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Scintec Surface Layer Scintillometer

Hardware Manual SLS

SLS20 / SLS40
SLS20-A / SLS40-A

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Contents

Important Note on Laser Safety Considerations

The SLS20 / SLS20-A / SLS40 / SLS40-A is a class 3a laser product.

During the operation of this instrument, harmful visible laser radiation is emitted.

Never look into the laser beam or at any specular reflections of the laser beam as long as you are not at a safe distance*.

Never use optical instruments, in particular binoculars or telescopes, to look at the laser beam, even if you are at a safe distance for the naked eye.

Attach appropriate warning signs and prevent unauthorized personnel from approaching the source.

*Always be at least 50 m away from the source when looking at it from the front (see section 2.3).

Quick Reference Guide

The following steps are required to perform a measurement with the SLS20(-A) / SLS40(-A):

1. Install the SLS software SRun (see Software Manual SRun) and configure the software's communication parameters.

2. Check the correct communication between the SPU and the PC, change the communication parameters if necessary (see Software Manual SRun)

3. Setup and align the SLS20(-A) / SLS40(-A) transmitter and receiver

4. Determine the background signal and crosstalk coefficients

5. Start the measurement

1 Introduction

The SLS20(-A) / SLS40(-A) is a sophisticated scintillometer system for accurate measurements of atmospheric turbulence. The instrument combines outstanding performance and ease-of-operation. It has the following features:

- reliable laser diode source
- modulated radiation for elimination of background
- extremely sensitive, shot noise limited detector unit
- interference filter for use in direct sunlight
- operation over a single path with displaced beam technique
- unaffected by turbulence inhomogeneities along the path
- correction for transmitter vibrations (SLS40, SLS40-A)
- automatic beam steering (SLS20-A, SLS40-A)
- heated windows to prevent dew and ice deposits
- path length and height user defined
- rapid installation and alignment with positioning device
- user-friendly software for real time data evaluation
- background calibration and crosstalk correction
- comprehensive error identification and correction
- calculation of structure function constant C_n^2 and inner scale ℓ_0 of refractive index fluctuations
- calculation of structure function constant C_T^2 of temperature and dissipation rate ε of kinetic energy
- calculation of Monin-Obukhov length and turbulent fluxes of heat and momentum
- screen graphics output in real time and from file
- possibility of data export via Ethernet cable link
- rugged weather-resistant design

The SLS20 / SLS20-A / SLS40 / SLS40-A is patented under U.S. PAT. 5,303,024 and DE 39 02 015 C2, others pending.

2 Hardware Preparation

2.1 Selection of Path

The propagation path length is defined as the distance between the centre of the transmitter and the centre of the receiver (see Fig. 1):

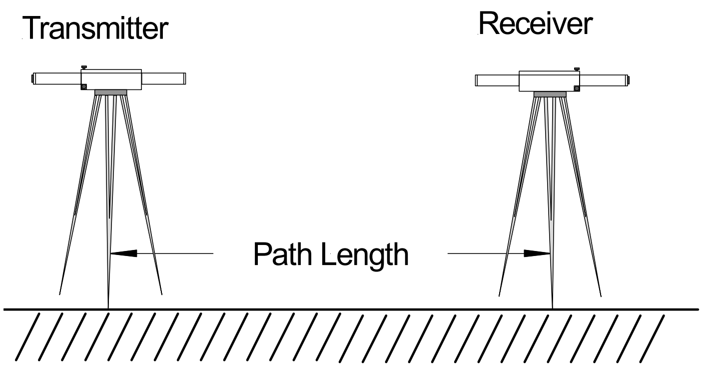


Figure 1: Illustration of the path length definition

Operation of the SLS20(-A) / SLS40(-A) is possible over paths in the range 50 to 300 m. The recommended path length is 100 to 200 m.

The propagation path should be as horizontal as possible, the ground should be as even as possible. A well defined measurement height is required for application of the Monin-Obukhov similarity theory. Note that the primarily measured quantities C_n^2, i.e. the structure function constant of refractive index fluctuations, and ℓ_0, i.e. the inner scale of refractive index fluctuations, strongly depend on height and a slant path would lead to an undesired averaging.

The path height is defined as the height of the straight line connecting the transmitter and the receiver above ground. 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 A., Figs. A.1 and A.2. A typical measurement height for a path length of 100 to 200 m is 1.50 to 2.00 m.

When selecting the path length and height, technical and site requirements should be considered:

a) The calculation of the turbulent fluxes and the Monin-Obukhov length is based on Monin-Obukhov similarity. Monin-Obukhov similarity requires the measurement height to be significantly larger than the height of the roughness elements.

b) Monin-Obukhov similarity also requires homogeneity of the site over several tens of times the measurement height upwinds. Therefore, poor site homogeneity suggests a lower measurement height.

c) For long propagation paths, saturation may occur under strong turbulence conditions (see Appendix A and Appendix D). 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.

d) The path length changes the measurement range and sensitivity. For typical turbulence conditions, a 100 - 200 m long path provides an optimum sensitivity to the inner scale and all derived quantities.

e) With short paths the intensity fluctuations are small, with long paths the average received intensity is small. Both affect the signal-to-noise ratio. A 100 - 200 m path length usually provides an optimum.

After you have chosen the path position and length you must:

a) Enter the path length and height in the SRUN software.

b) Adapt the amplifier dip switch setting in the receiver unit (see Appendix B.1.4).

2.2 Installing the instruments

The transmitter and receiver units must be mounted on stable platforms. The required angular pointing stability is in the order of 0.1 mrad / 1 mrad (SLS20(-A) / SLS40(-A)) at the transmitter and 1 mrad at the receiver.

We recommend the use of heavy tripods used for geodetic purposes. The 5/8 inch threads at the bottoms of the instruments allow an easy connection to such devices. Strong winds (around 10 m/s or more) may require additional measures to ensure pointing stability and to avoid measurement errors caused by vibration of the transmitter (see Appendix D.1), especially with the SLS20 / SLS20-A.

Before doing the alignment it is important to check:

1. The source and receiver tubes must be correctly placed in the positioning devices. Verify that the rotational positions around their main axes are correct (see Appendix B.1.2). Since the two beams are identified by polarization, incorrect orientation will produce a considerable crosstalk of the signals. For the same reason make sure later that the whole instruments are correctly mounted in the horizontal.

2. After transportation or mechanical shock, the spatial filter pinhole in the transmitter unit might need repositioning (see Appendix B.1.3).

Then connect the SLS20(-A) / SLS40(-A) receiver unit with the JCB. Connect the SLS20(-A) / SLS40(-A) transmitter unit with the JCB (required for auto background mode) or provide a local power supply for the transmitter unit.

Connect the SPU with the Ethernet cable link to a PC or network and the Junction/Control Box (JCB) with the SPU. Supply the SPU with +12 V operation power (see Appendix B.3.1.).

SLS20: Set the switch of the JCB to the "int" position.

SLS20-A, SLS40, SLS40-A: With one of these systems you must connect an external 12 to 18V power supply to the Junction/Control Box (JCB), the exact voltage value depends on the cable length to the transmitter or receiver. For details see Appendix B.2.1. Set the switch at the JCB to "ext" (extern). The instrument will not work properly with the internal 12V of the SPU (switch in "int" position), except if you have a transmitter standard cable length of 150 m or less and a receiver standard cable length of 50 m or less. When the switch is in the middle position, transmitter and receiver are disconnected.

Overvoltage protection:

To protect the instruments against damages caused by overvoltage (atmospheric electric discharges), connect the ground connector of the JCB to a suitable ground. Note that the JCB and the SPU are not weather proved and should be kept indoors close to the PC.

Weather protection:

It is important to avoid cases temperatures of more than 50°C during operation. In hot and sunny climates, the instruments should therefore be operated at a naturally ventilated place or a sun protection shield should be used.

The transmitter and receiver of the SLS20(-A) / SLS40(-A) withstand normal rain and snow and usually can be operated outdoors without further protection.

The instruments are not totally sealed. During heavy rain, small amounts of water may penetrate into the interior of the instruments. This will not affect the operation and will dry due to natural air exchange. However, after heavy rain, do not move or shake the instruments.

Measures to protect the instruments from direct precipitation are recommended for permanent installations or under severe weather conditions.

2.3 Alignment

It is recommended that two persons perform the alignment, one person at the transmitter and one person at the receiver. A set of Walky-Talkies might be a helpful tool.

The alignment is easiest in the following order:

a) Roughly align the transmitter unit: Look through the alignment hole in the transmitter (see figure in Appendix B.1.1) and adjust the platform (tripod) until you see the receiver in the middle of the hole.

   <u>Danger:</u> The source unit emits laser radiation which is harmful for the human eye in the vicinity of the instruments. Always make sure that you are at least 50 m away from the source when looking into the beam! Never look into the beam as long as you are not behind the receiver's position!

b) Roughly align the receiver unit: Look through the alignment hole in the receiver and adjust the platform (tripod) until the transmitter is in the middle of the hole.

   Attention: During the alignment of the transmitter and receiver, make sure that you do not tilt the platform out of the horizontal. A strictly horizontal transmitter and receiver position is required to maintain the defined polarization direction to each other. Otherwise you will later notice a considerable crosstalk.

c) Make the fine adjustment of the transmitter with the three positioning screws of the positioning device. It is recommended that you first align in the vertical direction. To do this, loosen the upper screw. By turning the lower screws in the same sense, you move the beam up and down.

   After you have found the correct vertical position, fasten the upper screw and perform the alignment in the horizontal. To do this, turn the lower screws in an opposite sense which moves the beam to the left or to the right.

   The goal of the transmitter alignment is to have the receiver as close as possible to the beam's centre. When judging the beam's position one must take into account that the beam has an elliptic cross section. The optimum position of the receiver is indicated by an "**O**" in the following sketch (Fig. 2):

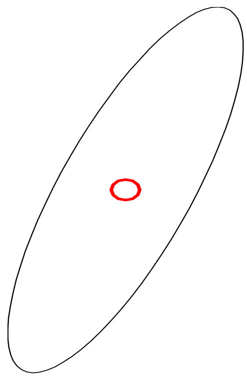


Figure 2: Illustration of the elliptic beam cross section

Do the fine adjustment very carefully, especially with the SLS20 and SLS40. Usually a few iterations are required. The SLS20-A and SLS40-A will do the final fine alignment automatically, if you have configurated the software accordingly in the Automatic Alignment submenu of the Settins pull-down menu (see section 3.4.8). When you finish the alignment, make sure that the screws are properly fastened.

d) To perform the receiver fine alignment, run the SRUN program and select the “Start Alignment” option in the SRun menu entry “Device”. Perform a scan-like movement of the receiver tube using the positioning screws as described above. SRun offers a graphical overview about alignment history and its current status. In the panel labelled “current”, the bars indicate the signal strengths at the two detectors. For details on the Alignment mode, see the SRun software manual.

e) When you scan the receiver in the vertical and horizontal you will notice that there is a range where the signals of both channels are at maximum. **The final position should be in the centre of this range (in the horizontal and in the vertical direction).**

Note that it is not required that the signal levels of the two channels are similar and that both channels have a slightly different field of view with a large overlapping region.

f) Adapt the signal levels with the channel level regulators at the Junction/Control Box for channels 1 and 2 (with the SLS40(-A): channels 1A and 2A) until they are in the optimum range. For path lengths of 100 to 200 m, this range is marked on the screen by two horizontal lines. Turn the regulators until the averaged signals have levels in between. It is not necessary that both signals have the same level.

For paths shorter than 100 m or longer than 200 m, set the levels as close as possible to the optimum range. For short paths (< 100 m), you can run the instrument with signal levels above the optimum range since the intensity fluctuations are expected to be small then. For long paths (> 200 m), you can run the instrument with signal levels below the optimum range since large intensity fluctuations will improve the signal-to-noise ratio.

If the average signals are too weak:

1. Check the alignment of the transmitter.
2. Check the alignment of the receiver.
3. Check the pinhole adjustment at the transmitter (see Appendix B.1.3).
4. Check the dip switch setting in the receiver unit (see Appendix B 1.4).
5. Check if there is dirt, dew or ice deposit on the windows.

If none of the above suggestions help, increase the receiver output by selecting the next higher amplifier dip switch setting in the receiver (see Appendix B.1.4).

If the signals are too strong, select the next lower amplifier dip switch setting in the receiver (see Appendix B.1.4).

Note that relative changes of the intensity will be evaluated. Therefore the adjustment of the signal levels only optimizes the operation and has only minor effects on the accuracy of the results.

g) Measure the background signal and crosstalk coefficients by invoking the “Background Measurment” option in the SRun menu entry “Device”. You will be asked in a dialogue to first allow measurement of the undisturbed signal, then to cover the whole beam to allow measurement of the background (manual action is not necessary if the transmitter is connected to the Junction/Control Box) and then to cover the beams of channel X and channel Y separately to allow measurement of the crosstalk.

The coverage of the beams must be performed directly at the beam exit of the transmitter. Use a small piece of paper which is transparent enough so you can see the position of the covered beam. Be careful to totally obscure the beam to be covered and not to touch the other beam.

If the software recognizes that the beam to be covered was not perfectly covered or the other beam was touched, you will be informed and asked to repeat the procedure.

After that procedure, the measured coefficients will be displayed. Check if they are ok:

The crosstalk coefficient should be below or at about 5%. If one or both of them are considerably larger, bring the transmitter and receiver in a correct horizontal position and repeat the Measure Background procedure.

The background values and crosstalk coefficients determined during this procedure are used to correct the data during the measurement.

Note: Alignment using a retroreflector (corner reflector)

A retroreflector (corner reflector) of at least 0.2 m diameter can support a single person to do the alignment. Put the retroreflector on top of the receiver. First align the transmitter for maximum reflection which can be seen at the transmitter side very close to the transmitter. After that, verify the correct position at the receiver side and re-adjust the transmitter if necessary. Finally align the receiver as described before.

2.4 Reduction in Laser Power

A reduction in laser power of the transmitter might be required for very short path lengths (under about 70 m). The reduction prevents a potential saturation of the receiver, which may result in an apparent loss of received signal. To reduce the power, follow the steps given below:

1. Remove the back-cover of the SLS Transmitter Unit. For this, unscrew the three Phillip head screws at the transmitter end hosting a connector with 4 pins (SLS20, SLS40) or 7 pins (SLS20-A, SLS40-A). Pull out carefully the metal cylinder (see Fig. 1). The latter contains a module controlling the laser operation. **Note: Do not extract the metal tube completely.**

Figure 1: Removing the back-cover of the SLS Transmitter Unit

2. There are three different potentiometers on the module. The furthest behind potentiometer allows a reduction in laser power (arrow in Fig. 2.).

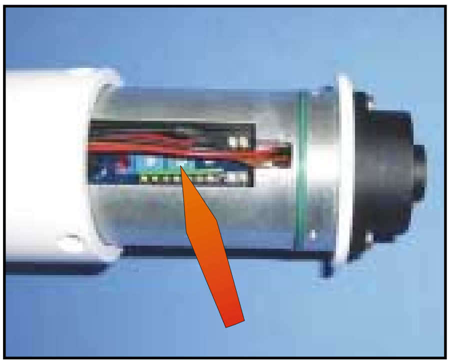


Figure 2: Identifying the appropriate potentiometer

3. To reduce the power of the laser, turn the potentiometer screw counter-clockwise to around 20-40% of its maximum position (default setting).

   <u>Note:</u> When changing to large path lengths, do not forget to increase the laser power to its nominal value.

Appendix A Theory

If radiation of wavelength λ and wavenumber $K = 2\pi / \lambda$ is emitted from two sources, which are separated by a distance d perpendicular to the propagation direction, and this radiation is independently observed by two detectors of diameter D, which are separated by the same distance d with the separation vectors pointing in the same direction (parallel paths), the covariance of the logarithm of the amplitude of the received radiation is given by

$$B_{12} = 4\pi^2 K^2 \int_0^R dx \int_0^\infty d\kappa \kappa \phi_n(\kappa) J_0(\kappa d) \sin^2\left[\frac{\kappa^2 x(R-x)}{2KR}\right] \frac{4J_1^2(\kappa Dx/2R)}{(\kappa Dx/2R)^2}, \qquad (1)$$

where R is the propagation path length, x is the coordinate along the propagation path, ϕ_n is the three-dimensional spectrum of the refractive index inhomogeneities and J_0 and J_1 are Bessel functions of the first kind. Eq. (1) is valid as long as scattering is weak, i. e. as long as B_{12} < 0.3. Otherwise saturation occurs. In this case the measured B_{12} is smaller than that predicted by Eq. (1).

With $d = 0$, Eq. (1) also provides the expression for the variances B_1 and B_2 at the single detectors.

The inner integral of Eq. (1) is the path weighting function. The path weighting functions of the variances and covariances for a 100 m propagation distance and values of the inner scale ℓ_0 of 2mm, 4mm and 10mm are given in Figs. A.1 and A.2.

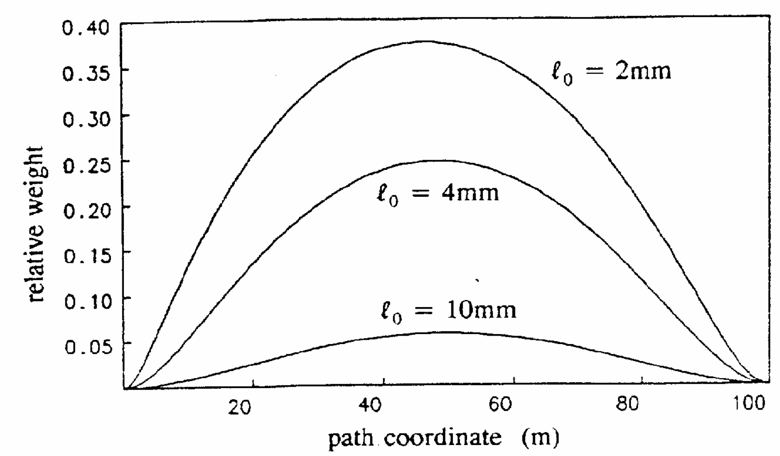


Figure A.1: Path weigthing functions (100 m path)

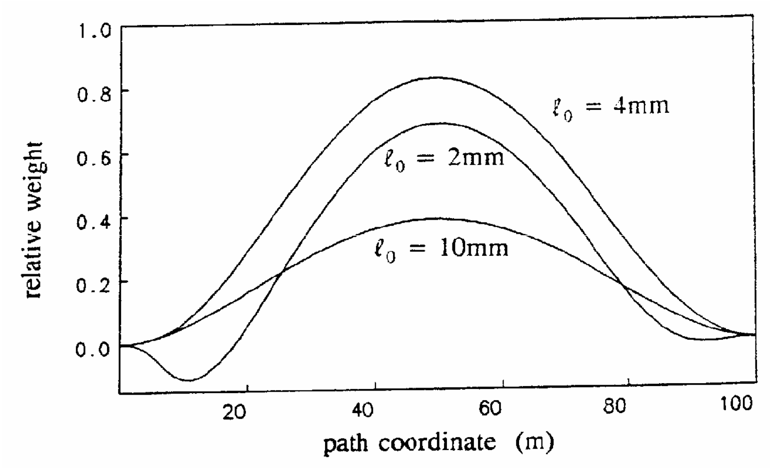


Figure A.2: Path weigthing functions (100 m path)

The function ϕ_n has the form

$$\phi_n(\kappa) = 0.033 C_n^2 \kappa^{-11/3} f_\phi(\kappa \ell_0), \tag{2}$$

where C_n^2 is the structure function constant of refractive index in the inertial subrange of turbulence and $f_\phi(\kappa\ell_0)$ is a function describing the decay of refractive index fluctuations in the dissipation range. The model of Hill is assumed for f_ϕ .

Inserting Eq. (2) into Eq. (1) defines the covariance and the variances if C_n^2, ℓ_0 and the physical dimensions of the instrument are known. Hence measurements of B_{12} and B_1 or B_2 can be used to derive C_n^2 and ℓ_0. Note that the correlation coefficient $r = B_{12}/(B_1 B_2)^{1/2} = B_{12}/B_1 = B_{12}/B_2$ is a function of ℓ_0 only. For a 100 m long path this relationship is given in Fig. A.3.

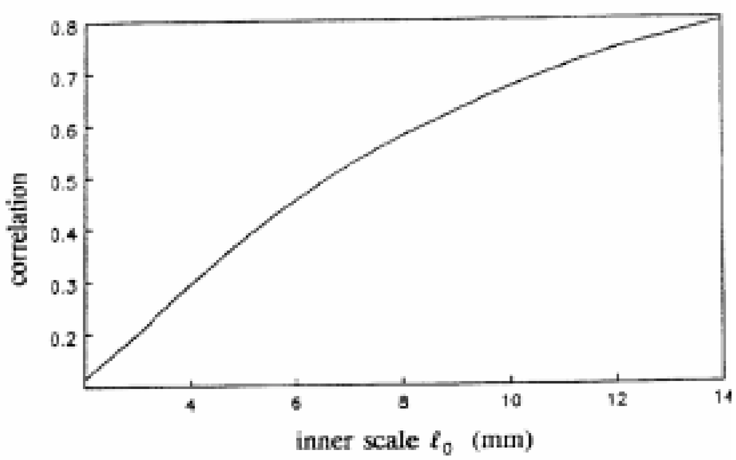


Figure A.3: Correlation versus inner scale ℓ_0

Note also that the variances B_1 and B_2 are not only proportional to C_n^2, but they also depend on ℓ_0.

Since variances of intensity σ_i^2 are measured rather than variances of log-amplitude B_i, σ_i^2 must be converted into B_i. For log-normally distributed amplitude one can apply the relation

$$B_i = \frac{1}{4}\log\left(1+\frac{\sigma_i^2}{\langle I_i\rangle^2}\right). \tag{3}$$

From C_n^2 the structure function constant of temperature C_T^2 can be calculated via

$$C_T^2 = C_n^2 T^4 (ap)^{-2}, \tag{4}$$

where T is the air temperature in Kelvin and p is the air pressure in hPa (mbar). The constant a is given by $7.89\cdot 10^{-5}$ K/hPa at 670 nm wavelength.

Eq. (4) neglects the contribution of humidity fluctuations. In the presence of humidity fluctuations a small error occurs. By use of similarity arguments, the error of C_T (and that of the later derived heat fluxes) can be estimated to be 3% times the inverse Bowen ratio (latent heat flux divided by sensible heat flux). Note that the error is quite exactly half as large as the humidity error of ultrasonic thermometers.

The inner scale ℓ_0 is closely related to the dissipation rate of the kinetic energy of turbulence ε:

$$\varepsilon = \nu^3 (7.4/l_0)^4. \tag{5}$$

Here ν is the kinematic viscosity of air which can be calculated in m²/s via

$$\nu = [1.718 + 0.0049(T-273.15)]\rho^{-1}\cdot 10^{-5}, \tag{6}$$

if T is the temperature in K and ρ is the air density in kg/m³.

From C_T^2 and ε, the turbulent kinematic fluxes of heat Q_0 (unit K m/s) and momentum $-u_*^2$ (unit m²/s²) can be computed by use of Monin-Obukhov similarity. If $T_* = -Q_0/u_*$ is the turbulent temperature scale, $L = T_* u^2{}_* / (kgT_*)$ is the Monin-Obukhov length, z is the height above ground, k = 0.4 is the von Karman constant, g = 9.81 m/s² is the gravitational acceleration, and β_1 = 0.86 is the Obukhov-Corrsin constant, then the following semi-empirical expressions have proven a quite high accuracy:

$$C_T^2 (kz)^{2/3} T_*^{-2} = 4\beta_1 \left(1 - 7\frac{z}{L} + 75\left(\frac{z}{L}\right)^2\right)^{-1/3} \tag{7}$$

and

$$\varepsilon kzu_*^{-3} = \left(1 - 3\frac{z}{L}\right)^{-1} - \frac{z}{L} \tag{8}$$

for $z/L < 0$ (unstable), and

$$C_T^2 (kz)^{2/3} T_*^{-2} = 4\beta_1 \left(1 + 7\frac{z}{L} + 20\left(\frac{z}{L}\right)^2\right)^{1/3} \tag{9}$$

and

$$\varepsilon kzu_*^{-3} = \left(1 + 4\frac{z}{L} + 16\left(\frac{z}{L}\right)^2\right)^{-1/2} \tag{10}$$

for $z/L > 0$ (stable).

Solving equations (7), (8), (9) and (10) for the turbulent fluxes requires a numerical iteration scheme.

The turbulent heat flux H with unit W/m² and the turbulent momentum flux M with unit kg $m^{-1} s^{-2}$ are calculated via the relations

$$H = -c_p \rho u_* T_* \tag{11}$$

and

$$M = -\rho u_*^2 \,. \tag{12}$$

Appendix B Description of the instruments

B.1 Transmitter and receiver units

B.1.1 General

The transmitter and receiver units consist of the tubes and the positioning devices. The tubes contain optics and electronics.

The electronics in the transmitter unit produces the modulation signal. Hence it requires only DC voltage for operation.

The electronics in the receiver unit consists of signal amplifiers and voltage regulators. The modulated signals are then transferred through the line to the Junction/Control Box and further to the Signal Processing Unit (SPU).

Both, transmitter and receiver have a heatable front glass to prevent ice or dew deposits (see Appendix B.2.1).

Do not open the transmitter or the receiver tubes since they will be difficult to re-adjust. An exception is the back-cover of the receiver, which must be opened to change the amplifier dip switch setting (see section B.1.4).

The only necessary maintenance to be performed by the user is the pinhole adjustment (see section B.1.3). Additionally, the user should regularly check the orientation of the tubes (see section B.1.2).

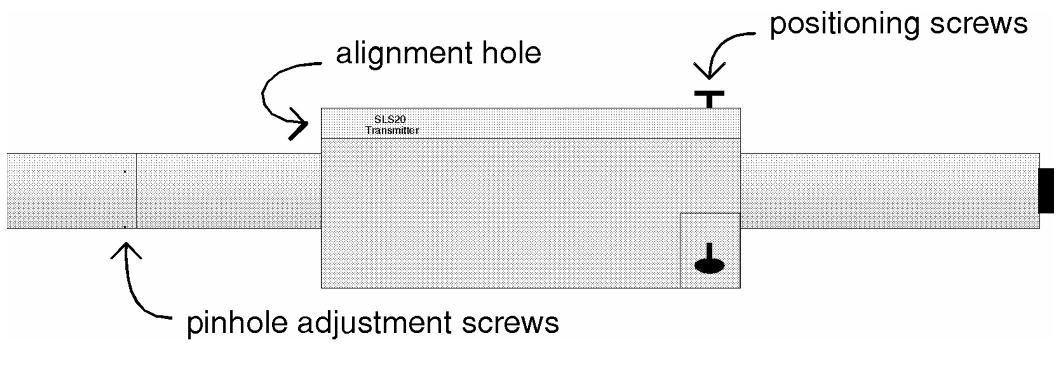


Figure B.1: SLS20 Transmitter Unit

B.1.2 Orientation of tubes

Since the two beams are identified by their polarization direction, the orientation of the transmitter and receiver relative to each other must be coordinated. Therefore it is necessary that the tubes have the correct rotational orientation within the positioning devices. Make sure also that the units are well horizontally positioned during the operation. Otherwise a noticeable crosstalk between the two channels will be noticed (more than a few percent).

The correct orientations of the tubes within the positioning devices are as follows:

Transmitter: The source emits two beams. These two beams must lie exactly in a horizontal line. Check with a (sufficiently transparent) piece of paper covering the frontal window. If necessary, open the positioning screws and turn the tube until the position is correct.

It is also required that the "down" mark on the tube (black triangle on red ground) shows downwards. If the down mark of the transmitter shows upwards and that of the receiver shows downwards (or inverse), crossed paths (instead of parallel paths) would result and will produce wrong data.

Receiver: Near the back of the receiver tube there is a small screw near the "down" mark. This screw must exactly show down.

B.1.3 Pinhole adjustment

After transportation, mechanical shock or strong temperature variations it might be necessary to re-adjust the spatial filter pinhole in the transmitter unit. It is recommended that a re-adjustment is made every time the instruments have been moved before the measurements start.

The three (small) pinhole adjustment screws are near the front end of the transmitter tube (see figure on the page before). Use two small screw drivers to perform the adjustment procedure as follows:

a) Put a screen (piece of paper) in front of the instrument or point the laser beam to a white wall. Operate the laser, you will see two red spots (these spots overlap in a short distance).

b) Loosen one of the pinhole adjustment screws a little (less than a quarter turn) and immediately follow with another screw by turning it in the opposite sense (tightening direction). You will notice the beam becoming more or less bright. Maximize the output intensity.

c) Repeat this procedure iteratively with two other screws, always trying to achieve the maximum beam output, until no further improvement is possible.

Caution: 1. Be very careful to never "lose" the beam. It is quite difficult to find it again. 2. Never loosen a screw without at the same time tightening another screw. The pinhole is fixed by the adjustment screws and may otherwise drop out.

d) Tighten the pinhole by tightening one screw.

B.1.4 Amplifier dip switch setting

The SLS20(-A) / SLS40(-A) can be operated over different path lengths. Different path lengths go along with different radiation intensities. The dip switches in the back of the receiver tube allow the adaptation of the voltage output range.

In order to reach the dip switches, unplug the receiver, turn out the three Phillips screws at the back and carefully pull off the back cover. Be cautious not to tear off one of the cables. The dip switch is now visible.

SLS20(-A): The first 4 dip switches (1-4) belong to channel 1 and the second 4 dip switches (5-8) belong to channel 2.

SLS40(-A): The first 4 dip switches (1-4) of the upper row belong to channel 1A and the second 4 dip switches (5-8) of the upper row belong to channel 2A. The first 4 dip switches (1-4) of the lower row belong to channel 1B and the second 4 dip switches (5-8) of the lower row belong to channel 2B.

If "0" means position "off" (up) and "1" means position "on" (down) then the following dip switch positions typically correspond to the following ranges:

Switch	1	2	3	4	5	6	7	8	Path Length
Position	0	0	0	1	0	0	0	1	< 100 m (see Note)
	1	1	1	0	1	1	1	0	90 – 120 m (factory setting)
	0	0	1	0	0	0	1	0	110 – 150 m
	1	1	0	0	1	1	0	0	140 – 190 m
	0	1	0	0	0	1	0	0	170 – 220 m
	1	0	0	0	1	0	0	0	210 – 300 m

Note: For paths much shorter than 100 m, the mean level may be higher than the indicated range. If the fluctuating signal does not hit the upper range limit (4095 digits), this can be tolerated. If regularly hits or even continuously is at the upper range limit and you cannot make the path longer, the laser output power should be reduced.

If for a well aligned set-up, the signal is too low or too high (and cannot be adjusted at the Junction/Control Box), use the next lower or higher dip switch setting, respectively. With the SLS40(-A), the dip switch settings of the upper and lower row usually is identical.

B.1.5 Source lifetime and operation temperature range

The SLS20(-A) / SLS40(-A) uses laser diodes as radiation sources which typically operate over more than 20.000 hours.

Laser diodes will be damaged or their lifetime will be decreased if they are operated at unfavourate temperatures. Therefore never operate the transmitter outside its given operation temperature range (see specifications in Appendix C). Make sure that the instrument is shielded from direct sun radiation on hot days. Also do not unattendedly operate the instrument when the temperature may drop below the lower temperature limit.

A damaged source emits a significantly reduced light intensity. In this case send the transmitter unit to the manufacturer for source replacement.

B.2 Junction/Control Box

The Junction/Control Box is an interface for connecting the transmitter and the receiver to the SPU. Depending on the lengths of the cables to the transmitter and receiver, an external power supply might be hooked up to the Junction/Control Box.

B.2.1 Power supply

If supply by the SPU is desired put the switch at the JCB to the "int" position. Otherwise put the switch to the "ext" position and connect the external power supply using the corresponding Junction/Control Box power supply cable. **If the switch is in the middle position, both source and receiver are disconnected.**

With the SLS20-A, SLS40 and SLS40-A, power supply by the SPU is only possible if the cables to the receiver or transmitter do not exceed the following lengths:

SLS20-A	cable to transmitter - 150 m
SLS40	cable to receiver - 50 m
SLS40-A	cable to transmitter - 150 m and cable to receiver - 50 m

If the cable length to the transmitter and/or receiver exceeds the cable lengths given above, an external power supply is required.

The external power supply must provide currents of

SLS20	100 mA at +12 V
	50 mA at -12 V
SLS20-A	500 mA at +12 to -18 V (required voltage, see below)
	150 mA at -12 to -18 V (required voltage, see below)
SLS40	350 mA at +12 to +18 V
	200 mA at -12 to -18 V
SLS40-A	550 mA at +12 to +18 V
	200 mA at -12 to -18 V

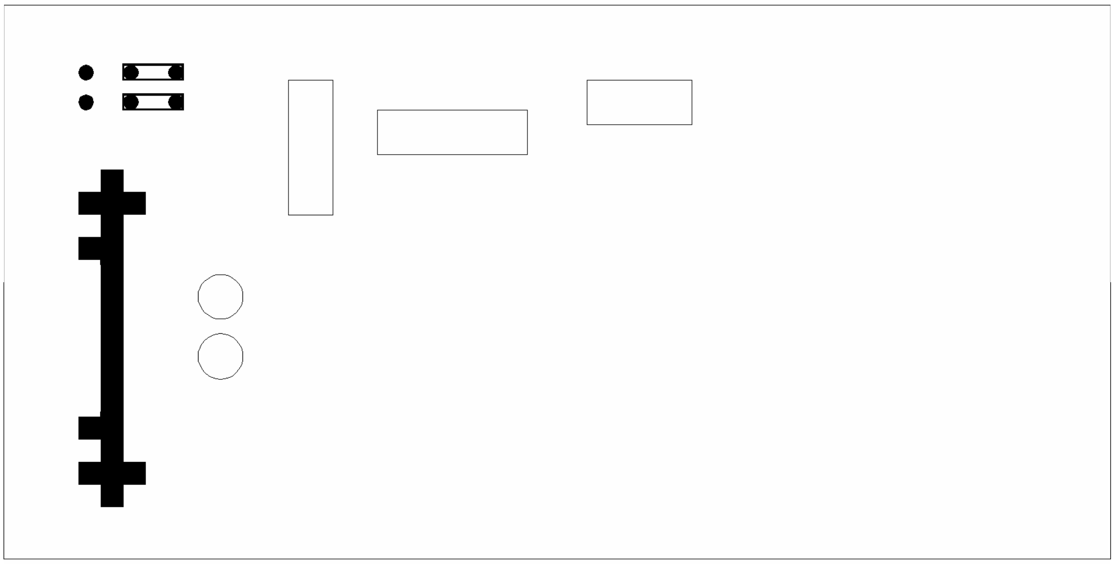
For external supply, the following operation voltages are required:

Model	Cable Lengths	Operation Voltage
SLS20	Up to 400 m to transmitter and up to 200 m to receiver	±12 V (18 V max.)
SLS20-A	Up to 150 m to transmitter and up to 200 m to receiver	±12 V (13.5 V max.)
	150 – 300 m to transmitter and up to 200 m to receiver	±16 V (17.6 V max.)
	300 – 400 m to transmitter and up to 200 m to receiver	±18 V (19.8 V max.)
SLS40	Up to 400 m to transmitter and up to 50 m to receiver	±12 V (18 V max.)
	Up to 400 m to transmitter and up 50 – 150 m to receiver	±16 V (18 V max.)
	Up to 400 m to transmitter and up 150 – 200 m to receiver	±18 V (19.6 V max.)
SLS40-A	Up to 150 m to transmitter and up to 50 m to receiver	±12 V (13.5 V max.)
	150 – 300 m to transmitter and up to 50 m to receiver	±16 V (17.6 V max.)
	300 – 400 m to transmitter and up to 50 m to receiver	±18 V (19.8 V max.)
	Up to 150 m to transmitter and 50 – 150 m to receiver	±16 V (17.6 V max.) **Attention: Set JCB Power Supply Jumper to “on” (see below)**
	150 – 300 m to transmitter and 50 – 150 m to receiver	±16 V (17.6 V max.)
	300 – 400 m to transmitter and 50 – 150 m to receiver	±18 V (19.8 V max.)
	Up to 150 m to transmitter and 150 – 200 m to receiver	±18 V (19.8 V max.) **Attention: Set JCB Power Supply Jumper to “on” (see below)**
	150 – 400 m to transmitter and 150 – 200 m to receiver	±18 V (19.8 V max.)

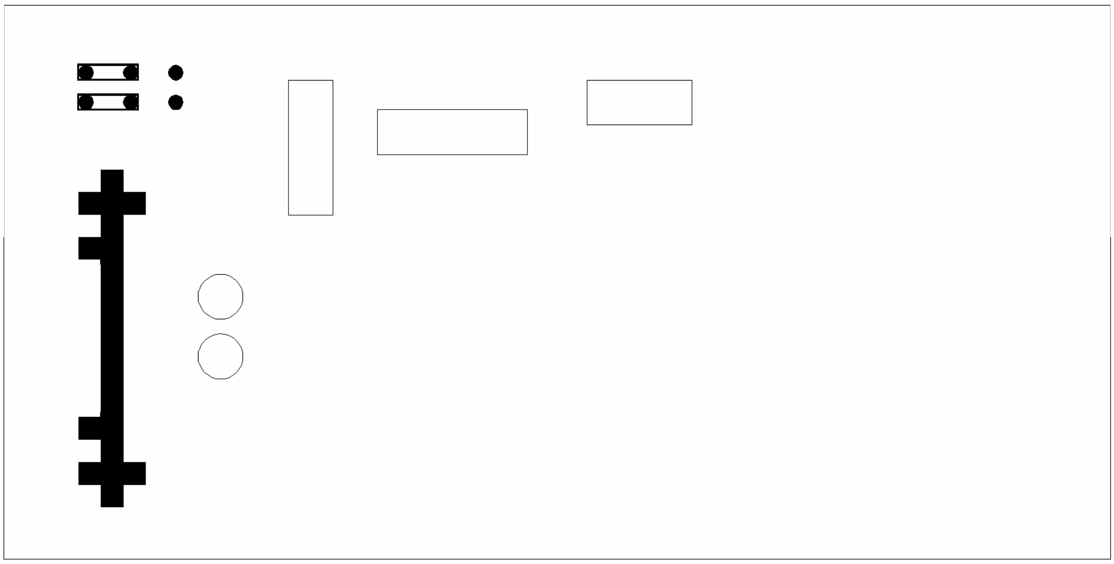
In the certain cases indicated above, the JCB Power Supply Jumper must be set to "on", otherwise it must be set to "off" (default). This is necessary to avoid a too high voltage at the transmitter in cases of a short transmitter cable and a long receiver cable.

To access the Power Supply Jumper, open the Junction/Control Box. The jumper position is defined in the following drawing:

JCB Power Supply Jumper "off"



JCB Power Supply Jumper "on"



If the transmitter is fed locally (e.g. by battery with a short supply cable), the transmitter output at the Junction/Control Box remains unconnected (only for SLS20 and SLS40, no "auto background" is possible then).

In order to heat the front windows of the SLS20 transmitter and receiver, connect 12V DC or AC (200 mA) to the respective inputs at the JCB. The windows will be heated to prevent ice and dew deposits under certain weather conditions.

The window of the SLS20-A, SLS40 and SLS40-A transmitter and receiver are always heated since the heating is connected to the general supply voltage.

B.2.2 Source control

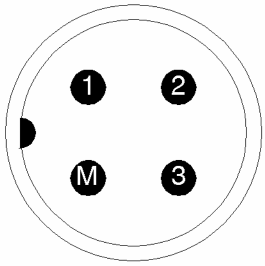
The transmitter is controlled by an electronic switch in the JCB. The LED on the top of the JCB is illuminated if this switch is "on". "LED on" does not automatically mean that the source is powered on. This additionally requires an internal or external power supply and the switch being in "int" or "ext" position.

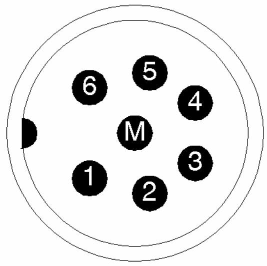
B.2.3 Overvoltage protection

In order to lower the sensitivity of the system to electrical discharges in the atmosphere, the JCB contains an overvoltage protection circuit. This requires connection of the ground connector at the case with a suitable ground.

B.2.4 Connectors

to transmitter





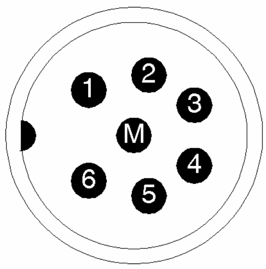
SLS20 / SLS40:

1: +12 V (+18 V max.)
2: ground (0 V)
3: window heating
M: window heating

SLS20-A / SLS40-A:

1: +12 to +18* V for beam steering and window heating
2: same as pin 1
3: +12 to +18* V for laser source
4: beam steering signal 1
5: beam steering signal 2
6: ground (0V)
M: same as pin 6

to receiver



SLS20 / SLS20-A:

1: +12 V (+18 V max.)
2: - 12 V (-18 V min.)
3: signal channel 1
4: signal channel 2
5: window heating
6: window heating
M: ground (0 V)

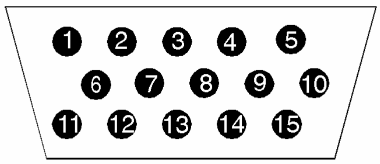
SLS40 / SLS40-A:

1: +12 to +18*V and window heating
2: - 12 to -18*V and window heating
3: signal channel 1A
4: signal channel 2A
5: signal channel 1B
6: signal channel 2B
M: ground (0 V)

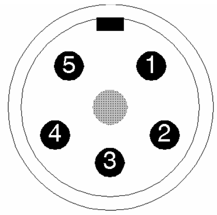
---

*) actual required voltage depends on cable length, see Appendix B.2.1

(I) Connectors at the Junction/Control Box (JCB)



to PC/SPU



power supply

1: +12 V from PC/SPU
2: - 12 V from PC/SPU
3: signal channel 1A
4: signal channel 2A
5: source on
6: signal channel 1B
7: signal channel 2B
8: beam steering signal 1
9: beam steering signal 2
10: n/c
11: n/c
12: n/c
13: n/c
14: ground (0 V)
15: ground (0 V)

1: +12 V, +18 V max. (SLS20)
+12 to +18*V (all other models)
2: - 12 V, -18 V. min. (SLS20)
- 12 to -18*V (all other models)
3: window heating (SLS20 only)
4: window heating (SLS20 only)
5: ground (0 V)

*) actual required voltage depends on cable length, see Appendix B.2.1

(II) Connectors at the Junction/Control Box (JCB)

Color code of supplied power supply connection cable:

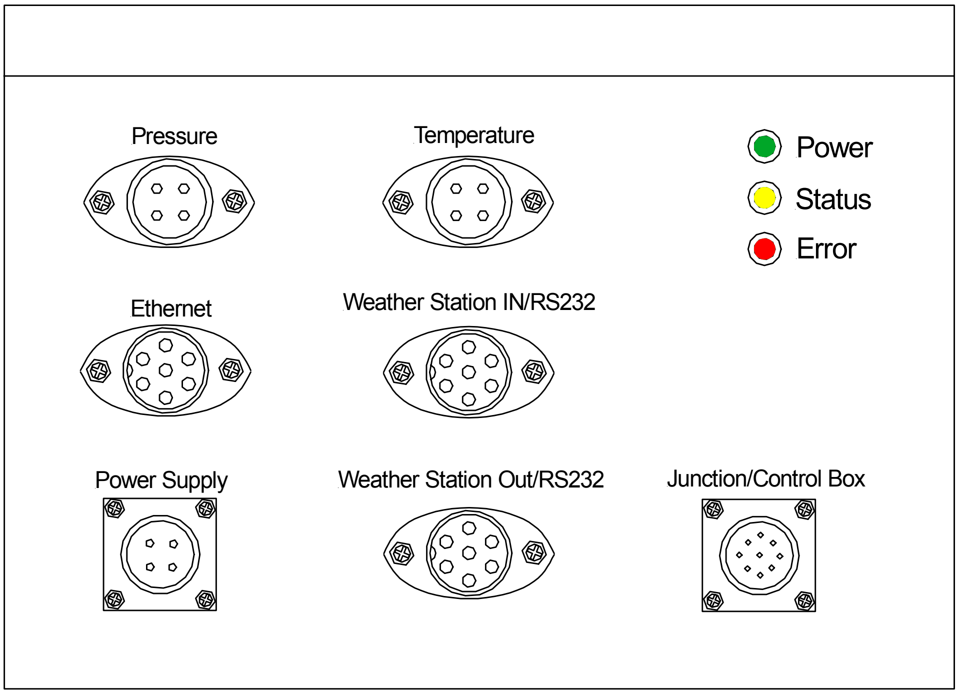
red:	pos. supply voltage + 12-18 V	(to pin 1)
blue:	neg. supply voltage - 12-18 V	(to pin 2)
black:	ground, 0 V	(to pin 5)
yellow:	window heating (SLS20 only)	(to pin 3)
yellow:	window heating (SLS20 only)	(to pin 4)

B.3 Signal Processing Unit (SPU)

The SPU is equipped with three LEDs. They give information about the following system properties:

Power	LED lights on green when proper voltage is applied to the system
Status	LED lights on yellow as follows: – The status LED blinks with a period of 2 seconds after having powered on the SLS system. The system is now ready for starting a measurement – In measurement mode, the LED is continuously illuminated with short interrupts every second. This indicates a 90% duty cycle.
Error	The SPU is equipped with a voltage monitoring system. In case of a voltage drop, the LED lights on red.

The overall configuration of the LEDs as well as connectors on the SPU front side is illustrated in the follwing figure:



B.3.1 Power Supply

The Signal Processing Unit (SPU) generates the 12V DC voltages needed for the SLS transmitter and receiver from an external power supply. For this, a single 12 V supply voltage with a peak current capability of around 2 A is required. Connection between the power source and the SPU is established via the supplied battery power supply cable having the following color code:

red cable: supply voltage +12 V (max 13.8 V, 2 A peak)
black cable: supply voltage ground

With the SLS20, the voltage for the window heating of transmitter and receiver (prevention of ice and dew deposits) must be connected to the JCB (see Appendix B.2.1). This can be the same voltage as used for the SPU.

B.3.2 Connectors

The standard SLS SPU is equipped with the following connectors:

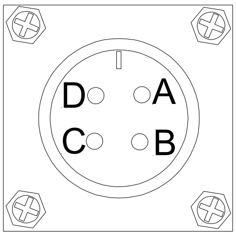
- Power Supply
- Ethernet
- Junction/Control Box
- Weather Station In/RS232
- Weather Station Out/RS232

With optional available SLSDMI-1 or SLSDMI-2 sensors, two additional connectors can be found on the front side of the SPU:

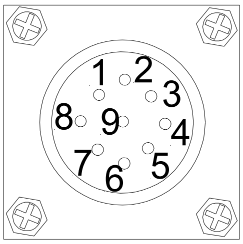
- Pressure
- Temperature

The following table gives an overview about all pin connection schemes:

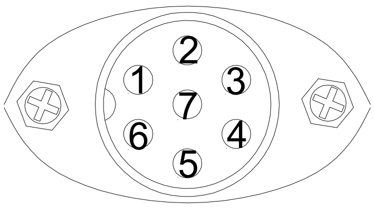
Male Connector: Power Supply	
Function	**Pin**
+12 VDC	A
+12 VDC	B
GND	C
GND	D



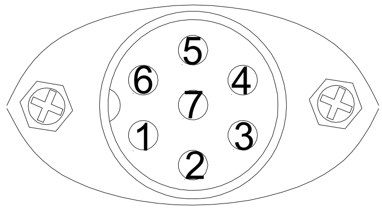
Male Connector: Junction/Control Box	
Function	**Pin**
-12V DC	1
+12V DC	2
GND	3
Signal XA	4
Signal YA	5
Signal XB	6
Signal YB	7
Not connected	8
Laser On	9



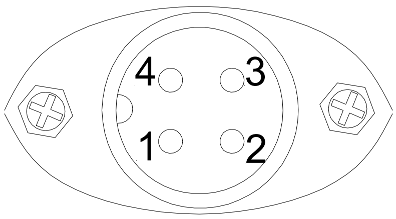
Male Connector: Ethernet	
Function	**Pin**
Signal TX-	1
Signal TX+	2
Signal RX-	3
Signal RX+	4
Not connected	5
Not connected	6
Not connected	7



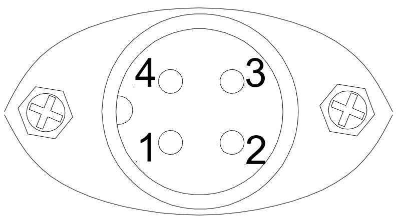
Female Connectors: Weather Station In/RS232 Weather Station Out/RS232	
Function	**Pin**
GND	1
Signal RX	2
Signal TX	3
+12V DC	4
+12V DC RS485	5
GND RS485	6
GND	7



Female Connector: Pressure	
Function	**Pin**
+12V DC	1
GND	2
Signal Pressure	3
Not connected	4



Female Connector: Temperature	
Function	**Pin**
+12V DC	1
GND	2
Signal Temperature 1	3
Signal Temperature 2	4



B.4 Direct Meteorological Input SLSDMI (Optional)

B.4.1 Overview

The SLSDMI-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.

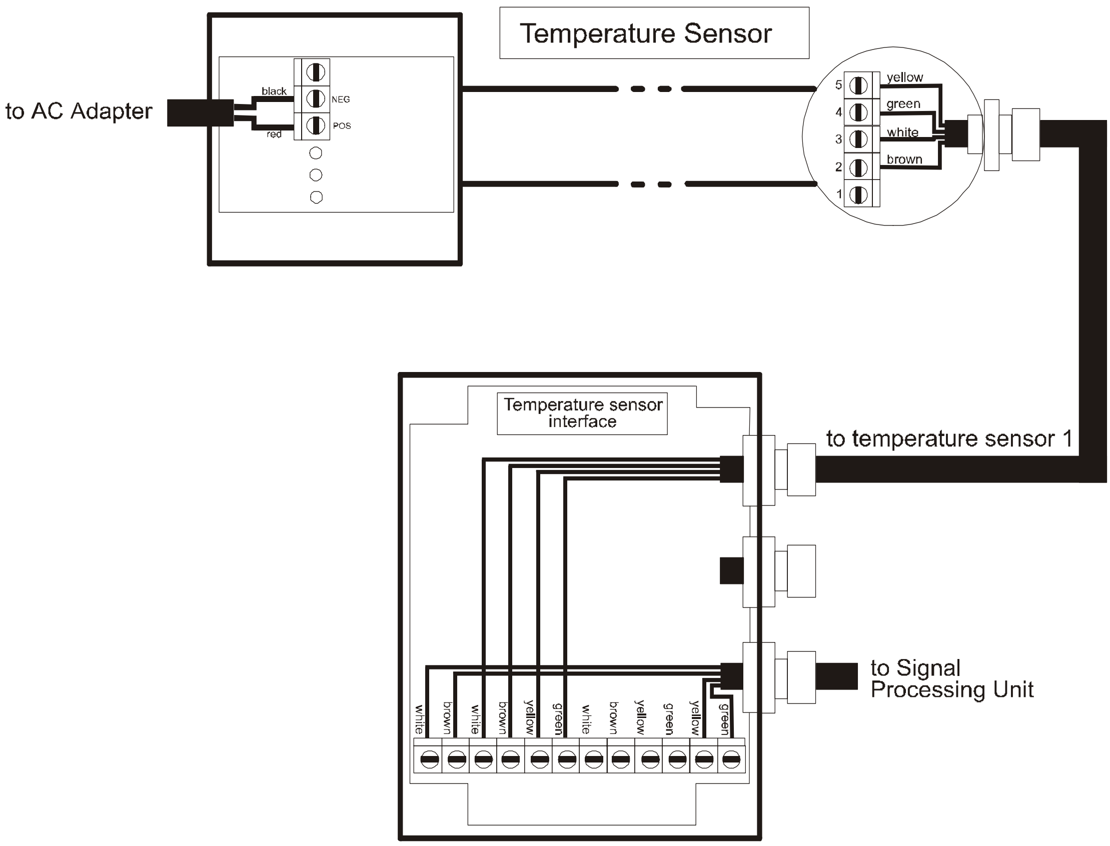
The PT1000 temperature sensor is plugged into a ventilated radiation shield which can be installed on the tower. The radiation shield avoids measurement errors due to sun radiation. The PT1000 is connected to a SLSDMI sensor interface which converts the PT1000 resistance into a voltage. The barometric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

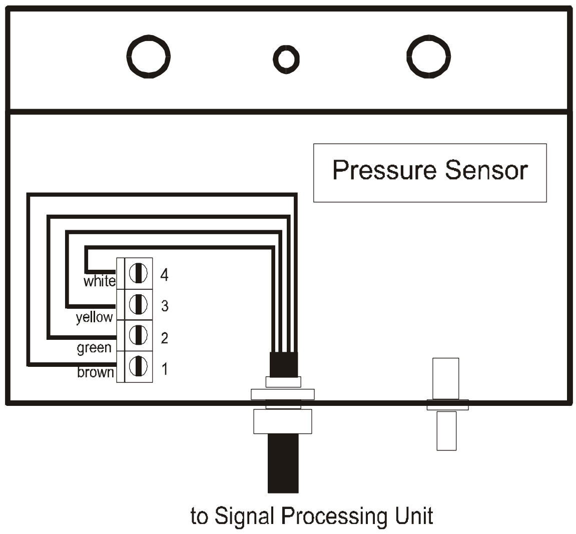
B.4.2 Appliance

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 10m 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. An electrical connection scheme of the SLSDMI-1 option is shown in the following figure:

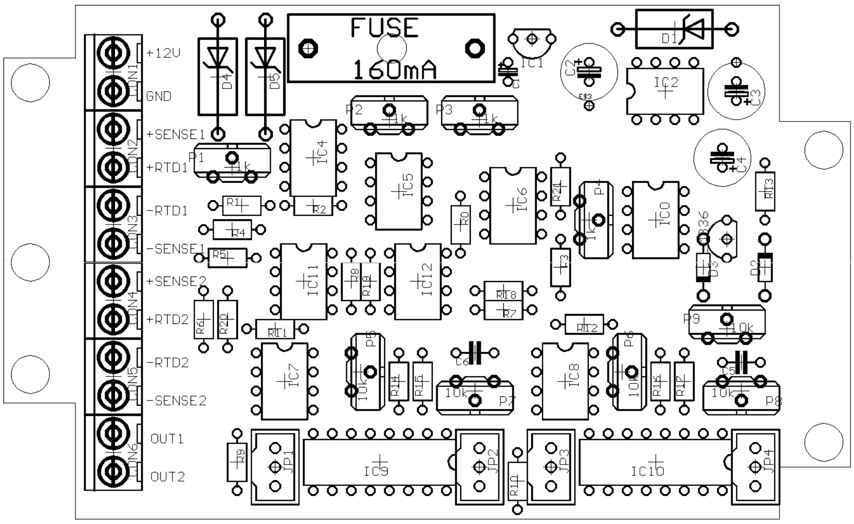

Temperature Sensor
to AC Adapter
black
NEG
POS
red
yellow
green
white
brown
5
4
3
2
1
Temperature sensor interface
to temperature sensor 1
to Signal Processing Unit
white
brown
white
brown
yellow
green
white
brown
yellow
green
yellow
green


Pressure Sensor
white
yellow
green
brown
4
3
2
1
to Signal Processing Unit

B.4.3 PT1000 Interface

The Temperature Sensor Interface SLSDMI-1 / SLSDMI-2 converts the resistance of two PT1000 Platinum temperature sensors into two output voltages 0 to 10 V corresponding to a temperature range of -50 to +50°C.

Connection scheme:



V+	+12 to +15 V supply voltage
GND	supply and output ground
+SENSE1	voltage out sensor 1, positive
+RTD1	current sensor 1, positive
-RTD1	current sensor 1, negative
-SENSE1	voltage out sensor 1, negative
+SENSE2	voltage out sensor 2, positive
+RTD2	current sensor 2, positive
-RTD2	current sensor 2, negative
-SENSE2	voltage out sensor 2, negative
OUT1	output voltage or current sensor 1
OUT2	output voltage or current sensor 2

Jumper positions:

Jumpers 1-4	upper position: voltage output lower position: current output

(The 4-20 mA current output is optionally available for lines of more than 300 m length.)

Appendix C Specifications

General:

source:	laser diode
wavelength:	670 nm±10 nm
lifetime:	20 000 hours typically
beam collimation:	by 3 lenses
beam divergence:	10 mrad x 3.5 mrad
scan cone radius:	1° (SLS20-A and SLS40-A only)
beam output power:	1 mW mean, 2 mW peak
modulation frequency:	20 kHz
modulation depth:	90%
beam displacement:	2.7 mm
number of detectors:	2 (SLS20 and SLS20-A) 4 (SLS40 and SLS40-A)
detector separation:	2.7 mm
detector diameter:	2.5 mm
receiver bandwidth:	4 kHz

Supply Voltages and Currents:

transmitter SLS20	+12 V 0.05 A
window heating	12 V 0.1 A
transmitter SLS40	+12 V 0.15 A (including window heating)
transmitter SLS20-A / SLS40-A	+12 V 0.35 A (including window heating)
receiver SLS20	+12 V 0.05 A -12 V 0.05 A
window heating	12 V 0.1 A
receiver SLS20-A	+12 V 0.15 A -12 V 0.15 A (including window heating)
receiver SLS40 / SLS40-A	+12 V 0.2 A -12 V 0.2 A (including window heating)

A larger voltage must be supplied at the remote cable end to allow for voltage drop over the cable (see table in Appendix B.2.1).

SPU	+12 V 0.7 A for SLS20(-A), peak 1.5 A +12 V 1.4 A for SLS40(-A), peak 2.0 A

Temperature Ranges:

Transmitter	-20°C to 50°C operation -40°C to 60°C storage
Receiver	-25°C to 60°C operation -40°C to 60°C storage
JCB	-25°C to 50°C operation -40°C to 60°C storage
SPU	-20°C to 40°C operation -40°C to 60°C storage

Dimensions and Weights:

SLS20/SLS40 transmitter	0.65 m x 0.11 m x 0.11 m,	3.0 kg
SLS20-A/SLS40-A transmitter	0.70 m x 0.11 m x 0.11 m,	3.5 kg
SLS20/SLS20-A receiver	0.60 m x 0.11 m x 0.11 m,	2.9 kg
SLS40/SLS40-A receiver	0.62 m x 0.12 m x 0.12 m,	4.1 kg
JCB SLS20	0.14 m x 0.12 m x 0.06 m,	0.4 kg
JCB SLS40	0.22 m x 0.19 m x 0.10 m,	1.8 kg
SPU	0.25 m x 0.22 m x 0.19 m,	5.5 kg

Appendix D Avoiding measurement errors

D.1 Stability of the mounting platforms

Wind induced mechanical vibrations of the instruments, in particular of the SLS20(-A) transmitter, may seriously affect the measurements. Since this error cannot be corrected for later, always verify that the transmitter and the receiver are stably mounted.

Instabilities of the mountings affect the measurement as follows: A vibration (mainly a twist) of the transmitter causes a wander of the laser beams at the receiver and hence produces a variation of the measured intensities. This intensity variation is added to the turbulent intensity fluctuations. The calculated values of C_n^2 will be too high, the calculated l_0 will be too low or too high. This causes errors in the heat and (even more pronounced) in the momentum flux. Note that stability problems generally are more important when the turbulent intensity fluctuations (or C_n^2) are small.

The SLS40(-A) receiver has a separate pair of detectors which allows automatic identification of and correction for the transmitter vibrations by the SLSRUN software. However also the SLS40(-A) transmitter should be mounted as stable as possible.

In principle, a vibration of the receiver may have a similar effect. However, since the field of view of the receiver is much larger than the beam's divergence, the stability of the receiver mounting is much less critical.

As a rule of thumb, the SLS20(-A) is affected by vibrations having such a magnitude that you can feel them with your hands at the transmitter. If you cannot improve the mounting (e.g. if you use tripods), apply a wind shield mounted upwinds to the transmitter tripod.

In order to test the stability of the mountings, you may also try to move and twist the instruments with your hands. Estimate the wind force acting: This force must not move the instruments. Take into account that already a fraction of
1 mrad (0.05 degrees) twist of the transmitter has an effect.

D.2 Low signal - to - noise ratio

The SLSRUN software displays an error message if the signal-to-noise ratio is unacceptable. Marginal cases pass the software test and may cause errors of a limited extend.

A low signal-to-noise ratio means that a significant amount of noise is added to the turbulent signal fluctuations. This noise is uncorrelated in both channels. Hence it tends to increase the calculated C_n^2 and decrease the calculated l_0 values. Accordingly the calculated heat and momentum fluxes will be too high.

Signal-to-noise problems only occur when C_n^2 is very small, i.e. near the measurement limit. They rapidly become negligible as C_n^2 increases. Since small C_n^2 values go along with small heat fluxes, possibly affected periods in heat flux time series are easily identified. The affected periods typically last several minutes until the heat flux (absolute value) has increased.

With the SLS20(-A)/ SLS40(-A), signal-to-noise limitations are rare. If observed, they are mainly due to transmitter vibrations (see above). They may also have some importance under special measurement conditions, e.g. if measurements are taken over water or under weather conditions which are connected with small heat fluxes (absolute values).

You improve the signal-to-noise ratio by

a. shortening the path if it is longer than 200 m or lengthening the path if it is shorter than 100 m

b. lowering the measurement height if the surface roughness and your measurement task allows.

D.3 Inner scale measurement range

There is a lower limit of the ℓ_0 values which can be accurately determined by the SLS20(-A) / SLS40(-A). If ℓ_0 falls below this limit, the instrument is susceptible to measurement errors.

The lower ℓ_0 limit depends on the path length. It is 2 mm for paths of 100 m or longer, 2.5 mm for a path of 80 m, and 3.5 mm for a path of 50 m. If small ℓ_0 values are to be measured, it is therefore advisable to use a minimum path length of 100 m.

Note that ℓ_0 becomes smaller at larger wind speeds or closer to the ground. The height dependence of ℓ_0 may allow you to adapt the height of the path to the given measurement range.

D.4 Crosstalk

The SRUN software corrects for crosstalk between the two channels. This correction can be essential.

The Measure Background procedure for the determination of the crosstalk coefficients should always be performed after the instruments have been newly installed (see section 2.3 g).

Incorrect crosstalk coefficients will systematically

either a) increase C_n^2, ℓ_0,
slightly change heat flux,
decrease (absolute value of) momentum flux

or b) vice versa,

depending on the crosstalk coefficients erroneously used. If crosstalk coefficients of 0.0 are used or the "ignore background" option is selected, the error direction is as described under a).

D.5 Misalignment

Misalignment of the transmitter (i.e. the receiver being at the edge of the laser beam) has only a minor effect on the accuracy of the measurements as long as the received intensities are sufficiently high. The main disadvantage of a transmitter misalignment is that it magnifies the influence of transmitter instabilities (see section 1, Appendix D). Also, of course, the signal-to-noise ratio becomes worse.

The alignment of the receiver is easier than that of the transmitter due to the larger field of view. However the correct receiver alignment is very essential to achieve correct measurement results. Special care must be taken to insure that the transmitter is within the field of view of both detectors.

D.6 Different intensities in the two channels

There is no error caused by a difference of the mean intensities in the two channels (SLS20(-A)) or four channels (SLS40(-A)).

Appendix E CE Declaration of Conformity

CE

Declaration of Conformity

according to EN 45014

Name and address of manufacturer:

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

We declare that the products

Surface Layer Scintillometer

Models SLS20, SLS20-A, SLS40, SLS40-A

comply with the Electromagnetic Compatibility Regulations (EMC) and, as far as 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, PCs, power supplies, cable, etc. by others than the manufacturer.

Applicable norms and standards:

EN 50081-1, EN 50082-1
EN 55022 Class B
EN 60555-2, EN 60555-3
EN 55014
IEC 801-1 (1988), IEC 801-2 (1991), IEC 801-3 (1984)
CCITT K20, IEC 65 (Sec) 144