RPG-MWSC-160

Microwave Scintillometer

Installation & Maintenance Guide

Version 1.21

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Safety Instructions

Instrument Use

The RPG-MWSC-160 Scintillometer is a microwave instrument for the measurement of sensible and latent heat fluxes from the ground. The transmitter emits a small amount of microwave power at 160.8 GHz and the receiver, separated from the transmitter by several kilometers, receives this power and analyses it in terms of fluctuations caused by the turbulent air motion close to the ground when being lifted upwards. The scintillometer is used in hydrology to determine the amount of evaporated surface water as a function of time, which is needed to optimize irrigation systems. The system should only be used for the purpose described here.

Before Starting Operation

Read these instructions carefully. They contain important notes for the use, safety and maintenance of the instrument. Make sure that all persons involved in the installation and maintenance of this hardware have registered the content of this document and have access to it any time.
Only use the instrument for the purpose mentioned in these instructions.
Before powering up any part of the hardware, it is important to consider guidelines for safe operation (meaning the instrument as well as the operators). In addition to the guidelines given here, the user should use **common sense** precautions to prevent damages to personnel and equipment.
The described hardware is intended for **outdoor use** only and should **never** be operated inside buildings unattended.

The instrument emits up to 25 mW (at 160.8 GHz) of microwave power during measurement operation, which may interfere with other high frequency equipment close to the instrument. When operated outside of buildings, this possible interference is considered to be negligible. **The outdoor operation of the instrument requires a permission of the national bureau responsible for the regulation of electromagnetic emission in the country where the instrument is deployed. The end user of the instrument is responsible for the acquisition of all required permissions related to electromagnetic emission at the place of deployment. The instrument must not be operated before all these permissions are in place.**

The instrument is often operated on tripods of up to 5 m height. All used tripods must be installed on solid ground and secured to ground by a steel cable. Otherwise the tripod (together with the scintillometer) may collapse in strong wind conditions and may lead to possible injuries. **It is therefore recommended to install a protection fence around the tripod (radius 1 m)**.
Any damages to the instrument or injuries of persons caused by the improper installation of tripods used in combination with the instrument are in the responsibility of the user.

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For safety reasons, install a fence around the scintillometer for warning people to enter the danger zone (a circle of 1 m radius around the centre of the tripod).

This instrument is not intended to be used or installed by children or persons with physical or mental disabilities or who lack experience or have not been supervised by personal responsible for their safety.

Before powering the instrument, make sure that all power cables and inter-connecting cables to accessory hardware (for instance weather station, GPS clock, LAS) are **completely and properly** installed, according to the instructions described in the following paragraphs.

Installation Related Technical Data

The instrument should be handled with the same care as other electronic equipment. The scintillometer should be protected from fire, over voltages (caused by lightning), falling/flying objects (debris during hurricanes, typhoons, and tornados), physical forces, shock and vibration at levels, which would be harmful to computer hardware or other sensitive electronic equipment.

The instrument is classified to **protection class IP44**.
The safe environmental parameters for **transport and storage** are:

Parameter	Range
Temperature	-40 °C to +50 °C
Humidity	1% to 100% relative humidity
Pressure	300 hPa to 1300 hPa (mbar)
Vibration	< 10 g acceleration
Shock	< 20 g acceleration

The safe environmental parameters for **operation** are:

Parameter	Range
Temperature	-40 °C to +50 °C
Humidity	1% to 100% relative humidity
Pressure	300 hPa to 1300 hPa (mbar)
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Power requirements:

Parameter	
Operating Voltage	12 V DC nominal
Power consumption	Receiver: 20 Watt typical, transmitter: 15 Watt typical

In order to protect the instrument from damages caused by lightning, it is recommended to install a grounding cable between a close-by grounding point and the tripod / scintillometer.
The scintillometer receiver / transmitter modules can be powered by any 12 V DC supply or battery.

RPG provides an optional AC to DC converter module to run the instrument from AC power lines. If this option is selected, follow these safety rules:

- Connect the power cables only to a shock- and water-proof socket that has been installed according to regulations. The power plugs must be kept dry under all conditions.
- For lightning protection, the use of **surge breakers** is strongly recommended. **Any damage to the instrument or its accessory hardware caused by lightning is not covered by RPG warranty!**
- Do not pull the power cables over sharp edges. Cables must be protected from heat and oil.
- Do not pull the power plugs by the cable or touch them with wet hands.
- Unplug the equipment immediately from power supply if the instrument or power cable / plugs appear to be damaged.
- Unplug the power cable, when GPS-clock, weather station or the LAS module are disconnected from or connected to the instrument.

When installing the scintillometer with an external AC to DC converter (connected to AC power line) **make sure the power connectors are plugged into power sockets with proper grounding pins (PE = protection earth)**. Otherwise, the scintillometer parts are electrically floating and the instrument may get more easily hit by lightning strokes.

If the PE pins of the power sockets are not properly connected to protective earth, the user may be exposed to electrical shock when touching the instrument.

Any malfunctions and failures arising from operating the scintillometer and its accessories (including cables and controlling host PC) outside of the specified environmental conditions, are not covered by the instrument warranty. Damages (and consequential damages) from either violating the instruments physical and electrical integrity, or arising from third parties (including animals, e.g. bird attack to the microwave window) are not covered by the instrument's warranty.

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Microwave Emission Safety Instructions

During measurements the scintillometer transmitter continuously emits about P =0.025 Watts of microwave power at 160.8 GHz. The computed antenna gain G is 52 dB with -20 dB sidelobes at 1° off-axis.
Most countries have determined a human exposure electrical field strength safety limit E_{lim}. For instance, the CE level for E_{lim} is 61 V/m, but in other countries outside of the European Union different safety limits may be in place. For the following computation of safety distances d_s the user should apply the E_{lim} value valid in the country where the instrument is deployed.
The on-axis safety distance is given by:

$$d_s = \frac{\sqrt{GPZ_0/(4\pi)}}{E_{lim}}$$

where Z_0 = 377 Ω is the vacuum space impedance. **With the numbers given above, the on axis safety distance is about 6 meters**. In off-axis direction of ±1° the safety distance drops down to 0.6 m (side lobe). **The user must ensure that the transmitter antenna beam does not hit persons within a range of 6 m! This requirement can be easily fulfilled by using tripods of at least 3 m height or by deployment on high buildings.**

Spare Parts

If any hardware of the instrument or its accessories, as well as inter-connecting cables or power cables need to be replaced due to damage or general maintenance intervals, **only original spare parts provided by RPG must be used**. No reliability is taken for any direct damages to the instrument and its accessories or indirect damages to the instrument's environment caused by using hardware not fabricated or delivered originally by RPG.

Fuse Protection

The receiver's and transmitter's DC ports are protected by fuses (*Figures 1/2*). If required, **replace fuses as marked only**.

Further Information

If further technical support is required, please contact:

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1. Scope of this Document

This document contains information about:

- Installation and maintenance of the RPG-MWSC-160 and optical LAS systems that are operated in combination with the microwave system.

2. Technical Description

The MicroWave Scintillometer (MWS) RPG-MWSC-160 consists of a receiver and transmitter. It is combined with a Large Aperture Scintillometer (LAS) observing in the near infrared spectral region. Any commercially available LAS can be used. The combined system includes two transmitters and two receivers and is henceforth called OMS (Optical/Microwave Scintillometer). This chapter describes the MWS units only. For technical information on the LAS system please refer to the manufacturer's manual.

Parameter		Specification
Frequency		160.8 GHz (λ=1.86 mm)
Radiated power		maximum power: <25 mW, 50 dB attenuator
Antenna type		Cassegrain with 300 mm aperture
Antenna gain		52 dB
Beam width		0.45° FWHM
Detection bandwidth		10 kHz
Gain stability		> 2.0 × 10^{-5}
Temperature stability		< 0.03 K (two-stage control)
Power supply		10.8-13.2 V DC
Power consumption		max. 60 W (per unit), 20 W typical (RX), 15 W typical (TX)
Output data	Level 0	• 1 kHz digital raw data for RPG-MWSC-160 and LAS • housekeeping data.
	Level 1	• (co)variances of the combined OMS system.
	Level 2	• structure parameters $C_n{}^2$ • sensible and latent heat fluxes H, $L_v E$ (with weather station)
Type of installation		Line of sight TX/RX system (transmit/receive)
Baseline length		500 m to 10 km

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The microwave signal is synchronously digitized with the analogue LAS signal and fed to the Scintillometer-PC (SP-C). The S-PC offers an Ethernet interface to set up a connection with an external Host-PC (H-PC). The H-PC is used to operate the combined OMS system:

- Measurement, setup and configuration.
- Complete data processing from digitized raw data to sensible and latent heat fluxes.
- Archiving of all data formats (see Appendix).

Once a measurement has been initialized via the H-PC, the scintillometer can be disconnected and work autonomously.

2.1 RPG-MWSC-160 Receiver

Figure 1 gives an overview on the receiver's connectors and components attached to the housing.

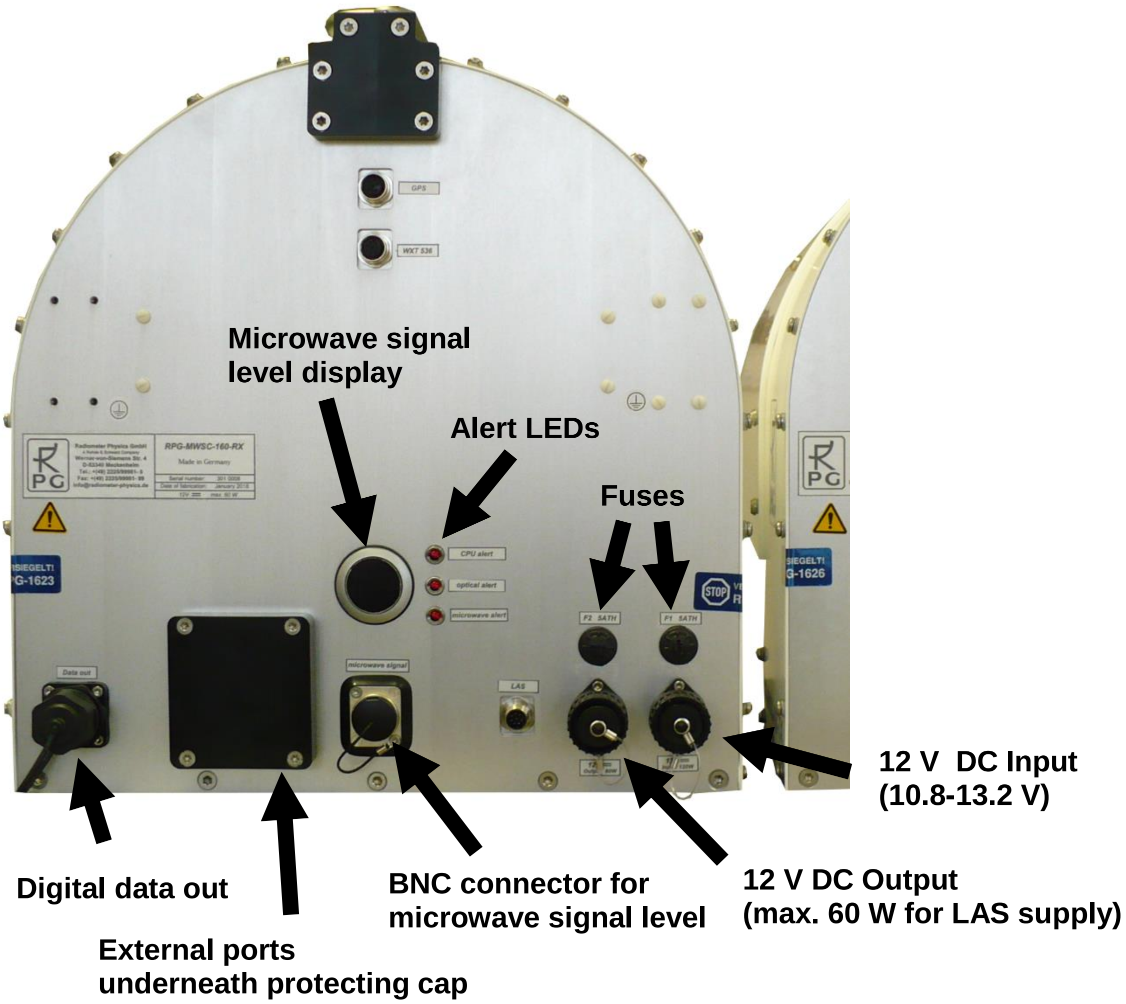

Figure 1: Rear view of the RPG-MWSC-160 receiver.

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The RPG-MWSC-160 is designed to provide the power supply for the connected LAS system:

- DC socket ***12 V ⎓ 120 W Input*** is either connected to an appropriate 12 V DC source or to the optional AC power supply that is mounted to the receiver back plane.

- DC socket ***12 V ⎓ 60 W Output*** is used for 12 V DC supply from the LAS device and provides the analogue demodulated voltage(s) from the LAS receiver.

LAS connects the internal S-PC to the external H-PC. Three LEDs on the backside of the receiver unit inform about the status of the combined system (*Figure 2*):

- **CPU alert** … if blinking, the S-PC is not running.
- **optical alert** … if on, the signal level from optical scintillometer is too low.
- **microwave alert** … if on, the signal level from microwave scintillometer is too low.

The ***microwave signal*** level can be directly measured on a BNC service connector. This connector should only be used in combination with a floating potential device like a battery powered digital volt meter. Otherwise ground loop problems may occur which deteriorate the microwave signal. The S-PC can be accessed via external ports for monitor, mouse and keyboard. The ports are protected by a removable protecting cap (*Figure 2*). A GPS clock for positioning and timing and the optional weather station for flux calculations are mounted to the receiver housing. *Figure 3* shows the back plane of the transmitter housing.

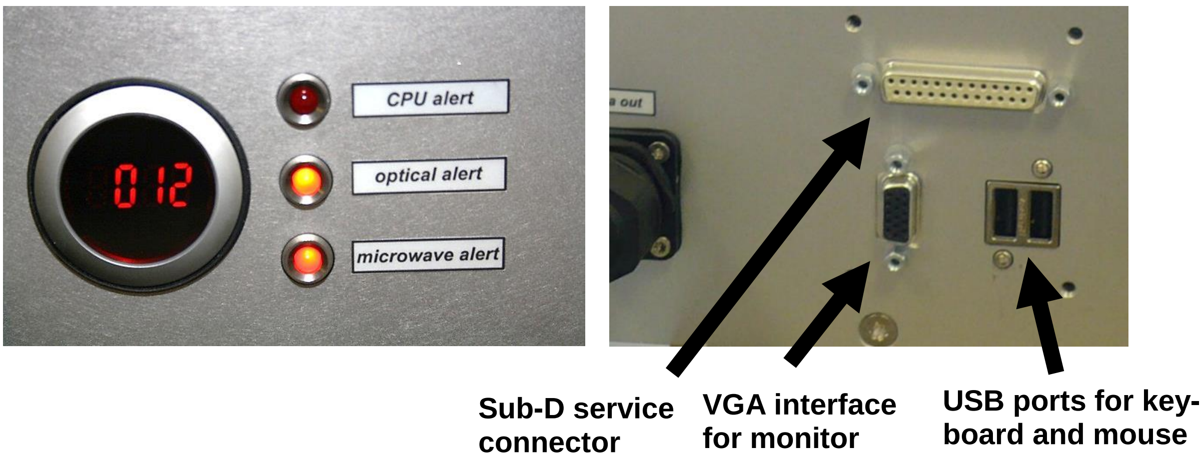

Figure 2: Left: Signal level and status alerts for the combined system. Right: External ports. Use Allen key to remove protecting cap.

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2.2 RPG-MWSC-160 Transmitter

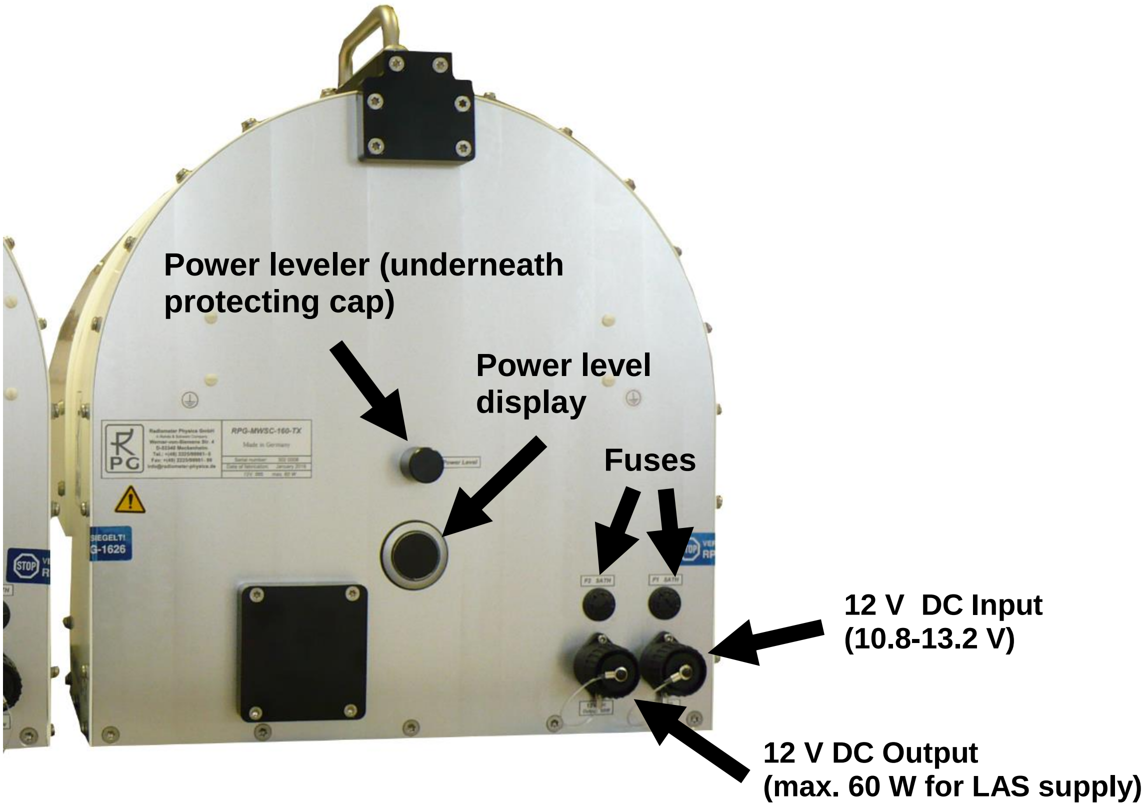

Figure 3: Rear view of the RPG-MWSC-160 transmitter.

The maximum ***Power Level*** of the transmitter signal of about 25 mW can be manually reduced using a turning knob at the backside of the transmitter unit. The turning knob is protected by a plastic cap. The power level display gives a value between 0 and 2000 as a proxy for the output power.

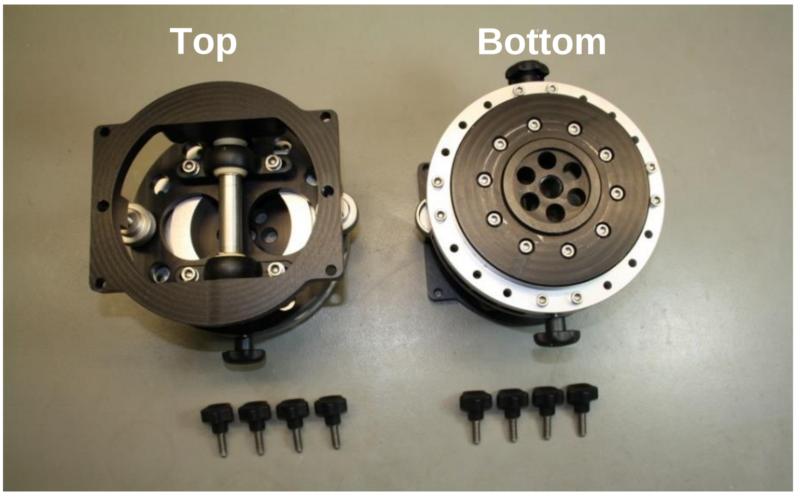

Figure 4: Top and bottom view of the alignment units for RPG-MWSC-160.

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Apart from the receiver and the transmitter, two alignment units are part of the RPG-MWSC-160 base package. These units are necessary for an accurate alignment of the receiver and the transmitter along the measurement path. The units allow for adjusting the instruments' pointing along two axes: ±10°in elevation and 0°-360° in azimuth direction (*Figure 4*).

2.3 RPG-MWSC-160 Accessories

Apart from the two base units of the RPG-MWSC-160, different optional accessories are available.
If the complete OMS system shall be mounted on tripods, different tripod heights with maximum heights between 3 m and 5 m are available (*Figure 5)*. Increasing path lengths need increasing observation height (*Figure 18*). When using the optional double base plate MWS and LAS transmitters/receivers can be mounted on a single tripod (*Figures 6*/7).

Figure 5: Tripods with different maximum heights are available (e.g. 3 m).

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Figure 6: Double base plate for combined mounting of MWS and LAS units.

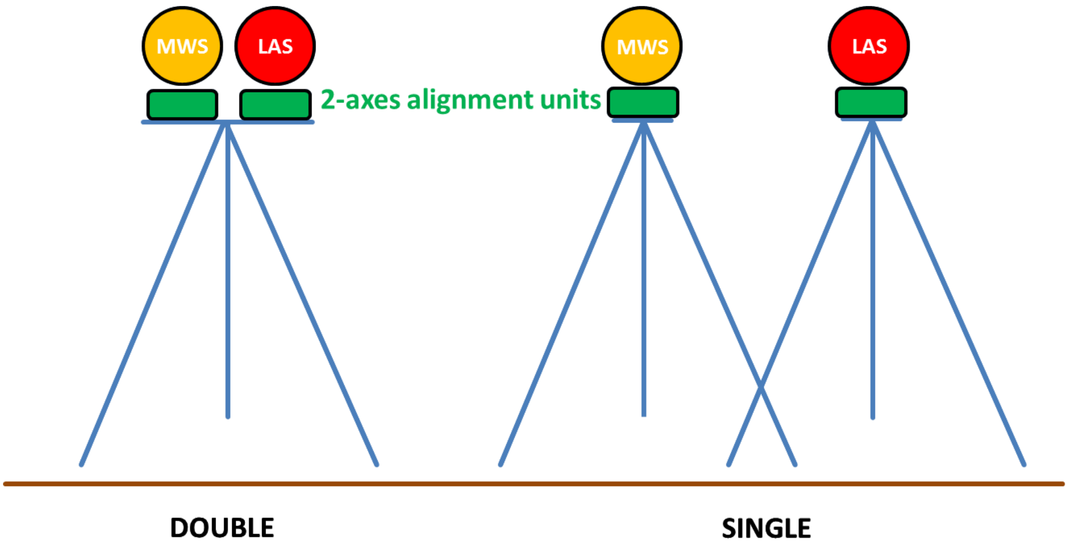

Figure 7: Mounting options for the combined OMS system.

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For the pre-alignment of the MWS units alignment telescopes are available (*Figure 8*).

Figure 8: Alignment telescopes for the RPG-MWSC-160.

For the optional AC supply two power supplies – mounted to backside of each unit – and 50 m power cables are available (*Figure 9*). The AC supplies power both the MWS and LAS receiver/transmitter. The only exception is transmitter of BLS2000 from Scintec. This unit must be supplied separately, because its power consumption is too large.

Figure 9: Left: AC power supply mounted to RPG-MWSC-160 transmitter,
Right: 50 m power cable.

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The external weather station Vaisala WXT-520 or WXT-536 (*Figure 10*) is needed for online calculation of the sensible and latent heat fluxes. The station is mounted to a pole attached to the receiver housing. Temperature, relative humidity, pressure, wind direction and speed (2D sonic) are automatically read by the operating software and used within the data processing chain.

Figure 10: Weather station Vaisala WXT-536.

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3. Installation

This chapter covers the complete installation and setup of the OMS system.

3.1 Unpacking RPG-MWSC-160

The RPG-MWS-160 transmit/receive system is shipped in a single flight case with the dimensions given in *Table 1*.

Content	Length [mm]	Width [mm]	Height [mm]	Total weight [kg]
• MWS transmitter • MWS receiver • Rain shields • Alignment units • Power cables • Data cables • Tool set • Weather station • Alignment telescopes • Double base plate	950	760	650	~80

Table 1: RPG-MWSC-160 packing list. Optional components in gray.

Figure 11: Unpacking the RPG-MWSC-160.

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The standard cable set consists of:

- Power/data cables for connecting LAS units with RPG-MWSC-160.
- 10 m power cable for 12 VDC supply.
- A fibre-optics-to-Ethernet-converter (including short network cable).
- 50 m fibre-optical data cable for connecting RPG-MWSC-160 receiver to H-PC.
- Grounding kit to protect the scintillometer units and the weather station.

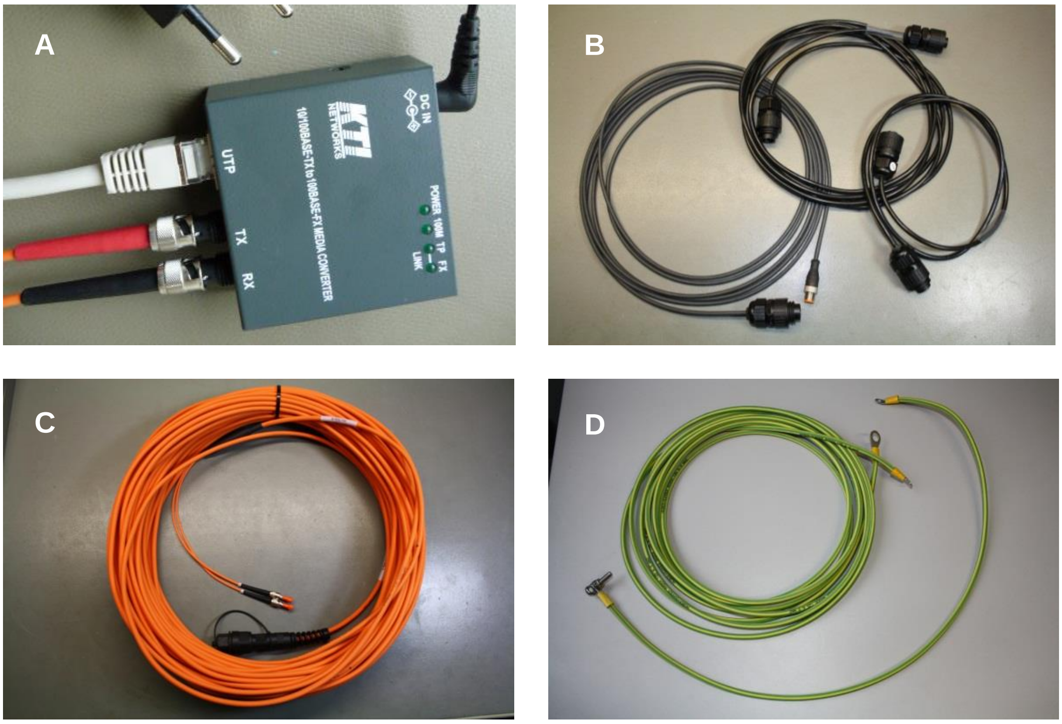

Figure 12: A: AC power cable (50 m), B: Connecting cables between MWSC and LAS units for data (only receiver) and power (these cable may differ for different LAS systems), C: Data cable (50 m), D: Grounding kit (only shown for receiver).

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Figure 13: Different views of RPG-MWSC-160 units.

3.2 Assembling the RPG-MWSC-160 Units

The RPG-MWSC-160 units are delivered with rain shields are already mounted to the instrument housing. The receiver's GPS clock is already installed as well. However, in case it is required by the specific measurement setup, the user can mount the GPS and the weather station (*Figure 14*) on the other side of the housing.

3.2.1 Mounting GPS Clock and Weather Station

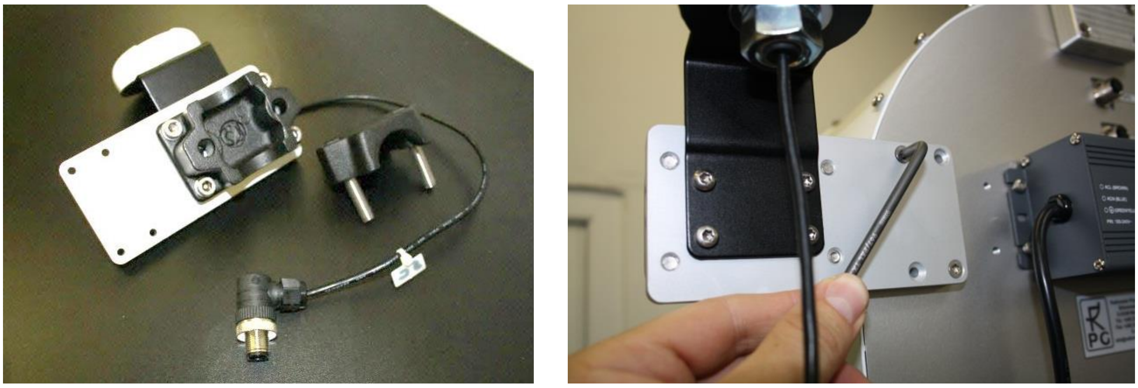

Figure 14: Mounting the GPS clock to the RPG-MWSC-160 receiver. The mounting plate can either be attached to the left or right side of the receiver box.

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Figure 15: Mounting the weather station Vaisala WXT-536. A: Fix the station on top of the pole. The "North" arrow has to be aligned with the instrument's side wall. B: Station, mounting pole and connecting cable. C: Use Allan key to mount the pole to the RPG-MWSC-160 receiver. D: Take care that the pole ends well above the receiver's bottom plate level.

Figure 16: Connecting GPS clock and weather station.

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3.2.2 Grounding of the instruments

The grounding kit consists of three cables. A short cable connects the weather station with the receiver housing. Two 5 m cables are used to connect the housings of receiver and transmitter with an external nearby grounding point. In case an AC supply is used, the latter cables are not needed, because the instruments are grounded via the power supplies.

Figure 17: Grounding kit.

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3.3 Setting up the Combined OMS System

The setup of the OMS system needs to comply with several requirements in order to guarantee a high data quality.

The setup is completely characterized by the …

- path length L, which is the distance between transmitters and receivers,
- beam heights above ground along L,
- beam distance d between LAS beam and MWS beam.

Figure 18 is a schematic overview of the measurement setup. The beam heights depend on the measured instruments' heights above ground and the topography along L. The topography and L are known from GPS measurements or can be derived from a map.

The beam heights are used to determine an effective path height H_{eff}, which is an important input parameter for flux calculations (refer to *Instrument Manual*). For horizontal beams over flat terrain, H_{eff} equals the observation height H_{obs}. The ratio between H_{obs} and L determines the strength of the observed scintillation signal. In order to **avoid saturation** of the LAS signal, long path length should go along with high observation heights (refer to *Instrument Manual*). *Figure 18* gives an orientation for the choice of both parameters.

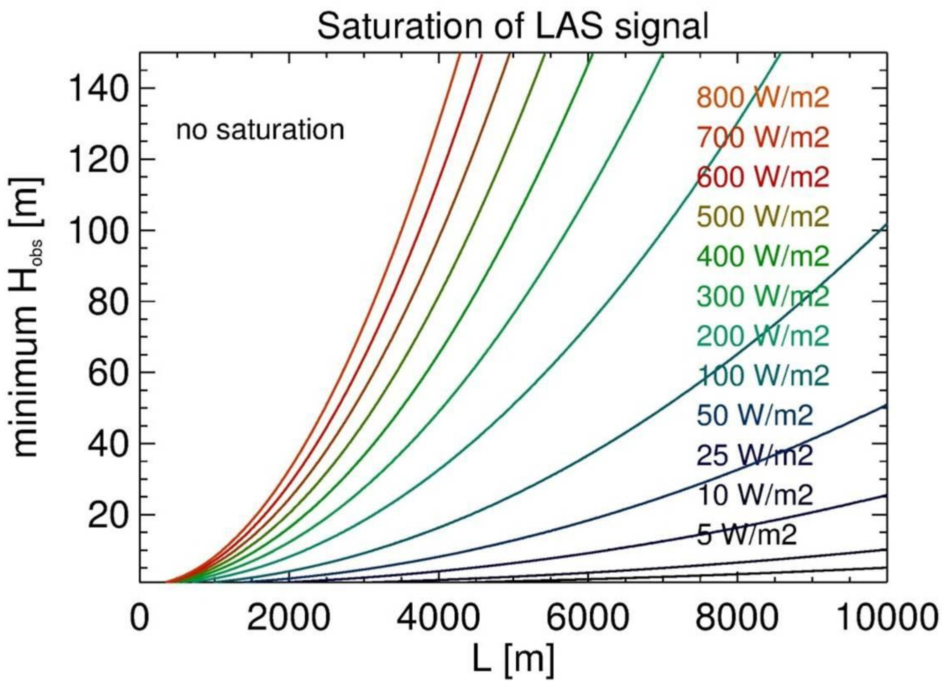

Figure 18: Saturation of the LAS signal in dependence of the observed sensible heat fluxes (T=300 K, RH=80%, p=1013.25 hPa), saturation criterion from Ochs and Wilson, 1993 [1].

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Furthermore, the measured relative instrument positions determine the displacements d_T and d_R between transmitters and between receivers, respectively. The displacements $d_T \ll L$ and $d_R \ll L$ give the beam distance d (*Figure 19*).The two instrument pairs are set up with crossing **signal paths**. This reduces d in the middle of the path and improves the overlap between the two scintillation signals observed at optical and microwave observations.

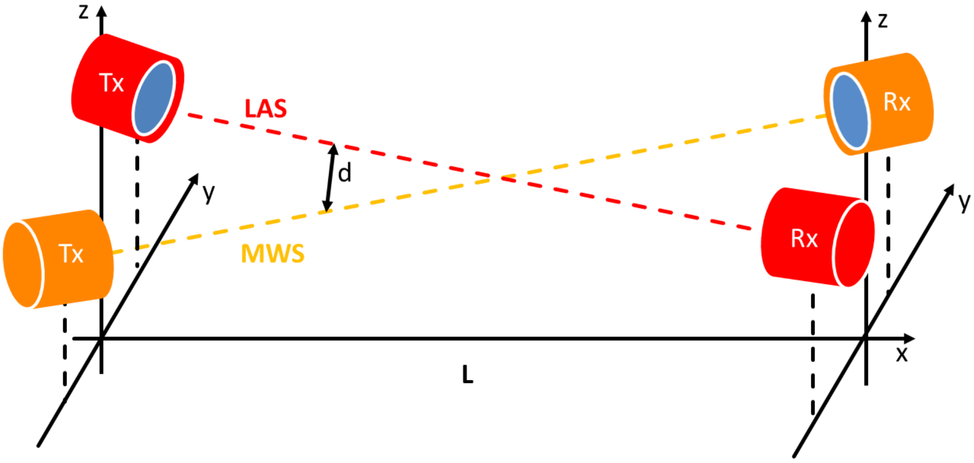

Figure 19: Setup of a combined Optical/Microwave Scintillometer (OMS) system with crossing beams. Tx: transmitter, Rx: receivers.

3.3.1 Mounting the Alignment Units

Figure 20: No tools are needed to fasten the alignment unit to the RPG-MWSC-160 units.

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For scintillometer measurements over short path lengths – where low observation heights of a few meters are sufficient (*Figure 18*) - using tripods is the usually the most practical way for setting up the instruments. The LAS and MWS transmitter / receivers can be mounted on separate tripods (*Figure 22*). In this case, the MWS transmitter / receiver – with the alignment unit attached to it – is directly mounted on top of the tripod. Optionally, RPG offers a double mounting plate to allow for a small distance between the microwave and optical scintillometers (*Figure 7*). The mounting on the double base plate is shown in *Figure 23*.

Figure 21: Fasten center bolt to mount RPG-MWSC-160 units on a tripod (single configuration).

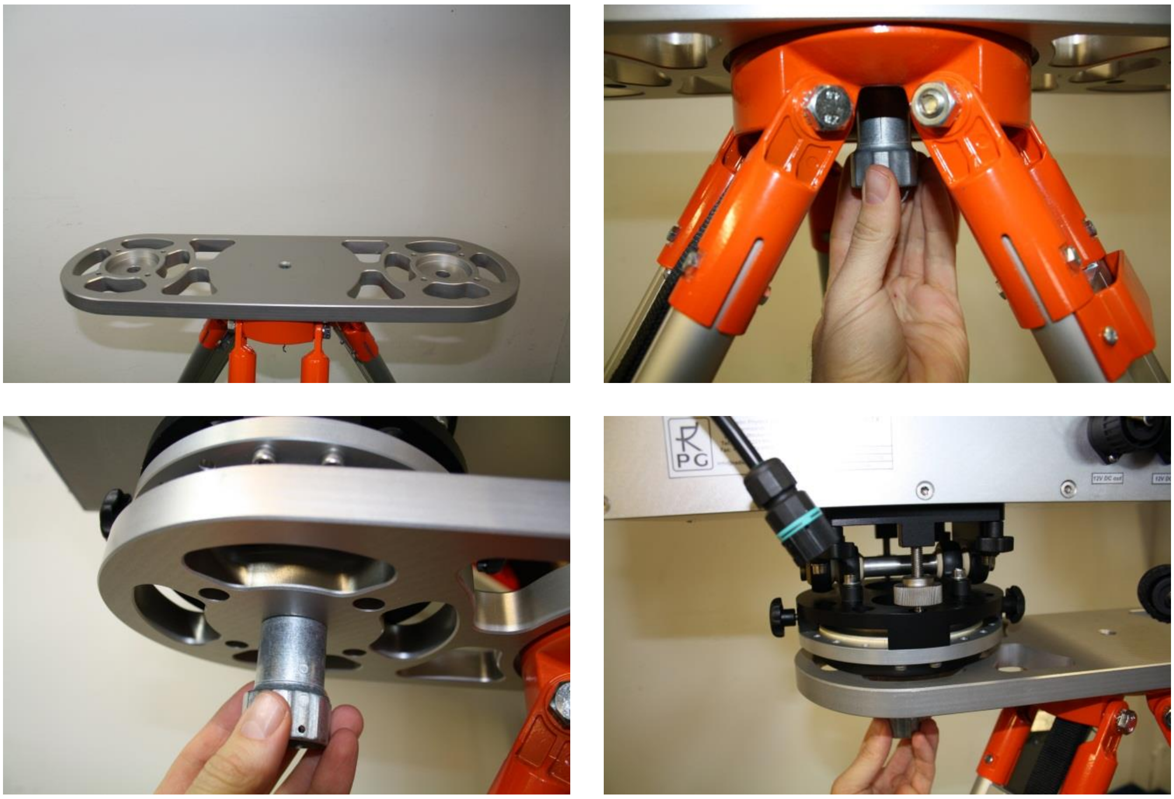

Figure 22: Mounting the MWSC units in the double configuration.

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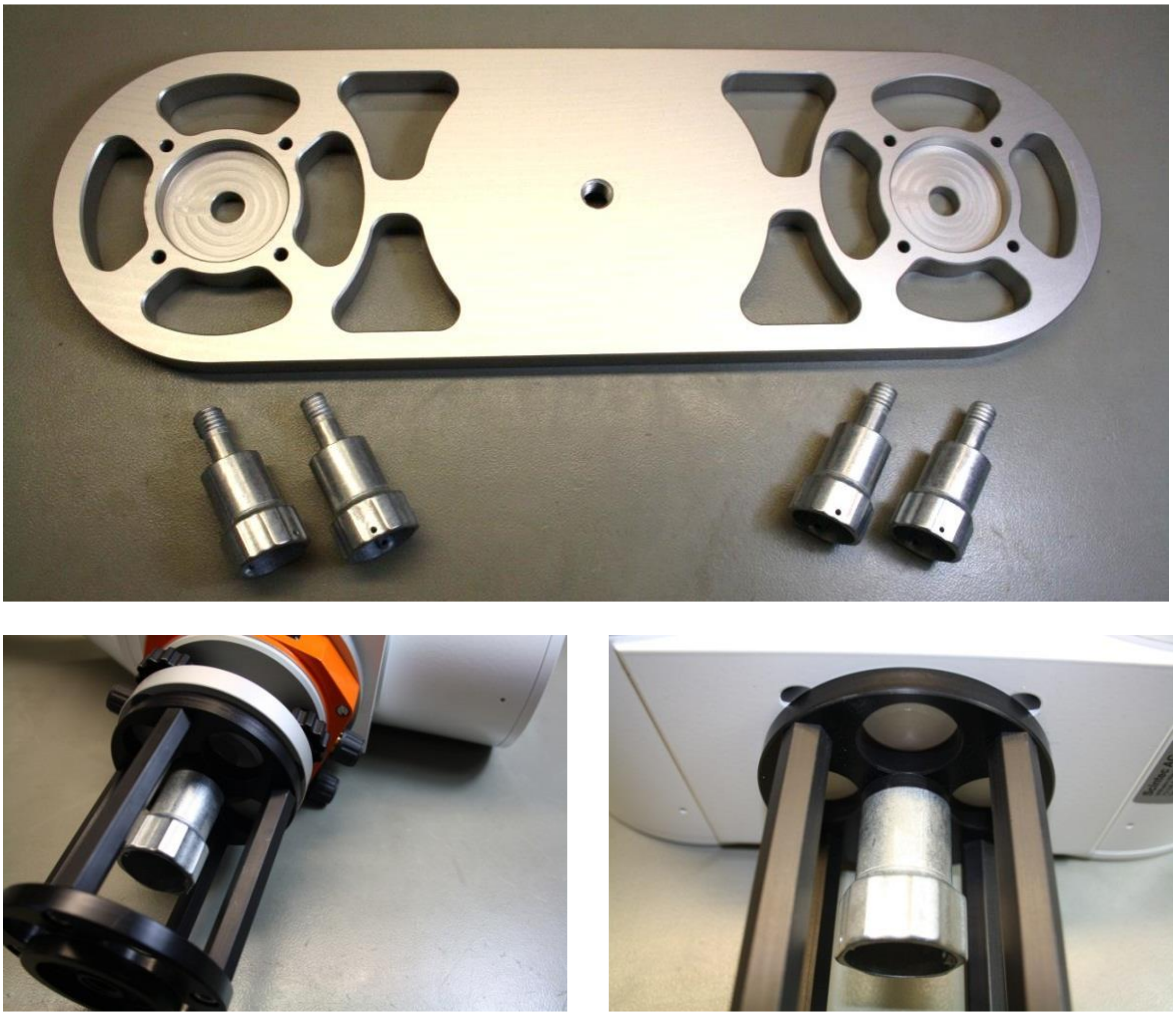

Figure 23: Double base plate and mounting adaptors for LAS transmitter and receiver.

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3.3.2 Mounting on Towers

With increasing path lengths the scintillometers have to be mounted at higher observations heights. For example, a path length of 5000 m needs an observation height above 40 meters to avoid saturation of the LAS signal (*Figure 18*).

Figure 24: OMS transmitters mounted on a measurement tower in Lindenberg, Germany.

Sometimes - e.g. when the OMS system is mounted on a measurement tower - it is difficult to read signal level display on the rear of the MWS receiver. In this case the MWS receiver provides a BNC-connector to read the signal level directly from the instrument (*Figure 25*).

Figure 25: BNC connector (left) to read the RPG-MWSC-160 detector voltage (only for diagnosis).

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3.3.3 Cable Connections and Power up

The RPG-MWSC units provide a connector for a direct 12 VDC supply. Optionally, two AC power supplies are mounted on the back panel of each instrument. In both cases the LAS transmitter and receiver are connected to the RPG-MWSC-160 units for power supply (exception: BLS2000 from Scintec). **Make sure that the connecting power cables are plugged-in as labeled before the system is powered**. Additionally, the LAS receiver provides the optical raw signal to the RPG-MWSC-160 receiver via a short data cable. For the LAS instruments the power and data connection is either combined on one socket (Kipp&Zonen Mk-I) or it is realized separately (Scintec, Kipp&Zonen Mk-II).

Figure 26: Example: power and data cables for the Kipp&Zonen Mk-II receiver. On the transmitter side there is only a power cable.

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The MWS and LAS raw signals are synchronously digitized inside the RPG-MWSC-160 receiver. The digital raw data is then transferred to the H-PC via a fibre cable connection (*Figures 27/28).* The fibre-optical data cable is connecting the MWS receiver with a fibre-to-LAN converter. Note that the fibres are protected by caps on both ends. **The red end is always connected with the converter's "TX" port, while the black end is plugged into the "RX" port.** The Ethernet cable can either be plugged into a local network or it can directly connect to the H-PC (peer-to-peer configuration) (refer to *Instrument Manual*).

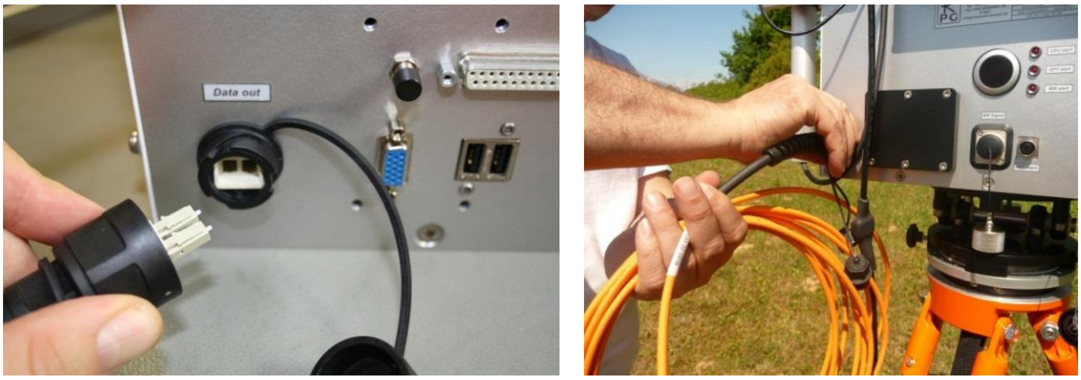

Figure 27: Setting up the fibre-optical cable for data transfer.

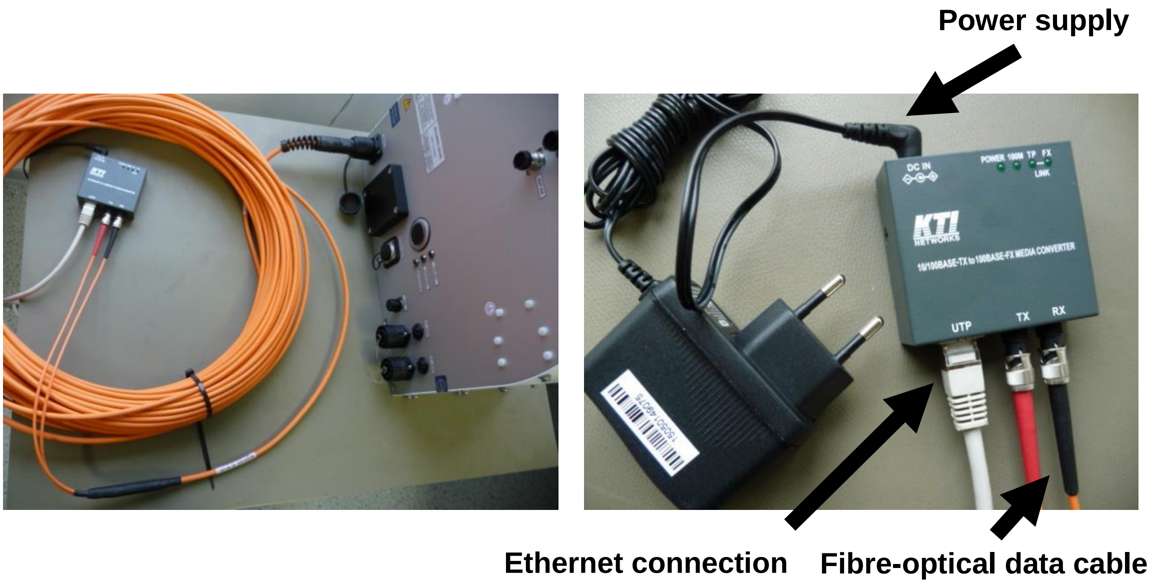

Figure 28: Data transmission and conversion.

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3.3.4 Alignment of the RPG-MWSC-160 units

An accurate alignment of the OMS system is important, because of the small beam width involved (for instance 0.42° HPBW for the MWS). Furthermore, it is beneficial for both MWS and LAS, because it helps to reduce the power consumption: A good alignment allows a reduction of the transmitter power level. It is recommended to perform the system alignment and power levelling is done in fair weather conditions. This guarantees that the received signal does not exceed the maximum level, when conditions become more humid afterwards.

Figure 29: Example: Alignment of an OMS system.

For the alignment of the receiver and transmitter units, the pointing of both instruments is adjusted by using the 2-axes alignment units. The alignment process includes two steps: At first, the alignment telescopes (*Figures 29/31*) help to catch the transmitted signal by adjusting the receiver and the transmitter by sight.

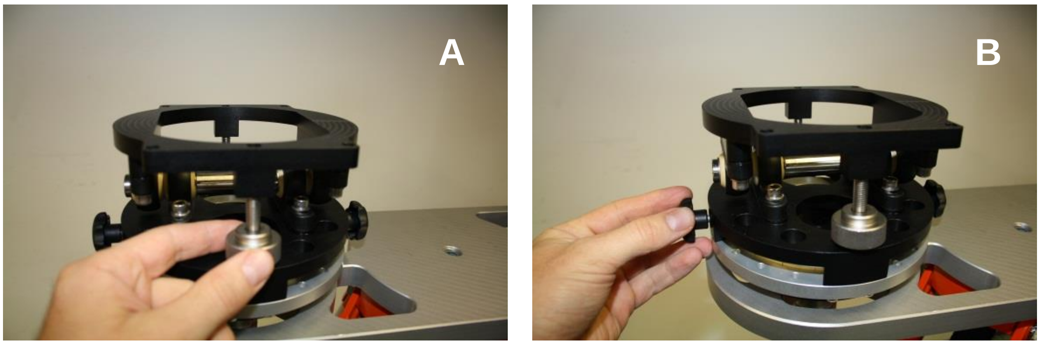

Figure 30: RPG-MWSC-160 alignment units allow adjustment of azimuth (A) and elevation (B) angle.

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Figure 31: Adjustment of the MWS/LAS alignment telescopes.

In a second step, the received signal level is maximized by fine tuning the receiver's pointing. When no transmitter signal is received, the displayed value is close to zero (*Figure 32*). If '1' is displayed, the signal level is out of range. Only one axis shall be adjusted at a time. As soon as the direction of maximum signal level is found, the power level of the transmitter is adjusted to a value close to **1000** (*Figure 33*, **maximum is 2000**).

Figure 32: Receiver signal level display.

Then the pointing of the receiver unit is fixed. Now the transmitter pointing is fine-tuned to further maximize the received signal level. When the signal maximum is found, the transmitter pointing is fixed and the transmitted power level (*Figure 33*) is adjusted to an optimal signal level of about **100%** (*Figure 32*), signal level range: 0-200%)[1]. The alignment can be further improved by iterating the described process. Finally, note down the according transmitter power level that is displayed on the transmitter rear panel.

[1] Instruments with serial number 3010001-3010004 use a different scaling with a signal range of 0-2000. It shall be tuned to 1000.

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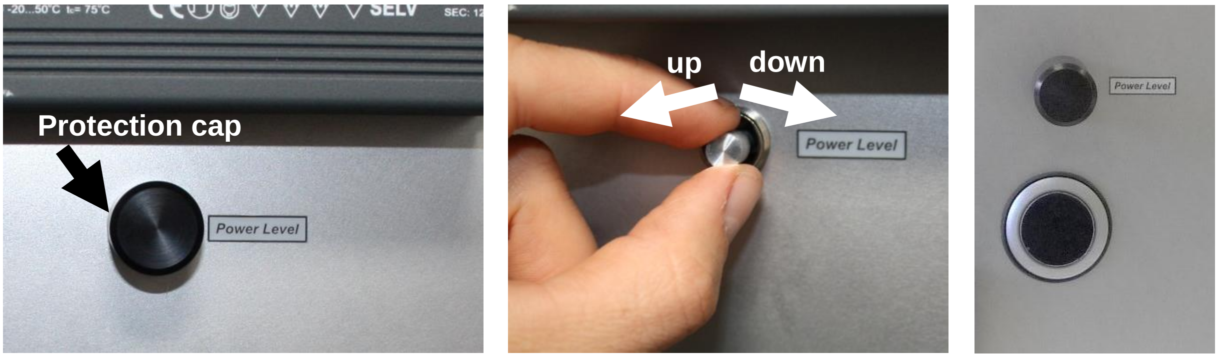

Figure 33: Remove protection cap on transmitter rear panel to adjust output power level.

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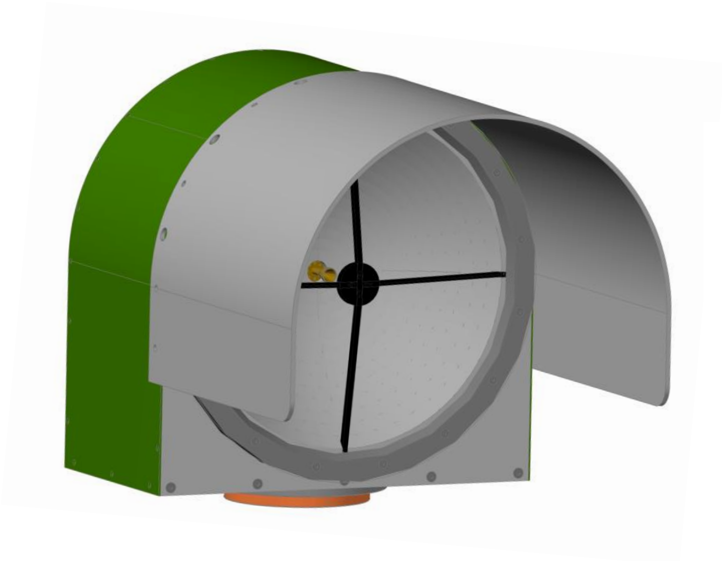
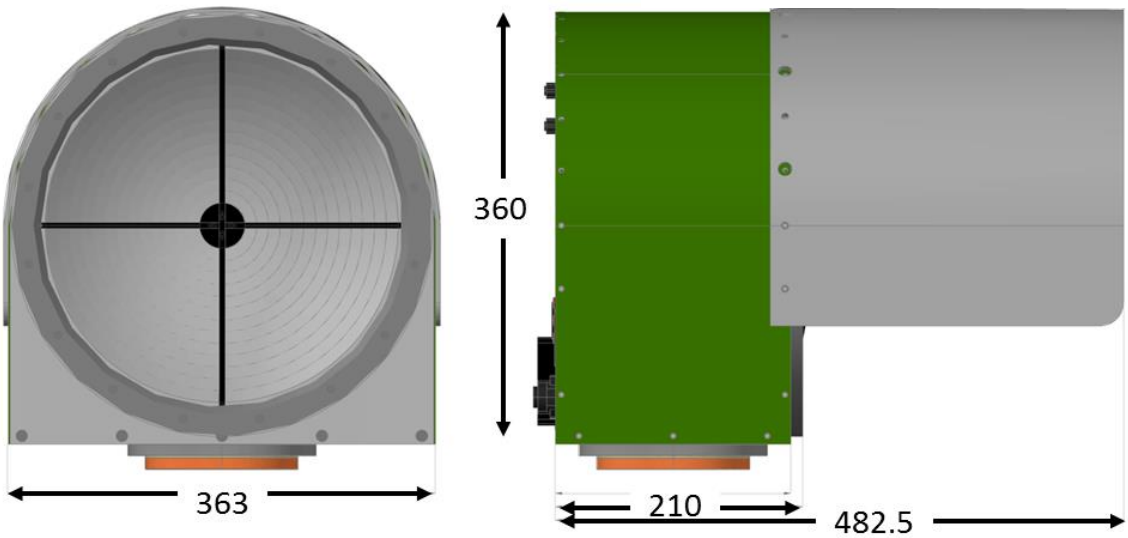
Appendix A (Instrument Dimensions)



Total weights:

- Receiver: **12 kg**
  (including weather station)
- Transmitter: **10 kg**



in mm

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