condition before. Correlation time can be read with the command 'corrtime'

Response: none

Default: FFFFFFF0 (43s)

Example: 'setmaxcnt 004C4B40' sets the max correlation time to $5.000.000 \cdot 10ns = 50ms$.

Command: **sernb**

Function:

Display FL's serial number.

Response:

A line with hex number XXXX.

Command: **setpow XX** (default XX=FF)

Function:

Set transmitter power to value \$XX with XX = 00 to FF. Value 00 doesn't correspond to zero but to a low power level.

Response: none

Command: **txcnfw XXXX** (default XXXX = 0000)

Function:

Forward transmitter shift register by \$XXXX clock cycles forward. This command can be executed repeatedly to achieve multiple offsets of 65535. Example: If a segment 100 km down the fiber should be measured at 1 meters resolution, choose **resfac 00** and **txcnfw FFFF + txcnfw 86A1**. Response: none

Command: **txcntres**

Function:

Reset transmitter shift register to zero clock cycles.

Response: none

3.6 Error messages

If a command is misspelled or if an unknown command is sent, the FL responds by sending a single line reading "Sorry?". Other error messages should not occur during normal operation. If the FL sends the "Hello message" without a previous hello command typed, this indicates a soft reset by the firmware. It should not occur during normal operation. Please contact our service personnel in case of such event taking place repeatedly.

4. Measurement examples

In the following some selected measurement examples are presented to demonstrate specific features of the Fault Locator Module.

The measurements are presented graphically; the conversion of counter channels to distance in the graphs is done by external software and not by the FL.

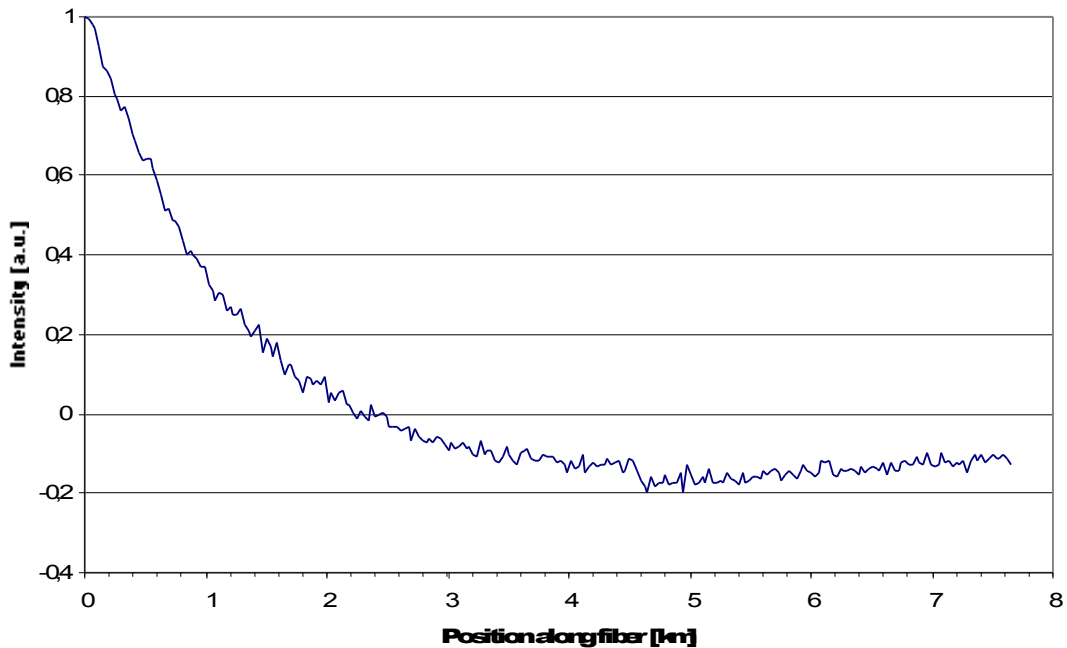


Figure 3: Rayleigh backscattering signal, end-o-f-fiber at km 4.6

Figure 3 shows a 30m-resolution measurement (single-shot) of a fiber with FC/APC connectors. Strong Rayleigh backscattering signal from early portions of the fiber triggers the first FL channel to overflow at value \$FFFF. No reflective events are visible. The end-of-fiber position manifests itself in a sudden drop of backscattering signal at km 4.6. The subsequent small increase in signal intensity behind the end-of-fiber is caused by effects discussed in chapter 2.4.

A larger transmitter power or averaging of several successive measurements may be considered to reduce the noise level.

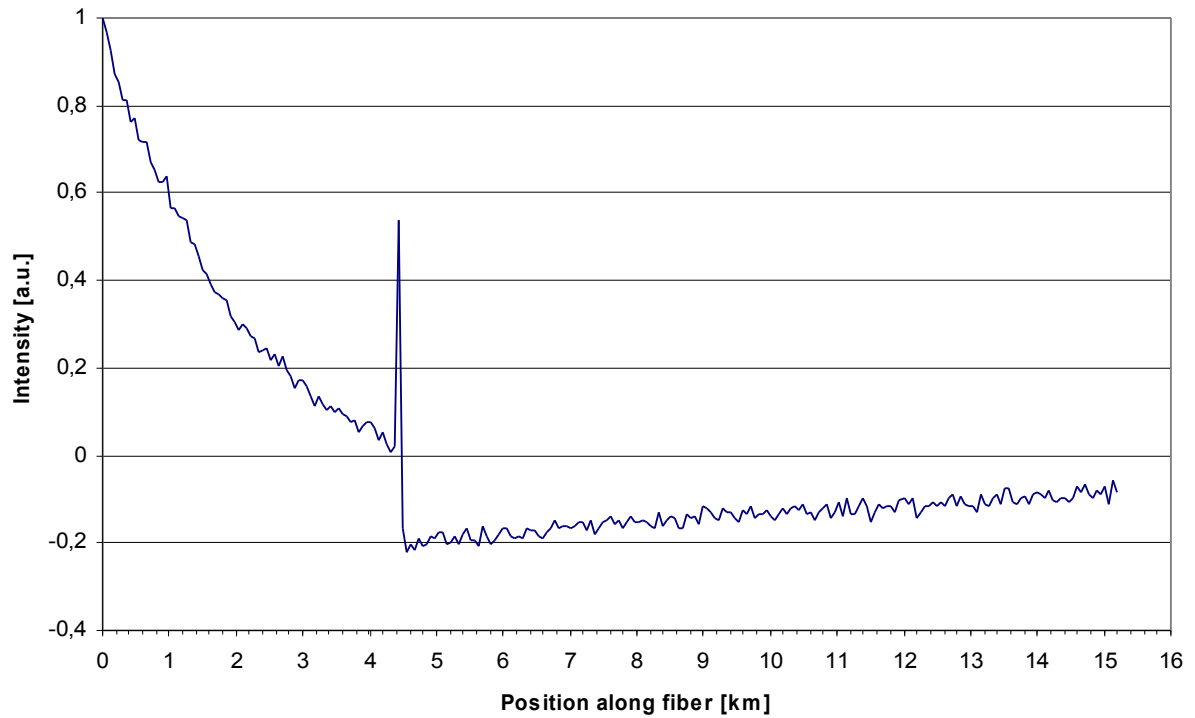


Figure 4: Rayleigh backscattering signal, end-o-f-fiber at km 4.6

Figure 4 shows a 60m-resolution measurement (single-shot) of a fiber terminated by an attenuator and a FC/PC connector. The attenuator reduces the reflection strength of the zero-angle fiber end-face to keep the Rayleigh signal visible. As lower the resolution as larger the Rayleigh signal generated per resolution slot. Weak absorptions along the fiber are most easily discovered at low resolution.

5. Technical Specifications

5.1 General

Power supply

Supply voltage	5.0 - 5.5 V dc stabilized
Supply current	< 0.5 A

Optical specifications

Laser safety class	1M
Output power	-40 - 0 dBm, adjustable
Wavelength	depending on version
Optical connector	FC/APC or MU/APC

Horizontal specifications

Fundamental frequency	100.000.000 MHz
Sampling points	256
Sampling resolution	1.01 to 516.5 m (@ n=1.48) in 256 steps
Distance ranges	0.25 to 132 km (@ n=1.48) in 256 steps
Maximum distance offset	$2^{18}-1$ times sampling resolution
Distance accuracy	$>10^{-4}$ of sampling resolution

Vertical specifications

Dynamic range	30 dB
---------------	-------

Others

Module size	145 x 100 x 17 mm
Operating temp. range	0 - 40 °C (non-condensing)
Storage temp. range	-40 - 85 °C