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Scintec Boundary Layer Scintillometer

User Manual

BLS450
BLS900
BLS2000

(including BLSDMI-1 option)

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Contents

List of Figures

List of Tables

Important User Information

Note on Hardware Manual:

This manual is intended for customers who have purchased a Scintec Boundary Layer Scintillometer BLS and/or the BLSDMI Option. A careful reading of this manual is substantial for a proper use and safe operation of the BLS.

Warranty and Liability:

Scintec guarantees that the product has been thoroughly tested. The warranty included in the conditions of delivery is valid only if the Boundary Layer Scintillometer, and where applicable the BLSDMI Option, has been installed and used according to the instructions supplied by Scintec.

Scintec shall in no event be liable for incidental or consequential damages resulting from the incorrect and faulty use of the product. Note that user made modifications might affect the validity of the CE declaration.

Scintec reserves the right to make modifications to the design and technical specifications of products without prior notice.

1 INTRODUCTION

1.1 FEATURES

The BLS series are sophisticated scintillometer systems for the evaluation of atmospheric scintillation caused by refractive index fluctuations[1]. Large apertures of the transmitter and receiver eliminate saturation and inner scale effects. The instruments have the following features:

- Transmitter with large emission angle
- Homogeneous emission due to a large number of radiation sources
- Pulsed transmission with selectable repetition rate
- Modulated radiation for elimination of background
- Extremely sensitive, shot noise limited detector unit
- Insensitive to transmitter vibrations due to the large emission angle
- Interference filter for use in direct sunlight
- Path length user defined
- Virtually no transmitter alignment necessary
- Rapid installation and alignment of receiver with positioning device
- SUDF data format for graphical data display in real time and from file
- Comprehensive error identification and correction
- Calculation of structure function constant C_n^2 of refractive index fluctuations
- Calculation of structure function constant C_T^2 of temperature fluctuations
- Calculation of Fried diameter r_o
- Calculation of turbulent surface heat flux H_0 under conditions of free convection
- Calculation of crosswind speed u
- Rugged weather-resistant design
- Eye-safe emission

1.2 DESCRIPTION

The BLS450, BLS900 and BLS2000 consist of an optical transmitter, an optical receiver with positioning device, a signal processing unit (SPU) and a data evaluation software (BLSRUN) for a Microsoft Windows® based operating system. The SPU/DL-version of the signal processing unit comes with an integrated data logger.

The BLS900 transmitter emits radiation through 924 light emitting diodes (LED) on two disks. The BLS450 transmitter uses one radiating disk only. The BLS2000 transmitter uses two disks, each equipped with 912 LEDs. The LEDs can be operated in 4 different pulse repetition rates from 1Hz to 125 Hz. A pulse rate of 125 Hz provides maximum accuracy and transverse wind speed measurement capability, whereas a pulse rate of 1 Hz results in a very low power consumption. The two-disk configuration of the BLS900 and BLS2000 allows for a correction of absorption fluctuations which is performed in the BLSRun software and increases the accuracy of the measurement. The two-disk configuration also provides crosswind measurement capability.

In the receivers of the BLS450, BLS900 and BLS2000, radiation is collimated by a lense onto 2 photodiodes. The lense is of convex glass type for the BLS450 and BLS900. In order to minimize spherical aberration, the BLS2000 holds a Fresnel lens. One photodiode is used for sensing the

[1] Patent DE 19751144

turbulence-induced fluctuations, the auxiliary detector is used as an alignment aid. For alignment purposes the receiver is mounted on a 3 axis-positioning device and comes with a mounted telescope. The receiver electronics pre-amplifies and filters the signals. Transmitter and receiver can easily be mounted on standard tripods with 5/8-inch threads.

The SPU houses two plugged-in cards: A signal processing card that filters, demodulates and digitises the received signals, and a microprocessor card for evaluating and storing the converted data. Additionally, the microprocessor handles the communication to a PC via a serial interface. The SPU/DL version is additionally equipped with non-volatile flash memory for storing up to approx. 700 days of measurement data.

The BLSRUN software reads the measured data either in real-time, from volatile SPU memory or from the non-volatile SPU/DL storage. All data are displayed in tabular form and can be stored in the SUDF format for graphical display with ScintecView.

2 QUICK REFERENCE GUIDE

The following steps are required to perform a measurement with the BLS900 / BLS2000:

1. Select path and site (Section 3.1)
2. Install the instruments (Section 3.2)
3. Install the software BLSRUN (Section 4.1)
4. Select the device type and set all parameters in the Settings menu (Section 4.4).
5. Align the instruments (Sections 3.3 and 4.5.2)
6. Determine the background signal (Section 4.5.3)
7. Start the measurement (Section 4.5.4)

The signalling of the Position Indicator LED at the SPU is as follows:

A) Continuous illumination with short interrupts (~80% duty cycle): Receiver is correctly aligned.

B) Short blinks with long interrupts (~20% duty cycle): Receiver is not correctly aligned.

C) Blinks with interrupts of the same duration (~50% duty cycle): Battery voltage is low.

Notes:

1. The Position Indicator is active in the Measurement Mode only. The Position Indicator will begin signalling approx. 2 minutes after the measurement is started.

2. In order to allow the Position Indicator to operate, the system has to be aligned correctly in the Alignment Mode before switching to the Measurement Mode.

3 HARDWARE PREPARATIONS

3.1 SELECTION OF PATH AND SITE

The propagation path length is defined as the distance between the glass window of the transmitter and the lens of the receiver (Figure 1)

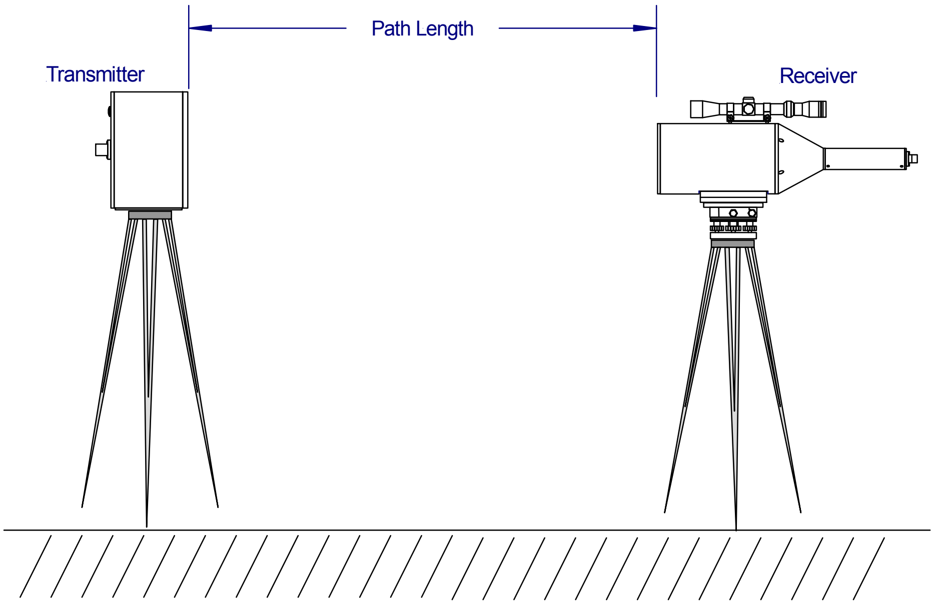


Figure 1: Illustration of path length definition

Operation of the BLS450 and BLS900 is possible over paths in the range 500 to 5000 m. The BLS2000 can be used from 1000m to 12000m.

After having chosen path and site

- the path length and height must be entered in the *Settings* menu of the BLSRUN software
- the amplifier dip switch in the receiver unit must be set.

3.1.1 PROPAGATION PATH

The ground along the propagation path should be as even as possible. A well defined measurement height is required for application of the free convection scaling for calculation of the turbulent sensible heat flux. Note that also the primarily measured quantities C_n^2 , i.e. the structure function constant of refractive index fluctuations strongly depend on height.

A correction for slant paths is included in the BLSRUN software.

3.1.2 PATH HEIGHT

The path height is defined as the height of the straight line connecting the transmitter and the receiver above ground. In case of a slant path the height of the transmitter and the receiver must be specified. If the surface is not totally flat, use the average height with an increased weight at the path's centre. The path weighting functions (describing the contribution of different positions along the path) are given in APPENDIX AA.5.

3.1.3 SITE REQUIREMENTS

The calculation of the turbulent heat flux is based on free convection scaling. The free convection scaling requires the measurement height to be significantly larger than the height of the roughness elements.

3.1.4 RECOMMENDED PATH LENGTH AND HEIGHT

For long propagation paths, saturation may occur under strong turbulence conditions. Saturation is avoided by using a sufficiently short propagation path or a large measurement height. In other words, larger path lengths suggest larger measurement heights.

The following table shows the measurement ranges of C_n^2, C_T^2 and heat flux for different path lengths. The ranges of C_T^2 are provided assuming a pressure of 1013 hPa. The turbulent heat flux ranges depend on the measurement height z in meters.

BLS450			
path length	C_n^2 [$m^{-2/3}$]	C_T^2 [$K^2 m^{-2/3}$]	heat flux [W/m^2] at height z [m]
500 m	3×10^{-14} - 1×10^{-10}	3×10^{-2} - $1 \times 10^{+2}$	> 8 z
1000 m	4×10^{-15} - 2×10^{-11}	4×10^{-3} - $2 \times 10^{+1}$	2 z – 980 z
2000 m	4×10^{-16} - 2×10^{-12}	5×10^{-4} - $2 \times 10^{+0}$	0.5 z – 175 z
3000 m	1×10^{-16} - 6×10^{-13}	2×10^{-4} - 7×10^{-1}	0.2 z – 70 z
5000 m	3×10^{-17} - 2×10^{-13}	4×10^{-5} - 2×10^{-1}	0.05 z – 30 z
BLS450 with Path Reduction Aperture			
path length	C_n^2 [$m^{-2/3}$]	C_T^2 [$K^2 m^{-2/3}$]	heat flux [W/m^2] at height z [m]
250 m	5×10^{-14} - 2×10^{-10}	6×10^{-2} - $2 \times 10^{+2}$	> 12 z
500 m	6×10^{-15} - 3×10^{-11}	7×10^{-3} - $4 \times 10^{+1}$	2 z – 1500 z
1000 m	8×10^{-16} - 6×10^{-12}	9×10^{-4} - $7 \times 10^{+0}$	0.5 z – 400 z
2000 m	1×10^{-16} - 6×10^{-13}	1×10^{-4} - 7×10^{-1}	0.1 z – 70 z
3000 m	5×10^{-17} - 2×10^{-13}	6×10^{-5} - 2×10^{-1}	0.07 z – 30 z
BLS900			
path length	C_n^2 [$m^{-2/3}$]	C_T^2 [$K^2 m^{-2/3}$]	heat flux [W/m^2] at height z [m]
500 m	3×10^{-14} - 3×10^{-10}	3×10^{-2} - $4 \times 10^{+2}$	> 8 z
1000 m	4×10^{-15} - 6×10^{-11}	4×10^{-3} - $7 \times 10^{+1}$	2 z – 2400 z
2000 m	4×10^{-16} - 6×10^{-12}	5×10^{-4} - $7 \times 10^{+0}$	0.3 z – 412 z
3000 m	1×10^{-16} - 3×10^{-12}	2×10^{-4} - 4×10^{-1}	0.2 z – 270 z
5000 m	3×10^{-17} - 6×10^{-13}	4×10^{-5} - 7×10^{-1}	0.05 z – 75 z

BLS900 with Path Reduction Aperture			
path length	C_n^2 [$m^{-2/3}$]	C_T^2 [$K^2\,m^{-2/3}$]	heat flux [W/m^2] at height z [m]
250 m	5×10^{-14} - 1×10^{-9}	6×10^{-2} - $1 \times 10^{+3}$	> 12 z
500 m	6×10^{-15} - 2×10^{-10}	7×10^{-3} - $2 \times 10^{+2}$	2 z – 5500 z
1000 m	8×10^{-16} - 3×10^{-11}	9×10^{-4} - $4 \times 10^{+0}$	0.5 z – 1500 z
2000 m	1×10^{-16} - 6×10^{-12}	1×10^{-4} - $7 \times 10^{+0}$	0.1 z – 412 z
3000 m	5×10^{-17} - 2×10^{-12}	6×10^{-5} - $2 \times 10^{+0}$	0.07 z – 174 z
BLS2000			
path length	C_n^2 [$m^{-2/3}$]	C_T^2 [$K^2\,m^{-2/3}$]	heat flux [W/m^2] at height z [m]
1000 m	1×10^{-14} - 1×10^{-10}	2×10^{-2} - $1 \times 10^{+2}$	5 z – 3600 z
2000 m	2×10^{-15} - 2×10^{-11}	2×10^{-3} - $2 \times 10^{+1}$	1 z – 980 z
3000 m	5×10^{-16} - 6×10^{-12}	6×10^{-4} - $7 \times 10^{+0}$	0.4 z – 413 z
5000 m	1×10^{-16} - 2×10^{-12}	1×10^{-4} - $2 \times 10^{+0}$	0.1 z – 175 z
7000 m	4×10^{-17} - 6×10^{-13}	5×10^{-5} - 7×10^{-1}	0.06 z – 73 z
10000 m	2×10^{-17} - 3×10^{-13}	2×10^{-5} - 4×10^{-1}	0.03 z – 48 z
BLS2000 with Path Reduction Aperture			
Path length	C_n^2 [$m^{-2/3}$]	C_T^2 [$K^2\,m^{-2/3}$]	heat flux [W/m^2] at height z [m]
500 m	3×10^{-14} - 6×10^{-10}	3×10^{-2} - $7 \times 10^{+2}$	> 8 z
1000 m	3×10^{-15} - 1×10^{-10}	4×10^{-3} - $1 \times 10^{+2}$	2 z – 3575 z
2000 m	4×10^{-16} - 1×10^{-11}	5×10^{-4} - $1 \times 10^{+1}$	0.3 z – 635 z
3000 m	1×10^{-16} - 6×10^{-12}	2×10^{-4} - $7 \times 10^{+0}$	0.2 z – 412 z
5000 m	8×10^{-17} - 1×10^{-12}	9×10^{-5} - $1 \times 10^{+0}$	0.1 z – 113 z
7000 m	1×10^{-16} - 6×10^{-13}	1×10^{-4} - 7×10^{-1}	0.1 z – 73 z

Table 1: Measurement ranges of C_n^2, C_T^2 and heat flux for BLS450, BLS900 and BLS2000

3.2 INSTALLING THE INSTRUMENTS

The transmitter and the receiver units must be mounted on stable platforms. The required angular pointing stability is in the order of 0.1 mrad for the receiver. There is virtually no pointing stability required for the transmitter. The use of heavy tripods used for geodetic purposes is recommended. The 5/8-inch threads at the bottoms of the instruments allow an easy connection to such devices. Strong winds (around 10 m/s and more) may require additional means to ensure pointing stability and to avoid measurement errors caused by vibration of the transmitter or receiver.

3.2.1 TRANSMITTER SET-UP

The transmitter must be connected to an appropriate power supply (see specifications in APPENDIX C). A transmitter power supply cable is included. The power supply cable must not be prolonged as the additional resistance may cause instabilities in the switching power supply inside the transmitter. When using a battery as transmitter power supply the transmitter operation time is limited dependent on the transmitter pulse repetition rate (Table 2). The maximum operation time given is based on a battery capacity of 120 Ah. Larger capacities prolong operation time while lower capacities reduce it.

BLS450 Transmitter Operation Time		
Pulse Repetition Rate	Current Consumption (@12VDC)	Operation Time (C = 120 Ah)
1 Hz	0.075 A	> 8 weeks
5 Hz	0.25 A	> 2 weeks
25 Hz	0.8 A	> 6 days
125 Hz	3.5 A	> 30 hours
BLS900 Transmitter Operation Time		
Pulse Repetition Rate	Current Consumption (@12VDC)	Operation Time (C = 120 Ah)
1 Hz	0.15 A	> 4 weeks
5 Hz	0.5 A	> 1 weeks
25 Hz	1.6 A	> 3 days
125 Hz	7 A	> 15 hours
BLS2000 Transmitter Operation Time		
Pulse Repetition Rate	Current Consumption (@12VDC)	Operation Time (C = 120 Ah)
1 Hz	0.3 A	> 2 weeks
5 Hz	1 A	> 5 days
25 Hz	3 A	> 36 hours
125 Hz	13 A	> 8 hours

Table 2: Transmitter Operation Time for BLS450, BLS900 and BLS2000

The transmitter is switched on by pressing the red button at the back side (Figure 11). The green LED in the centre of the red button starts blinking at the same rate as the red LED's at the front side. With the red and the black button the pulse repetition rate can be set. The black button decreases the repetition rate while the red one increases it. The transmitter is switched off by pressing the red and the black button simultaneously.

If the supply voltage is cut off during operation the transmitter automatically starts with the last pulse repetition rate when the voltage is applied again. If the supply voltage is cut off while the transmitter is switched off it remains switched off when the voltage is applied again.

The red LED in the centre of the black button is also used as battery voltage control. The red LED blinks when the supply voltage drops below 9 V. A voltage of 9 V instead of 12 V reduces the signal 10 % at 25 Hz and 30 % at 1 Hz.

3.2.2 RECEIVER AND SPU SET-UP

The receiver is directly connected to and supplied by the SPU. The SPU requires a 12 V power supply (see specifications in APPENDIX C) and must be connected to a PC via serial cable for alignment or data transfer.

3.2.3 RECEIVER DIP SWITCH SETTINGS

Before starting the alignment or measurement the amplifier dip-switch inside the receiver must be set (Figure 2).

- Choose the correct settings for your measurement path from Table 3.
- Remove the three screws at the back part of the receiver unit.

– Pull out the rear panel, be careful not to damage the cables to the connector.

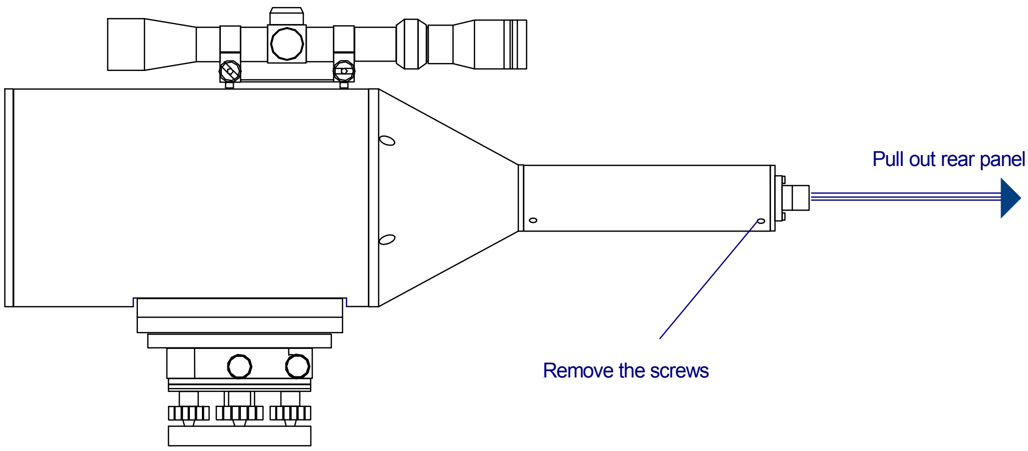


Figure 2: Receiver side view

Set the receiver dip switch according to Figure 3.

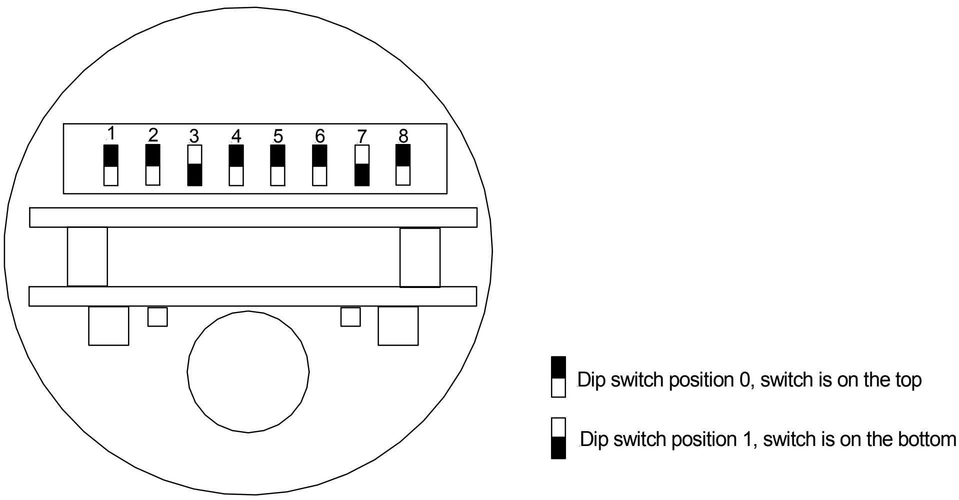


Figure 3: Dip switch inside the receiver tube (example illustrates the factory setting for a BLS900)

Note that during the measurement, the software will evaluate relative changes of the intensity. Therefore the adjustment of the signal levels has no direct effect on the accuracy of the results. However, the full measurement ranges (as provided in Table 1) can only be achieved if the measured signal levels of the X and Y channel remain within an optimum signal level range between 400 and 1800 digits.
For shorter path lengths (< 1000 m) the signal levels can be set higher (up to 3000 digits), for longer path lengths (> 3000 m) lower signal levels should be used (200 to 1000 digits). The following dip switch settings are only recommendations. The signal heights depend on transmitter adjustment and temperature, receiver alignment and atmospheric transmission. If the signal is still too low or too high the next higher or lower amplification should be selected, respectively.
Please note that the Z channel signal level will always be lower than the signals of the X and Y channel (typically the Z values are roughly a third of the X and Y values).

Measurement range	Dip switch BLS450/BLS900 1234 5678	Dip switch BLS2000 1234 5678
500 m – 750 m	1111 1111	n/a
750 m – 1500 m	0001 0001	1111 1111
1500 m – 2000 m	0110 0110	0001 0001
2000 m – 3000 m	0010 0010 (factory setting)	0110 0110
3000 m – 4000 m	0100 0100	0010 0010
4000 m – 5000 m	1000 1000	
5000 m – 8000 m	n/a	0100 0100 (factory setting)
8000 m – 12000 m	n/a	1000 1000

Table 3: Recommended dip switch settings for different measurement ranges

3.3 ALIGNMENT

To align the instruments the software BLSRUN must be installed and executed and the SPU program must be transferred to the SPU. Refer to section 4.1 for installation, section 4.5.2.for the description of the alignment screen and section 4.5.1 for the SPU software transfer.

3.3.1 TRANSMITTER ALIGNMENT

As the emission angle of the LED's is approximately 10° the transmitter has to be aligned only roughly to the direction where the receiver is located.

3.3.2 RECEIVER ALIGNMENT

The receiver can be aligned to the direction of the transmitter by looking through the telescope and adjusting the positioning device until the transmitter is located at the centre of the crosshair. The magnification of the telescope can be varied from 3 to 9 by rotating the power ring.

Positioning Device for BLS450 and BLS900
The positioning device for BLS450 and BLS900 is equipped with 6 screws for adjustment (Figure 4). Screws 1 to 3 are for vertical adjustment, screws 4, 5 and 6 for adjusting the receiver in the horizontal. When screw 4 is tightened screws 5 and 6 can be used for small changes in the horizontal orientation. When screw 4 is loose the receiver can be rotated directly and screws 5 and 6 are not used.

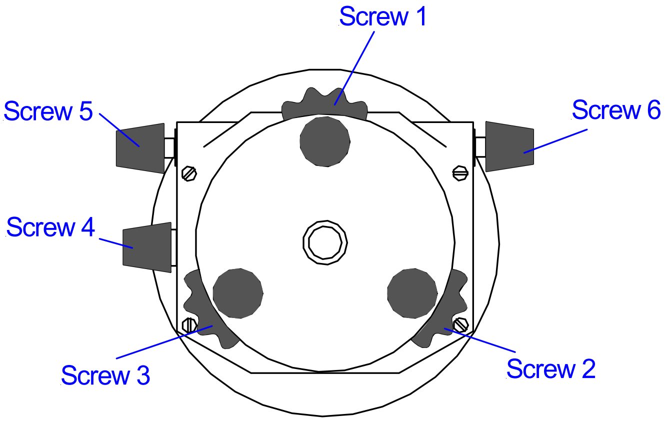


Figure 4: Receiver positioning device for BLS450 and BLS900

Positioning Device for BLS2000

The positioning device for the BLS2000 is equipped with 4 screws for adjustment (Figure 5). Screws 1 and 2 are for horizontal adjustment, whereas screws 3 and 4 allow an adjustment of the receiver in the vertical.

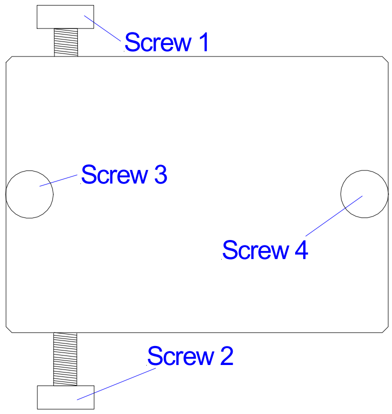


Figure 5: Receiver positioning device for BLS2000

For fine alignment the *Alignment* Option in the *Start* menu must be selected to start the alignment screen (= Alignment Mode). The signals in the alignment screen should be adjusted to a maximum by using the screws of the positioning device. As described in section 4.5.2, the signal of the channel Z is the most relevant indicator. It is recommended to iteratively adjust the receiver horizontally and vertically. Usually some iteration is necessary for optimal adjustment. If the signal level is too low or too high, the amplifier dip-switch inside the receiver tube must be changed, respectively (see section 3.2.3).

When the received intensities are too small, check the following points:

- The transmitter is switched ON
- The transmitter power supply voltage exceeds 9V
- The SPU power supply is switched on and the supply voltage is 12 V
- The receiver unit is properly connected to the SPU

After you start a measurement with correct alignment (outside the Alignment Mode!), the Position Indicator LED on the SPU will blink with short interrupts ("long blink"). If the alignment becomes incorrect because of a movement of the receiver, the Position Indicator LED will blink with long interrupts ("short blink"). In this case, the receiver has to be readjusted. Note that poor atmospheric transmission (fog, strong precipitation) may also cause "short blink".

The RAM capacity of the SPU allows an operation of the receiver up to approximately 2 years. When the amount of data exceeds the storage capacity, the next results are stored at the address of the first results, which will be overwritten (loop storage).

The only maintenance required will be to clean the windows and to check the position indicator. Re-adjust the alignment if necessary ("short blink"). The required re-alignment period depends on the stability of the mounting. With tripods, it mainly depends on the type and condition of the ground. With a concrete mounting, re-alignments will only rarely be necessary.

3.4 RECOMMENDATIONS

In hot and sunny climates, the instruments (at least the transmitter) should be operated at a naturally ventilated place or a sun protection shield should be used to avoid overheating. The use of a metallic platform to mount the transmitter, e.g. aluminium tripods, is also recommended. Especially at a pulse repetition rate of 125 Hz the transmitter surface temperature can be 70°C – 80°C.

To avoid a high background signal the transmitter should be installed such that little radiation from the sky or the sun is seen from the receiver.

4 SOFTWARE

The following list summarizes the basic system requirements that should be met by the PC running BLSRun.

	Minimum Requirements
processor (CPU)	500 MHz
memory (RAM)	500 MB
free hard disk capacity	100 MB
I/O ports	serial port (RS232) or serial port adapater (USB or PCMCIA)
optical devices	CD-Rom drive
graphics adapter	1024x768 pixels
operating system	Windows 2000, Windows XP Windows Server 2003 Windows Vista

4.1 INSTALLATION

To install the software, insert the installation CD in the CD-ROM drive and run the setup program *Setup.exe*. Now follow the setup instructions on the screen.

4.2 DIRECTORY STRUCTURE

The following directory structure is created during installation (assuming that the default installation folder has not been changed during setup):

Folder	**Content**
C:\BLS\BLSRun 1.xx\	Program files, calibration files
C:\BLS\BLSRun 1.xx\ScintecView\	Visualization software ScintecView
C:\BLS\settings	BLSRun stores its configuration here.
C:\BLS\data	Output data files are stored here by default.

Table 4: BLSRun Directory Structure

4.3 BLSRun WINDOW

After starting BLSRun the main window appears.

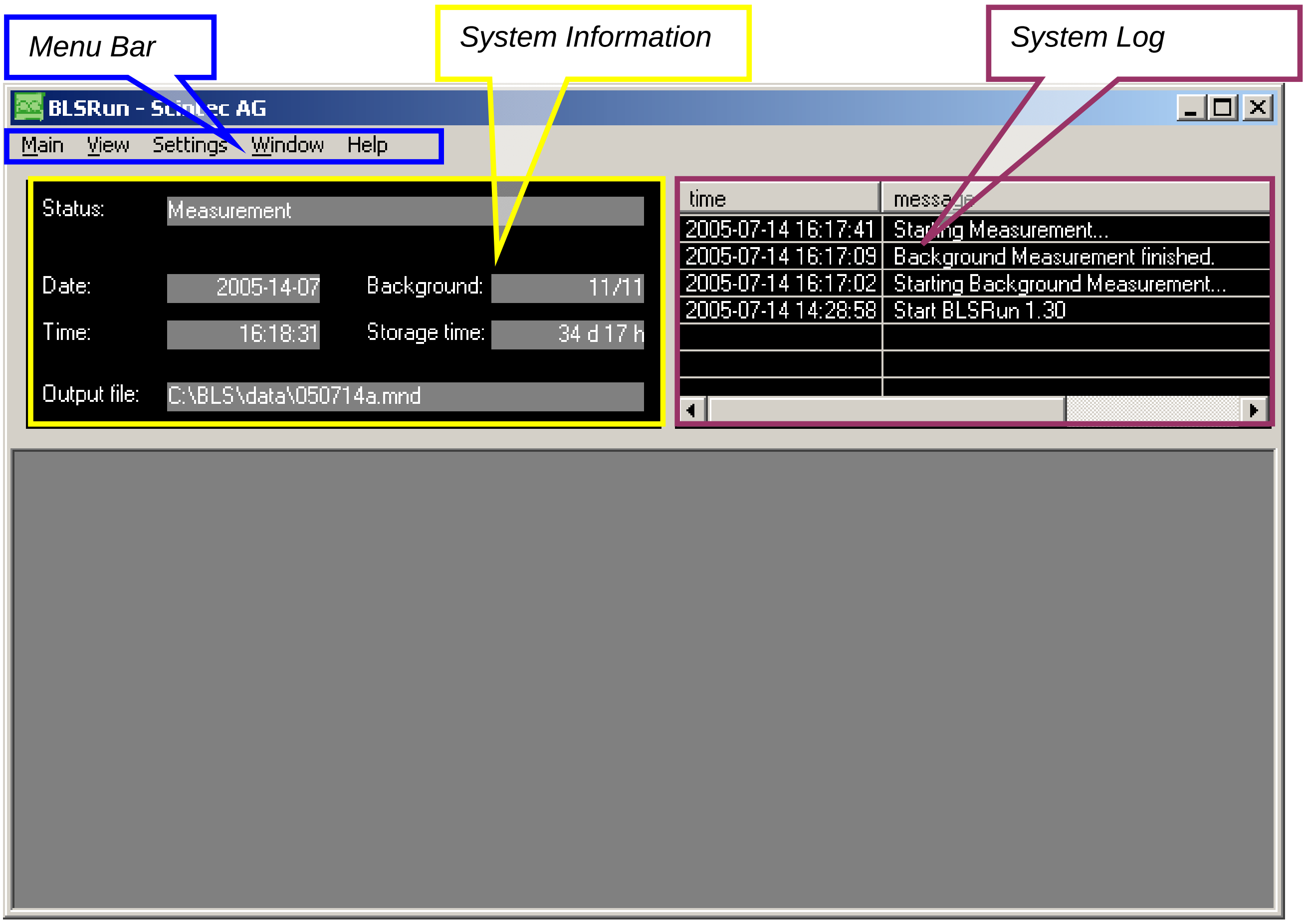


Figure 6: BLSRun Main Window

The *System Information* frame displays the following information:

Status	The Status field indicates the current state of BLSRun. If the SPU is not connected a red warning message is shown.
Date, Time	Displays the current system date and time.
Background	Background signal in digits (range 0 to 4095) as measured during background measurement. For the BLS900/BLS2000 two background values are displayed for channel X and channel Y respectively.
Storage time	The remaining measurement time in days and hours until the SPU Storage will be filled and the SPU software will start to overwrite the oldest of the previously measured data.
Output file	The latest main data file to which new data has been appended during measurement.

Table 5: Content of BLSRun System Information Frame

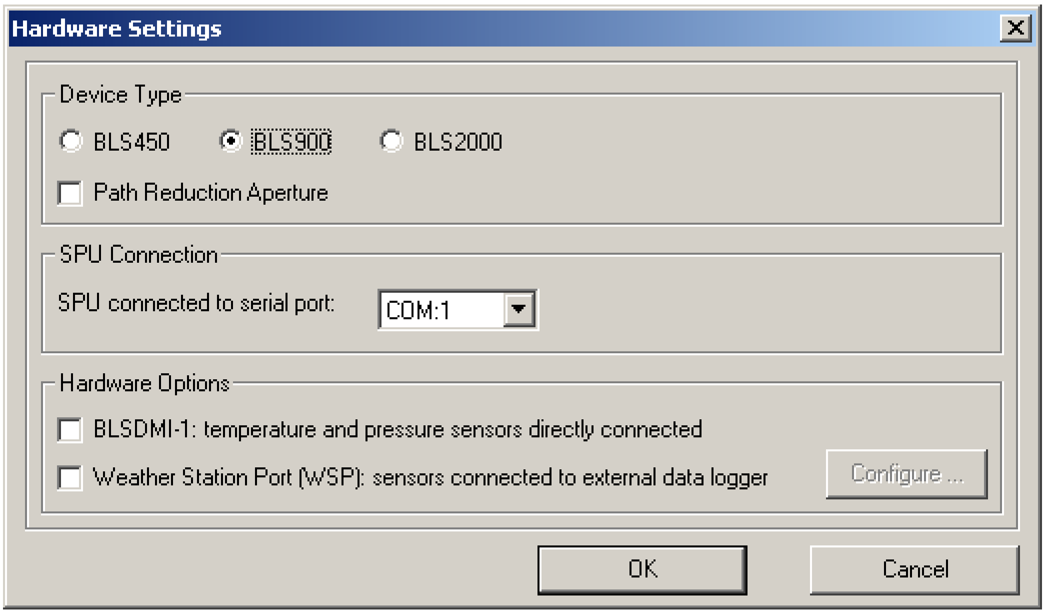
The *System Log* displays recent status and error messages.

The content of the *Menu Bar* is described in the following.

4.4 SETTINGS

All measurement parameters are defined in the *Settings* menu, containing the following items:

4.4.1 HARDWARE SETTINGS



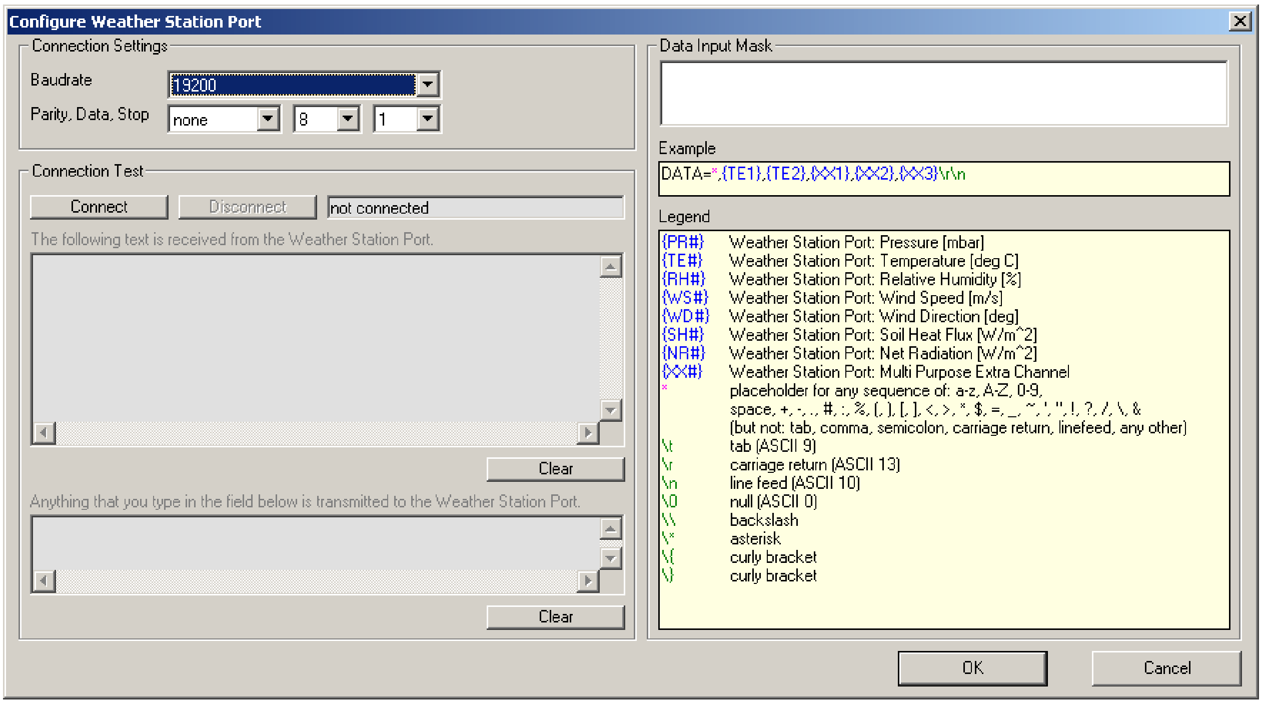
Device Type
Select the model used: BLS450, BLS900 and BLS2000.
If the Path Reduction Apertures are used the respective box has to be checked in order to achieve the correct system calibration.

SPU Connection
The serial port where the Signal Processing Unit is connected can be selected.

BLSDMI-1
This option should be checked if a pressure and a temperature sensor are connected to the (optionally available) BLSDMI-1 connectors of the Signal Processing Unit. Pressure and Temperature are read 20 times per minute and the average values can be used for accurate calculation of the heat flux. Do not forget to enable the usage of BLSDMI sensor data for calculations in the Processing Settings.

Weather Station Port
Check this option to enable the (optionally available) Weather Station Port of the Signal Processing Unit. You may connect an external Datalogger to this port in order to read, store and process the data from a variety of additional meteorological sensors. Click 'Configure...' to set the connection parameters and configure connected sensors.

4.4.2 HARDWARE SETTINGS – WEATHER STATION PORT



Connection Settings

The connection settings specify the parameters for the serial communication line between the external datalogger and the Weather Station Port of the Signal Processing Unit. Please carefully consult your datalogger's documentation or check any userdefined datalogger program to find out the serial baudrate, data parity, the number of data bits and the number of stop bits. If these parameters do not match exactly the communication parameters that the datalogger is using, the data will not be correctly transferred. Typical settings for Parity, Data, Stop are 'none, 8, 1'.

Data Input Mask

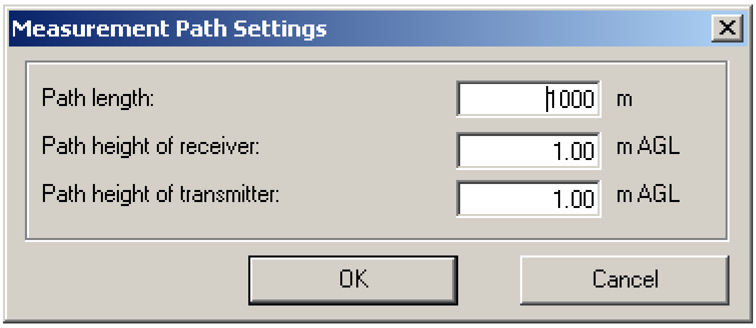
The Data Input Mask is a template that permits the BLS to recognize and understand the data received from the datalogger that is connected to the Weather Station Port. You must specify the precise syntax and format of the data records that are transmitted from the datalogger to the Weather Station Port. The legend contains a list of known sensor data types that may be used for calculations in the Processing Settings (see there). Any other type of sensor data that shall be stored should be declared as 'Multi Purpose Extra Channel'.

Some hints:

- The Data Input Mask *must* match exactly the data format that is provided by the datalogger, otherwise the received data will not be processed and an error code will be set.
- The Data Input Mask *should* begin with a unique identifier that marks the beginning of the data record. For example every data set might begin with the letters DATA.
- The Data Input Mask *must* end with a unique termination identifier such as for example a carriage return (\r) and a newline character (\n).
- You may use the placeholder (*) to define positions with arbitrary words or numbers that will be ignored during processing.
- The placeholder *should* not be used at the beginning and *must* not be used at the end of the Data Input Mask.
- For each sensor data position replace the '#' character with a number between 1 and 31 (e.g. {TE1},{TE2},{PR1} ,{XX17})
- If you use the same identifer with the same number at multiple positions within the Data Input Mask, an average value will be calculated (e.g. {RH1},{RH1},{RH1} will store the average results of three relative humidity sensors.)

Connection Test
After setting the Connection Parameters you may click 'Connect' to test the external datalogger connection and immediately display any data records that are received from the datalogger. This may also help when defining the Data Input Mask.

4.4.3 MEASUREMENT PATH SETTINGS



Path length
Enter the optical propagation path length in m here. The path length ranges from 500 m to 5000 m for the BLS900 and from 1000 m to 12000 m. for the BLS2000. The correct path length setting is required for the correct calculation of all derived turbulence parameters.

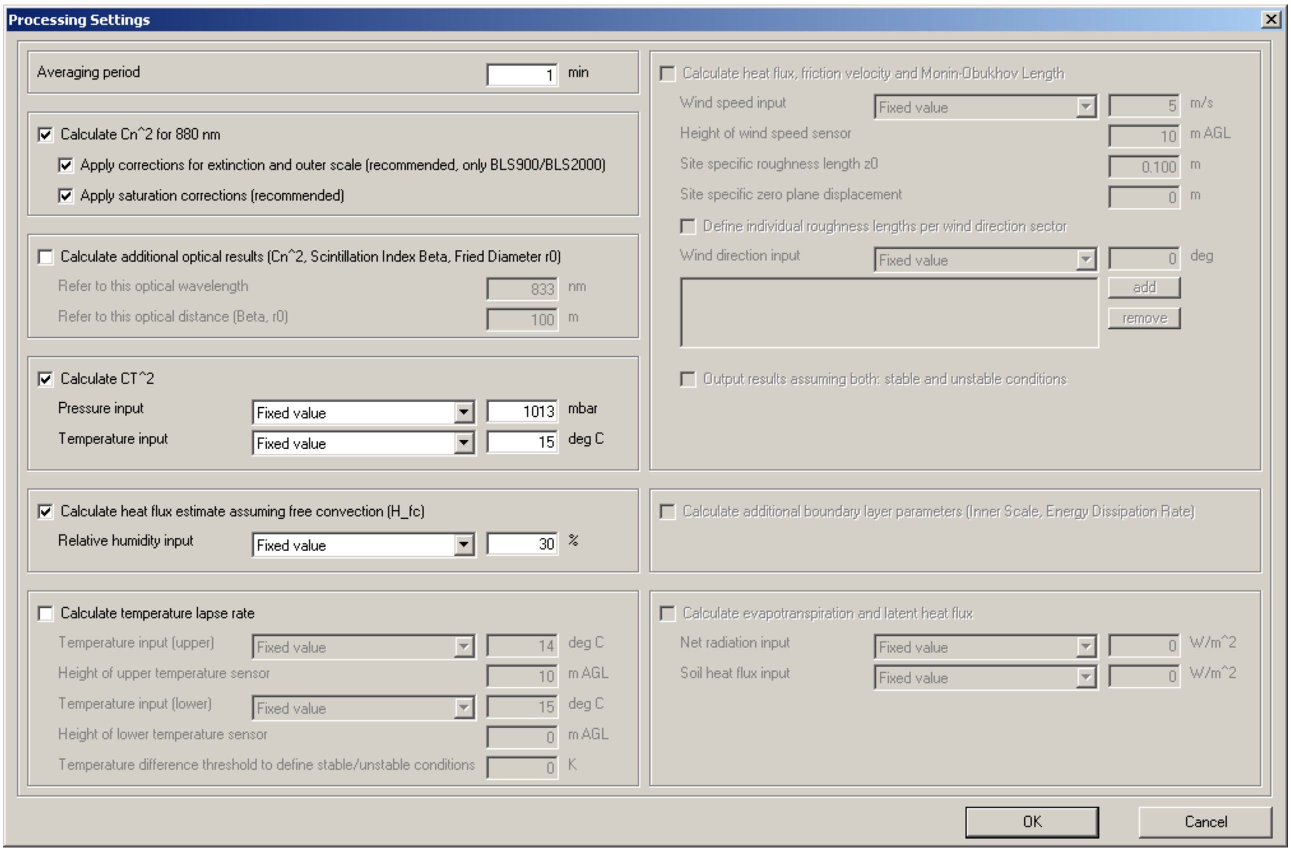
Path height of receiver
Here the height of the receiver above ground must be entered in cm. This parameter is valid from 0.10 m to 300 m AGL (above ground level) and is needed only for the correct calculation of the turbulent sensible heat flux H.

In the case of a linear slant path, you can enter both the heights of the receiver and transmitter, respectively, into the corresponding fields of the "Settings" dialog. The software will then automatically calculate an effective average height.

If the path is more complex and you apply the path averaging yourself, you should enter the single resulting effective path height into both fields. In this case, transmitter and receiver height will be the same.

Path height of transmitter
As before the height of the transmitter above ground must be entered in cm. This parameter is valid from 0.10 m to 300 m AGL (above ground level): It is needed only for the correct calculation of the turbulent sensible heat flux H.

4.4.4 PROCESSING SETTINGS



Averaging period
The averaging period for the main data can be set in the range from 1 to 180 min. Diagnosis data is always provided with a temporal resolution of 1 min. The signal to noise ratio and thus the data quality will be improved by increasing the averaging period.

Calculate C_n^2 for 880 nm

If checked BLSRun calculates C_n^2 from the diagnosis data signal intensities and standard deviations for the actually used 880 nm wavelength. This output is required for most other calculations.

In case of BLS900 or BLS2000 systems, which are equipped with two separate transmitter disks, you should enable the extinction and outer scale correction, which will increase data quality by automatically correcting for any errors due to varying atmospheric extinction (such as fog, clouds or dust that is moving through the optical measurement path) and additionally correcting for outer scale bias effects.

If checked the turbulence saturation correction permits you to extend your valid measurement range to atmospheric conditions where the fluctutations get so strong that turbulence saturation effects have to be considered. It is recommended to have this correction always enabled.

Calculate additional optical results
Even though measured at a wavelength of 880 nm and with a measurement path length that is defined by the setup, C_n^2 and other optical output variables (Fried diameter r_0, Scintillation Index) can be calculated for another reference wavelength and reference path length. The valid wavelength range is 100 to 30000 nm. Valid reference path lengths for r_0 range from 100 to 30000 m. This option requires the calculation of C_n^2 for 880 nm above.

Calculate C_T^2

This option enables the calculation of C_T^2 using the provided temperature and pressure values.

You may enter a fixed userdefined value or choose to automatically use online data that is obtained from the (optionally available) BLSDMI-1 sensors or sensors that are connected to the (optionally available) Weather Station Port.

Air pressure must be provided at the measurement location in hPa (= mbar, not reduced to sea level). Estimation within ±10 hPa is sufficient in most cases, since the effect on the results is small. The accepted input range is from 600 to 1100 hPa. A deviation of 10 hPa leads to an error of approximately 0.5% in the heat flux calculation as $H_0 \sim p^{-1/2}$.

The temperature must be provided in °C. The accepted input range is from –50 °C to 50 °C. A deviation of 10° leads to an error of approximately 5% in the heat flux calculation as $H_0 \sim T^{3/2}$.

This option requires the calculation of C_n^2 for 880 nm.

Calculate heat flux estimate assuming free convection

This basic turbulent sensible heat flux calculation is based on Monin-Obukhov Similarity Theory and assumes free convection scaling. The heat flux estimate will be most precise during calm and sunny days. The accuracy can be slightly improved by entering a typical relative humidity value specifically for your site. You may also automatically use online data that is obtained from sensors that are connected to the (optionally available) Weather Station Port. This option requires the calculation of C_T^2 above and makes also use of the temperature data that is defined there.

Calculate temperature lapse rate

The temperature lapse rate is derived by calculating the temperature difference between two temperature sensors which are mounted at two different height levels and connected to the Weather Station Port. The temperature difference $\Delta T = T_{upper} - T_{lower}$ is checked against a userdefined threshold value which should be close to 0 Kelvin. If ΔT is below this threshold the atmospheric stratification is assumed to be stable, otherwise it is considered unstable. This classification is then used for selecting the appropriate atmospheric model for further calculations. The lower temperature sensor should be installed at a very low height between 0.3 m and 0.7 m above ground level. The upper temperature sensor should be installed at the top of a meteorological mast of at minimum 3 m height, but preferably at 10 m height above ground level.

Calculate heat flux, friction velocity and Monin-Obukhov Length

If online wind speed data is obtained from the Weather Station Port, BLSRun can derive the turbulent sensible heat flux and other boundary layer parameters such as friction velocity and Monin-Obukhov Length by numerically solving a set of boundary layer model equations, which are based on Monin Obukhov Similarity Theory. The applied set of model equations is selected depending on the stability classification obtained from the temperature difference measurement above. The validity of these results is not restricted to unstable convective situations. It is applicable for conditions of unstable, neutral or stable stratification with any wind speeds.

The wind speed sensor should be installed in terrain, that is representative for the area being covered, preferably near the center of the optical measurement path. The area should be as homogeneous as possible and away from obstacles that might obstruct the wind flow. The aerodynamic roughness length for the measurement site must be estimated and entered in the respective field. In case of non-homogeneous terrain you may enter specific roughness lengths for any wind direction sectors. You should also enter an aerodynamic zero level displacement height.

The wind speed sensor should be installed on a meteorological mast at a height of approximately 20 to 100 times the roughness length plus the zero level displacement height.

You may choose to output any results assuming both cases: stable and unstable conditions. If checked, you will get for example three values for heat flux: (1) 'H', which is calculated using the stability classification obtained from the temperature difference measurement above, then (2) 'H_unstable' and (3) 'H_stable' which are calculated under the assumption of (2) stable and (3) unstable stratification. If this option is unchecked, only (1) is reported.

These calculations depend on the calculation of C_T^2 and heat flux (free convection) and make also use of the pressure, temperature und humidity settings that are configured there.

Calculate additional boundary layer parameters
If checked the inner scale and energy dissipation rate are additionally calculated.
This option requires the above calculation of heat flux, friction velocity and Monin-Obukhov Length.

Calculate evapotranspiration and latent heat flux
If net radiation and soil heat flux data are available from the Weather Station Port, the latent heat flux and therefore the actual evapotranspiration can be calculated., i.e. the amount of water that is evaporated from the ground and transpirated by vegetation. The latent heat flux is obtained as residual term from the following energy balance equation:

$$NetRadiation = H + SoilHeatFlux + LatentHeatFlux$$

This option requires the calculation of turbulent sensible heat flux H.

4.5 PULL-DOWN MENU MAIN

This menu contains the necessary steps to perform a measurement in a chronological order.

4.5.1 TRANSFER SPU PROGRAM

After having started the BLSRUN program, the *Status* field in the *System Information* frame shows *connected – SPU program not transfered.* This means that the SPU program *Blsrun.spu* has to be transferred from the PC to the SPU. This is done by selecting *Main – Transfer SPU program*. After invoking the command a window appears and shows the data quantity in kByte that has been transferred.

The file length of *Blsrun.spu* is approximately 100 KB. The transfer takes about 40 seconds, the SPU initialisation takes another 5 seconds. The completion of the initialisation process is given in %. Finally, when the SPU is ready for further operation the message *connected – SPU ready* in the *Status* field from the *System Information* frame is displayed.

4.5.2 ALIGNMENT

The alignment of the receiver is the next step to perform before starting the measurement. The receiver must be adjusted with the screws of the positioning device while looking at the alignment screen. After loading of the alignment screen the *Status* field in the *System Information* frame displays *running alignment* (= Alignment Mode).

4.5.2.1 BLS450

For the BLS450, the alignment screen consists of a bar graph display, a time series graphical display and a numerical display. The bar graph display indicates the intensities of the main channel X as a vertical bar. The numbers correspond to the output of the 12 bit A/D converter with a range from 0 to 4095 digits. The instantaneous intensities are displayed by the left bar and a sliding temporal average of the intensities is displayed by the right bar. The averaging eliminates a large part of the fluctuations and allows to judge the mean intensity levels more easily. At the top of each bar two triangles mark the maximum and minimum values observed so far.

The lower part of the bar graph display is magnified for the A/D converter range from 0 to 50 digits. This facilitates finding the signals at low levels and also permits a visual check of the offset which should be in the range 5 to 25.

The optimum signal level range during the measurement depends on the path length (section 3.2.3) If the signals are generally too low or too high a re-adjustment of the receiver dip switch settings might be necessary (section 3.2.3)

In the time series display the recent temporal behaviour of the instantaneous intensities of the main channel is displayed as a curve.

The numerical display includes channel Z besides the main channel X. Channel Z measures the position of the focus in the receiver telescope. A high values means a good position.

The numerical display shows the following values:

- instantaneous values X, Z of channels X and Z.
- average values <X>, <Z> of channels X and Z.
- maximum values Xmax, Zmax of channels X, and Z.
- minimum values Xmin, Zmin of channels X, and Z.

During alignment the channel Z values shall be adjusted to a maximum. The receiver is then aligned optimally.

Note that the values of channel X is a measure of the signal intensity after demodulation while the value of channel Z is a measure of the signal intensity before demodulation. This is useful to check for saturation or high dc level due to strong background radiation.

4.5.2.2 BLS900 and BLS2000

For the BLS900 and BLS2000, the alignment screen consists of a bar graph display, a time series graphical display and a numerical display. The bar graph display indicates the intensities of the two main channels X and Y as vertical bars. The numbers correspond to the output of the 12 bit A/D converter with a range from 0 to 4095 digits. The instantaneous intensities are displayed by the left two bars and a sliding temporal average of the intensities is displayed by the right two bars. The averaging eliminates a large part of the fluctuations and allows to judge the mean intensity levels more easily.

Channel one (= channel X) is plotted yellow while channel two (= channel Y) is plotted green. At the top of each bar two triangles mark the maximum and minimum values observed so far.

The lower part of the bar graph display is magnified for the A/D converter range from 0 to 50 digits. This facilitates finding the signals at low levels and also permits a visual check of the offset which should be in the range 5 to 25.

The optimum signal level range during the measurement depends on the path length (section 3.2.3) If the signals are generally too low or too high a re-adjustment of the receiver dip switch settings might be necessary (section 3.2.3)

In the time series display the recent temporal behaviour of the instantaneous intensities of both channels are displayed as curves.

The numerical display includes channel Z besides the main channels X and Y. Channel Z measures the position of the focus in the receiver telescope. A high values means a good position.

The numerical display shows the following values:

- instantaneous values X, Y, Z of channels X, Y, and Z.
- average values <X>, <Y>, <Z> of channels X, Y, and Z.
- maximum values Xmax, Ymax, Zmax of channels X, Y, and Z.
- minimum values Xmin, Ymin, Zmin of channels X, Y, and Z.

During alignment the channel Z values shall be adjusted to a maximum. The receiver is then aligned optimally.

Note that the values of channels X and Y are a measure of the signal intensity after demodulation while the value of channel Z is a measure of the signal intensity before demodulation. This is useful to check for saturation or high DC level due to strong background radiation.

For comfortable alignment, a transmitter pulse repetition frequency of at least 5 Hz should be chosen.

After having finished the alignment the alignment screen is closed by clicking on the cross located in the right top corner.

4.5.3 BACKGROUND MEASUREMENT

Before performing a measurement the background must be determined by invoking the *Main – Background Measurement* menu command. The *Status* field in the *System Information* frame shows *measuring background* and a message box with the following dialogue appears:

“Cover receiver unit now and press ‘START’”. After following the instructions the background is sampled for 10 seconds and the result is displayed. The background is indicated for channel X and Y (BLS900 and BLS2000) or channel X only (BLS450) in digits ranging from 0 to 4095.

The result is now displayed in the *Background* field of the *System Information*.

4.5.4 START MEASUREMENT

To enter the Measurement Mode, select the *Main - Start Measurement* menu command. A dialogue window pops up asking for the output folder. A filename is selected automatically by using Scintec’s Universal Data Format (SUDF) to store the data in daily files (refer to section 4.8).

During measurement the data is sent to the PC running BLSRun (if connected).

If it is not possible to have a PC at the measurement site, you may start the measurement with the option ‘store data on SPU only’. The PC can be plugged off and reconnected only for transferring the measurement results from time to time. If the SPU Storage is full before the data are deleted the oldest data are automatically overwritten.

Data are stored in the non-volatile flash memory of the SPU. You may safely disconnect your PC from the SPU during measurement. In case of a power cut all data will be preserved and the measurement will be automatically resumed five minutes after power returns.
SPU storage capacity: approx. 2 years.

4.5.5 STOP MEASUREMENT

This menu item stops the measurement on SPU. After a few seconds the SPU has terminated the measurement routine and waits for further commands if the message *connected - SPU ready* is displayed in the *System Information Status* field.

4.5.6 SPU DATA STORAGE

In order to retrieve or erase data stored on the SPU the PC must be properly connected to the SPU.

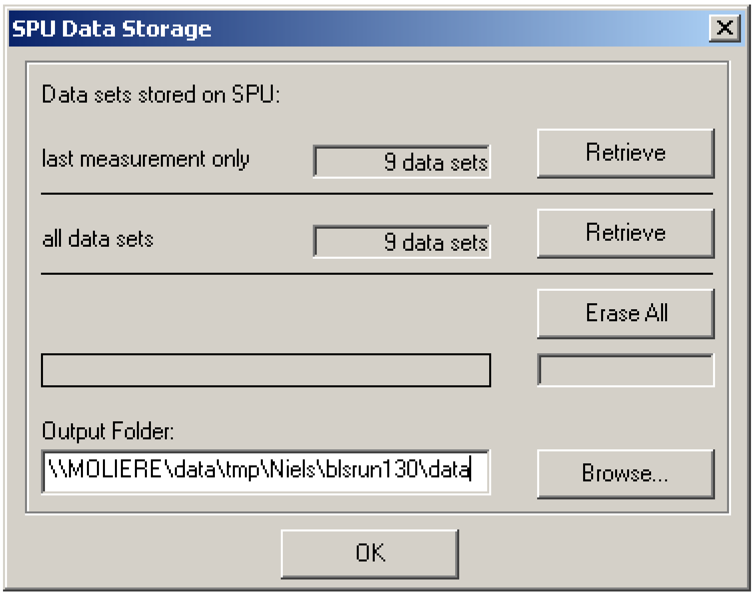


Figure 7: SPU Data Storage Dialog

Three options concerning the measured data are offered:

1. Retrieve data from last measurement only
2. Retrieve data from all stored measurements
3. Erase all stored data

4.5.7 REPROCESS DIAGNOSIS DATA

BLSRun allows reprocessing of diagnosis data (files with extensions *.dgn) for parameters being different from those which have been used for an already completed measurement. Turbulence parameters listed in the corresponding main data files (extension *.mnd) are then recalculated for the new setting. The following parameters might be changed prior to starting the reprocess procedure:

- Path Length
- Path Height of Receiver
- Path Height of Transmitter
- Averaging Period
- Reference Wavelength for C_n^2
- Reference Path Length and Wavelength for r_o

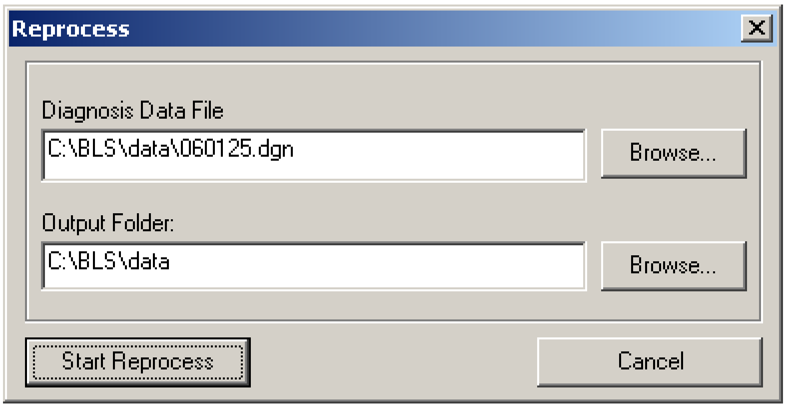


Figure 8: Reprocess Diagnosis Data Dialog

4.5.8 QUIT BLSRun

Quit Blsrun terminates only the Blsrun program. The software on the SPU is not affected by this command so that a started measurement will go on.

4.6 MENU VIEW

4.6.1 MAIN DATA SCREEN

The main data screen contains the measurement results. The data are written at the end of each main data period. The data are plotted horizontally in the following order. Some variables may not be available depending on the current Processing Settings and available hardware.

Parameter	Description
Time	Date and time at the end of the main data period
Norm. StdDev.	Normalized standard deviation (average of channels X and Y)
Cn^2 (880 nm)	Structure function constant of refractive index fluctuations in $m^{-2/3}$ (calculated for 880 nm wavelength)
Cn^2 EO-Corr-Factor	The correction factor that is applied to the Cn^2 and any derived results by the extinction and outer scale correction. This factor is already taken into account. Do not double-correct!
Cn^2 Saturation-Corr-Factor	The correction factor that is applied to the Cn^2 result and any derived results by the saturation correction. This factor is already taken into account. Do not double-correct!
Cn^2 (xxx nm)	Structure function constant of refractive index fluctuations in $m^{-2/3}$ (calculated for the userdefined wavelength of xxx nm)
Beta-Plane (xxx nm, yyy m)	Scintillation Index (i.e. the normalized standard deviation that a point detector would observe) for a plane wave of xxx nm wavelength that travelled an optical distance of yyy m.
Beta-Spherical (xxx nm, yyy m)	Scintillation Index (i.e. the normalized standard deviation that a point detector would observe) for a spherical wave of xxx nm wavelength that travelled an optical distance of yyy m.
r_o (xxx nm, yyy m)	Fried diameter for xxx nm wavelength and an optical distance of yyy m
CT^2	Structure function constant of temperature fluctuations in K^2 $m^{-2/3}$
H_FC	Turbulent sensible heat flux in W/m^2 (calculated assuming free convection)
dT	Temperature difference (upper temperature – lower temperature)
-dT/dz	Temperature lapse rate
dt Stability	Stability classification derived from dT: 0 – no classification 1 – unstable stratification (typically during day time) 2 – stable stratification (typically during night time)
H	Turbulent sensible heat flux in W/m^2
u*	Friction veloctiy in m/s
L	Monin-Obukhov-Length in m
epsilon	Energy dissipation rate m^2/s^3
l0	Inner scale in m
LH	Latent heat flux in W/m^2
Evapotranspiration	Evapotranspiration in mm/day
Crosswind	Crosswind speed in m/s *not available for BLS450*
Crosswind Std.Dev.	Estimated standard deviation of crosswind speed in m/s *not available for BLS450*
DMI-Pressure	BLSDMI pressure sensor data
DMI-Temperature	BLSDMI temperature sensor data
WSP-XXX	Weather Station Port: individual sensor data
WSP-NumData	Weather Station Port: number of data records received and averaged

WSP-Error	Weather Station Port: Error code
Error	Error code

Table 6: Main Data

4.6.2 DIAGNOSIS DATA

The Diagnosis Data table displays basic statistics and contains the measurement results. It allows a deeper understanding of the measurements and can be used to analyse problems. The data are plotted horizontally in the following order:

Parameter	**Remark**
Time	Date and time at the end of the main data period
<X>	Average signal in channel X after background correction
<Y>	Average signal in channel Y after background correction *not available for BLS450*
sigX	Standard deviation of the signal in channel X
sigY	Standard deviation of the signal in channel Y *not available for BLS450*
cor	correlation of the signal in channel X and channel Y *not available for BLS450*
Xmin	Smallest detected signal level in channel X
Xmax	largest detected signal level in channel X
Ymin	Smallest detected signal level in channel Y *not available for BLS450*
Ymax	largest detected signal level in channel Y *not available for BLS450*
Zalign	alignment indicator signal level in channel Z
NumValid	number of used pulses related to the number of detected pulses
NumTotal	number of used pulses related to the number of detected pulses
Crosswind	Crosswind speed in m/s *not available for BLS450*
Crosswind Std.Dev.	Estimated standard deviation of crosswind speed in m/s *not available for BLS450*
DMI-Pressure	BLSDMI pressure sensor data
DMI-Temperature	BLSDMI temperature sensor data
WSP-XXX	Weather Station Port: individual sensor data
WSP-NumData	Weather Station Port: number of data records received and averaged
WSP-Error	Weather Station Port: Error code
Startup-Count	The total number of Processing Unit startups (i.e. how often did the Processing Unit booted). This counter is resetted when a new SPU program version is installed.
Measurement-Count	The total number of measurements that have been started (i.e. how often was a new measurement started). This counter is resetted when a new SPU program version is installed.
Data-Count	The total number of data sets that have been recorded in the current measurement.
SPU+12V	Monitor of the internal +12VDC voltage of the Processing Unit. This is not the external supply voltage but an internally stabilized voltage.
SPU-CPU-Temp	Monitor of the internal microprocessor temperature of the Processing Unit.
Error	Error code

Table 7: Diagnosis Data

4.6.3 SPU COMMUNICATION WINDOW

The *SPU Communication* frame displays all commands and data transferred between the PC and the SPU. It is only used for software diagnostic purposes.

4.6.4 START ScintecView

By clicking the *Start ScintecView* menu item the visualization program ScintecView is executed. This program can display all main data as time series. For more information about ScintecView refer to the separate ScintecView manual.

4.7 CROSSWIND MEASUREMENT

Crosswind measurements can be performed with the BLS900 and BLS2000. The crosswind is measured only in case of a selected 125 Hz pulse repetition rate at the transmitter.

As illustrated in Figure 9, the sign of the crosswind is negative when the wind is blowing from Channel X to Channel Y. If the result is positive, the wind is blowing from Channel Y to Channel X.

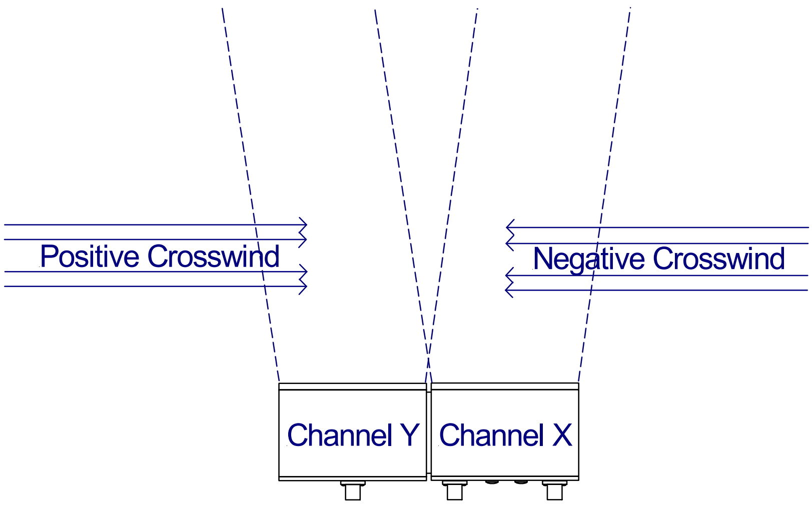


Figure 9: Definition of the Sign of the Crosswind

4.8 OUTPUT FILE DATA FORMAT

This chapter describes the output file formats of the main data output file (extension *.mnd) and the diagnosis (or statistics) data output file (extension *.dgn).

Main data file and diagnosis data file are stored in Scintec's FORMAT-1 data format for use with the graphical data display software ScintecView.

4.8.1 Scintec's FORMAT-1 Data Format

The data files obeys the following principles:

- All data are stored in ASCII format

- The decimal separator is a dot, no matter which operation system and programming environment is used
- There is no change of file format within one data file
- FORMAT-1 uses daily files with all files closed at midnight.

4.8.1.1 FILENAME

The filename of a FORMAT-1 file is YYMMDDII.ext, where

- YY are the last two numbers identifying the year (00-99)
- MM is the month (01 – 12)
- DD is the day (01 – 31)
- II is an index characterizing the measurement periods within one day (a – zz)
- ext is the file extension

The filenames are no longer than 8 characters plus 3 characters extension. The alphabetical order of the filenames corresponds to the chronological order of the data contained in the files.
A new file with changed index is opened when a new measurement is performed. The BLSRun software automatically detects for existing files.

Example:
Diagnosis data files created after starting and ending a measurement three times:

010912.dgn	(diagnosis data created on Sept. 12th, 2001, first measurement period)
010912a.dgn	(diagnosis data created on Sept. 12th, 2001, second measurement period)
010912b.dgn	(diagnosis data created on Sept. 12th, 2001, third measurement period)

4.8.1.2 DATA FORMAT

The data format is defined as follows:

```
[begin file (not in file)]
A$
A1$ A2$ A3%
B$
H% D% 0

H$
G$
YA$(1) # YB$(1) # YC$(1) # YD$(1) # YE$(1)
YA$(2) # YB$(2) # YC$(2) # YD$(2) # YE$(2)

...
YA$(H%) # YB$(H%) # YC$(H%) # YD$(H%) # YE$(H%)


DateTime$(1) Y(1,1) Y(1,2) Y(1,3) ... Y(1,H%)
DateTime$(2) Y(2,1) Y(2,2) Y(2,3) ... Y(2,H%)
...
DateTime$(n) Y(n,1) Y(n,2) Y(n,3) ... Y(n,H%)
[end file (not in file)]
```

With

	Remark	

A$	format identifier	FORMAT-1 (string)
A1$	Date when file was opened	YYYY-MM-DD (string)
A2$	Time when file was opened	HH:MM:SS (string)
A3$	Serial number of files generated during the same day	integer
B$	Type of the instrument	string
H%	Number of subsequent header lines	integer
D%	number of data points for each time and height segment	integer
E%	Number of height segments	0 (integer)
H$	header in free ASCII format with H% lines	
G$	Data tyoe description	String
YA$(n)	name of the n-th parameter	string
YB$(n)	abbreviation or symbol of the nth parameter	string
YC$(n)	unit of the nth parameter	string
YD$(n)	identifier for display information of the n-th parameter	string
YE$(n)	number composed of 1...n bits controlling the selection of error codes 1...n for purposes of masking parameter values in the display	integer
DateTime$(i)	date and time at end of period i	YYYY-MM-DD HH:MM:SS
Y(i,j)	value of the j-th parameter in the i-th data line	float

Table 8: SUDF Data Format

YE$ is a number composed of 1..n bits controlling the selection of error codes 1..n for purposes of masking parameter values in the associated data column: For example, YE$ = 3 selects the first (0) and second (1) column ($3=2^0+2^1$). Data is displayed after the error codes in these columns have been masked with the current error mask and been combined by logical OR and if the result has at least one bit set. Bits not corresponding to data columns are ignored.

4.8.1.3 DATA FORMAT EXAMPLE

```
FORMAT-1
2007-09-26 14:17:00 0
BLS900
2 28 0

Software Version: BLSRun 1.42
Data reprocessed on 2007-10-08 17:48:59
Main Data
Time # Time #  # T1 # 1
Normalized Std.Dev. # Norm. StdDev #  # S # 1
Cn^2 (880 nm) # Cn^2 (880 nm) # m^-2/3 # S # 1
Cn^2 Extinction and Outer Scale Correction Factor # Cn^2 EO-Corr-Factor #  # S # 1
Cn^2 Saturation Correction Factor  # Cn^2 Saturation-Corr-Factor #  # S # 1
Cn^2 (833 nm) # Cn^2 (833 nm) # m^-2/3 # S # 1
Scintillation Index Beta (plane wavefront) (833 nm, 100 m) # Beta-Plane (833 nm, 100 m) #  # S # 1
Scintillation Index Beta (spherical wavefront) (833 nm, 100 m) # Beta-Spherical (833 nm, 100 m) #  # S # 1
Fried Diameter r0 (833 nm, 100 m) # r0 (833 nm, 100 m) # m # S # 1
CT^2 # CT^2 # K^2 m^-2/3 # S # 1
Heat Flux (Free Convection) # H_FC # W/m^2 # S # 1
Temperature Difference # dT # K # S # 1
Temperature Lapse Rate # -dT/dz # K/m # S # 1
Temperature Difference Stability Id # dT Stability #  # S # 1
Heat Flux # H # W/m^2 # S # 1
Friction Velocity u* # u* # m/s # S # 1
Monin Obukhov Length # L # m # S # 1
Dissipation Rate of turbulent kinetic energy # epsilon # m^2/s^3 # S # 1
```

```
Inner Scale l0 # l0 # m # S # 1
Latent Heat Flux # LH # W/m^2 # S # 1
Evapotranspiration # Evapotranspiration # mm/day # S # 1
Crosswind # Crosswind # m/s # S # 1
Crosswind Std.Dev. # Crosswind Std.Dev. # m/s # S # 1
DMI-Pressure # DMI-Pressure # mbar # S # 1
DMI-Temperature # DMI-Temperature # deg C # S # 1
Weather Station Port: Temperature (TE1) # WSP-Temperature (TE1) # deg C # S # 1
Weather Station Port: number of included datasets # WSP-NumData #  # S # 1
Weather Station Port: Error Code # WSP-Error #  # S # 1
Error Code # ALIGN LEVEL NUL NUL NUL NUL NUL NUL WSP-ERR BATT ALG NOSIGNAL NUL NUL
NUL NUL #  # E # EEIIIIIIIEEEIIII


2007-09-26 14:17:00    0.140    2.6012e-13      1.0042  1.0831  2.6070e-13      0.412    0.256    0.0210 ...
2007-09-26 14:18:00    0.140    2.8711e-13      1.1016  1.0919  2.8776e-13      0.435    0.270    0.0198 ...
2007-09-26 14:19:00    0.143    2.9480e-13      1.0739  1.0944  2.9546e-13      0.441    0.273    0.0194 ...
2007-09-26 14:20:00    0.139    2.5832e-13      1.0042  1.0825  2.5890e-13      0.411    0.255    0.0211 ...
...
```

4.9 ERROR CODES

4.9.1 ERROR CODES IN MAIN DATA AND DIAGNOSIS DATA

The meanings of the error codes in the Diagnosis Data and Main Data are:

Error code		Meaning
0000		no error or warning
0001	2^0	misalignment of receiver
0002	2^1	saturation of output levels channel X or Y
0004	2^2	reserved
0008	2^3	reserved
0016	2^4	reserved
0032	2^5	reserved
0064	2^6	reserved
0128	2^7	reserved
0256	2^8	Weather Station Port error or warning (see WSP-Error for details)
0512	2^9	SPU battery low
1024	2^{10}	algorithms error by pulse detection
2048	2^{11}	signal too low
4096	2^{12}	reserved
8192	2^{13}	reserved

Table 9: Error Codes

Simultaneously occurring error codes sum up as in the following example.

Error Code	Meaning		
2561		2048	signal too low
(= 2048 + 512 + 1)	*and*	512	SPU battery low
	and	1	misalignment of receiver

4.9.2 WEATHER STATION PORT ERROR CODES

The meanings of the error codes in the Diagnosis Data and Main Data are

WSP-Error		Meaning
0000		no error or warning
0001	2^0	no data is received within this measurement period (1 min)
0002	2^1	input buffer overrun, the amount of received data within this measurement period (1 min) exceeds the available input buffer space, some data records are lost
0004	2^2	the data contains an invalid value that could not be read as a number
0008	2^3	syntax error: the received data does not match the Data Input Mask (1)
0016	2^4	syntax error: the received data does not match the Data Input Mask (2)
0032	2^5	syntax error: the received data does not match the Data Input Mask (3)
0064	2^6	the Data Input Mask has syntax errors (1)
0128	2^7	the Data Input Mask has syntax errors (2)
0256	2^8	the Data Input Mask has syntax errors (3)
0512	2^9	the Data Input Mask has syntax errors (4)
1024	2^{10}	the Data Input Mask has syntax errors (5)
2048	2^{11}	reserved
4096	2^{12}	reserved
8192	2^{13}	reserved
16384	2^{14}	another runtime error occured while processing the sensor data

Table 10: Error Codes

Simultaneously occurring error codes sum up as in the following example.

Error Code	Meaning		
0018 (= 0016 + 0002)	 *and*	0016 0002	syntax error input buffer overrun

5 HARDWARE

The refractive index turbulence measurement system consists of an optical transmitter with tripod, an optical receiver with tripod and positioning device, a signal processing unit (SPU) and a data evaluation software for a PC.

5.1 TRANSMITTER

5.1.1 OVERVIEW

The BLS900 transmitter emits radiation through 924 light emitting diodes (LED). It consists of two round cases, each housing a disk with 444 infrared and 18 red LEDs and two power supply boards. The BLS450 transmitter uses one radiating disk only and emits radiation through 462 LEDs. The BLS2000 transmitter uses two disks, each equipped with 878 infrared, 34 red LEDs and four power supply boards. A microcontroller board with overvoltage protection is included in the BLS450, BLS900 and BLS2000 transmitters. The LEDs can be operated in 4 different pulse repetition rates from 1Hz to 125 Hz. A pulse rate of 125 Hz provides maximum accuracy and transverse wind speed measurement capability, whereas a pulse rate of 1 Hz results in very low power consumption. The divergence of the emission is about 16°, therefore transmitter adjustment has to be done only very roughly.

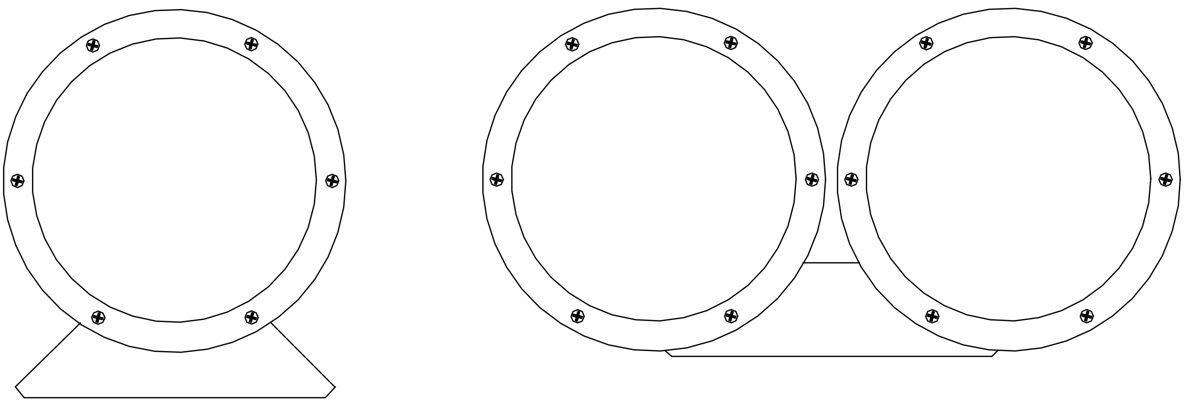


Figure 10: Transmitter front view, Left: BLS450, Right: BLS900/BLS2000

The 18 (34 for the BLS2000) red LED’s on each disk work as an indicator for the correct function of the infrared LED’s and show the current pulse repetition rate. Each red LED is connected with a segment consisting of 26 (27 for the BLS2000) infrared LED’s.

Each LED disk emits pulses with a different modulation frequency: 1750 Hz for disk 1 (with the black and red buttons) and 2500 Hz for disk 2 (BLS900 and BLS2000).

5.1.2 APPLIANCE

The transmitter is switched on by pressing the red button located on the rear panel of the transmitter (Figure 11). By pressing the button again, the pulse repetition rate is increased from 1 Hz to 5 Hz. By pressing the red button once again, the pulse repetition rate is increased from 5 Hz to 25 Hz, then to 125 Hz and then the pulse repetition rate starts from 1 Hz again. With the black button, the pulse group frequency is decreased in the same manner. The transmitter is switched off by pressing the red and black button simultaneously. The pulse repetition rate is also indicated by the green LED in the red button.

Besides the red and black button, the back side of each transmitter hosts a connector for the power supply (Figure 11). The standard power supply cable has a length of 3 m.

In case of the BLS900 and BLS2000, the two rear panels are each equipped with an additional connector. The two LED disk boxes are connected via a short cable plugged into these connectors. The two connectors can be 4-pole or 7-pole.

The transmitter can easily be mounted on geodetic tripods using a thread adapter on the instruments bottom.

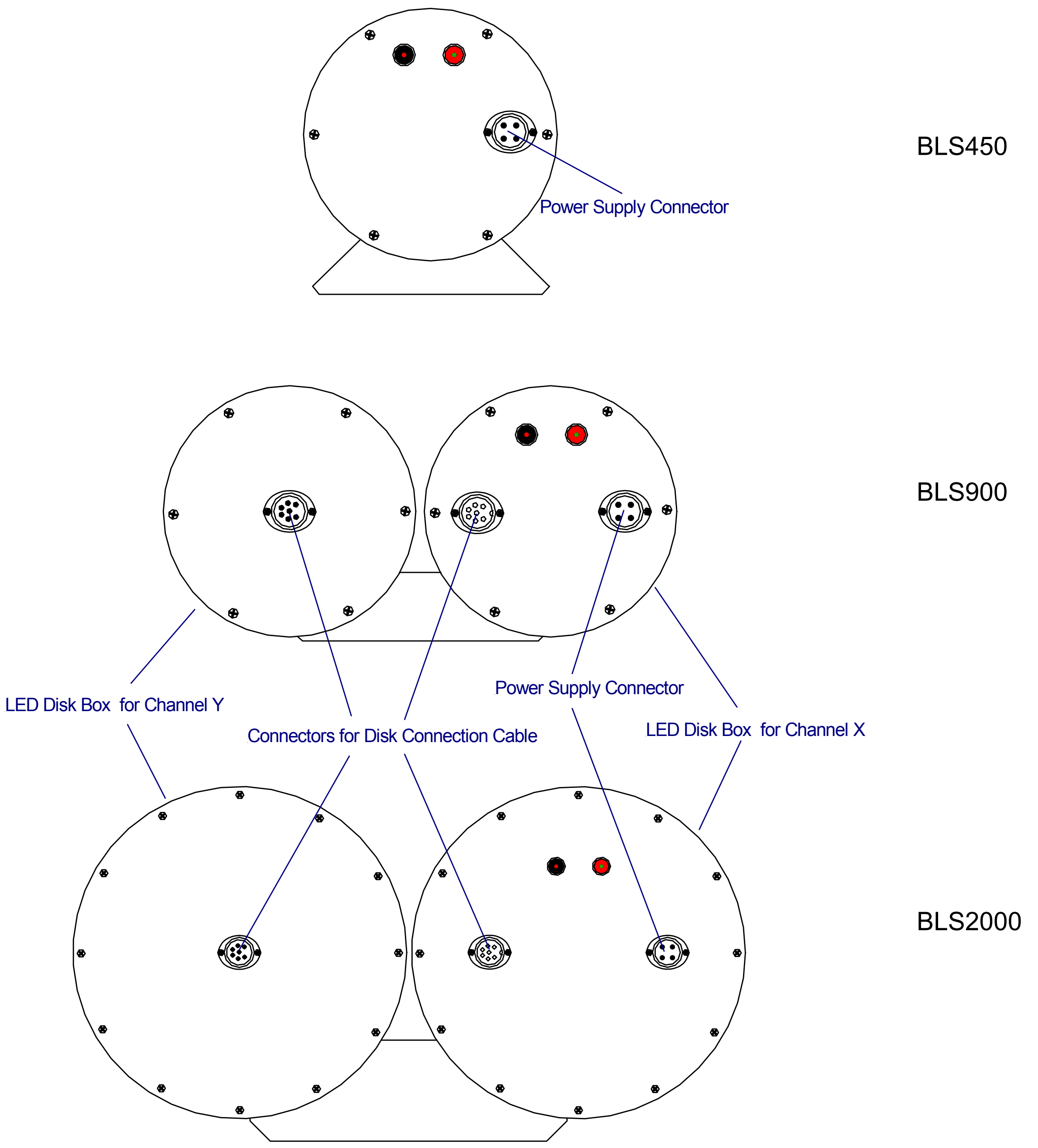


Figure 11: Connectors at BLSTransmitter

5.2 RECEIVER

5.2.1 OVERVIEW

With the BLS450 and BLS900, the modulated radiation is collimated by a plan convex lens (∅ =145 mm, f = 450 mm) onto 2 Si photodiodes with different sensitive areas. The BLS2000 uses a fresnel lens of 265 mm diameter and a focal length of 495 mm. The main detector on the optical axis is used for sensing the turbulence-induced fluctuations of the received modulated pulses. After demodulation the signals X and Y are available for the user during alignment. The auxiliary detector is used as an alignment aid. It provides the modulated signal Z.

The receiver (Figure 12) is held by a 3 axis-positioning device allowing easy alignment adjustments. A telescope is used to adjust the receiver's optical axis to the transmitter optically. The receiver can be mounted on geodetic tripods using a thread adapter on the instruments bottom.

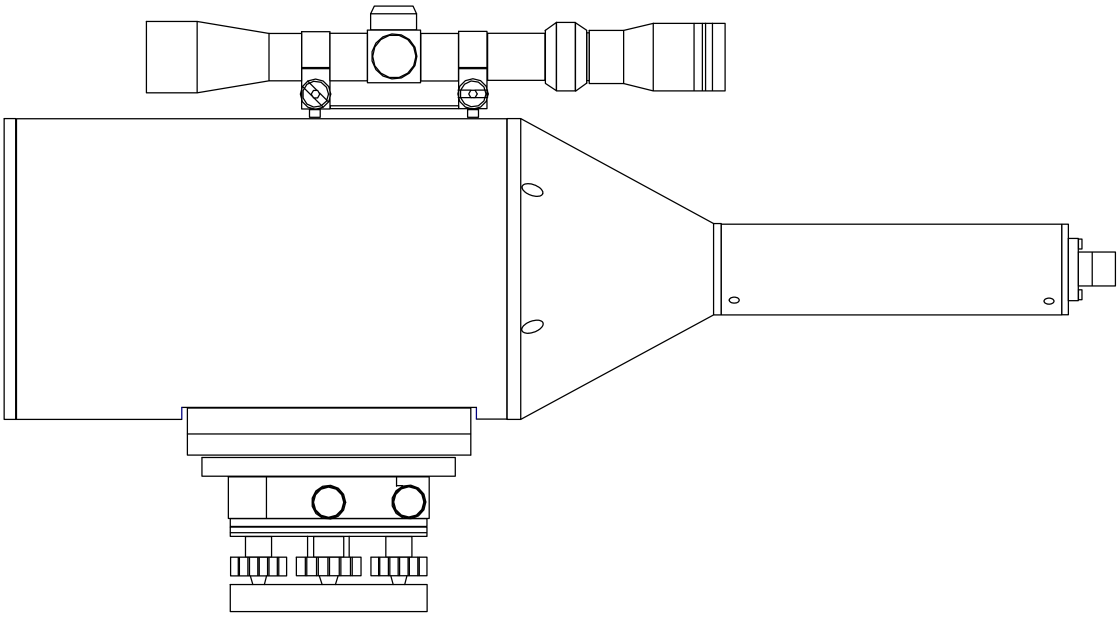


Figure 12: BLS900 Receiver side view

5.2.2 APPLIANCE

The receiver is connected to the SPU via a cable with a 9-pole-connector located on the rear panel of the receiver (Figure 13).

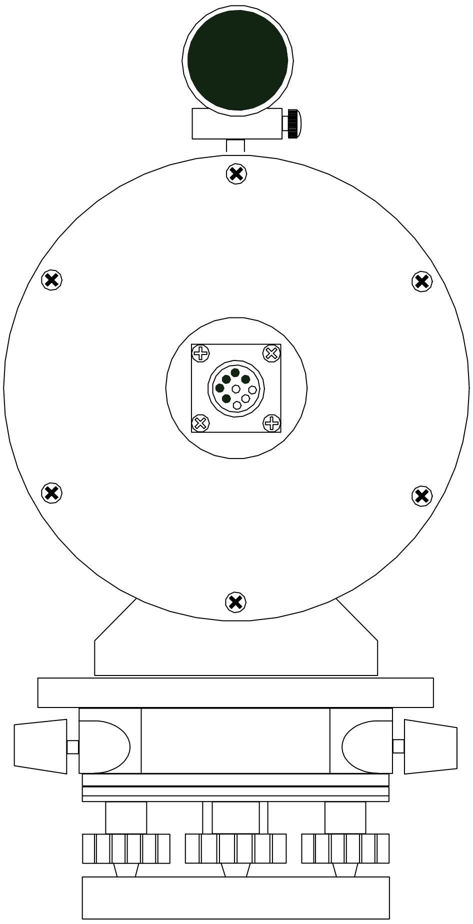


Figure 13: BLS900 Receiver rear view

5.3 SIGNAL PROCESSING UNIT (SPU)

The SPU is used for data acquisition and evaluation. It is directly connected to the receiver and communicates with the PC via serial (RS232) protocol. There is no connection between receiver and transmitter needed. The pulse repetition rate is determined automatically.

The SPU contains 2 cards:

- a card SPC20 to perform the filtering and demodulation of the signals X and Y. It also contains a sample and hold circuit and an A/D converter.
- a microprocessor card to do further signal processing, calculating the results, storing the results and transferring the data via RS232 to the PC

The Signal processing unit also generates the ±12V voltages needed for the receiver from a single external +12V power supply.

An indicator on the SPU confirms the correct receiver alignment relative to the optical axis.

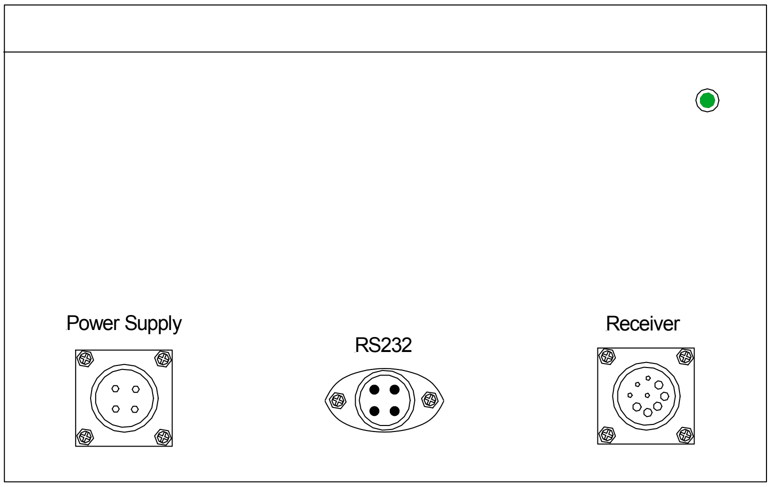


Figure 14: SPU front view

The data held in the memory of the SPU are read out by a PC via a serial RS232 data line and are finally stored as ASCII files on the internal hard disk. From the stored data the software displays in tabulated or graphical form the time series of C_n^2, r_o and u. The pulse height statistics are equally available, and a data quality rating is given.

The software allows the path length definition to be made after the measurement has been performed. In this way, the instrument can be set up and operated before the exact propagation path length is known.

The software can also be used to analyse the system performance in real time, when a PC is connected to the processing unit. This is particular helpful during set-up or alignment.

5.4 BLS POWER SUPPLY (OPTIONAL)

On request, the BLS system is available with additional BLS Power Supply units for the SPU and the transmitter, respectively. One BLS Power Supply comes with an attached 10 m cable for mains connection (AC In) and a second cable for establishing power support to the SPU or the transmitter (DC Out). The standard length is 3 m and 4 m to the SPU and the transmitter, respectively.

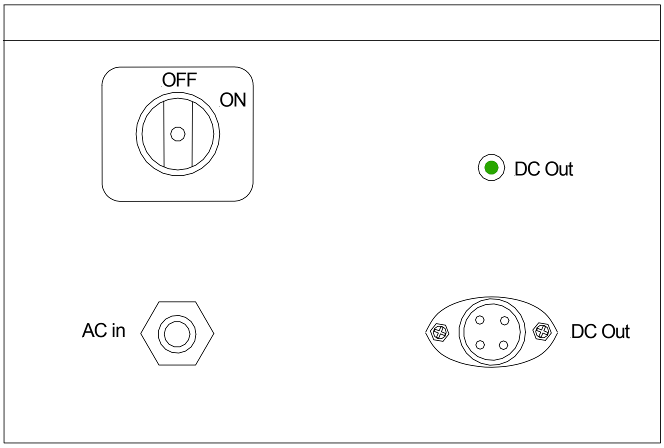


Figure 15: BLS Power Supply front view

5.5 BLS UNINTERRUPTIBLE POWER SUPPLY (OPTIONAL)

On request, additional BLS Uninterruptible Power Supply (UPS) units are available for the BLS Power Supply units. A BLS UPS comes with a 1 m cable (DC In) for connection to the BLS Power Supply. A BLS UPS serves as a battery backup with around 40 Ah. Based on Pulse Width Modulation (PWM), the battery is automatically recharged. The BLS UPS is also equipped with a low voltage disconnect, which disconnects the battery once the battery voltage falls below a certain threshold.

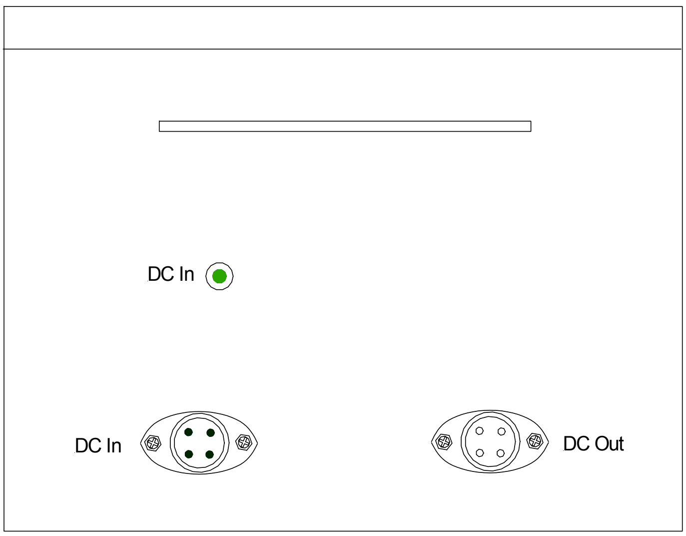


Figure 16: BLS UPS front view

5.6 WEATHER STATION PORT (OPTIONAL)

On request, the BLS SPU can be equipped with an additional connector, the so-called Weather Station Port (Figure 17). It establishes cable bound RS232 serial communication between the BLS SPU and a data logger, which might be connected to a large variety of different sensors. The serial cable has a standard length of 10 m. It also provides for proper power supply (regulated +12 VDC) of the data logger and attached sensors for a current consumption up to 500 mA.

In case that a larger distance between BLS SPU and data logger is required, the use of a radio link extension or an optional RS485 converter system is available. The latter allows cable bound serial communication between the BLS SPU and the data logger up to around 1000 m apart. It compromises three boxes: a RS485 converter box for use with the BLS SPU, a RS485 converter box for use close to data logger and a power supply unit for the data logger RS485 converter box. However, in case that the RS485 converter system is employed, the data logger and attached sensors are not supported with +12 VDC by the BLS SPU, as it is the case for RS232 connection.

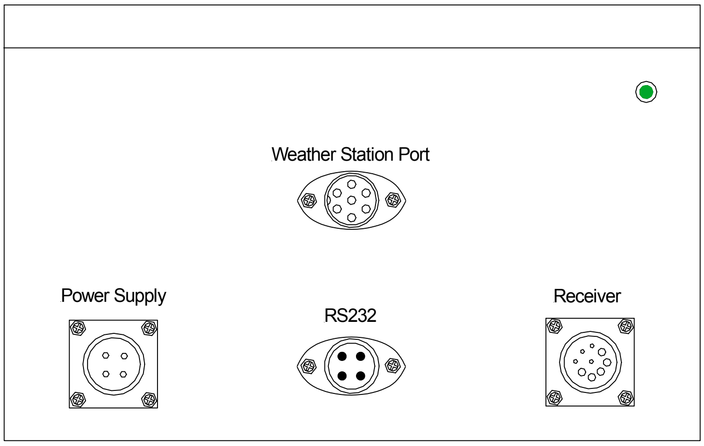


Figure 17: SPU front view with Weather Station Port

5.7 DIRECT METEOROLOGICAL INPUT BLSDMI-1 (OPTIONAL)

5.7.1 OVERVIEW

The BLSDMI-1 option consists of a temperature sensor, a barometric pressure sensor, a small tower and cables to connect the sensors to the SPU. The sensors measure continuously air pressure and temperature and the software uses these measured parameters in real-time for the heat flux calculation.

The PT1000 temperature sensor is plugged into a ventilated radiation shield which can be installed on the tower. The radiation shield avoids measurement errors due to sun radiation. The PT1000 is connected to a BLSDMI sensor interface which converts the PT1000 resistance into a voltage. This voltage output is connected to the analogue input board of the SPU.
The barometric pressure sensor includes a voltage output which is connected directly to the SPU.

5.7.2 APPLIANCE

The temperature sensor can be fixed on the tower, and should be located next to the measurement range to account for accurate results. The cable between the temperature sensor interface and the SPU is 100m as standard.

The DC power for the sensor interface is supplied via cable from the SPU. The AC power for the shield aspiration must be provided next to the tower. The pressure sensor is delivered with a 5 m cable and can be fixed next to the SPU. The DC power for the pressure sensor is supplied via cable from the SPU.

The SPU includes two additional connectors for temperature and pressure. Figure 18 shows the respective signals of the connector pins. An electrical connection scheme of the BLSDMI-1 option is shown in Figure 19.

Connector Pins	Pressure	Temperature
1	Supply voltage (+12V)	Supply voltage (+12V)
2	GND	GND
3	Pressure (0 – 5 V)	Temperature1 (0 – 10 V)
4	GND	Temperature2 (0 – 10 V, not used)

Figure 18: BLSDMI-1 connectors at SPU and respective pin signals

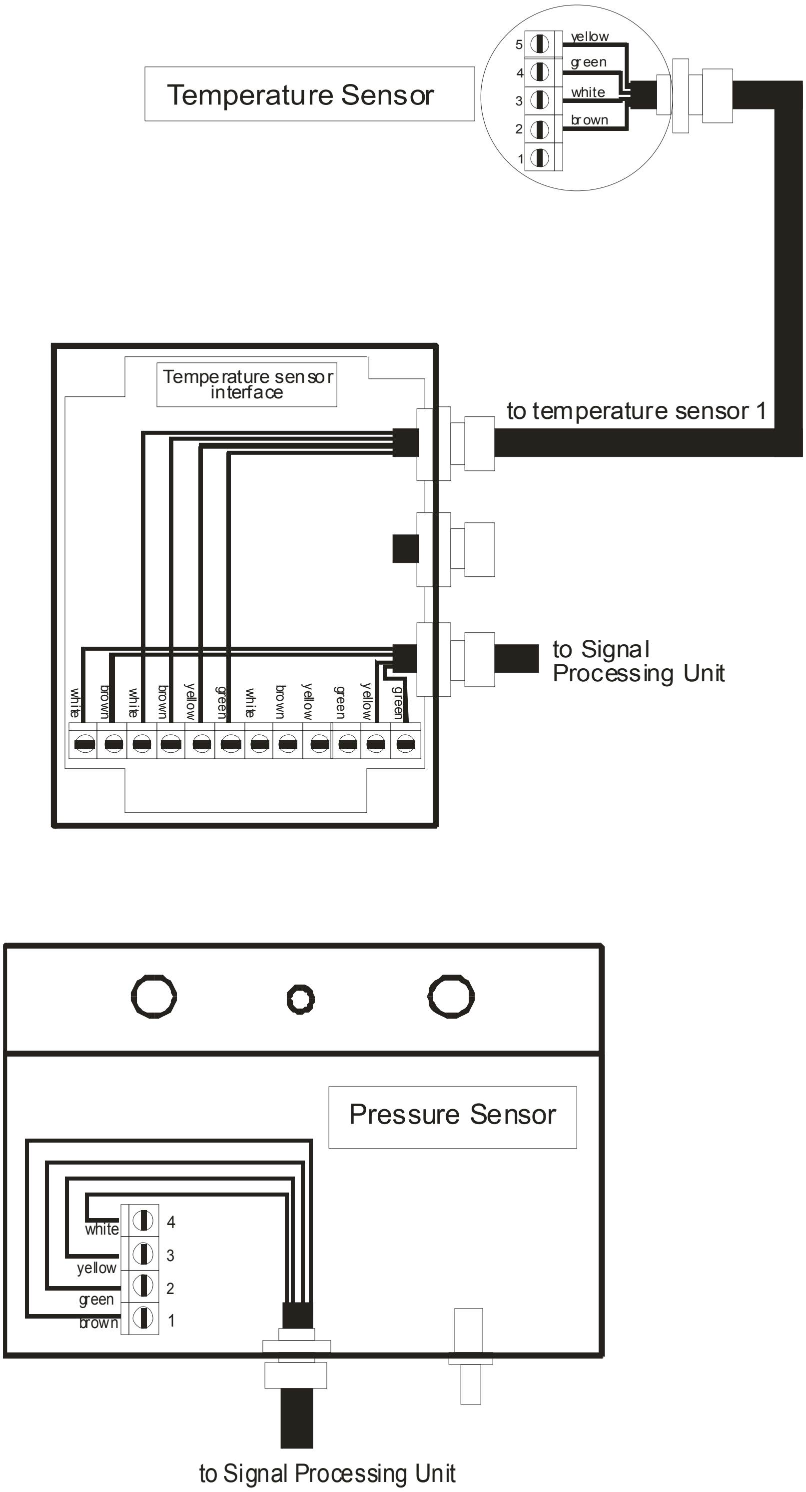


Figure 19: Electrical connections of the BLSDMI-1 sensors

5.7.3 SOFTWARE PREPARATIONS

The calibration data for the temperature and pressure sensors are contained in the file 'BLSDMI.CAL'. This file is structured as follows:

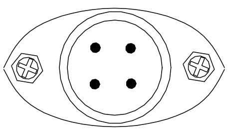
Parameter	Default Value	Remark
Pressure Offset	600	resulting pressure in hPa at 0 V input voltage
Pressure Increase	100	increase of the pressure in hPa per 1 V increase of input voltage
Temperature1 Offset	-50	resulting temperature1 in °C at 0 V input voltage
Temperature1 Increase	10	increase of the temperature1 in °C per 1 V increase of input voltage
Temperature2 Offset	-50	Not used
Temperature2 Increase	10	Not used

Table 10: Parameters of the calibration file BLSDMI.CAL

By editing the file 'BLSDMI.CAL', the output can be adjusted to correct for the voltage offset over the ground line and to further increase the accuracies of the sensors and the sensor interface.

5.8 BLS2000 RECEIVER HEATING (OPTIONAL)

On request, the BLS2000 Receiver is available with an additional heating system for the collimating Fresnel lens. The BLS SPU is then equipped with an additional connector labeled "Heating 12 VDC":



Pin #	Signal
1	+12 VDC
2	GND
3	Not Connected
4	Not Connected

Figure 20: BLS2000 Heating connector at SPU and corresponding pin signals

To operate the BLS2000 Receiver with lens heating, plug the corresponding battery power supply cable into the connector and connect the two open ends to a battery. The DC power for the lens heating is supplied via the cable connecting the SPU and the BLS2000 Receiver.

5.9 PATH REDUCTION APERTURE (OPTIONAL)

The optional available path reduction aperture is a set of special disks. This set enables one to reduce the path length between the BLS Receiver and the Transmitter. By using the path reduction aperture, shorter path lengths down to 250 m and 1000 m can be realized for the BLS450/BLS900 and the BLS2000, respectively. For details on the changed measurement ranges, see Table 1.

The Path Reduction Aperture comprises 1 disk for the BLS Receiver and 1 or 2 disks for the BLS450 or BLS900/BLS2000 Transmitter, respectively. Note that the path reduction aperture disks must always be used at the transmitter and the receiver simultaneously.

5.9.1 RECEIVER PATH REDUCTION APERTURES

The Receiver Path Reduction Aperture is placed in front of the collimating lens of the BLS Receiver and is mechanically fixed to the BLS Receiver by three screws (Figure 21 and Figure 22).

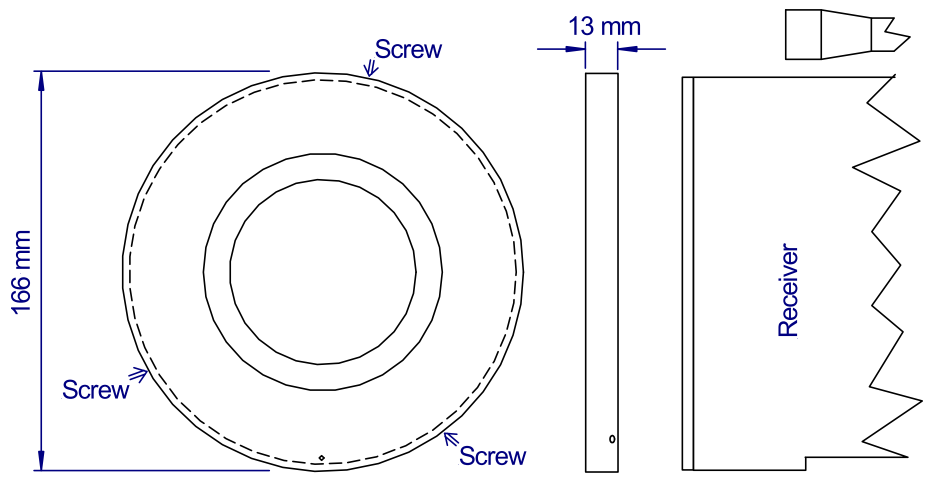


Figure 21: Receiver Path Reduction Aperture for BLS450 and BLS900

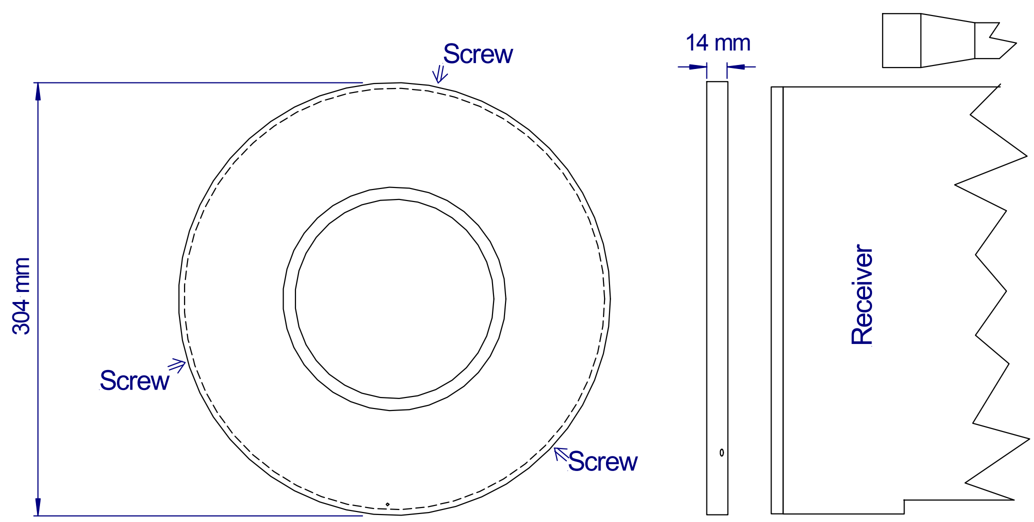


Figure 22: Receiver Path Reduction Aperture for BLS2000

5.9.2 TRANSMITTER PATH REDUCTION APERTURES

The Transmitter Path Reduction Apertures are placed in front of each radiating disk of the BLS Transmitter. They are mechanically fixed to the BLS Transmitter by three screws (Figure 23 and Figure 24). The Transmitter Path Reduction Apertures disks for BLS900 and BLS2000 Transmitters are flattened at the side.

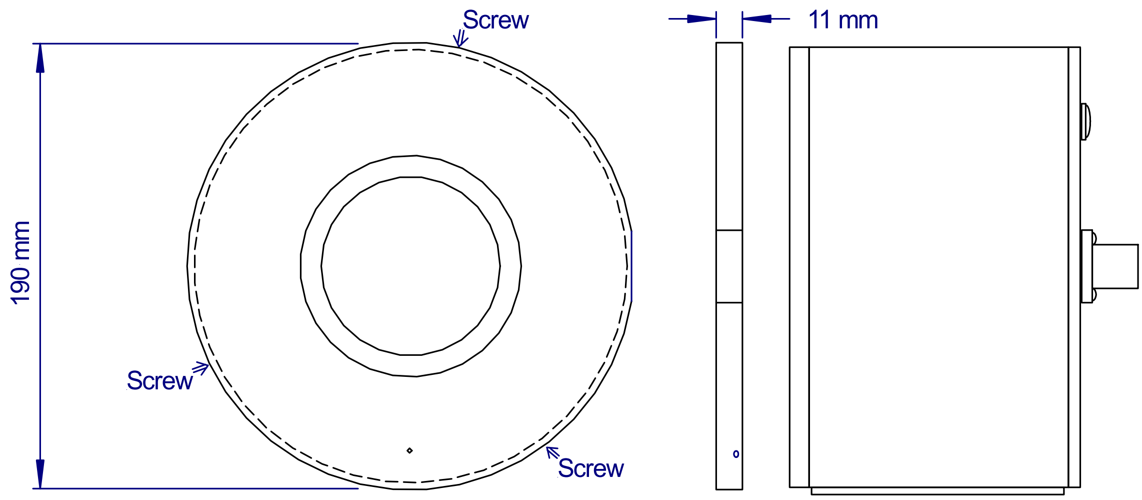


Figure 23: Transmitter Path Reduction Aperture for BLS450 and BLS900

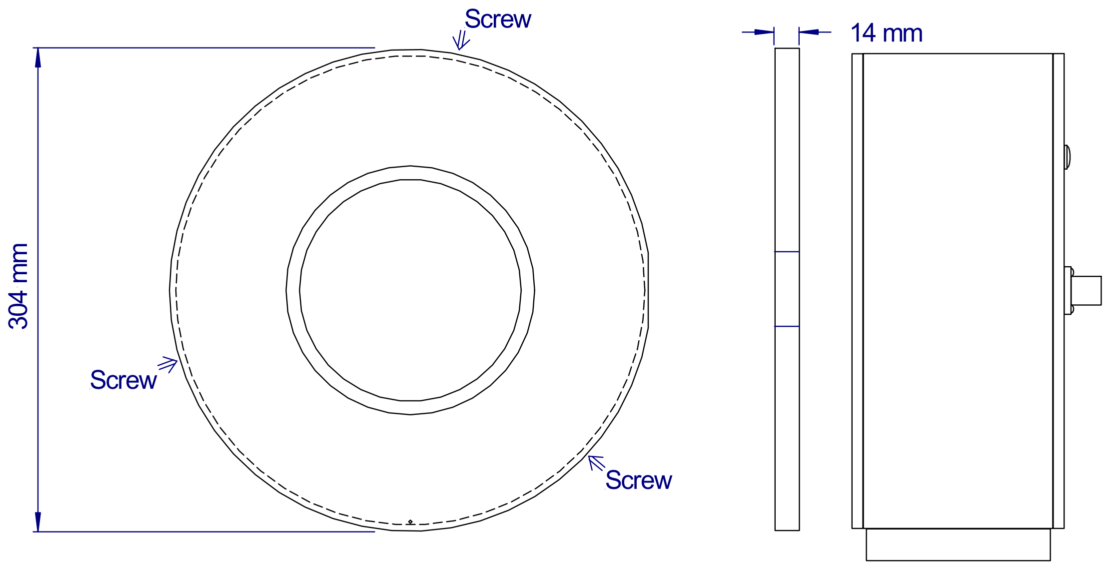


Figure 24: Transmitter Path Reduction Aperture for BLS2000

APPENDIX A THEORY

A.1 OVERVIEW

Intensity fluctuations caused by atmospheric turbulence are called "weak", when the observed log-amplitude (or intensity) variance is proportional to the refractive index structure function constant C_n^2 with all other instrumental characteristics unchanged. This is also often called "weak scattering" or "weak turbulence". If proportionality is not given, the turbulent intensity fluctuations are called "strong". Intensity fluctuations transit from weak to strong with increasing C_n^2 and/or increasing path length. When during this transition, the proportionality between intensity fluctuations and C_n^2 is no longer observed, the phenomenon is called "saturation".

The assumption of weak turbulence facilitates the theoretical treatment. Therefore it should be used whenever possible. Physically it means that the perturbations of the phase fronts are sufficiently small to construct interference patterns simply by overlaying the distorted with the undistorted electromagnetic field.

The question whether scattering is weak or not has always to be related to the system under consideration. For the same atmospheric turbulence condition (C_n^2), one electro-optical (EO) system may have to be treated with strong scattering theory while a second system may still be described using weak scattering theory.

Due to its large emission and reception apertures, the BLS450, BLS900 and BLS2000 are relatively insensitive to saturation. Therefore the operation can often sufficiently be described by use of weak scattering theory. This is done in section A.2. For extension into conditions of strong turbulence, see section A.3.

The theoretical description is for the BLS900 and BLS2000. For the BLS450, all calculations and algorithms involving disk 2 are not applied.

A.2 MEASUREMENTS UNDER CONDITIONS OF WEAK SCATTERING

The BLS900 and BLS2000 measure the following statistics:

Average received intensity originating from disk 1:	$\langle I_1 \rangle$
Average received intensity originating from disk 2:	$\langle I_2 \rangle$
Variance of received intensity originating from disk 1:	σ_{11}
Variance of received intensity originating from disk 2:	σ_{22}
Covariance of rec. intensities originating from disks 1 and 2, resp.:	σ_{12}

(Note that standard deviations and correlations are output in the diagnosis files instead of variances and covariances.)

Since the theory is for log-amplitude variances B_{11}, B_{22}, and covariances B_{12}, the above measured statistics must be converted first. This is done using the relations

$$B_{11} = \frac{1}{4} \ln\left[1 + \frac{\sigma_{11}}{< I_1 >^2}\right]$$

and (1)

$$B_{22} = \frac{1}{4} \ln\left[1 + \frac{\sigma_{22}}{< I_2 >^2}\right]$$

$$B_{12} = \frac{1}{4} \ln\left[1 + \frac{\sigma_{12}}{\sqrt{\sigma_{11}\,\sigma_{22}}}\left[\left(\frac{\sigma_{11}}{< I_1 >^2} + 1\right)^{\frac{1}{2}}\left(\frac{\sigma_{22}}{< I_2 >^2} + 1\right)^{\frac{1}{2}} - 1\right]\right] \tag{2}$$

which are valid for statistics having log-normal distribution. In the above equations, it has also to be considered that the intensity is the square of the amplitude.

Weak scattering theory relates B_{11}, B_{22} and B_{12} to the three-dimensional spectrum of the refractive index fluctuations φ_n [1]:

$$B_{11} = B_{22} = 4\,\pi^2\,k^2 \int_0^\infty d\kappa\,\kappa\Phi_n(\kappa) \int_0^R dx\,\sin^2\left(\frac{\kappa^2\,x\,(R-x)}{2\,k\,R}\right)$$

$$\left[2\,\frac{J_1\left(\frac{\kappa\,D_r\,x}{2\,R}\right)}{\frac{\kappa\,D_r\,x}{2\,R}}\right]^2 \left[2\,\frac{J_1\left(\frac{\kappa\,D_t\,(R-x)}{2\,R}\right)}{\frac{\kappa\,D_t\,(R-x)}{2\,R}}\right]^2 \tag{3}$$

and

$$B_{12} = 4\,\pi^2\,k^2 \int_0^\infty d\kappa\,\kappa\Phi_n(\kappa) \int_0^R dx\,\sin^2\left(\frac{\kappa^2\,x\,(R-x)}{2\,k\,R}\right)\,J_0\left(\kappa\,S_t\,(1-\frac{x}{R})\right)$$

$$\left[2\,\frac{J_1\left(\frac{\kappa\,D_r\,x}{2\,R}\right)}{\frac{\kappa\,D_r\,x}{2\,R}}\right]^2 \left[2\,\frac{J_1\left(\frac{\kappa\,D_t\,(R-x)}{2\,R}\right)}{\frac{\kappa\,D_t\,(R-x)}{2\,R}}\right]^2 \tag{4}$$

Here k=2π/λ is the wave number of the radiation, κ is the spatial wave number, x is the length coordinate along the propagation path and J_0 and J_1 denote Bessel functions of the first kind.

The three-dimensional spectrum of the refractive index fluctuations is given by the model equation

$$\Phi_n(\kappa) = 0.033\, C_n^2\, \kappa^{-11/3}\, f(\kappa\, \ell_0)\, F(\kappa\, L_0) \tag{5}$$

where $f(\kappa\ l_0)$ and $F(\kappa\ L_0)$ are functions describing the decay of the refractive index fluctuations at eddy sizes below the inner scale l_0 and above the outer scale L_0, respectively. f is 1 for $\kappa << 1/l_0$ and approaches 0 for $\kappa >> 1/l_0$. F is 1 for $\kappa >> 1/L_0$ and approaches 0 for $\kappa << 1/L_0$.

Using Eqs.(3) and (4) it can be shown that the BLS900 and BLS2000 respond to refractive index eddy sizes in the order of the size of the emitting disks D_t = 0.15 m and D_t = 0.26 m, respectively. The inner scale is a few millimetres only, the outer scale is a few meters to a few hundred meters, depending on the meteorological conditions. Both scales are very different from D_t, hence inner and outer scale effects are negligible. This formally means that in Eq.(5), the assumptions $f(l_0\ \kappa) = 1$ and $F(L_0\ \kappa) = 1$ are justified for calculation purposes.

Since D_t (and D_r) is much larger than the Fresnel zone $(\lambda\ R)^{1/2}$, the wavelength dependence also becomes negligible. Under these conditions, insertion of Eq.(5) into Eq.(3) and integration leads to the following approximate expression (Ting-i Wang et al., 1978):

$$C_n^2 = \alpha_r\, B_{11}\, D_t^{7/3}\, R^{-3} = \alpha_r\, B_{22}\, D_t^{7/3}\, R^{-3} \tag{6}$$

The factor α_r depends on the ratio of the transmitting to the receiving aperture. For the BLS900 α_r = 4.629, for the BLS2000 α_r = 4.49.

The relationship between the variances and the third power of the path length R^3 is shown in Figure 25 for the BLS900 and for $C_n^2 = 10^{-12}\ m^{-2/3}$. The solid line is plotted using equation (6), the symbols are calculated using equation (3).

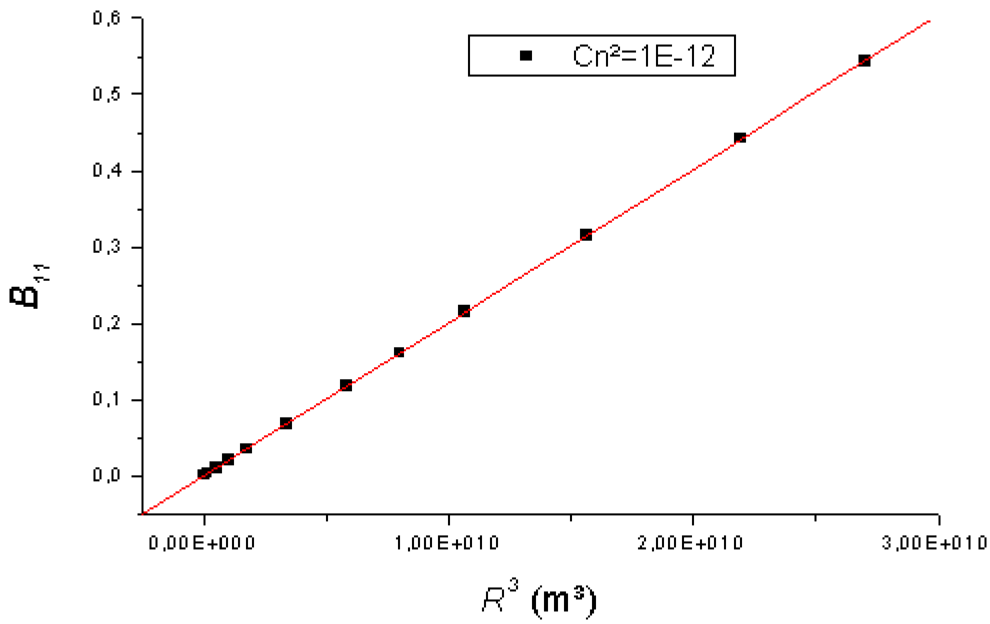


Figure 25: Relation between the log-amplitude B11 and the path length R3 for the BLS900

A.3 MEASUREMENTS UNDER CONDITIONS OF STRONG SCATTERING

After propagation through sufficiently strong integrated turbulence, the coherence of the phase fronts is reduced such that the theory given in section A.2 requires modification. In order to describe the resulting effect of saturation of scintillation, Clifford et al. [2] suggest that a short term MTF

$$M_{ST}(y,x) = \exp(-0.05\,\pi^2\,k^2\,C_n^2\,x\,y^{5/3}\int_{0.35\kappa y}^{\infty} d\xi\,\xi^{8/3}\,[1 - J_0(\xi)]) \tag{7}$$

has to be applied during numerical integration, where the length coordinate y perpendicular to the propagation direction has to be substituted by $\kappa x(1 - x/R)/k$.

Accordingly, the log-amplitude variances and covariances which include the effect of saturation are

$$B_{11} = B_{22} = 4\,\pi^2\,k^2\int_0^{\infty} d\kappa\,\kappa\,\Phi_n(\kappa)\int_0^{R} dx\,\sin^2\left(\frac{k^2\,x\,(R - x)}{2\,k\,R}\right)$$

$$M_{ST}(\kappa\,x\,(1 - \frac{x}{R})/k, R)\left[2\,\frac{J_1\left(\frac{\kappa\,D_r\,x}{2\,R}\right)}{\frac{\kappa\,D_r\,x}{2\,R}}\right]^2\left[2\,\frac{J_1\left(\frac{\kappa\,D_t\,(R - x)}{2\,R}\right)}{\frac{\kappa\,D_t\,(R - x)}{2\,R}}\right]^2 \tag{8}$$

and

$$B_{12} = 4\,\pi^2\,k^2\int_0^{\infty} d\kappa\,\kappa\,\Phi_n(\kappa)\int_0^{R} dx\,\sin^2\left(\frac{k^2\,x\,(R - x)}{2\,k\,R}\right)\,J_0\left(\kappa\,S_t\,(1 - \frac{x}{R})\right)$$

$$M_{ST}(\kappa\,x\,(1 - \frac{x}{R})/k, R)\left[2\,\frac{J_1\left(\frac{\kappa\,D_r\,x}{2\,R}\right)}{\frac{\kappa\,D_r\,x}{2\,R}}\right]^2\left[2\,\frac{J_1\left(\frac{\kappa\,D_t\,(R - x)}{2\,R}\right)}{\frac{\kappa\,D_t\,(R - x)}{2\,R}}\right]^2 \tag{9}$$

In Figure 26, B_{11} according to equation (3) is plotted against B_{11} according to equation (8) for path lengths of 1000 m, 2000 m and 3000 m and different values of C_n^2. The effect of saturation is clearly visible: values of B_{11} do not increase so quickly with C_n^2 when the strong scattering effect is taken into account. It can also be seen that the magnitude of the effect differs with the propagation path length.

The BLS900 and the BLS2000 use a numerical look-up table to correct for the effect of saturation. In this look-up table, also a maximum value for $(B_{11}+B_{22})/2$ is defined. If a larger value is measured, an unambiguous determination of C_n^2 is impossible and an error message is output by the instrument.

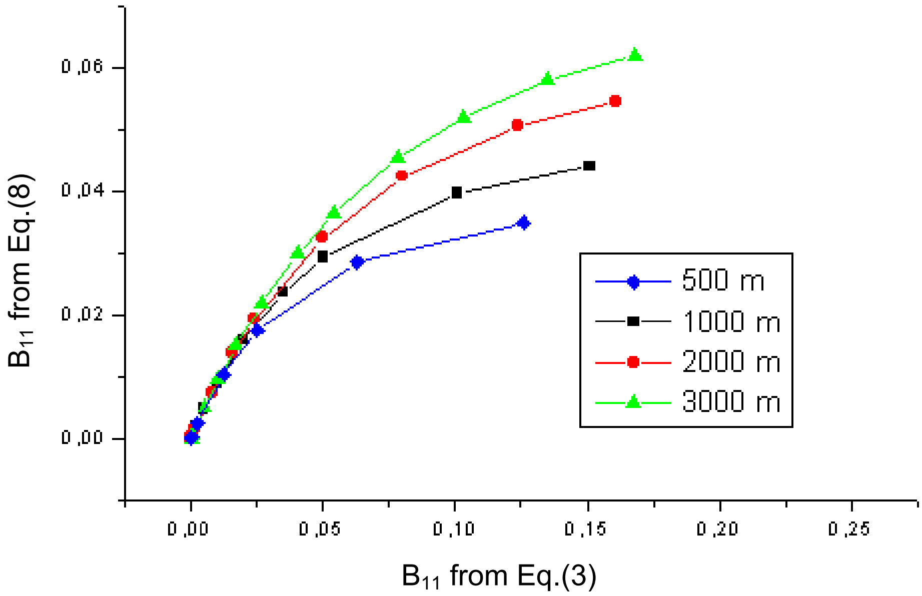


Figure 26: Comparison of log-amplitude variances B11 including and excluding saturation

A.4 ABSORPTION FLUCTUATIONS

For weak turbulence, the BLS900 and the BLS2000 evaluate the quantity $Q = (B_{11} + B_{22})/2 - B_{12}$ instead of the variances B_{11} and B_{22} or the average variance $(B_{11} + B_{22})/2$. The advantage of using Q compared to using the variances B_{11} or B_{22} is that Q is not affected by absorption fluctuations. The expression "absorption fluctuations" means changes of the received intensity due to changes of the transmission over the propagation path for example due to dust or fog. This is different from changes of the received intensity due to scintillation which is caused by interference (focusing and defocusing) at temperature inhomogeneities with unchanged transmission. If not distinguished, however, absorption fluctuations may be falsely interpreted as scintillation, hence causing erroneous results.

Because absorption fluctuations are caused by inhomogeneities which have a spatial scale in the order of the path length, the changes of the intensity due to absorption will be nearly identical and highly correlated over the two paths (the paths leading to B_{11} and B_{22}). Therefore the magnitude of absorption fluctuations contributing to B_{11}, B_{22} and B_{12} is nearly identical, and absorption fluctuations are widely eliminated by subtracting B_{12} from $(B_{11} + B_{22})/2$ in Q.

Temperature (and refractive index) inhomogeneities causing scintillation, on the other hand, have a spatial scale which is in the order of the size of the radiating disks (in general: size of emitting aperture or size of receiving aperture, whichever is larger). Since the separation between the disks is larger than the disk size, the covariance B_{12} is much smaller than the variances. Fig.16 shows the relation between Q and R^3, again for $C_n^2 = 10^{-12}$ $m^{-2/3}$. The symbols were calculated using Eqs.(3) and (4). The line is a good approximation. The ratio of the covariances to the variances can be calculated to be $B_{12} / B_{11} = 0.106$ for the BLS900 and $B_{12} / B_{11} = 0.127$ for the BLS2000 independent of path length.

For measured log-amplitude variances above 0.02, the evaluation is no longer based on the quantity Q but on the quantity $(B_{11}+B_{22})/2$. This separation is made because the effect of saturation is less pronounced for B_{11} than for Q and also because the relative contribution of absorption fluctuations is smaller when there is stronger turbulence.

In Figure 27 the relation between Q and the path length R^3 is plotted for $C_n^2 = 10^{-12}$. The straight line is calculated using equation 6 with $B_{12} / B_{11} = 0.106$, the dots are calculations using equations (3) and (4). Saturation effects are not included.

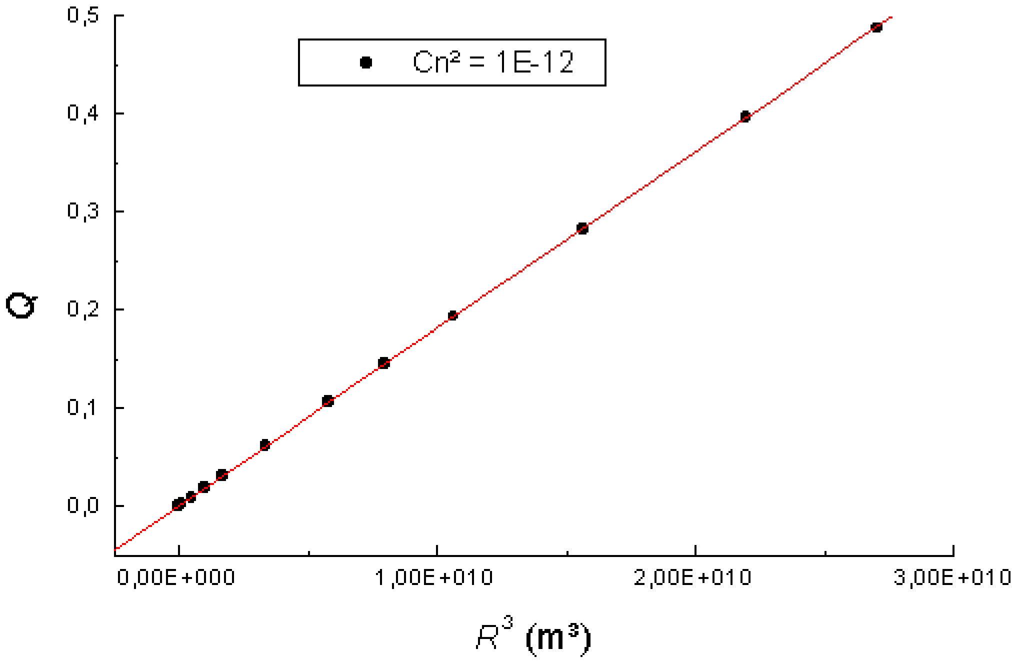


Figure 27: Relation between Q and the path length R3 for the BLS900

A.5 WEIGHTING FUNCTIONS

Integrals like Eq.(3) can be written in the form

$$B_{11} = \int_0^\infty d\kappa \;\; SWF(\kappa) \qquad (10)$$

or

$$B_{11} = \int_0^R dx \;\; PWF(x) \qquad (11)$$

$SWF(\kappa)$ is the spectral weighting function describing the contribution of different regions of the refractive index spectrum (as a function of spatial wave number κ) to the measured statistics, here B_{11}. Figure 28 and Figure 29 show the normalized spectral weighing function $\kappa SWF(\kappa)$ for the variance B_{11} and Q at a path length of 1000 m. Tabular values are presented in the next section. Q is less sensitive to smaller spatial wave numbers between 1m^{-1} and 10 m^{-1} than B_{11} while the weighting functions around the peak value around κ = 40 m^{-1} are nearly identical. Absorption fluctuations (see section A.4) are therefore widely eliminated.

Because the diameters of the transmitting and receiving apertures, D_t and D_r, are larger than the fresnel zone $(\lambda\, R)^{1/2}$, the weighting functions for different path lengths are nearly identical.

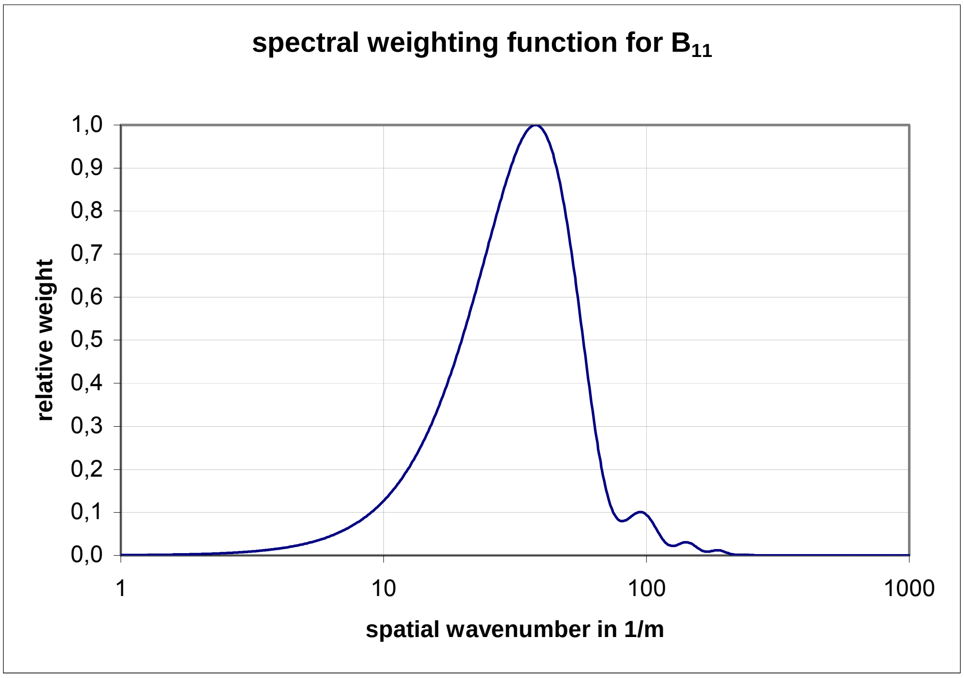


Figure 28: Spectral weighting function for B11, path length is 1000m

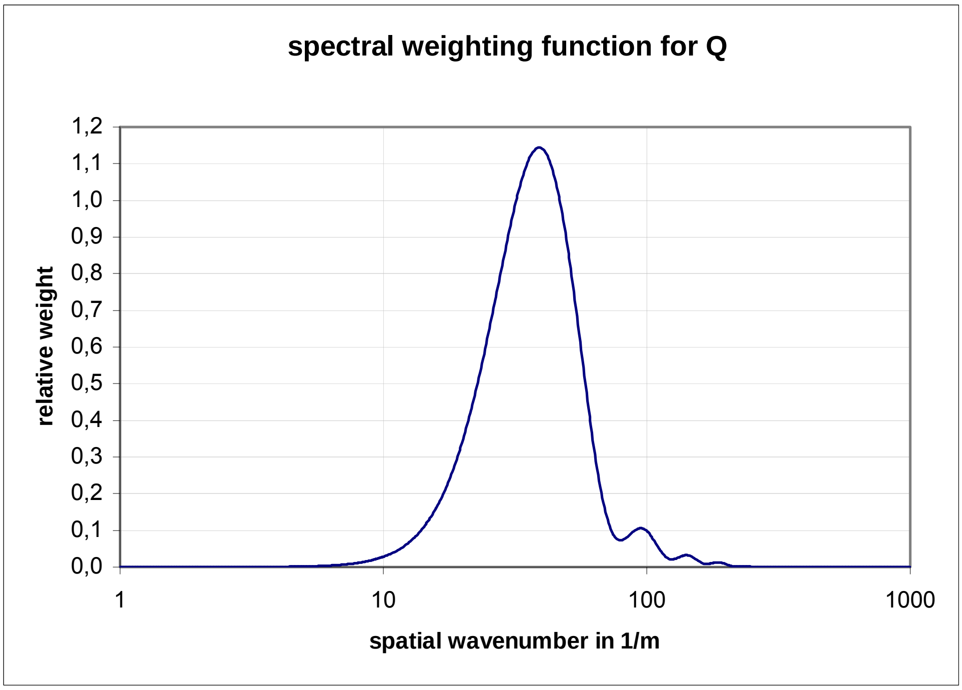


Figure 29: Spectral weighting function for Q, path length is 1000m

Accordingly, $PWF(\kappa)$ is the spatial weighting function describing the contribution of different regions of the propagation path (as a function of path coordinate x). The path weighting functions for B_{11} and Q as well as path weighting functions for different path lengths are quite similar and peak in the paths centre (Figure 30 and Figure 31). Tabular values and an analytic approximation are presented in later sections. The contributions of fluctuations next to the instruments are negligible leading to virtually no flow distortion by the instruments.

For heat flux calculations, in the case of uneven ground, the height of the instruments must be corrected by using the spatial weighting function. As the BLS900 / BLS2000 is most sensitive to fluctuations at the centre of the path it should be selected to be as homogenous and even as possible.

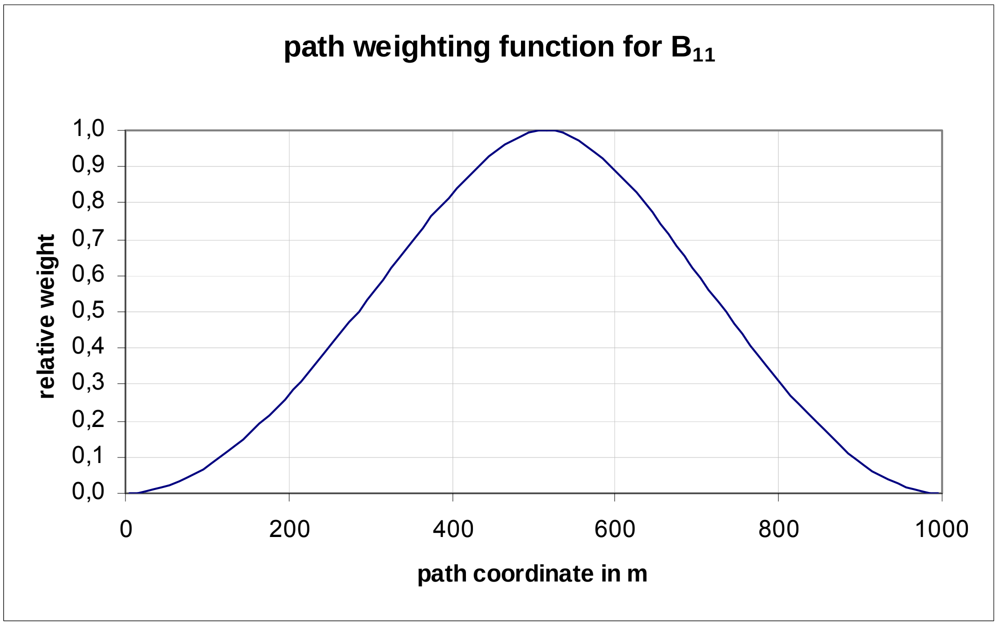


Figure 30: Spatial weighting function for B11, path length is 1000m

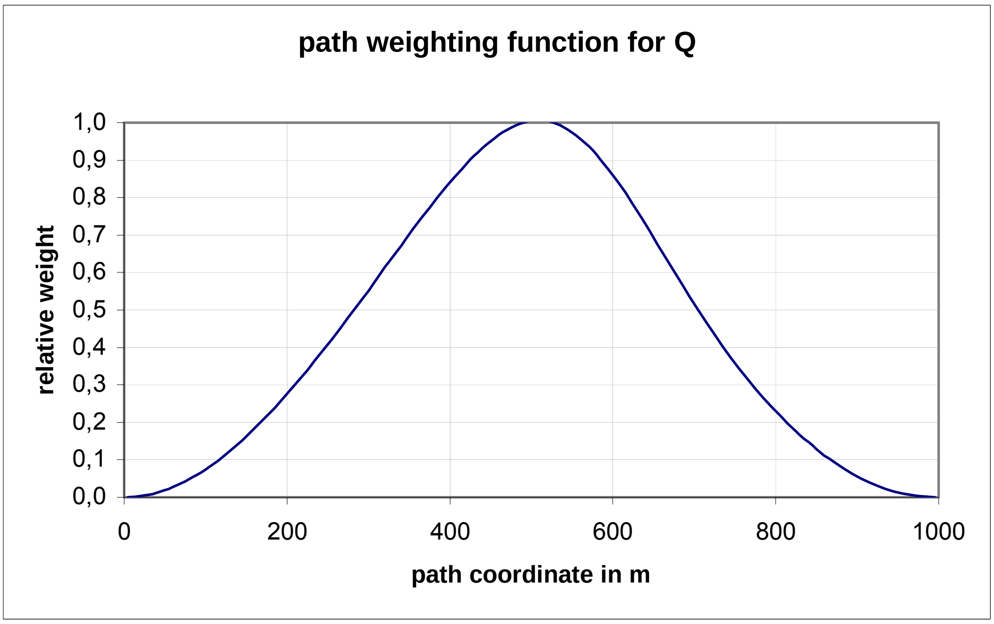


Figure 31: Spatial weighting function for Q, path length is 1000m

A.5.1 TABULAR VALUES OF SPECTRAL WEIGHTING FUNCTION

Wavenumber	Weight for B_{11}	Weight for Q	Wavenumber	Weight for B_{11}	Weight for Q
0,109	0,000	0,000	10,915	0,153	0,091
0,119	0,000	0,000	11,970	0,187	0,115
0,131	0,000	0,000	13,126	0,227	0,146
0,143	0,000	0,000	14,393	0,273	0,185
0,157	0,000	0,000	15,783	0,328	0,234
0,172	0,000	0,000	17,308	0,392	0,295
0,189	0,000	0,000	18,979	0,464	0,369
0,207	0,000	0,000	20,812	0,544	0,458
0,227	0,000	0,000	22,822	0,630	0,560
0,249	0,000	0,000	25,026	0,720	0,674
0,273	0,000	0,000	27,443	0,810	0,792
0,300	0,000	0,000	30,094	0,892	0,907
0,328	0,000	0,000	33,000	0,957	1,003
0,360	0,000	0,000	36,188	0,995	1,065
0,395	0,000	0,000	39,682	0,994	1,076
0,433	0,000	0,000	43,515	0,944	1,026
0,475	0,000	0,000	47,718	0,841	0,909
0,521	0,000	0,000	52,326	0,688	0,734
0,571	0,000	0,000	57,380	0,503	0,526
0,626	0,000	0,000	62,921	0,319	0,323
0,687	0,000	0,000	68,998	0,173	0,167
0,753	0,000	0,000	75,662	0,094	0,088
0,826	0,000	0,000	82,970	0,081	0,079
0,906	0,001	0,000	90,983	0,098	0,100
0,993	0,001	0,000	99,770	0,095	0,097
1,089	0,001	0,000	109,406	0,060	0,059
1,194	0,001	0,000	119,972	0,026	0,025
1,310	0,001	0,001	131,559	0,025	0,025
1,436	0,001	0,001	144,264	0,030	0,031
1,575	0,002	0,001	158,197	0,015	0,015
1,727	0,002	0,001	173,476	0,009	0,009
1,894	0,003	0,001	190,230	0,012	0,012
2,076	0,003	0,002	208,602	0,003	0,003
2,277	0,004	0,002	228,749	0,002	0,002
2,497	0,005	0,002	250,842	0,001	0,001
2,738	0,007	0,003	275,068	0,000	0,000
3,002	0,008	0,004	301,633	0,000	0,000
3,292	0,010	0,005	330,765	0,000	0,000
3,610	0,013	0,006	362,710	0,000	0,000
3,959	0,016	0,007	397,740	0,000	0,000
4,341	0,019	0,009	436,154	0,000	0,000
4,761	0,024	0,011	478,277	0,000	0,000
5,221	0,030	0,014	524,469	0,000	0,000
5,725	0,036	0,018	575,122	0,000	0,000
6,278	0,045	0,022	630,667	0,000	0,000
6,884	0,055	0,028	691,576	0,000	0,000
7,549	0,068	0,035	758,368	0,000	0,000
8,278	0,084	0,045	831,610	0,000	0,000
9,077	0,103	0,056	911,927	0,000	0,000
9,954	0,126	0,071	1000,000	0,000	0,000

Table 11: Tabular values of spectral weighting function.

A.5.2 TABULAR VALUES OF PATH WEIGHTING FUNCTION

Path Position	Weight for B_{11}	Weight for Q	Path Position	Weight for B_{11}	Weight for Q
0,5%	0,000	0,000	50,5%	0,999	1,000
1,5%	0,002	0,002	51,5%	1,000	0,999
2,5%	0,005	0,005	52,5%	0,998	0,995
3,5%	0,009	0,009	53,5%	0,993	0,987
4,5%	0,015	0,015	54,5%	0,984	0,975
5,5%	0,022	0,023	55,5%	0,972	0,960
6,5%	0,031	0,031	56,5%	0,958	0,941
7,5%	0,042	0,042	57,5%	0,941	0,920
8,5%	0,053	0,054	58,5%	0,921	0,895
9,5%	0,067	0,067	59,5%	0,900	0,869
10,5%	0,081	0,081	60,5%	0,877	0,840
11,5%	0,097	0,097	61,5%	0,853	0,809
12,5%	0,113	0,114	62,5%	0,827	0,776
13,5%	0,131	0,132	63,5%	0,800	0,742
14,5%	0,151	0,151	64,5%	0,772	0,707
15,5%	0,171	0,171	65,5%	0,743	0,672
16,5%	0,192	0,193	66,5%	0,714	0,636
17,5%	0,214	0,215	67,5%	0,684	0,600
18,5%	0,236	0,238	68,5%	0,653	0,565
19,5%	0,260	0,262	69,5%	0,623	0,530
20,5%	0,284	0,286	70,5%	0,592	0,496
21,5%	0,310	0,311	71,5%	0,561	0,463
22,5%	0,335	0,337	72,5%	0,530	0,431
23,5%	0,362	0,364	73,5%	0,499	0,400
24,5%	0,389	0,391	74,5%	0,469	0,370
25,5%	0,416	0,419	75,5%	0,439	0,342
26,5%	0,444	0,448	76,5%	0,409	0,314
27,5%	0,473	0,476	77,5%	0,380	0,288
28,5%	0,501	0,505	78,5%	0,351	0,263
29,5%	0,530	0,535	79,5%	0,324	0,239
30,5%	0,560	0,565	80,5%	0,296	0,216
31,5%	0,589	0,594	81,5%	0,270	0,195
32,5%	0,618	0,624	82,5%	0,245	0,174
33,5%	0,648	0,654	83,5%	0,220	0,155
34,5%	0,676	0,683	84,5%	0,196	0,137
35,5%	0,705	0,712	85,5%	0,174	0,119
36,5%	0,733	0,741	86,5%	0,152	0,103
37,5%	0,761	0,769	87,5%	0,132	0,088
38,5%	0,788	0,796	88,5%	0,112	0,074
39,5%	0,814	0,822	89,5%	0,094	0,061
40,5%	0,840	0,848	90,5%	0,078	0,050
41,5%	0,864	0,872	91,5%	0,063	0,039
42,5%	0,887	0,895	92,5%	0,049	0,030
43,5%	0,908	0,916	93,5%	0,037	0,022
44,5%	0,928	0,935	94,5%	0,026	0,016
45,5%	0,946	0,953	95,5%	0,018	0,010
46,5%	0,962	0,968	96,5%	0,011	0,006
47,5%	0,975	0,981	97,5%	0,005	0,003
48,5%	0,986	0,990	98,5%	0,002	0,001
49,5%	0,994	0,997	99,5%	0,000	0,000

Table 12: Tabular values of path weighting function.

A.5.3 ANALYTIC APPROXIMATION OF PATH WEIGHTING FUNCTION

The path weighting function for the BLS can be analytically approximated by the following expression (by Henk de Bruin, October 2008):

$$PWF_{approx}(x) = 2.163 \cdot JJ_1\left(2.283 \cdot \pi \cdot (x - 0.5)\right)$$

where x is the relative path position in the range $0 \leq x \leq 1$ and the function JJ_1 is defined as follows:

$$JJ_1(y) = \begin{cases} 1 & if\ y = 0 \\ \left(2 \cdot \dfrac{J_1(y)}{y}\right)^2 & otherwise \end{cases}$$

J_1 denotes the first order Bessel function of the first kind.

A.6 RELATION TO OTHER TURBULENCE STATISTICS

Even though derived from large aperture scintillation, measurements of C_n^2 obtained from the BLS900 / BLS2000 can be used to predict other turbulence statistics. A selection of corresponding formulae is given in this section [3]:

Scintillation at point detector, plane wave, C_n^2 constant over path length:

$$B_{11} = 0.31\, C_n^2\, k^{7/6}\, L^{11/6} \tag{12}$$

Scintillation at point detector, plane wave, C_n^2 varying over path length:

$$B_{11} = 0.56\, k^{7/6} \int_0^R C_n^2(x)(R - x)^{5/6}\, dx \tag{13}$$

Scintillation at point detector, spherical wave (point source), C_n^2 constant over path length:

$$B_{11} = 0.125\, C_n^2\, k^{7/6}\, L^{11/6} \tag{14}$$

Scintillation at point detector, spherical wave (point source), C_n^2 varying over path length:

$$B_{11} = 0.56\, k^{7/6} \int_0^R C_n^2(x)(x/R)^{5/6} (R - x)^{5/6}\, dx \tag{15}$$

Equations (12), (13), (14) and (15) are valid as long as $l_0 << (\lambda\ R)^{1/2}$ and $B_{11} < 0.3$ (weak scattering).

Structure function of phase between two locations separated by ρ, plane wave, C_n^2 constant over path length:

$$D_p\, \rho) = 2.92\, C_n^2\, k^2\, L\, \rho^{5/3} \tag{16}$$

Structure function of phase for two locations separated by ρ, spherical wave, C_n^2 constant over path length:

$$D_p(\rho) = (1.089\, k^2\, L\, \rho^{5/3} - 0.25\, k^{7/6}\, L^{11/6})\, C_n^2 \tag{17}$$

Equations (16) and (17) are valid as long as $l_0 << (\lambda\ R)^{1/2}$ and $\rho >> (\lambda\ R)^{1/2}$. Note that absolute phase fluctuations cannot be evaluated due to the dominating influence of the outer scale L_0.

$$\sigma_\alpha^2 = \frac{D_p(b)}{k^2 b^2} \tag{18}$$

With good approximation, angle-of-arrival fluctuations σ_α^2 can be calculated from the structure function of phase by setting the diameter b of the receiving telescope equal to the separation ρ:

Laser beam wander can be treated as angle-of-arrival fluctuations in reverse configuration.

For constant C_n^2, the Fried diameter r_0 at the wavelength $\lambda_0 = 2\pi/k_0$ and over the path length R_0 can be calculated via the relation [4]:

$$r_0 = \left[0.423\, k_0^2\ R_0\, C_n^2\right]^{\frac{3}{5}} \tag{19}$$

A.7 MEASUREMENT OF WIND SPEED

The transverse wind speed u is derived by an evaluation of the time lagged cross-covariance function $B_{12}(t)$:

$$B_{12}(t) = 4\,\pi\,k^2 \int_0^\infty d\kappa\,\Phi_n(\kappa) \int_0^R dx \sin^2\left(\frac{k^2\,x\,(R-x)}{2\,k\,R}\right)$$

$$J_0\left(\kappa\,(S_t - u\,t)(1-\frac{x}{R})\right)\left[2\frac{J_1\left(\frac{\kappa\,D_r\,x}{2\,R}\right)}{\frac{\kappa\,D_r\,x}{2\,R}}\right]^2\left[2\frac{J_1\left(\frac{\kappa\,D_t\,(R-x)}{2\,R}\right)}{\frac{\kappa\,D_t\,(R-x)}{2\,R}}\right]^2 \tag{20}$$

A stepwise numerical de-convolution technique is applied to provide accurate results even for transverse wind speeds that vary over the propagation path and temporally fluctuate within the averaging period, including changes of sign

A.8 MEASUREMENT OF HEAT FLUX

The calculation of the surface heat flux is based on the application of the unstable limit ($\xi = z/L \rightarrow \infty$) of Monin-Obukhov similarity (free convection scaling). Here the stress becomes insignificant and the surface stress ceases to be a scaling parameter. Under these conditions the kinematic surface heat flux Q_0 [unit K m/s] is

$$Q_0 = 1.165 K z\, C_T^{2\,\frac{3}{4}} (\frac{g}{T})^{\frac{1}{2}} \tag{21}$$

where K = 0.4 is von Kármán's constant, z is the height above ground, C_T^2 is the structure function constant of temperature fluctuations, g is gravitational acceleration and T is the air temperature. The dynamic surface heat flux H_0 [unit W/m²] can be calculated by multiplication of this quantity with the density of air (1.225 kg/m³ at standard temperature and pressure) and the heat capacity of air at constant pressure c_p (1004 J/kgK).

C_T^2 can be calculated using

$$C_n^2 = \alpha_1^2 \frac{p^2}{T^4} C_T^2 \tag{22}$$

In this formula, p is the air pressure, T is the air temperature and α_1 is wavelength dependant proportionality factor:

$$\alpha_1 = \alpha_2 (1 + \frac{\lambda_0{}^2}{\lambda^2}) \tag{23}$$

with α_2 = 77.6x10^{-6} K/hPa, λ is the wavelength of the radiation passing through the atmosphere in µm, and $\lambda_0^{\ 2}$ = 7.53x10^{-3} µm^2.
With application of equation (22) the humidity contribution to C_n^2 is neglected, which is one order of magnitude smaller than the temperature contribution. There are situations, however, especially over water, where the contribution of C_T^2 is small and the humidity effect is larger.

On non-even paths the change of C_T^2 must be taken into account. As C_T^2 ~ $z^{-4/3}$, the contribution of the temperature fluctuations is smaller with higher heights. In this case an effective height z_{eff} instead of z is calculated and equation (21) can be rewritten to

$$Q_0 = 1.165 K z_{eff}\, C_T^{2\,\frac{3}{4}} (\frac{g}{T})^{\frac{1}{2}} \tag{24}$$

with

$$z_{eff} = \left(\int_0^1 z(x)^{-\frac{4}{3}} \cdot PWF(x)\, dx \right)^{-\frac{3}{4}} \tag{25}$$

where PWF(x) is the path weighting function for the BLS, which is described in a previous section, and z(x) gives the actual path height at relative path position $0 \le x \le 1$.

For slant paths, where z_T is the height of the transmitter and z_R is the height of the receiver, the path height function is given by

$$z(x) = z_T + x \cdot (z_R - z_T) \tag{26}$$

Heat flux measurements over very rough surfaces are influenced by the ground surface as well as by individual roughness elements. The reference ground (zero-plane displacement) for the height of the receiver and transmitter should therefore lie somewhere between the actual ground level and the tops of the roughness elements.

A.9 REFERENCES

[1] Ochs, G.R., S.F. Clifford and Ting-I Wang, Appl. Opt., 15, 403 (1976)
[2] Clifford, S.F., G.R. Ochs and R.S: Lawrence, J. Opt. Soc. Am., 64(2), 148 (1974)
[3] Lawrence, R.S., and J.W. Strohbehn, Proc. Of the IEEE, 58(10), 1523 (1970)
[4] Rousset, G., Wave Propagation in Random Media (Scintillation), SPIE Bellingham & IOP Bristol, 216 (1993)
[5] De Bruin, H., Private communication (2008)

APPENDIX B TRANSMITTER AND RECEIVER DIMENSIONS

B.1 TRANSMITTER

B.1.1 BLS450 TRANSMITTER

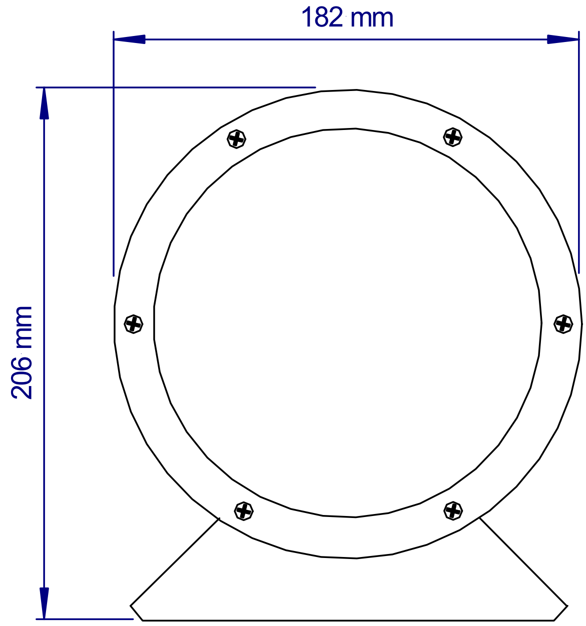


Figure 32: BLS450 Transmitter – Front View

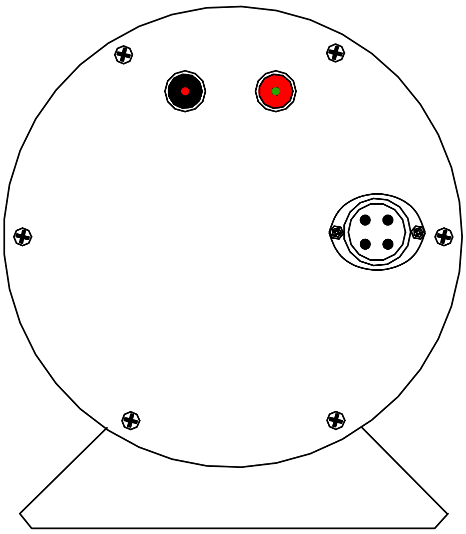


Figure 33: BLS450 Transmitter – Rear View

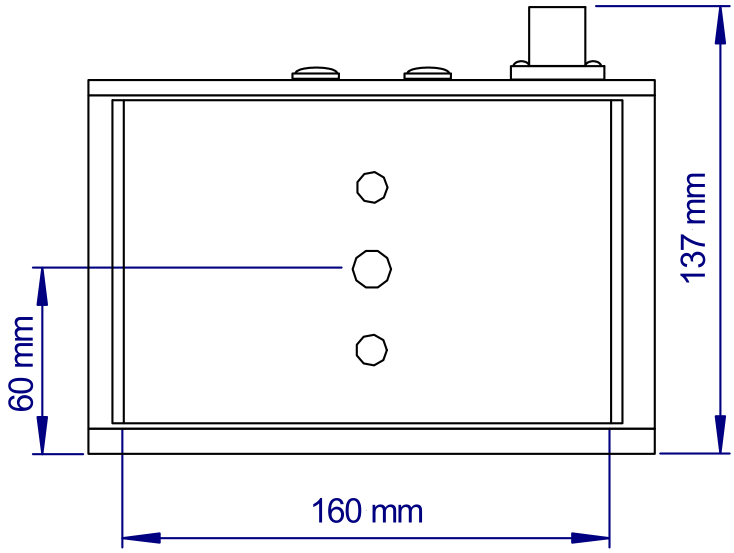


Figure 34: BLS450 Transmitter – Bottom View

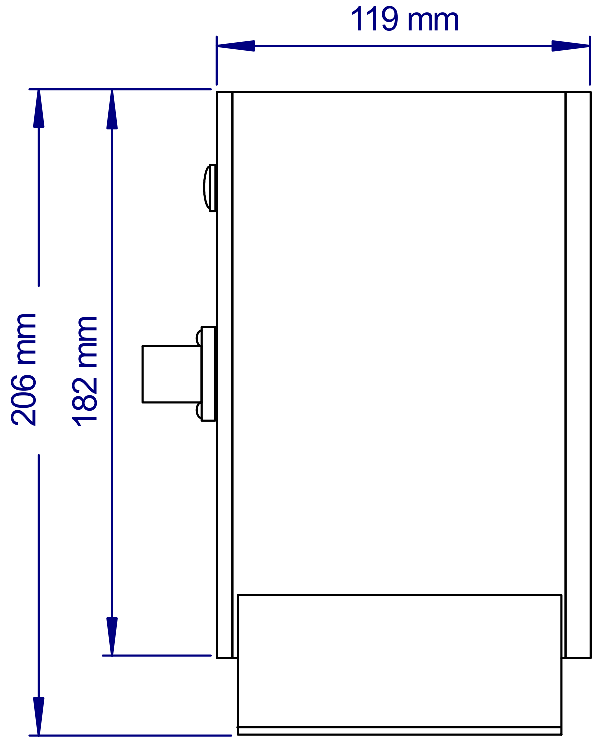


Figure 35: BLS450 Transmitter – Side View

B.1.2 BLS900 TRANSMITTER

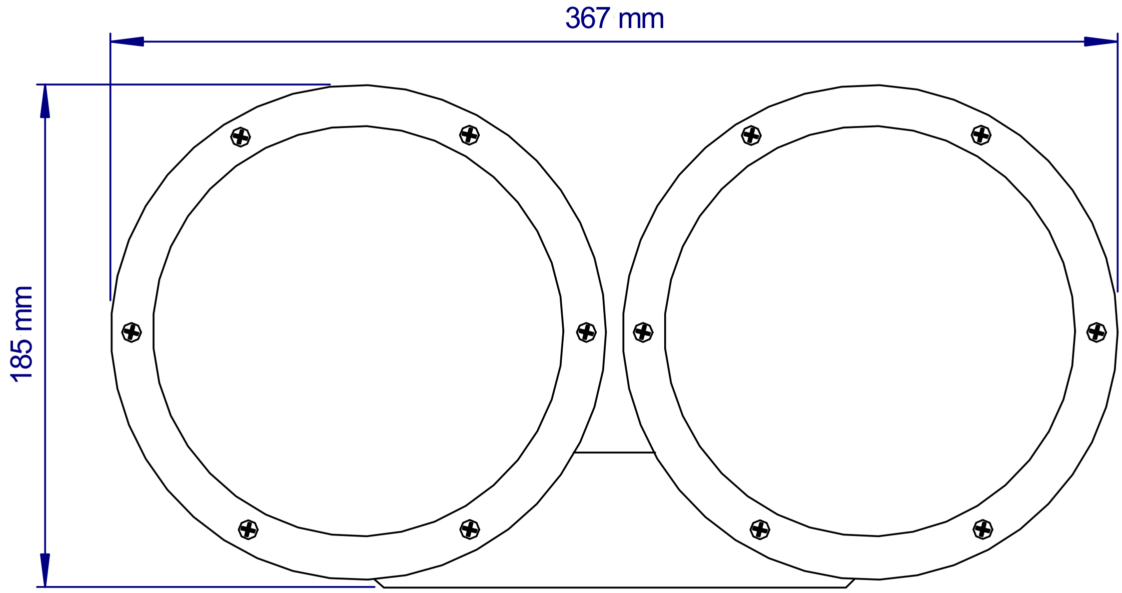


Figure 36: BLS900 Transmitter – Front View

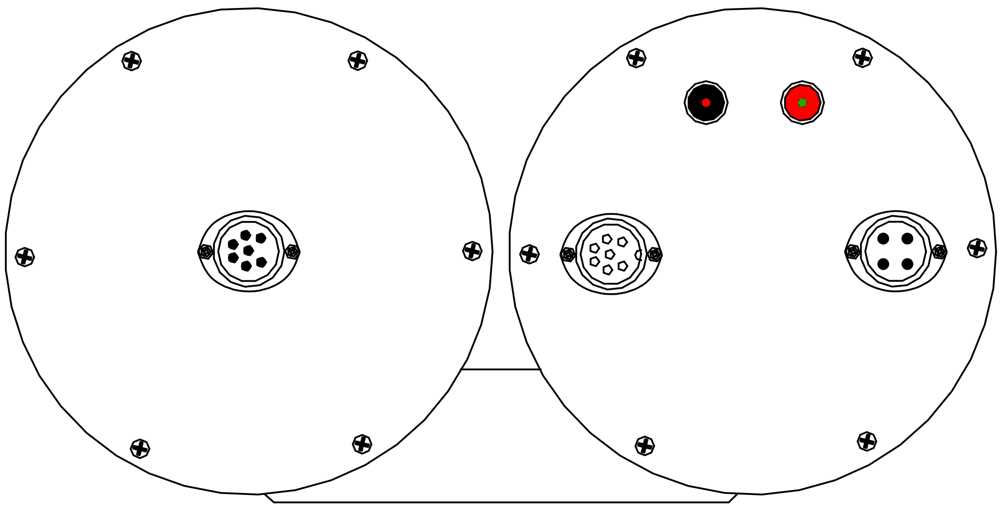


Figure 37: BLS900 Transmitter – Rear View

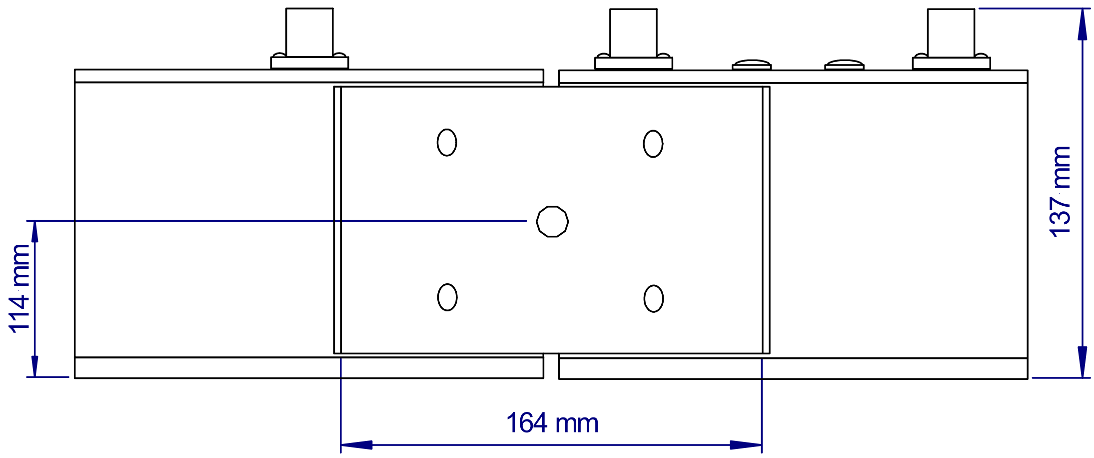


Figure 38: BLS900 Transmitter – Bottom View

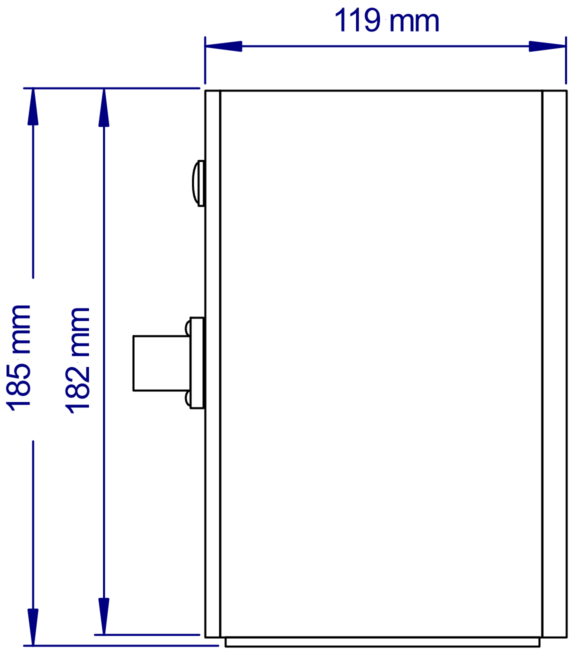


Figure 39: BLS900 Transmitter – Side View

B.1.3 BLS2000 TRANSMITTER

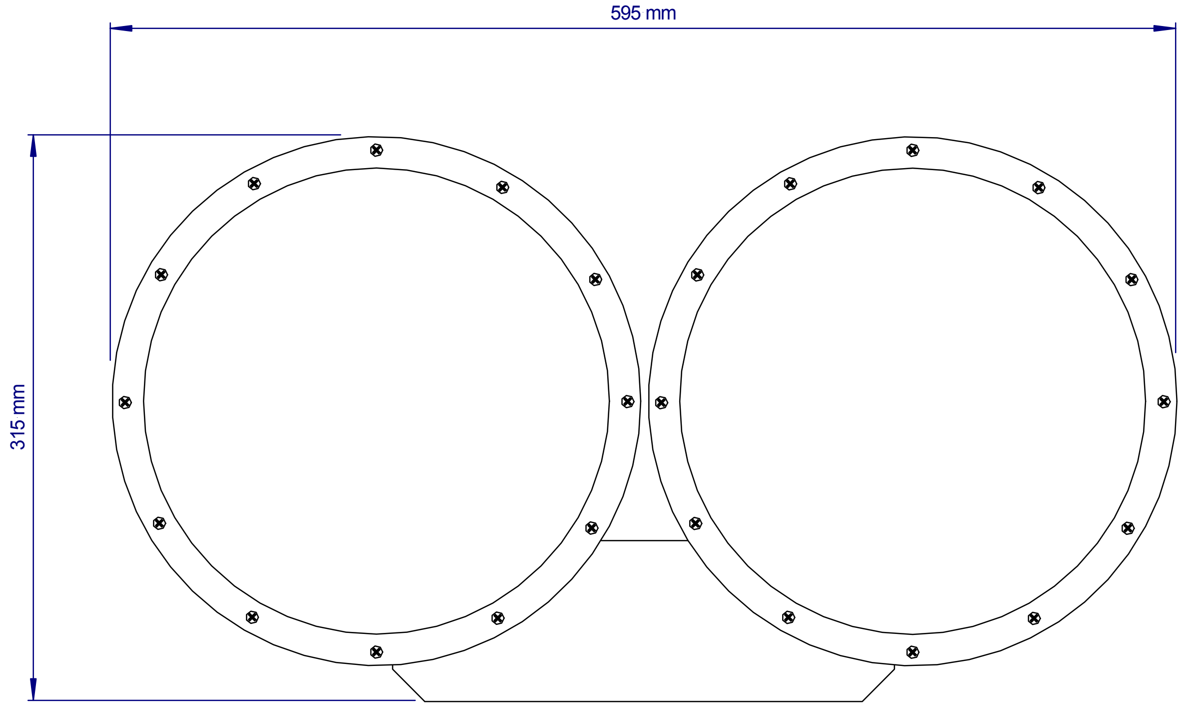


Figure 40: BLS2000 Transmitter – Front View

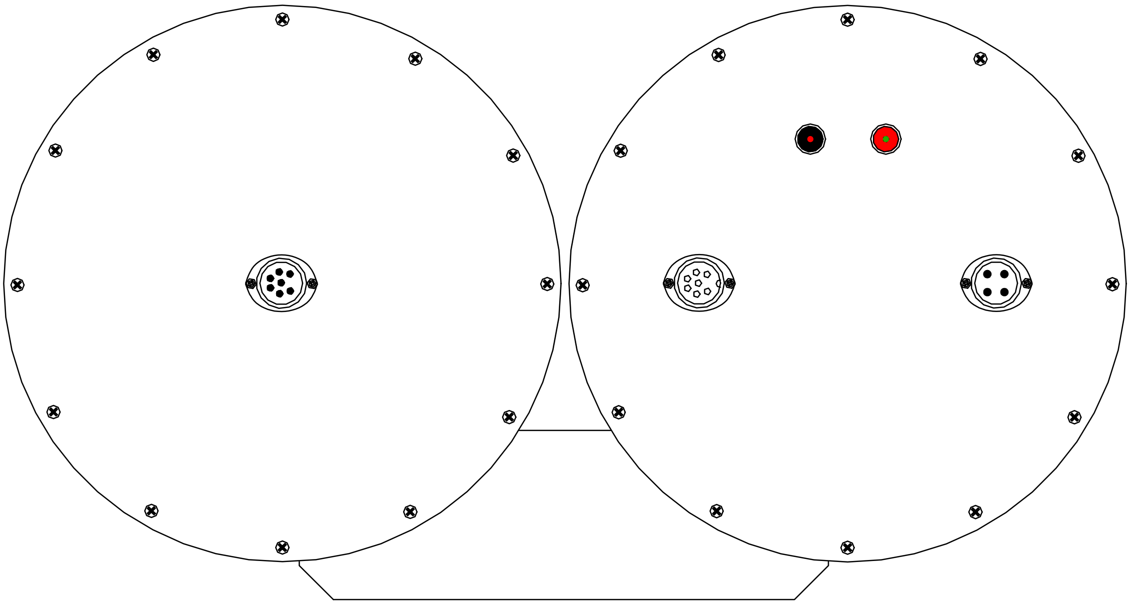


Figure 41: BLS2000 Transmitter – Rear View

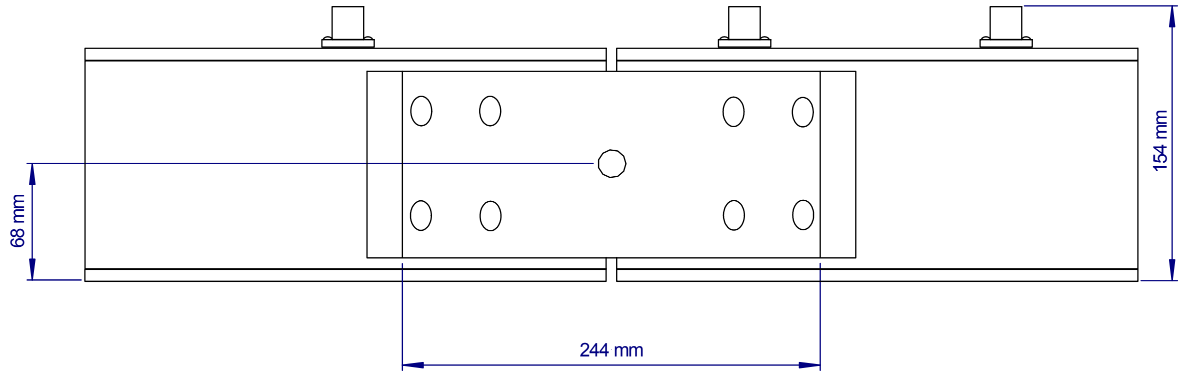


Figure 42: BLS2000 Transmitter – Bottom View

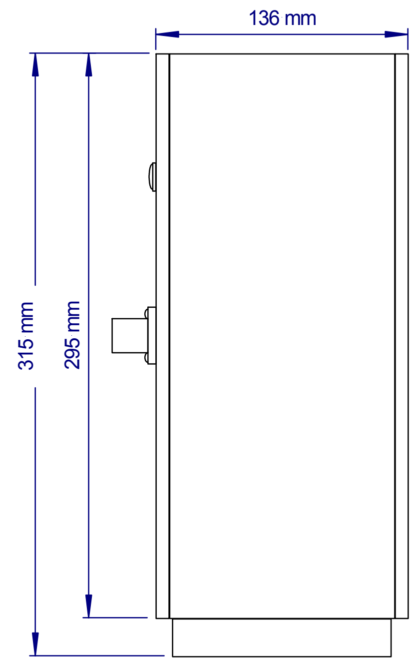


Figure 43: BLS2000 Transmitter – Side View

B.2 RECEIVER

B.2.1 BLS450 / BLS900 RECEIVER

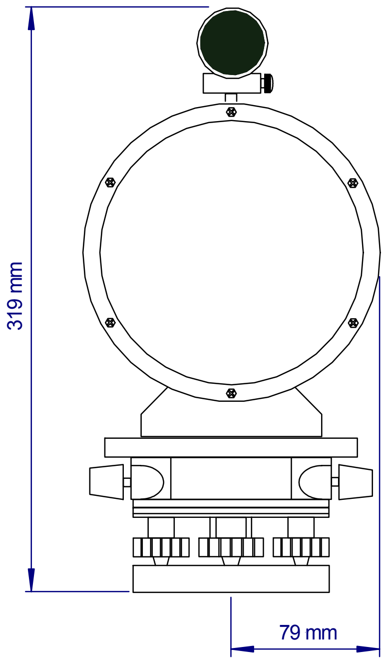


Figure 44: BLS450 / BLS900 Receiver – Front View

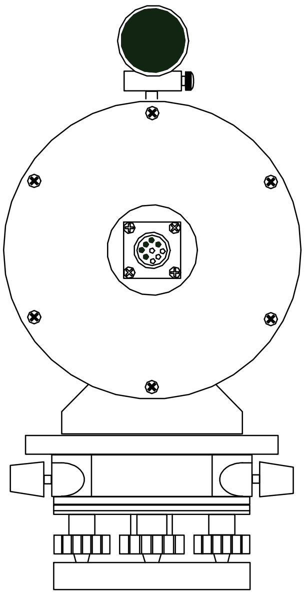


Figure 45: BLS450 / BLS900 Receiver– Rear View

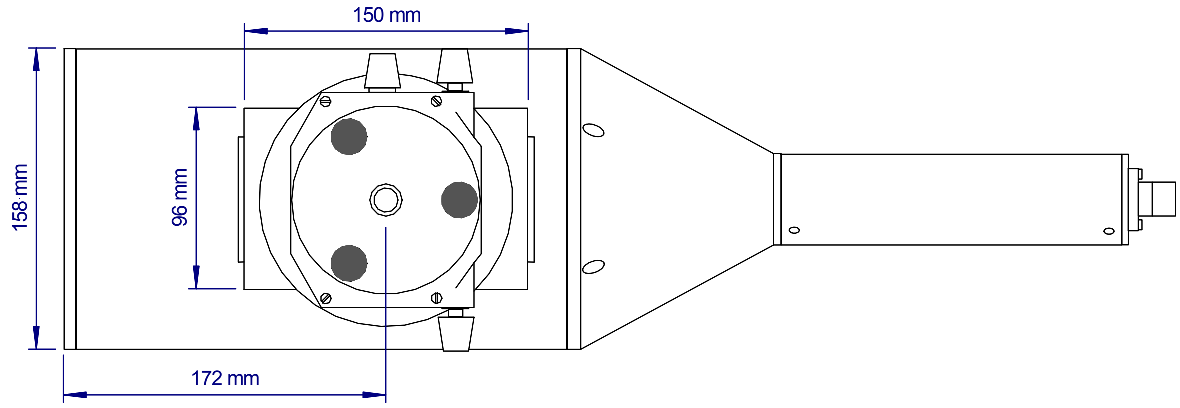


Figure 46: BLS450 / BLS900 Receiver – Bottom View

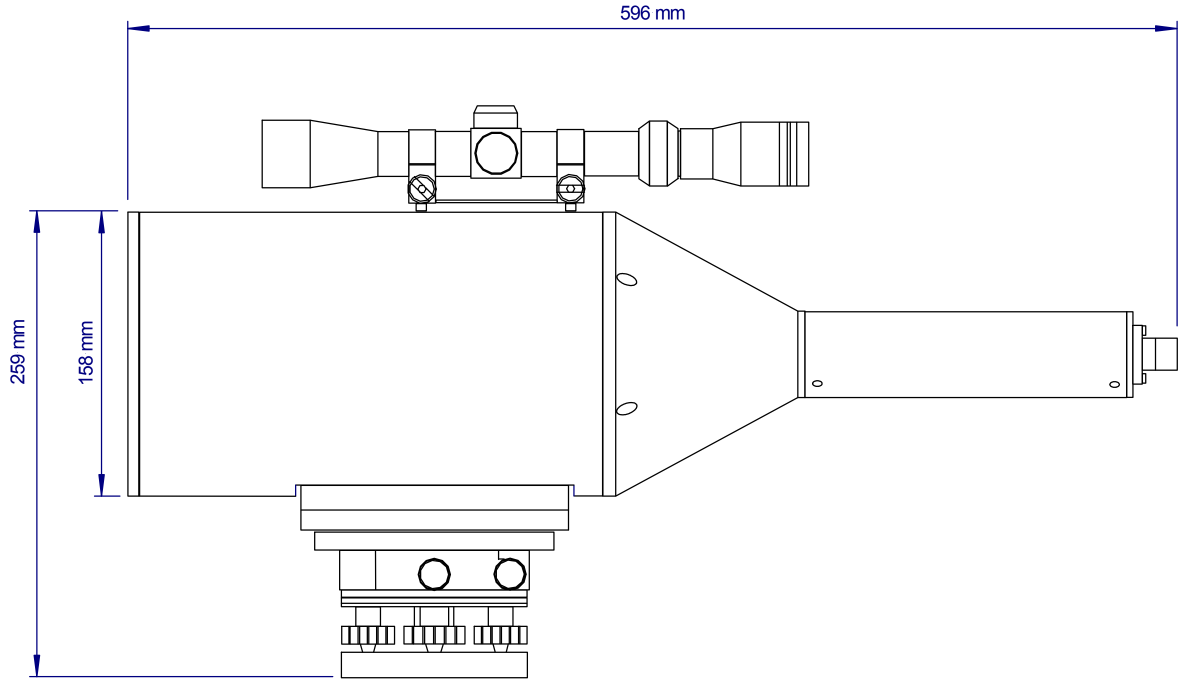


Figure 47: BLS450 / BLS900 Receiver – Side View

B.2.2 BLS2000 RECEIVER

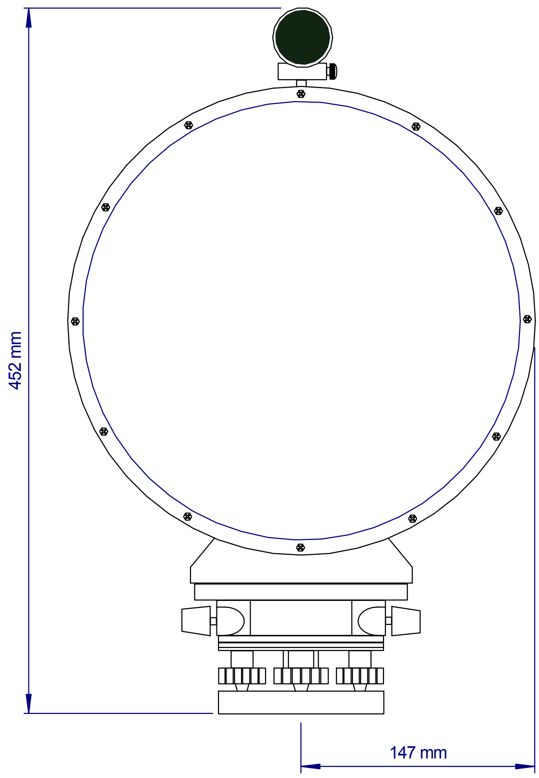


Figure 48: BLS2000 Receiver – Front View

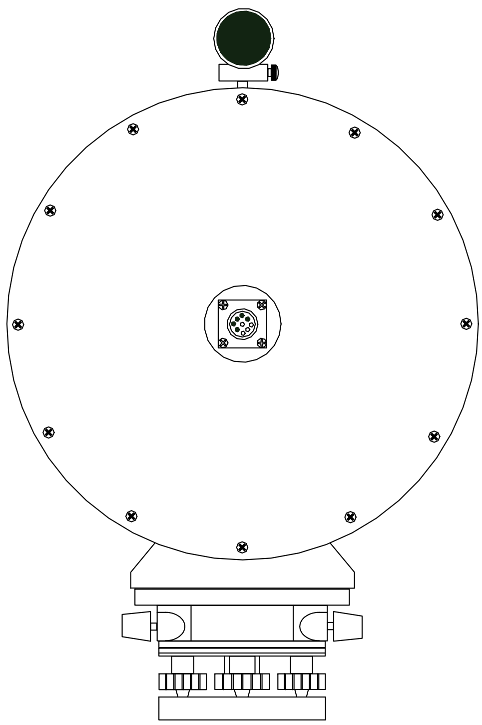


Figure 49: BLS2000 Receiver– Rear View

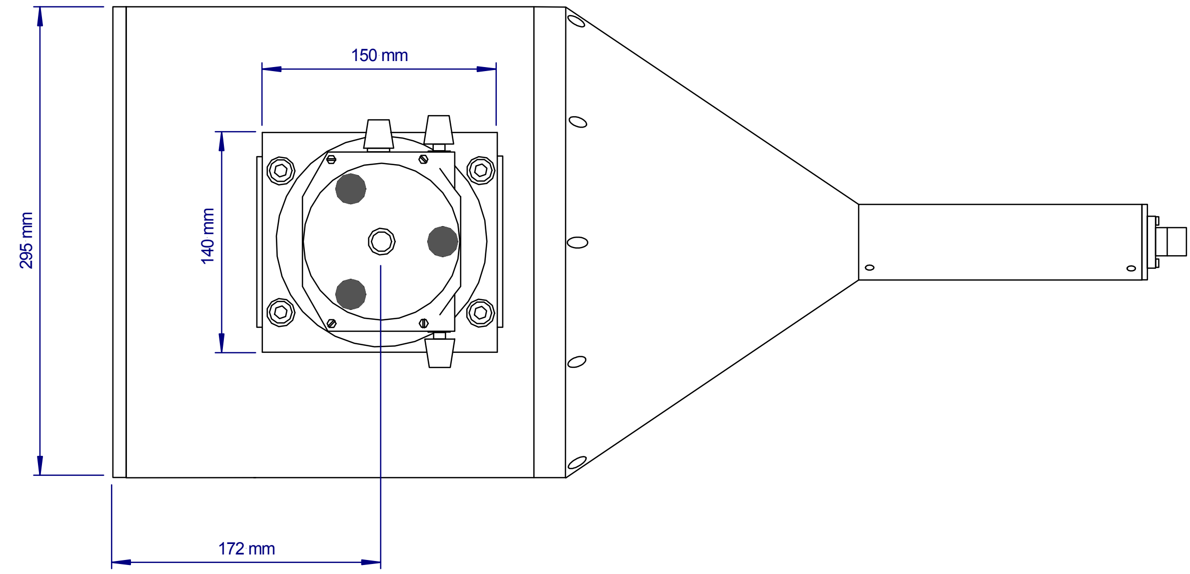


Figure 50: BLS2000 Receiver – Bottom View

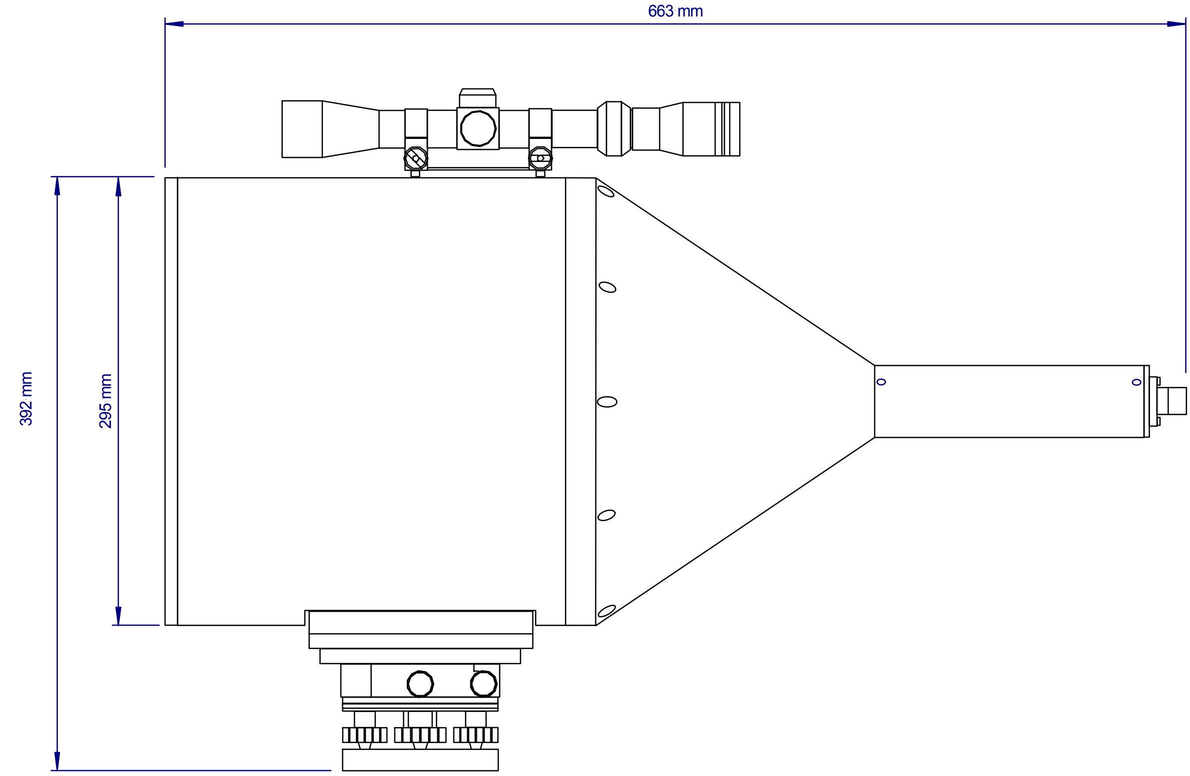


Figure 51: BLS2000 Receiver – Side View

APPENDIX C SPECIFICATIONS

C.1 TRANSMITTER

Specifications	BLS450	BLS900	BLS2000	Remarks
Main radiation source	444 LEDs GaAlAs	888 GaAlAs LEDs	1756GaAlAs LEDs	Infrared
Degradation time MTTF	55 000 hours	55 000 hours	55 000 hours	With PRR= 125 HZ
Auxiliary radiation source	18 LEDs visible	36 LEDs	68 LEDs	Red
Maximal optical power	7.5 W	15 W	28 W	
Wavelength	880 nm	880 nm	880 nm	$\Delta\lambda$ = ± 20 nm
Beam Divergence	16°	16°	16°	Full width half max
Pulse Repetition Rates (PRR)	1Hz, 5Hz, 25 Hz, 125Hz	1Hz, 5Hz, 25 Hz, 125Hz	1Hz, 5Hz, 25 Hz, 125Hz	± 5%
Pulse length	8 ms	8 ms	8 ms	
Modulation frequency	1750 Hz	1750 Hz and 2500 Hz	1750 Hz and 2500 Hz	
Operation voltage	12 VDC	12 VDC	12 VDC	Max. Voltage 15 VDC
Power consumption	40 W 8 W 2 W 1 W	80 W 16 W 4 W 1 W	150 W 30 W 70 W 2 W	PRR=125 Hz PRR= 25Hz PRR= 5Hz PRR= 1Hz
Dimensions	180 x 180 x 135 mm	364 x 180 x 135 mm	590 x 330 x 170 mm	
Weight	4.5 kg	8.5 kg	22 kg	

Table 13: Specifications of BLS Transmitter

C.2 RECEIVER

Specifications	BLS450 and BLS900	BLS2000	Remarks
Lens Focal length Diameter Field of view	Plan convex 450 mm 145 mm 8 mrad	Fresnel, plan 495 mm 265 mm 7.5 mrad	
Detectors Sensitive area Sensitive area	2 Si Photodiodes 15 mm² 5 mm²	2 Si Photodiodes 15 mm² 5 mm²	 Signal 1 Signal 2
Dimension	Ø160 x 590 mm	570 x 480 x 300 mm	
Weight	7.6 kg	19 kg	

Table 14: Specifications of BLS Receiver

C.3 SPU

Specifications	BLS450, BLS900, BLS2000	Remarks
Integration time	1 min	
Data Storage Capacity	Approx. 2 years	Between data downloads, Non-volatile flash storage
Internal clock	Date and time	
Operation temperature range	-20°C ~ + 50°C	
Operation voltage	12 VDC	Maximum voltage :15 VDC
Weight	4.7 kg	
Dimension	230 x 200 x 180 mm	
Power consumption (including Receiver)	15 W	Independent of PRR
Power consumption BLS2000 Heating	9.6 W	

Table 15: Specifications of BLS SPU

C.4 BLS POWER SUPPLY

Specifications	BLS450, BLS900, BLS2000	Remarks
Output voltage	15 VDC	
Output current	8.5 A	
Weight	10 kg	
Dimension	230 x 200 x 180 mm	

Table 16: Specifications of BLS Power Supply

C.5 BLS UPS

Specifications	BLS450, BLS900, BLS2000	Remarks
Input voltage	15 VDC	when connected to BLS Power Supply
Output voltage	11 VDC to max. 14 VDC	
Output current	10 A	
Capacity	40 Ah	
Weight	23 kg	
Dimension	400 x 230 x 225 mm	

Table 17: Specifications of BLS UPS

APPENDIX D DECLARATION OF CONFORMITY

Name and address of manufacturer:

Scintec AG
Wilhelm-Maybach-Str. 14
72108 Rottenburg
Germany

We declare that the products

Boundary Layer Scintillometer, Models BLS450, BLS900, BLS2000

comply with the Electromagnetic Compatibility Regulations (EMC) and, as far a applicable, the Low Voltage Directive (LVD) of the European Community.

Conformity is guaranteed for delivered complete systems and independently operable components. This declaration does not refer to systems resulting from an integration of external components such as data loggers, PC's, power supplies, cables, etc. by others than the manufacturer.

Applicable norms and standards:

EN 50081-1 (EMC Generic Standard - Radiated and Conducted Emissions)
EN 55014 (EMC Product Standard - Radiated and Conducted Emissions)
EN 55022 Class B (EMC Product Standard (IT)– Radiated and Conducted Emissions)

EN 50082-1 (EMC Generic Standard - Radiated and Conducted Immunity)
EN 60555-2, 60555-3 (EMC Product Standard - Radiated and Conducted Immunity)
EN 55024 / IEC 801-1 - 801-6 (EMC Product Standard (IT) – Radiated and Conducted Immunity)