Radiometer Physics
A Rohde & Schwarz Company

RPG-FMCW-94 Cloud Radar
(Installation Manual)

RPG-FMCW-94-SP/DP
94 GHz W-band Cloud Doppler Radar
Instrument Installation Guide

Radiometer Physics
A Rohde & Schwarz Company

Document Change Log

Date	Issue/Rev	Change
11.11.2017	01/01	Release
18.06.2018	01/02	Update to safety instructions and voltage ratings
13.09.2019	01/03	Set-up of the scanning system included
06.03.2020	01/04	Grounding instructions included
16.06.2020	01/05	Major revision
12.05.2022	01/06	Draft revision for CE review
17.05.2022	01/07	Revision for CE review
28.06.2022	01/08	Add visual target inspection
27.02.2023	01/09	Revision, correction power line requirements
06.03.2024	01/10	Add chapter “Maintenance”, standardization of terminology
15.03.2024	01/11	Additions in chapter 4

Table of Contents

1 Safety Instructions

1.1 Instrument Use

The RPG-FMCW-94 radar is a microwave instrument for the detection of cloud particles. It emits continuous microwave power at 94 GHz and detects the reflected power from cloud droplets, rain droplets, ice and snow particles. The evaluation of the Doppler frequency shift from falling particles enables the radar to determine a velocity spectrum. Most observations are performed at zenith angle but the radar is also capable of scanning at other angles in order to determine wind speeds, rain rates and particle properties like dropsize distribution and particle shape (ice crystals and aggregates). The instrument should not be used for other detection purposes than described above.

1.2 Before Starting Operation

Carefully read this installation manual before deploying the radar system. The manual contains important information for a safe installation, operation and maintenance of the instrument.

Installation, operation and maintenance of the radar system is restricted to people, who have attended RPG's cloud radar user training or have been instructed by trained users accordingly. Make sure that all persons involved 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.

The instrument emits 1.5 Watts (over up to 100 MHz bandwidth) of microwave power during measurement operation that may interfere with other high frequency equipment close to the instrument. When operated outside of buildings, this possible interference is considered to be negligible, except for other microwave instruments (e.g. cloud radars and radiometers) running in the same frequency band.

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 may be operated with a powerful position scanner. **Before turning the instrument on, it is required to install a protection fence around it (radius 1.5 m)** to prevent possible injuries caused by rotation of the instrument.

When using position scanners: For safety reasons, install a fence around the radar for warning people to enter the danger zone (a circle of 1.5 m radius around the centre of the radar).

The 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 personnel 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, position scanner, and blower control) are **completely and properly** installed, according to the instructions described in the following paragraphs.

1.3 Installation Related Technical Data

The instrument should be handled with the same care as other electronic equipment. The radar should be protected from fire, over voltages (caused by lightning or malfunctions in electric power networks), 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**.

Do not store the radar hardware outdoors unprotected. Once installed, keep the radar system switched on. You may only switch off the radar for short time periods, e.g. during maintenance.

The safe environmental parameters for **transport and storage** are:

Parameter	Range
Temperature	-30 °C to +50 °C
Humidity	non-condensing
Pressure	300 hPa to 1300 hPa (mbar)
Vibration	< 10 g acceleration
Shock	< 20 g acceleration

Make sure that the **radar is only switched on**, when the environmental temperature is **above the minimum storage temperature**.

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

Parameter	Range
Temperature	-30 °C to +40 °C
Humidity	1 % to 100 % relative humidity
Pressure	300 hPa to 1300 hPa (mbar)
Vibration	< 1 g acceleration
Shock	< 10 g acceleration

Power line requirements:

Parameter	Range
Voltage	AC 230 V 3 ~ 16A 50-60 Hz
Power consumption Instrument and blower are one phase 1 Position Scanner is on phase 3	Instrument: average 700 W Blower: 750 W maximum Position Scanner: 800 W max.

- Before turning on the main power switch, the radar **MUST** be separately connected to ground by a short PE cable (earth anchor)!
- **Do not power** the radar and its optional scanner **via an isolating transformer.**
- **Only use the delivered power cable and plugs.**
- Connect the power cable only to a shock- and water-proof socket that has been installed according to the local regulations by skilled technical personnel.
- The radar and its optional scanner are powered by two independent phases, which must be connected to separately fused power lines (16 Amp each).
- 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. The power plugs must be kept dry under all conditions.
- Unplug the equipment immediately from power supply, if the instrument or power cable / plugs appear to be damaged.
- Turn off the instrument (ON/OFF switch) when GPS-clock, weather station, blower or scanner need to be disconnected from or connected to the instrument.

When installing the radar, **make sure the power connectors are plugged into power sockets with proper grounding pins (PE = protection earth)**. Otherwise, the radar 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 protection earth, the user may be exposed to electrical shock when touching the instrument.

The radar is equipped with a strong blower unit. **The air inlets and outlets of the blower unit must never be blocked,** e.g. by walls, accumulated snow or tape**.**

Any malfunctions and failures arising from operating the radar 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.

Instrument weight and dimensions:

Parameter	Range
Weight	Radar: approx. 90 kg Blower: approx. 90 kg El/Az Scanner: approx. 100 kg
Dimensions	Radar + Blower: 115x90x90 cm^3

Persons involved in the radar installation process, shall wear hard-toed safety shoes during (un)packing and (dis)assembly. For transportation and installation purposes, the radar can be unmounted from the blower and scanner units. Because of the instrument's weight of approx. 90 kg, it must be lifted by at least **four** people (adult persons with no physical or mental disabilities) when unpacking or lifting it on the blower / scanner unit. The instrument is delivered with four removable handles and each handle should be used by one person.

1.4 Safety Instructions for Handling Liquid Nitrogen

For performing absolute instrument calibrations, it is required to handle liquid nitrogen (LN2). The boiling temperature of this liquid is about -196°C at 1000 mbar barometric pressure. Therefore, in order to prevent serious injuries when touching LN2 with naked skin the following precautions must be followed:

All persons handling LN2

- shall be trained in the handling of LN2
- shall wear suitable protective gloves
- shall wear protective glasses / goggles
- shall wear a protective apron
- shall follow the general safety guidelines for handling cryogenic liquids

Failures to comply with these safety measures may result in freezing injuries from the cold LN2 temperature.

The following list of safety instructions must be followed when using the radar calibration target delivered with the instrument:

- Perform a visual inspection of the target **before filling it with LN2** to mitigate the risk of a potential LN2 leakage.
- The target maximum upper LN2 filling is 6 cm below the container's maximum level (only fill the container to a level that the inner absorber sheet is just covered with LN2). If the target is filled to its maximum level, there is a significant risk of LN2 spill out of the target during target transportation.
- After target filling, mount the top target lid and fasten it with the four rubber locks. Without the target lid, there is a risk of LN2 spill out of the target during transportation.
- The maximum target filling count is limited to 30 fillings total. Replace the target if this number is exceeded. Otherwise, there is a risk of LN2 leakage.
- Store the target in a dry and dark place (no UV or direct sun light!). Otherwise, the target foam material can develop cracks which may cause an LN2 leakage even before the maximum number of fillings (30) is reached.

1.5 Precautions during Scanner Operation

In addition to the normal common-sense precautions when handling electric equipment and heavy equipment, the user needs to avoid injuries from moving parts.

If the instrument is equipped with the optional position scanner (azimuth range = 0° to 360°, elevation range 0 - 180°) all persons should stay away from the radar by at least one meter. This safety distance should be ensured by the installation of a warning fence as described above.

When servicing the instrument (for instance during maintenance activities), electric power should be turned off or attention must be paid for staying outside of the movement range of the scanner. Otherwise, injuries may occur from clamping or squeezing. The scanner's mechanical power is high enough for breaking bones (torque of 350 Nm on each axis).

1.6 Microwave Emission Safety Instructions

During measurements the radar continuously emits about P = 1.5 Watts of microwave power at 94 GHz. The measured antenna gain G is 50.1 dB with sidelobes lower than -20 dB at 1° off-axis.

Most countries have determined a human exposure safety electrical field strength 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 60 meters**. In off-axis direction of ±1° the safety distance drops down to 4 m (side lobe).
When observing in zenith direction only, a safety fence as described above is sufficient to protect personal from electric field exposures exceeding E_{lim}.

When the radar is used in scanning mode, the user must ensure that the antanna beam does not hit persons within a range of 60 m! This requirement can be easily fulfilled by a deployment on high buildings or platforms.

1.7 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 liability 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.

1.8 Further Information

If further technical support is required, please contact:

Radiometer physics GmbH
Werner-von-Siemens-Str.4
53340 Meckenheim

Tel: +49-2225-99981-0

e-mail: remotesensing-service@radiometer-physics.de

2 Instrument Installation

RPG-FMCW-94 radars are delivered with a complete set of accessories to operate the radar in an outdoor environment and to perform regular instrument calibrations. This includes (in addition to the radar itself) a radar stand with a rain mitigation system, a set of power and data cables, a signal converter, an external calibration target and target frame, a weather station plus GPS receiver, a complete software package for the radar PC (R-PC), optional external host PC (H-PC) and several tools to assemble the system.
As optional hardware, an elevation/azimuth scanner can be added that replaces the radar stand (which is only configured for zenith observations).

2.1 Setup of Zenith Observation System

The radar deployment without a scanner requires a space of at least 2 m by 2 m on plain and solid grounds, which can easily carry the instrument plus personnel for installation and maintenance (> 600 kg). The ideal solution is a leveled concrete platform or a flat roof top.
The installation starts with the setup of the radar stand. Unload the stand from the flight case.

Zenith observation radar table.

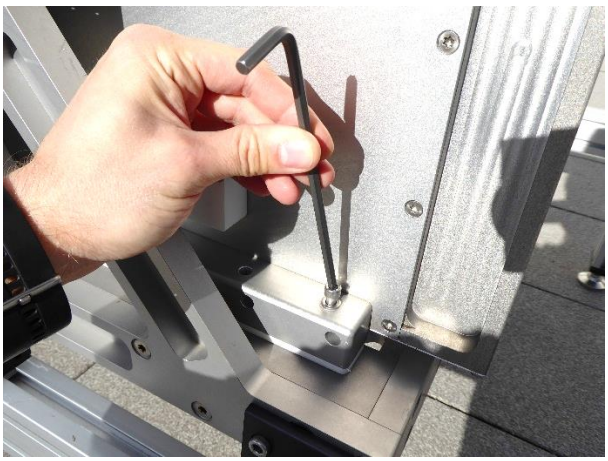
The next step is unloading the radar from the flight case. Prepare a couple of wooden or metal bars (100 mm x 100 mm x 500 mm, not included in the shipment) to put the radar body on. This is required not to damage the cooling system of the radar PC.

Do not put the radar vertically directly on a surface without the bars. Otherwise, the metal housing of the fans at the bottom of the radar body may block the fan blades. This, in turn, may lead to the overheating of the radar PC during the operation.

Make sure that no cables are connected to the radar body. Unscrew 32 M6 holding the air guides and remove the guides.

***Unmounting the air guides.* Only use the Allen key!**

Remove 8 M6 x 45 screws holding the radar body on the blower.



Use Allen key to release the radar body.

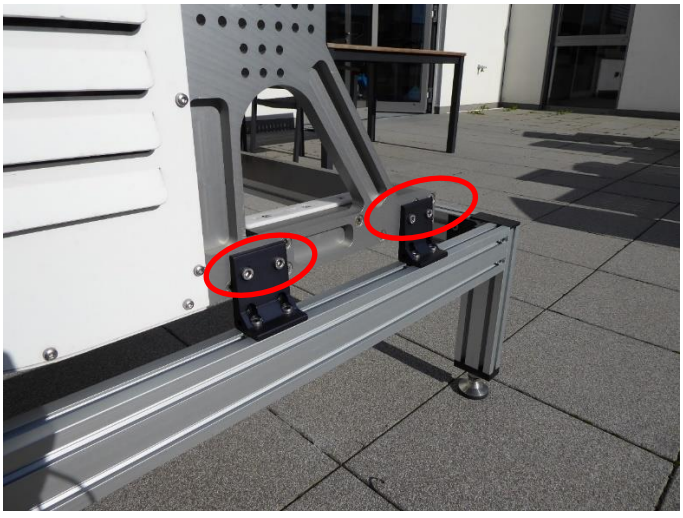
Mount four handles (placed in the accessories flight case) to the four M10 threads on the radar body. Put the radar on the prepared wooden/metal bars. The bars may be put on the groud/floor or on a table as shown in the figure below. The weight of the radar body is about 90 kg so four people are required for carrying.

Left: Handles. Right: The radar body settled on two metal bars.

Unmount the four handles from the radar body and mount them to the blower.

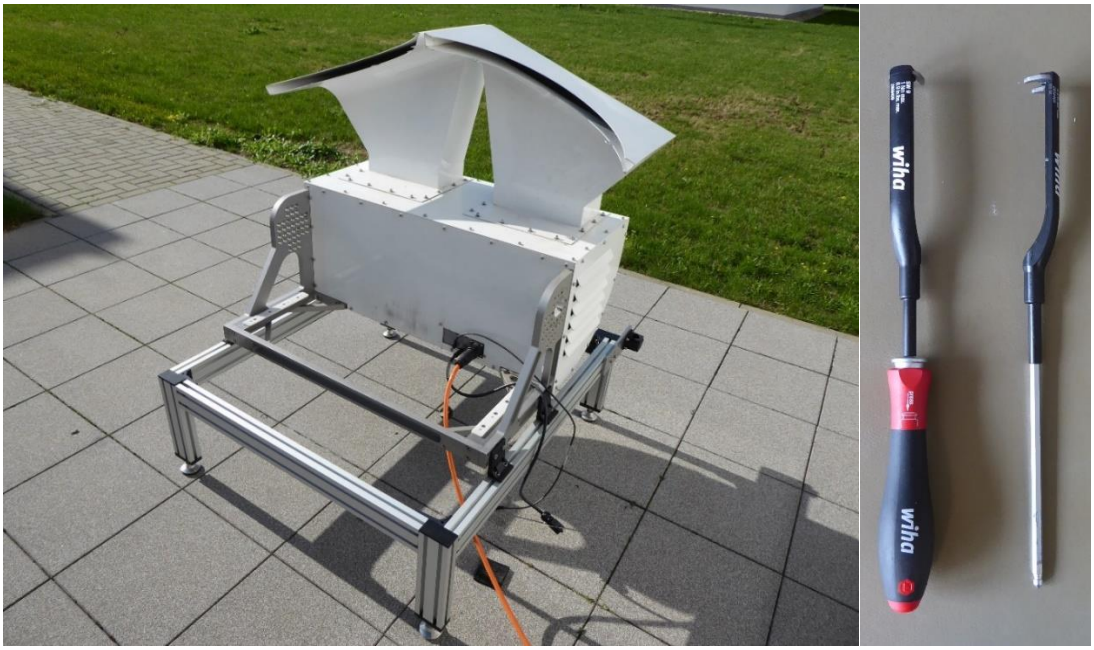
Threads for the handle mounting.

At least two people should carry the blower to the stand. Another person should fix the blower to the stand using 8 M6 screws (4 on each side). Please position the mounting angles and the blower as shown on the figure below.



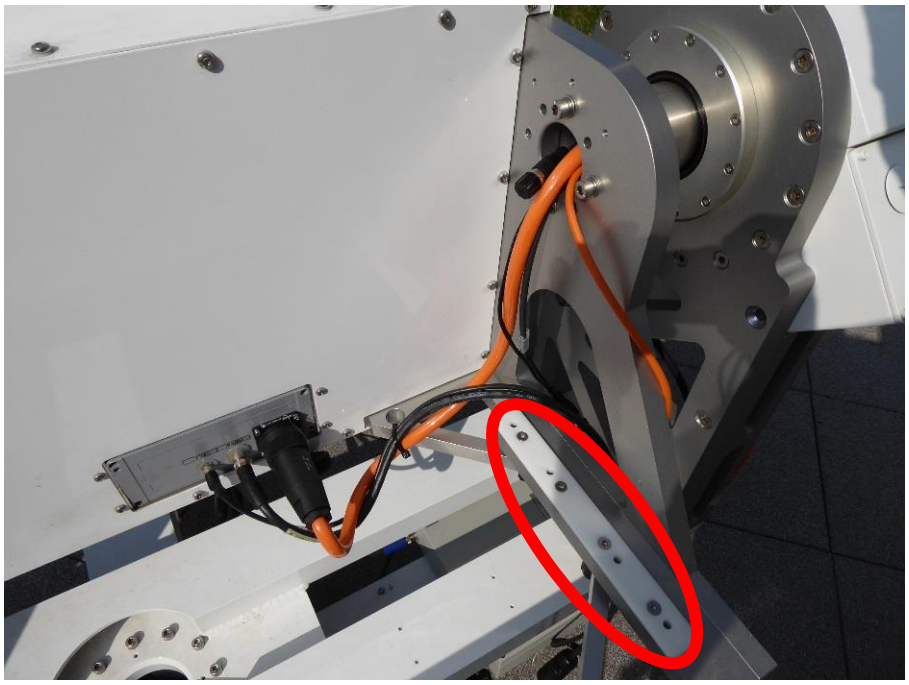
Mounting of the blower to the stand.

Mount the air guides to the blower. Position them on the blower and fix them with the 32 M6 screws. **Please do not pull the screws tight at this step.**
Connect 3 cables to the blower: “Mains” (main power cable), “TTL” (blower control), and “Radar” (radar power). Please use the special tool from the toolbox to properly tighten the “TTL” and “Radar” connectors.



Left: The blower with air guides and connected cables. Right: Tool to tighten the connectors.

Make sure that no cables are lying on the radar mounting surfaces.

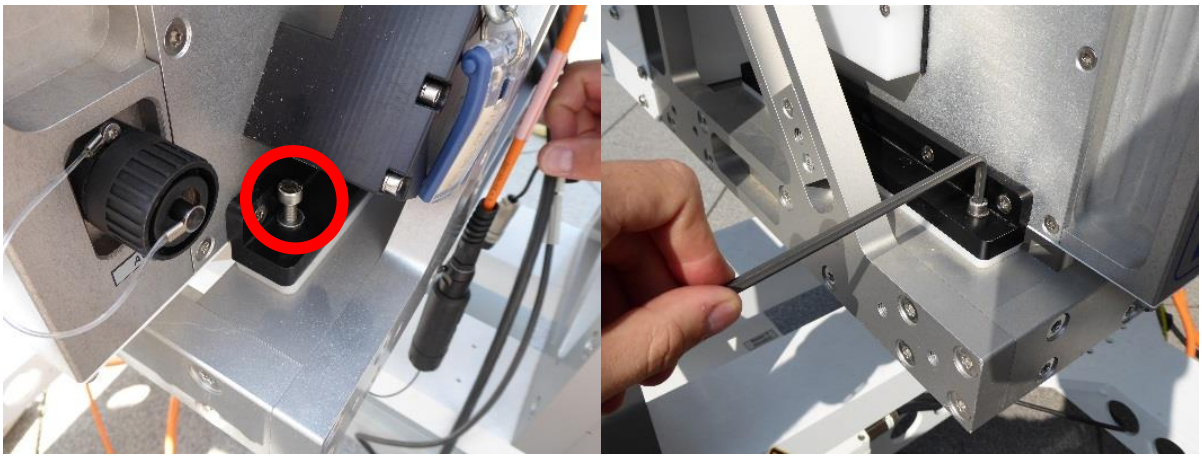


No cables must be on the radar mounting surfaces.

Mount the four handles to the radar body. Install the radar on the stand. Please note that the radar body weight is about 90 kg. Four people are required for carrying.

The radar body installed on the stand.

Once the radar body is put on the stand, make sure that all cables can reach their corresponding plugs on the radar body. **Please do not connect cables at this step.** Fasten the radar body to the scanner with 8 M6 x 45 screws (four on each side).



Use Allen key to fasten the screws.

Use Allen key to fasten the air guides.

Mount the pole and the GPS clock to the stand.

Mounting the GPS clock and the pole to the stand.

Connect the cable to the Vaisala meteorological weather station (MWS) and mount the station on the pole. Before clamping the station on the pole orient the ‚North' mark towards the North direction.

Mounting the Vaisala meteorological weather station.

Connect the fiber optics data cable to the radar body.

Connecting the fiber optics data cable.

Make sure that the plug slides smoothly into the socket and finally turn the outer cylinder of the plug clockwise (by applying some force) to seal the connector from water. Without sealing the connector, the connection will not be water-proof.

Connect the “TTL”, “GPS”, and “MWS” cables. Use the special tool (shown in figure below) from the toolbox to tighten the “TTL” and “MWS” connectors.

Please do not apply strong force and do not use pliers. This may lead to damages of the connector pins.

The stand has four adjustable feet for horizontal alignment. A metric 24 mm wrench is needed to turn the adjustable feet and pipe wrench pliers to finally lock the nuts.

Use a small spirit level for the horizontal alignment in both directions. Place a spirit level on the reference plane between the antennas.

Connect the power cable coming from the blower to the radar body. Please do not forget to connect the caps with each other so precipitating water cannot get into them.

Connection of the power cable to the radar body.

Remove all handles from the radar body. Protect the handle threads by special plastic screws.

Plastic screw for protection of handle threads in the radar body.

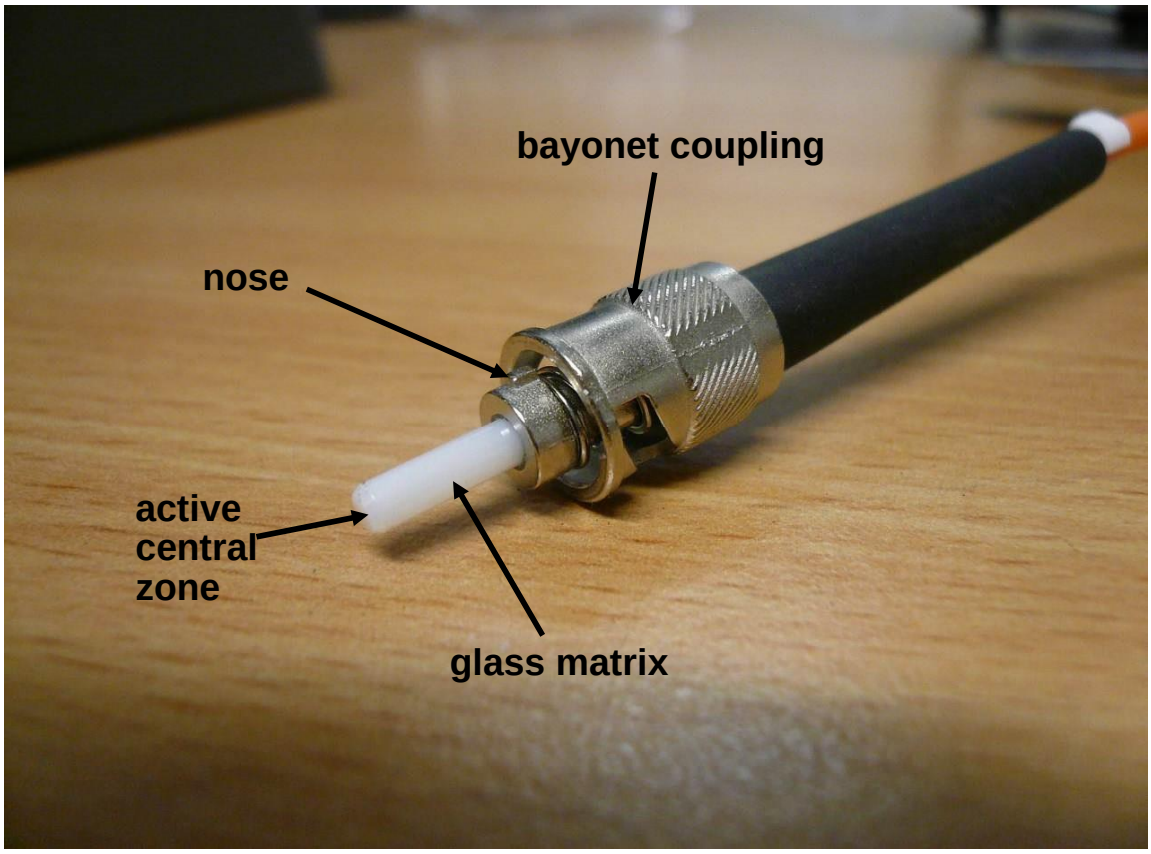
Turn the key on the radar body clockwise to the “on” position in order to switch on the radar.

Switching on the radar.

Once the radar is on, the blower shall work on full until the radar PC boots up. Depending on the setting in the software, the blower can continue to work on switch off. Both situations are normal.

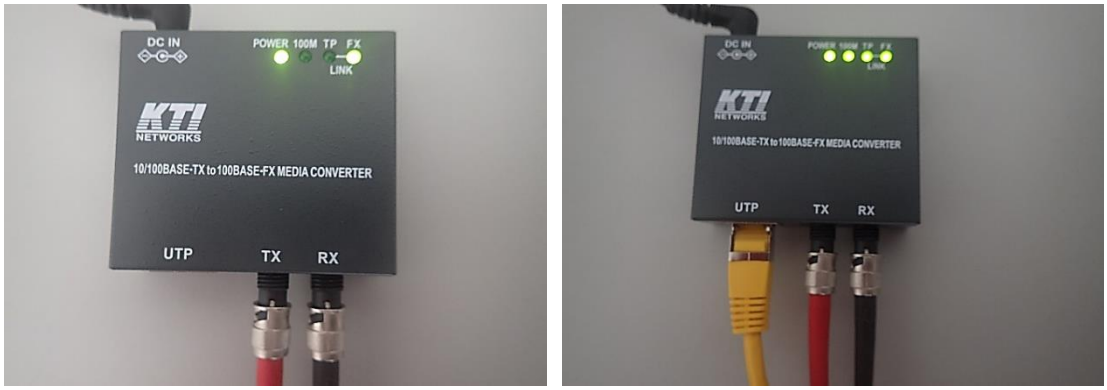
Connect the other end of the fiber cable to a MOXA Fiber-to-LAN-TCP/IP converter as indicated below. Each of the two line ends has a nose, which fits into the fiber socket. After the connector is sliding into the socket (nose guided by the slit), the bayonet coupling has to be pushed against a spring inside the coupling and then turned clockwise.

MOXA Fiber-to-LAN-TCP/IP converter.



Details of the glass fiber connector.

The converter has an external power cable. When the power cable and the two fiber lines are connected, the power LED and FX LED are turned on. Make sure that the TX fiber line (orange) gets connected to the TX converter output and the RX fiber line (blue) to the RX converter input. Via LAN-TCP/IP connection the converter can be connected either directly to the Host PC or to a network. If the LAN cable is connected, the power and FX LEDs are on and the 100M and TP LEDs are flashing. Connect the Ethernet cable of the converter to a host PC (with pre-installed radar software) and follow the procedure in chapter 3 in order to establish a data connection to the radar.



2-line fiber optics to LAN-TCP/IP converter.

This finishes the hardware installation procedure.

2.2 Setup of a Scanning System

Unpacked scanner with one air guide installed.

The radar deployment with a scanner requires a space of at least 3 m by 3 m on plain and solid grounds, which can easily carry the instrument plus personnel for installation and maintenance (> 750 kg). The ideal solution is a leveled concrete platform or a flat roof top.
The scanner is typically delivered in a single box. The blower without air guides is already installed on the scanner. Unloading the scanner requires a fork lifter since the weight is about 200 kg (scanner + preinstalled blower). During unloading the 0° position of the scanner that is marked by the orange arrow has to be oriented towards the North direction. Take care that no cables are damaged during the unloading. Leveling of the scanner is recommended after the whole radar system has been assembled.

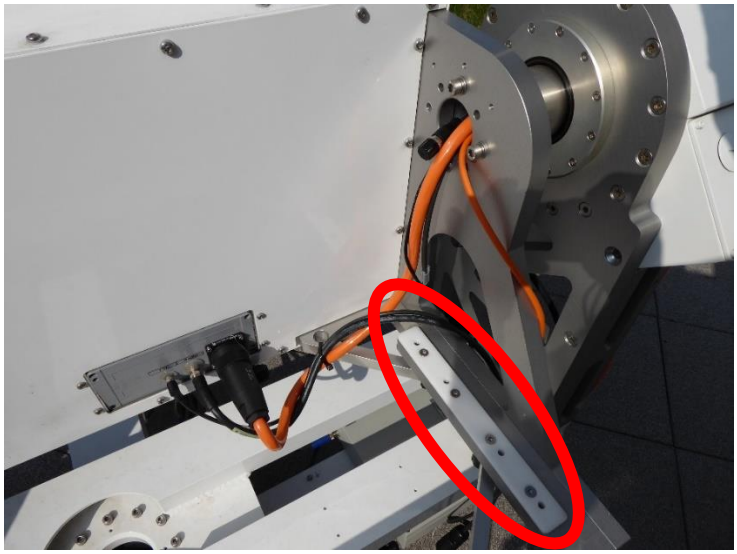
The arrow indicating 0° position of the scanner.

Unpack the two air guides. Position them on the blower and fix them with the screws. Please do not tighten the screws at this step.

Do not tighten the screws to make the installation of the radar body easier.

Unpack the radar body and mount three handles as shown in figures below.

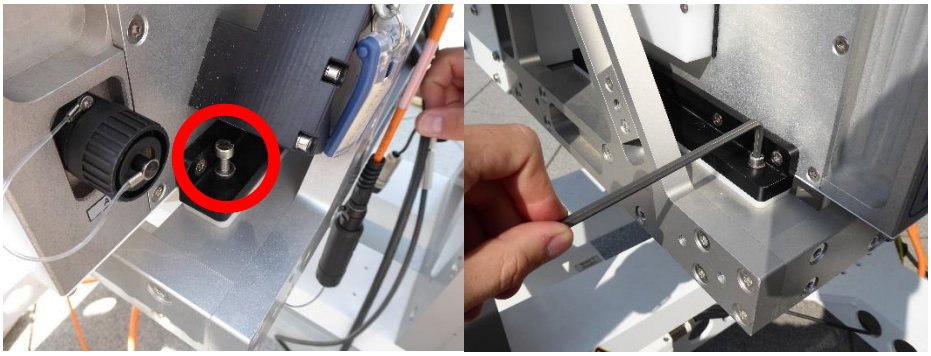
Make sure that only three handles have been mounted.



Make sure that no cables are lying on the radar mounting surfaces.

Put the radar body on the scanner. Please note that the radar body weighs about 90 kg. Four people are required for carrying. Once the radar body is placed on the scanner, make sure that

all cables can reach their corresponding plugs on the radar body. Then fasten the radar body to the scanner with 8 M6 x 45 screws (four on each side).



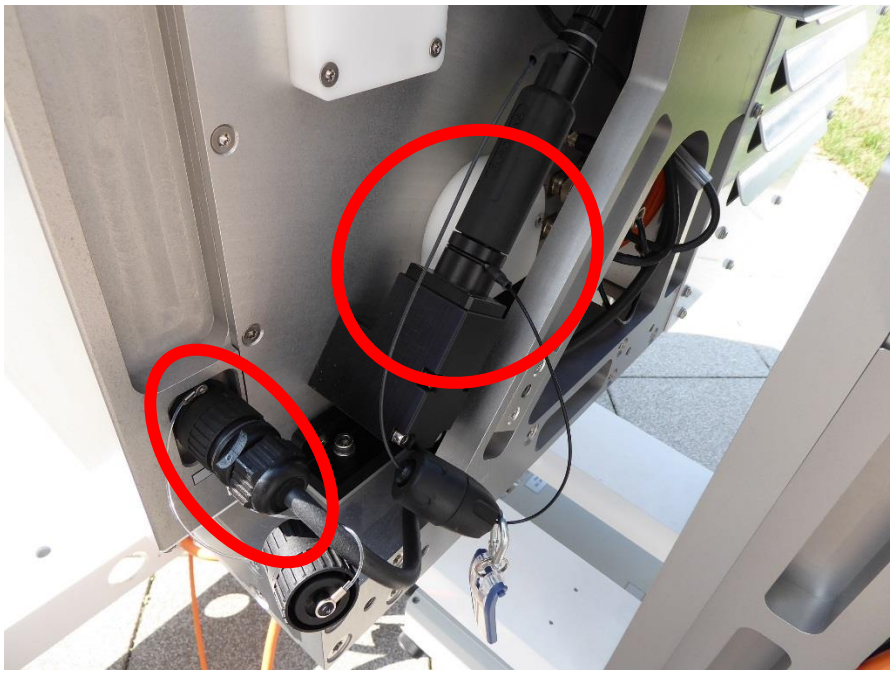
Use Allen key to fasten the screws.

Then fasten the air guides to the blower (16 M6 x 12 screws for each guide).

Use Allen key to fasten the air guides.

Remove all three handles. **Please note that scanning with mounted handles may lead to a damage!**

Connect the power and the fiber optic cables to the radar body. Please carefully read notes on the connection of the fiber optic cable in the previous section.



Connected power and fiber cables.

Make sure to connect the caps with each other so the precipitating water cannot get into them.

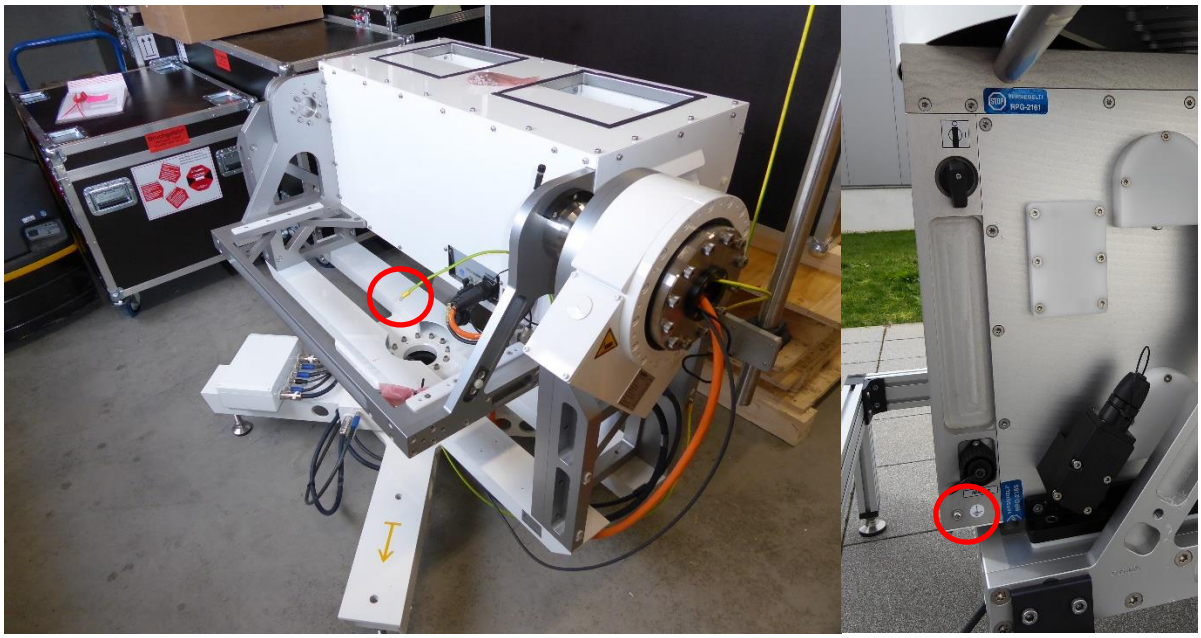
Connect the “Positioner” cable.

Connected positioner cable.

Connect the “TTL” cable.

Connected “TTL” cable.

Connect the grounding cable, which has been premounted on the scanner to the radar housing!



Left: Grounding cable for the radar body. Right: Grounding point on the radar body.

Mount the Vaisala weather station on the pole.

Please follow instructions on the weather station installation given in the previous section.

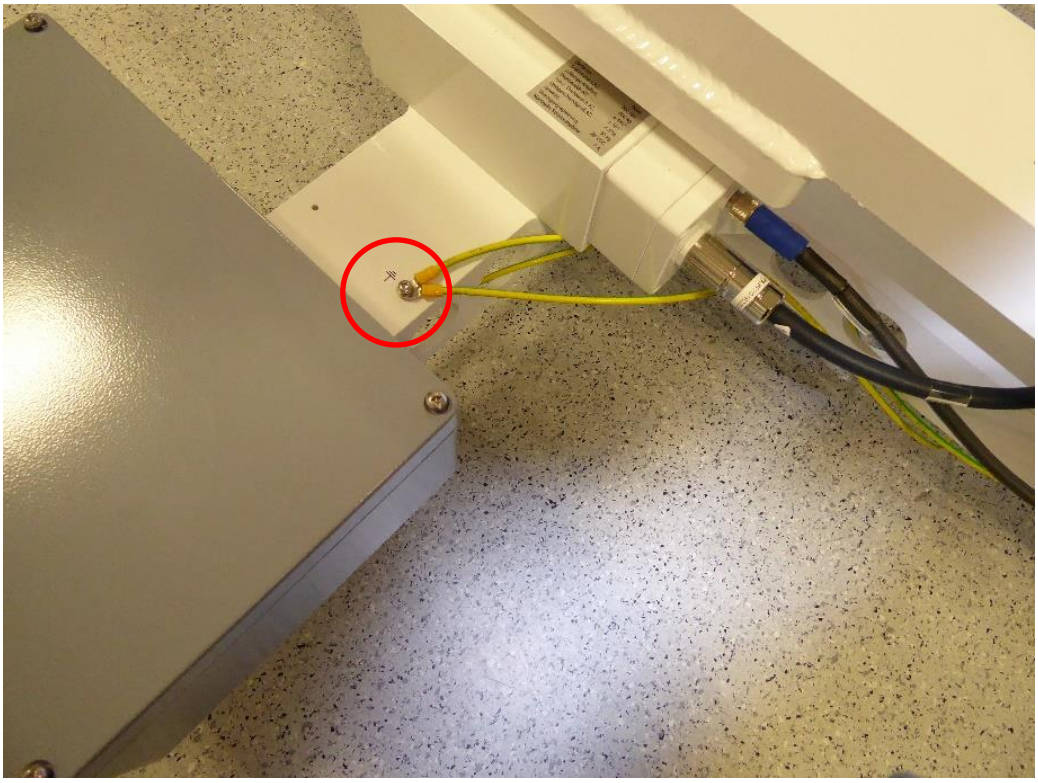
Plug in the GPS and the weather station (“MWS”) cables.

Please do not apply strong force and do not use pliers. This may lead to damages of the connector pins.

Connect the grounding wire premounted to the scanner to the weather station! Please follow the instructions given in the Grounding Kit from Vaisala.

Grounding point on the weather station.

Connect one end of the 5 m grounding wire to the grounding point of the radar!



Grounding point on the scanner.

The second end of the 5 m grounding wire must be connected to a grounding system at the installation site!

Put a spirit level on the reference plate on which the antennas are mounted and level the scanner. A metric 24 mm wrench is needed to turn the adjustable feet and a pipe wrench pliers is used to finally lock the nut.

Use a small spirit level for the horizontal alignment in both directions. Place a spirit level on the reference plane between the antennas.

Use a metric 24 mm wrench to turn the adjustable feet and a pipe wrench pliers to finally lock the nut.

Connect the 50 m power cable to the power supply of the scanning unit.

Connection of the power cable to the scanner.

Please do not forget to connect the caps with each other so the precipitating water cannot get into them. The main power line includes a load-break switch classified according to IP67. In order to prevent long-term intrusion of water, this power switch shall be fixed/stored at least 1 m above ground.

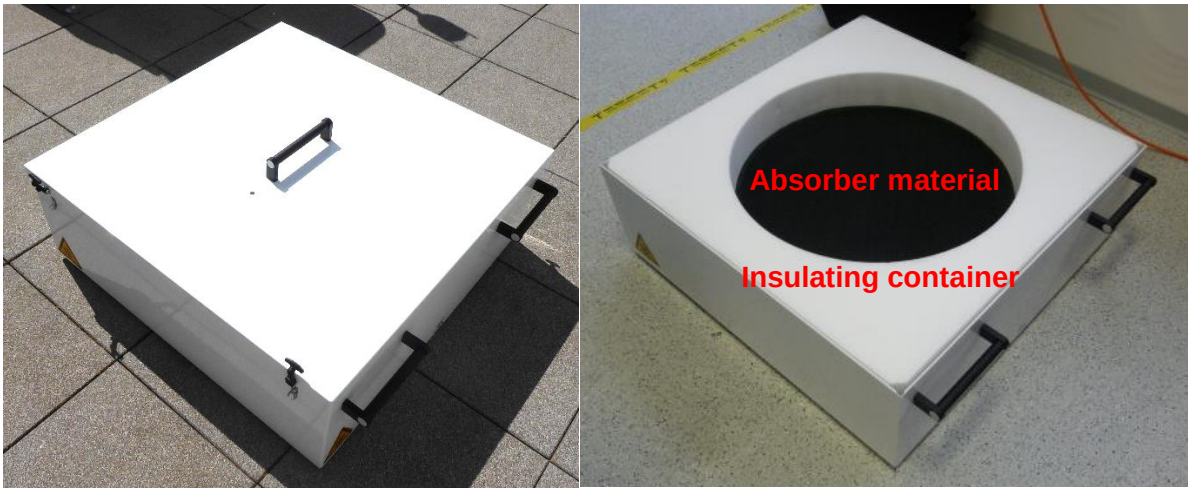
Turn the key on the radar body clockwise to the “on” position in order to switch on the radar.

Switching on the radar.

Once the radar is on, the blower shall work on full until the radar PC boots up. Depending on the setting in the software, the blower can continue to work on switch off. Both situations are normal.

2.3 Absolute Calibration

The radar receiver and its direct detection channel need to be calibrated by two absolute temperature standards, namely a target at ambient temperature and another one at liquid nitrogen (LN2) temperature. The following calibration procedure assumes that the radar has been turned on and that a host PC is connected to it while its radar software is communicating with the radar. Let the radar warm up for 30 minutes before the calibration is started.
The cold calibration target can be either the cloud free sky with known sky temperature at the frequency of the radar (measured by a 90 GHz radiometer, if available) or a LN2 cooled absorber stored in a thermally insulating container:



LN2 calibration target with and witout the lid.

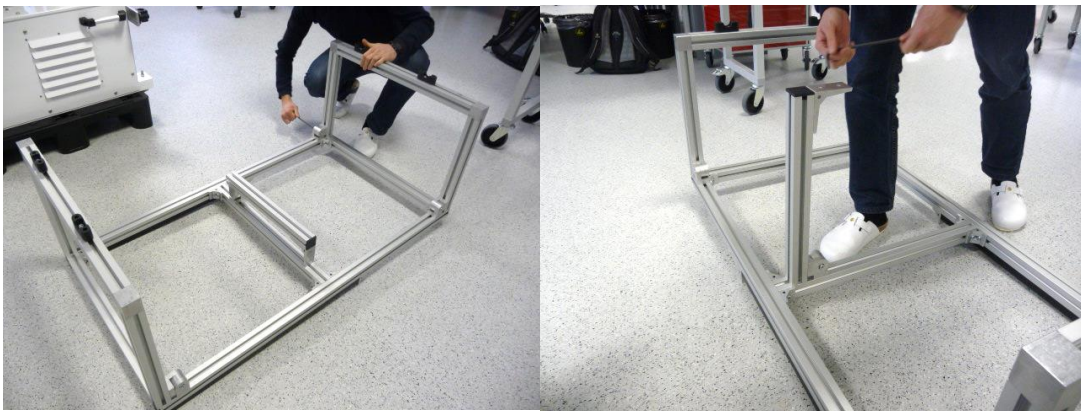
Before the LN2 target can be used for calibration, a mounting frame has to be installed. This frame is delivered together with the LN2 target in a folded configuration:

Frame for the LN2 target installation.

The next photo sequence describes how to setup the target frame:

Use Allen key to release the screws.

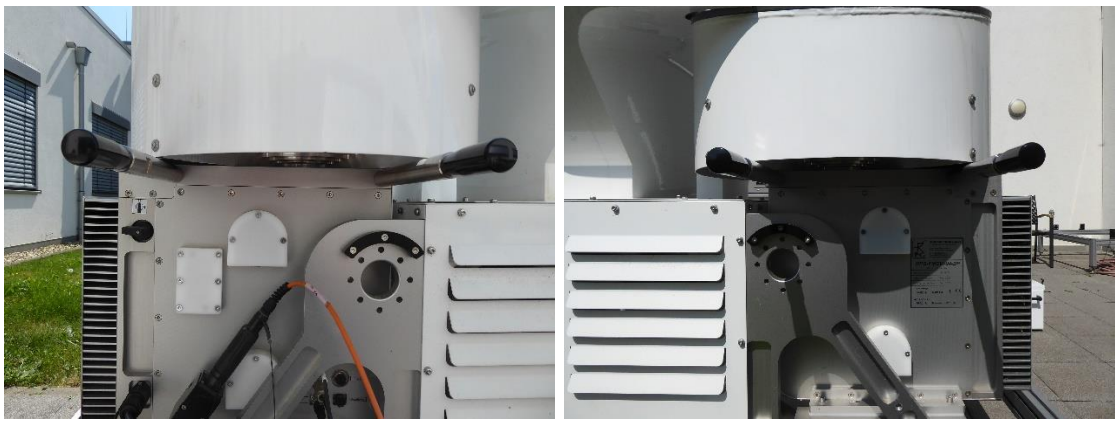
Unclamp the hinges of the frame and unfold it. After unfolding the frame, tighten the hinge screws.



Tighten the screws when the frame has been unfolded.

Firmly fix the frame structure using the angle elements.

Mount the four rods with the black handles to the radars housing's M10 threads.



Mounted handles. Use a wrench M19 to fix the handles firmly to the radar body.

Move the frame to the radar (two persons are required) and rest it on the four handles. Finally fasten the target frame as indicated in the figures:

Mounting the frame to the radar housing.

The radar with the properly mounted frame.

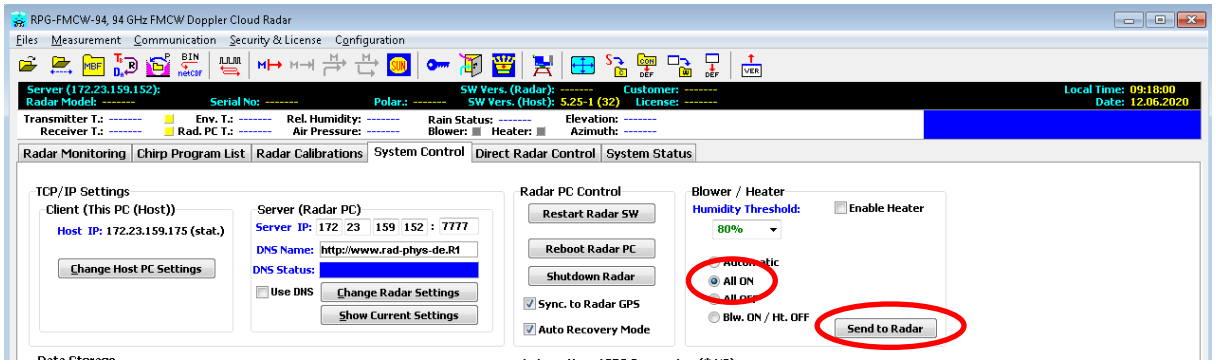
Now the LN2 target needs to be prepared. **Please follow your national regulations on handling liquid nitrogen. Carefully read the safety instructions given in Section 1 of the current manual. It is recommended to wear proper protection gloves, goggles, shoes, and an apron.**
Place the LN2 target on a plain and solid surface. Open the lid of the target. Start to fill it with liquid nitrogen. **Make sure that the target is intact and that no liquid nitrogen is leaking out from the bottom of the target. Only fill the target to half full until the black absorber is covered with the liquid! If the target is completely filled, it is too dangerous to remove it from the target frame after calibration due to spilling liquid nitrogen. The target will also be too heavy in this case.** Approximately 30 L are required to fill the target. Close it properly with the lid. Position the filled LN2 target onto the black plastic sliding bars. Please note that at least two persons should carefuly lift the LN2 target.

Mounting the LN2 target over the receiving antenna.

Take the ambient temperature target (a simple black foam absorber) in order to slip it over the receiver (RX) window (the pyramidal structure facing down towards the window). Fasten the ambient target with a tape on both sides of the RX radiation shield and guide:

The mounted ambient target.

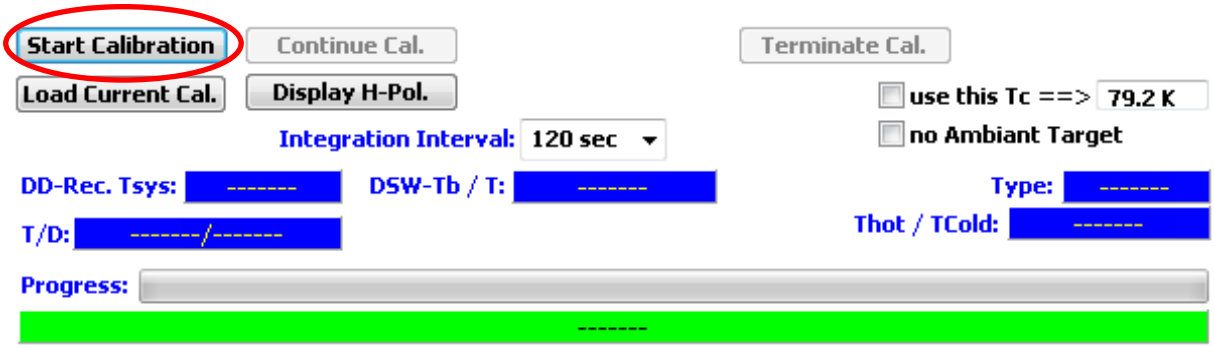
Now turn on the blower using the host software (if it is not already running). This can be done on the ***System Control*** tab. Please choose the ***All ON*** option and click the ***Send to Radar*** button.



Turning on the blower.

The blower will cool the absorber to the environmental temperature within a short time (about 1 minute) due to the low thermal capacity of the absorber material.

After the ambient target is thermally stabilized, go to the ***Radar Calibrations*** tab:



Starting the calibration.

Start the calibration with ***Start Calibration***. The radar will then integrate on the environmental temp. target (default integration time is 120 sec, but can be changed, if needed) while measuring the environmental temperature through the weather station. When the integration period has passed, the user is requested to change to the LN2 calibration target.
Remove the ambient target from the RX antenna. Then go back to the radar calibration box on the host PC and click ***Continue Calibration*** to start the integration on the cold target. When this is finished the radar will automatically add another integration cycle on the Dicke Switch (turned on). This completes the absolute calibration and the results are graphically displayed.

The cold target has 4 handles to be moved from the target frame after calibration. The black plastic bars simplify the sliding of the target from the frame.

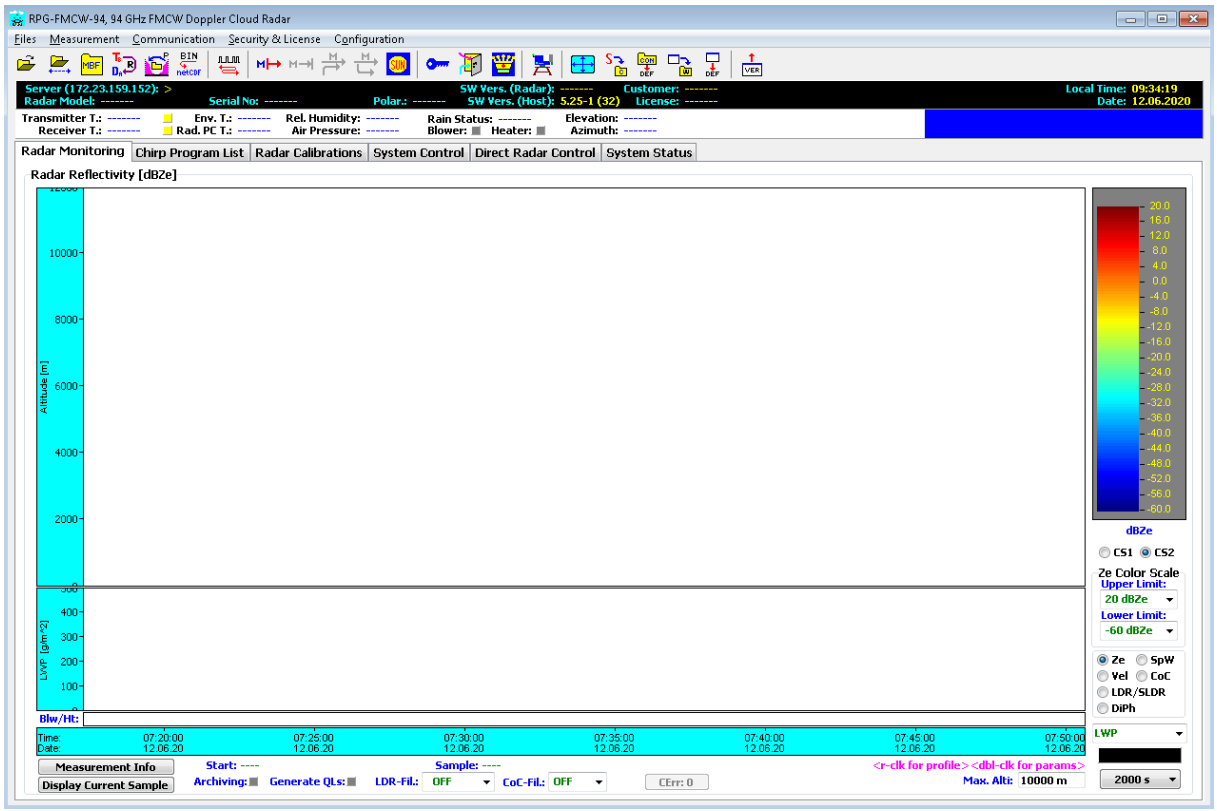
Pay attention to general safety guidelines while using liquid nitrogen for calibration. RPG is not responsible for injuries caused by improper handling or insufficient clothing.
The minimum requirements regarding clothing are:

1. **Cryogenic hand gloves**
2. **Plastic apron covering chest, legs and arms**
3. **Face protection shield**
4. **Closed shoes**

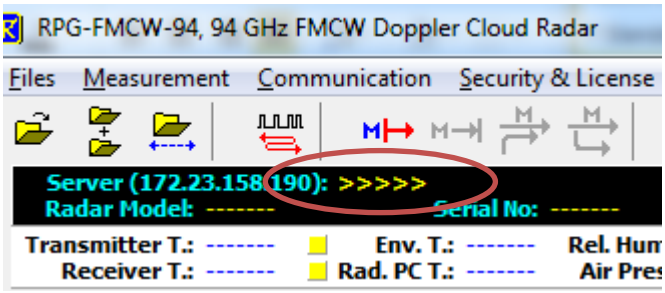
Follow the general guidelines for handling cryogenic liquids!

3 Running Measurements Quickstart

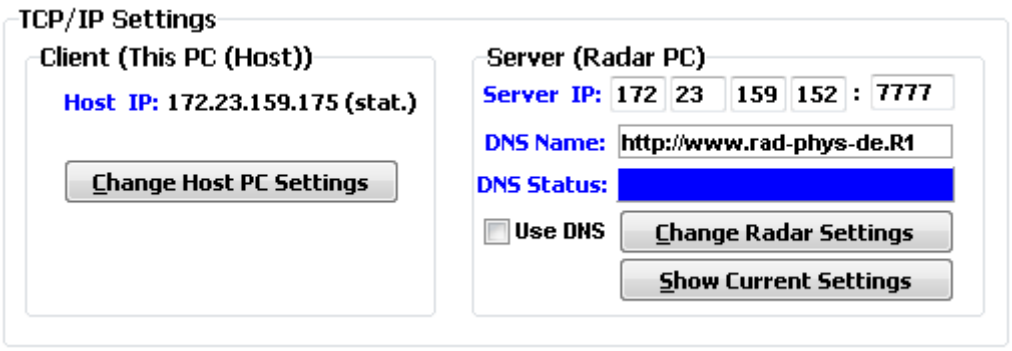
Start the host PC application with  from the desktop.



The screen is showing the ***Radar Monitoring*** tab. On top of the tab, environmental parameters (surface sensor data), position and blower status are displayed. The black panel summarizes the radar ID information, as model number, polarization, customer code, software version and license status.
As soon as the H-PC application starts, it is looking for an Ethernet connection to a radar, assuming the H-PC is connected to a network, router or switch. When a connection cannot be established, the TCP-IP command entry in the black top panel is filled with search indicators:

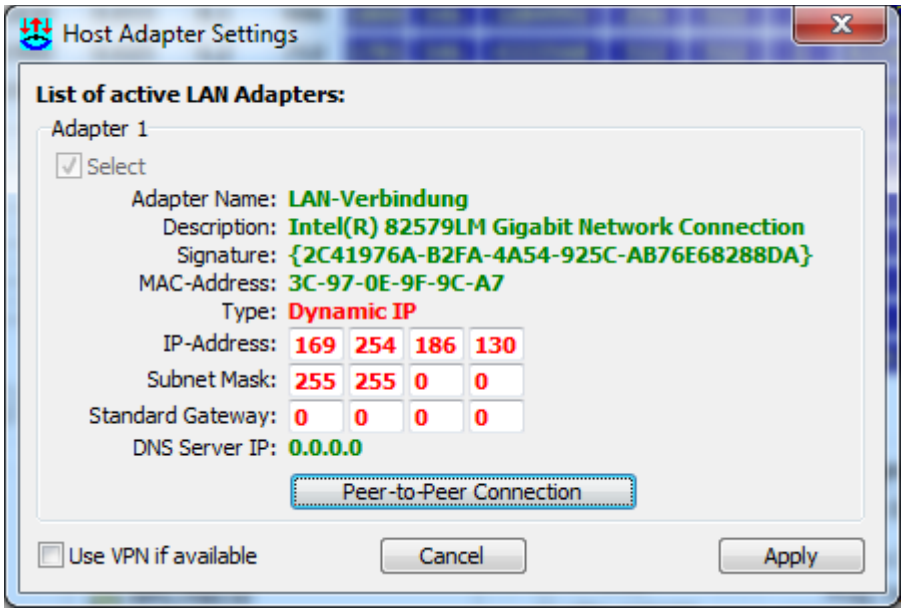


The Host assumes a radar (Server) with a certain IP connected to the network or directly connected (peer-to-peer connection). This IP is defined on the ***System Control*** tab in the ***TCP / IP*** box:



When a new radar is shipped, its IP setting is 192.168.0.1:7777 (default), subnet mask 255.255.255.0. This IP must be entered to the fields right of the label ***Server IP***. Because the radar's subnet mask is 255.255.255.0, the host IP should be in the same subnet, e.g. 192.168.0.x (x can be any number except for 0 and 1).

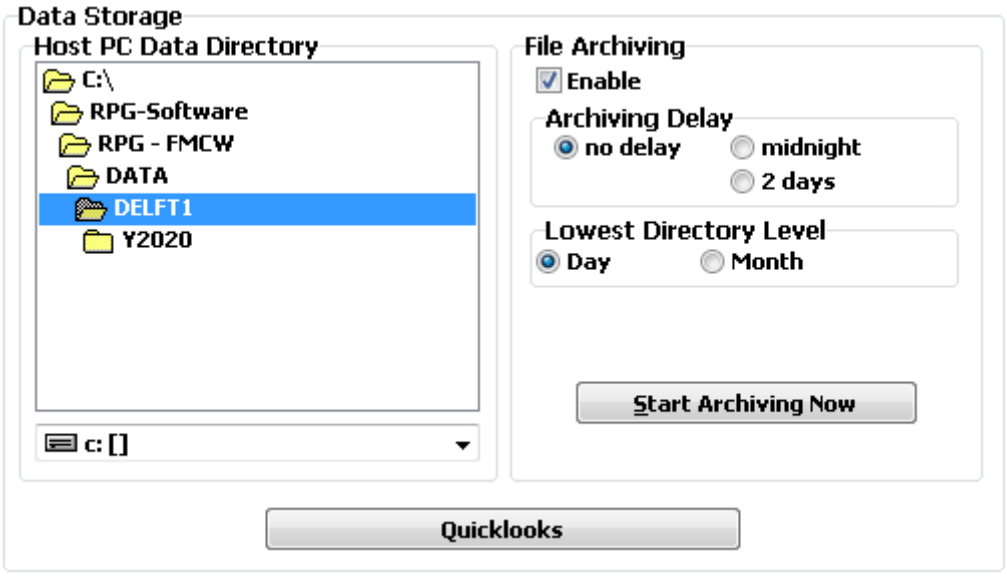
The H-PC IP settings may be changed from within the radar application when clicking ***Change Host PC Settings*** (you must run the host software with Administrator rights for this command):



If the IP address you enter here is available within the network the host is connected to, the ***Apply*** command will automatically change the host IP accordingly. An alternative, of course, is the standard procedure using the Windows IP setting menu.

Once connected to the radar, its IP setting can be modified remotely with ***Change radar settings***.

3.1 Data Storage



During measurements the recorded radar data is automatically stored in binary format to the directory selected in the ***Host PC Data Directory*** box.

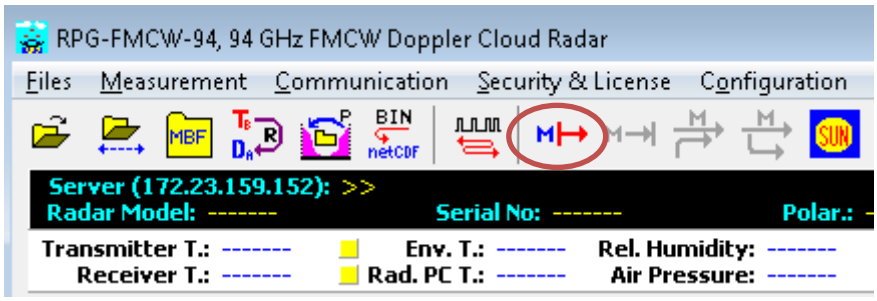
If other formats are required, they may be selected in ***Additional File Formats***. These other formats are stored to the same data directory as the binary files.

Data archiving is a useful feature to prevent the data directory from being filled with ten thousands of files, which may overload the operating system. MS operating systems cannot handle many (in the order of ten thousands) files in a single directory. If ***Enable*** is checked, the program automatically creates sub-directories in the data directory and stores the data files according to the year, month and day they are created. For example, a file ***200302_000001_P07_ZEN.LV0*** would be stored in a directory ***…\Y2020\M03\D02*** if ***Lowest Directory Level*** ***Day*** is checked or in ***…\Y2020\M03*** if ***Month*** is checked. Archiving, if enabled, is performed for data files immediately (***no delay*** option), after midnight (***midnight*** option) or after 2 days (***2 days*** option), depending on the radio button selection in the ***Archive Delay*** section. If the user wants to immediately archive data files, the ***Start Archiving Now*** button should be clicked.

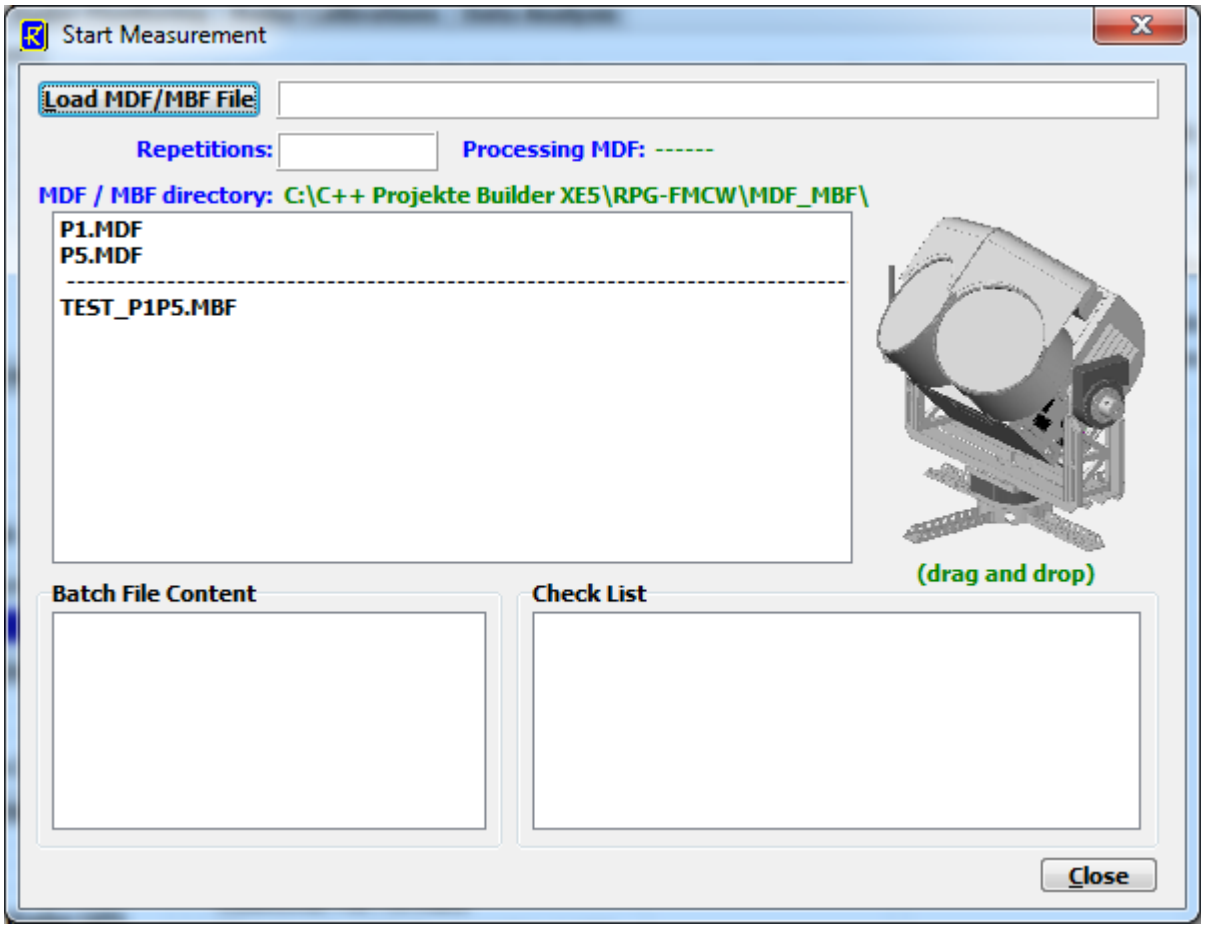
3.2 Starting Measurements

Before a measurement can be started on the radar PC, a measurement definition file (MDF) needs to be created first, containing all details of the measurement setup. This file is then sent to the radar for execution. Refer to the Operation and Software Manual for detailed information of how to create MDFs.

When a host successfully connects to the radar and the radar is in STANDBY mode, the radar is ready to start a measurement. This status is indicated by the enabled  button in the application's shortcut panel:

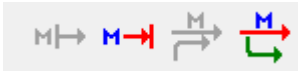


When an MDF or MBF is loaded (***Load MDF/MBF File***), its contents and repetition factor are displayed. In addition, some pre-checks are performed, e.g. radar configuration, MDF version number, availability of chirp program number, etc. A variety of other checks ensure that no erroneous command data is sent.
When the consistency check of an MDF is finished, the test result is displayed in the ***Check List***. The batch can only be sent to the radiometer if all consistency checks have been finished with the status OK. Then the MBF is transmitted automatically.
The H-PC 'remembers' the directory where MDFs and MBFs are stored from a previous ***Load MDF/MBF File*** command. This directory is listed in green. In the MDF / MBF list, MDFs are separated from MBFs by a dashed line. Dragging a file from the list and dropping it on the radar image on the right (or simply double clicking the file) is starting the measurement, if the consistency checks have been passed successfully. In this case the measurement launcher is closed automatically.



Measurement Launcher.

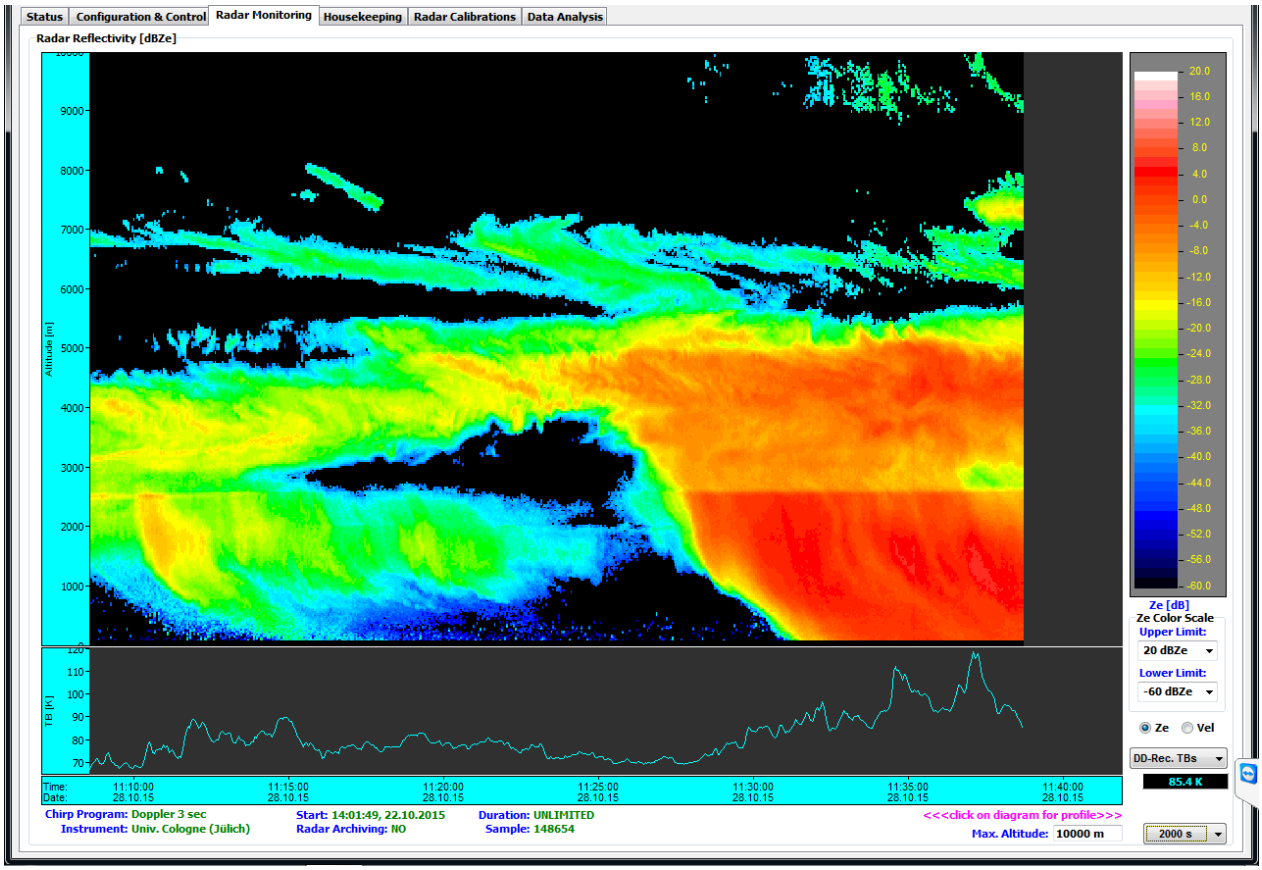
Once a measurement has been launched, the control buttons in the shortcut panel change in the following way:



The  button is used to terminate the running measurement on both, the radar and the host, while the  button enables the host to drop off the measurement and leave the radar alone to continue. In both cases, all monitored data samples are stored and the associated files are closed.

If the radar is running a measurement and the host connects to it, the H-PC realizes the active status and enables the  button for the host to jump on the measurement and start monitoring it. The  and  buttons do not affect the radar activities during a measurement, but act as host monitoring toggle switches.

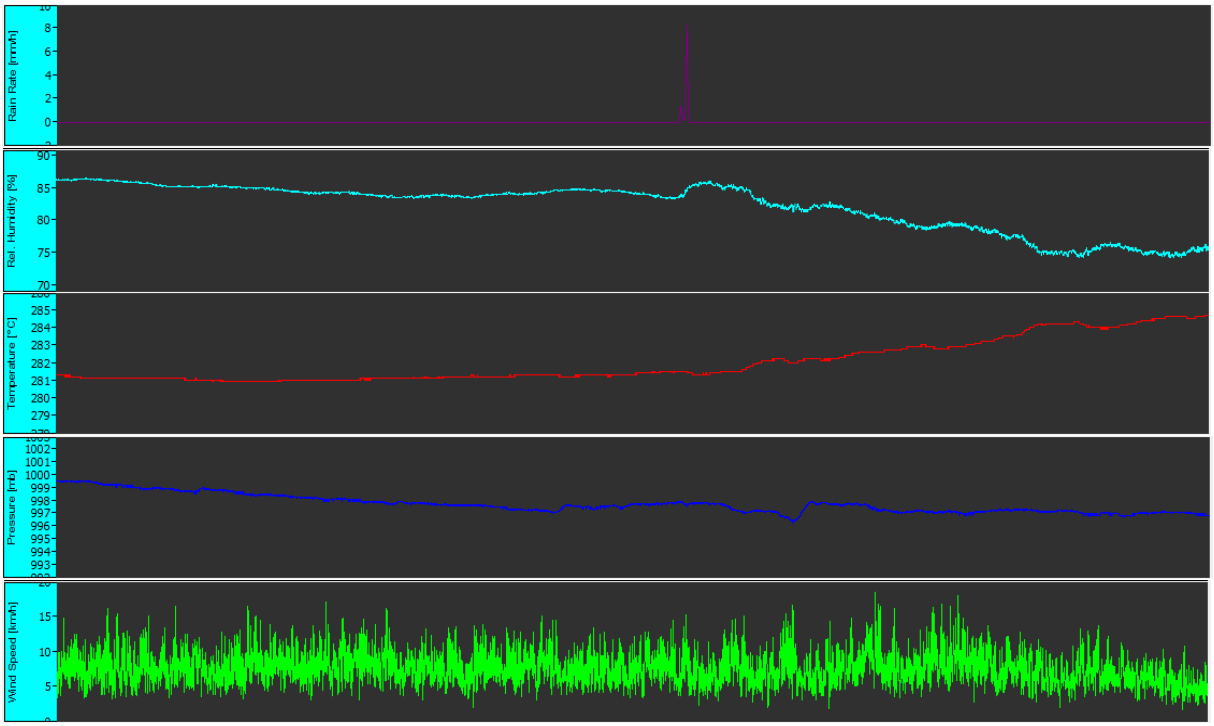
The radar profiles are displayed in the register page ***Radar Monitoring*** which acts as a real time display. In the main graphics area a color coded time series of reflectivity, mean velocity, spectral width, and polarimetric variables are shown. Radio buttons ***Ze, Vel, SpW, CoC, LDR/SLDR, DiPh*** switch between the alternatives. The color coding limits are user adjustable.



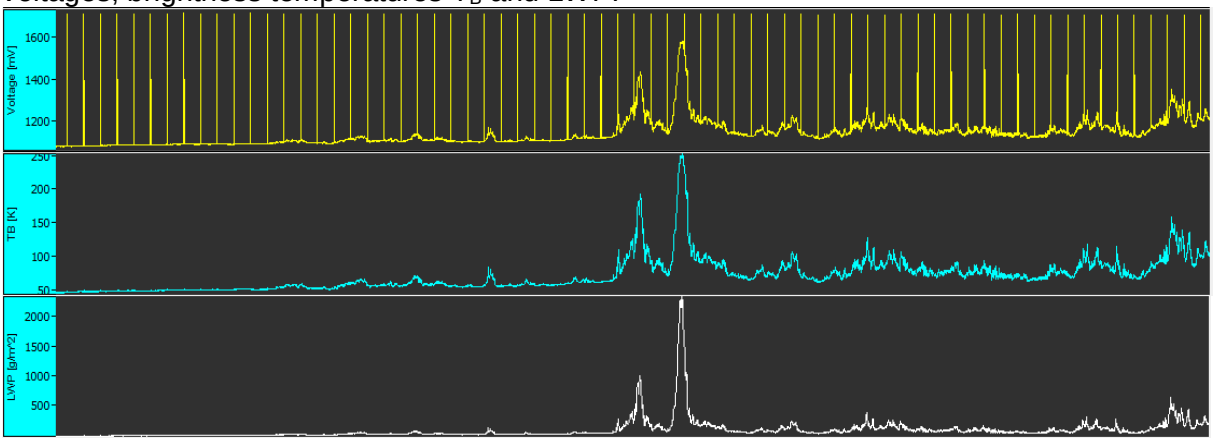
***Radar Monitoring* register page.**

Underneath the main display area a switchable time series of different useful parameters is plotted. The parameter is selected from a combo box on the right side of the time series.

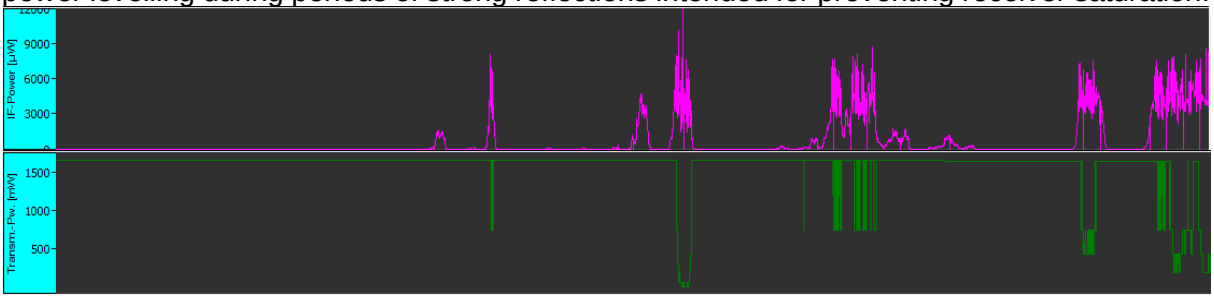
The radar is equipped with a weather station, providing information about environmental temperature, rel. humidity, barometric pressure, wind speed / direction and rain / snow rate:



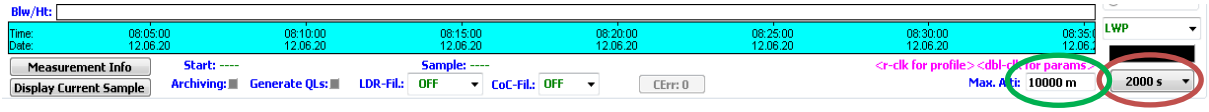
Another time series group is related to the direct detection passive channel at 89 GHz, which is intended for deriving LWP. Implemented are the DDR (Direct Detection Receiver) detector voltages, brightness temperatures T_B and LWP:



Additionally, information about the IF power level at the ADC board input (end of IF chain) as well as the transmitter power level are presented. The later one demonstrates the automatic power levelling during periods of strong reflections intended for preventing receiver saturation:



The time span of the time series is set in another combo box (red ellipse in the figure below) at the bottom line of the screen. Also, the maximum vertically displayed altitude in the main screen area can be modified (green ellipse in the figure below). The measurement start and duration and radar PC archiving status are shown in the lower left corner of the window. Additional information e.g. about the chirp program in use can be accessed by clicking the Measurement Info button.



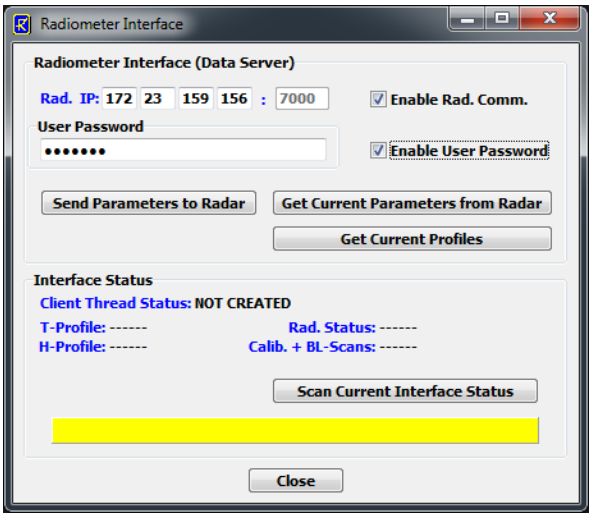
3.3 Connecting Radar to RPG-Radiometers

RPG radars provide a passive channel close to the radar observation frequency in order to derive useful parameters as LWP (Integrated Liquid Water Path). Other data of interest in combination with cloud radar data are thermodynamic profiles (temperature and humidity profiles). Such products can be provided by passive RPG microwave instruments like the RPG-HATPRO and do not require a well-matched beam of radar and passive microwave sensor.

The two instruments can be operated independently but connected to the same network. The passive radiometers provide a data server interface (RDS = Radiometer Data Server) for downloading the currently measured profiles online by external software. The radar software provides the data interface to locate a radiometer within the network and automatically downloads the newest temperature and humidity profiles when the connected radiometer is a profiler and currently running a measurement. If the radar does not detect a radiometer, it creates standard atmosphere profiles tuned by the met station's surface parameters.

The thermodynamic profiles are stored to both, level 0 and level 1 data files, together with the radar samples data.

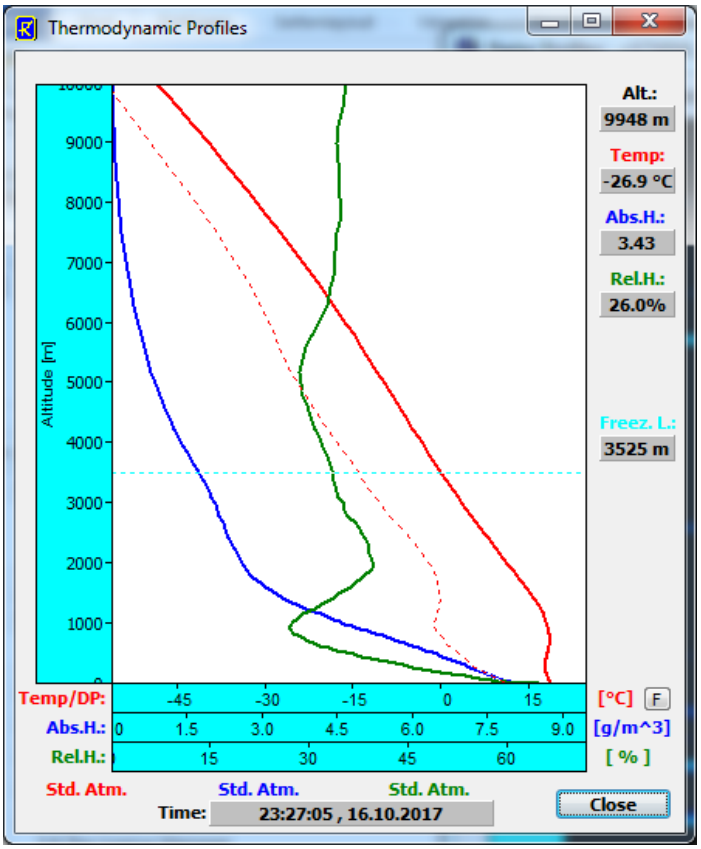
In order to establish a connection between the radar and a passive radiometer like the RPG-HATPRO, interface parameters need to be defined. This is accomplished by starting the ***Radiometer Interfacing*** menu ():



Radiometer Interface menu.

The most fundamental parameter is the RDS' IP address within the common network (the radar itself is connected to). It is important to note that only the radar PC is connecting to the RDS, but NOT the radar Host PC itself! Therefore, the thermodynamic profiles will also be stored to

file backup data files on the radar PC and not just to archived data files on the host PC. The process even works for radars not connected to a host PC, running in stand alone mode.
The RDS provides a fixed port address (7000) which cannot be changed. It also utilizes a User Password (UPW) to authorize access to radiometer data. When the radar downloads profiles from the radiometer, it needs this UPW (only if the password checking is enabled). The UPW and enabling password checking are both set on the radiometer PC and cannot be changed via the radar interface. The UPW entered to the dedicated box in the ***Radiometer Interfacing*** menu is NOT necessarily identical to the UPW defined for the radar Host PC ➔ radar PC communication. If password checking is activated for the RDS, the checkbox ***Enable User Password*** must be checked and the valid password should be entered. The communication between the radar PC and a radiometer can be enabled / disabled (***Enable Rad. Comm.*** checkbox).
The current interfacing settings can be loaded with ***Get Current Parameters from Radar*** and stored to the radar PC by ***Send Parameters to Radar***. If a communication to the RDS is established, this is indicated by a corresponding message in the yellow message field and the latest profiles are displayed by clicking ***Get Current Profiles***. In order to continuously check for the Interface status, the ***Scan Current Interface Status*** button is clicked. The status checking automatically stops when the menu is exited.
During measurements, the current radar reflectivity profiles and Doppler maps are displayed within the ***Radar Reflectivity Profile*** window which contains the checkbox ***Display Thermodynamic Diagrams*** which controls the display of the radiometer profiles. The same checkbox can be found in the ***Reflectivity and Sensitivity Profile*** window when opening existing data files from the datra archive: The display looks like this:



Thermodynamic Profiles Display.

The following profiles are shown:

- temperature profile (in red)
- dew point profile (in dotted red)
- absolute humidity profiles (in blue)
- relative humidity profile (in green)

The freezing layer is indicated as a light dotted blue line. The temperature axis can be switched between °C, °F and K. Profile types, as standard atmosphere (Std. Atm.) and radiometer profile (Radiom. Prof.) are shown below the diagram along with the profile sample time. When running over the profile diplay with the mouse, a display of cursor coordinates is given on the right side of the diagram.
The thermodynamic profiles are important information for the level 2 processor (separate software product available at RPG), which uses humidity profiles for the correction of radar signal gas absorption and temperature profiles for the classification of hydro meteors, the determination of ice particle types in certain altitudes and detection of undercooled liquid water. The freezing level should also be consistent with the melting layer height detected by the radar.

4 Maintenance

4.1 Cleaning

RPG radars are designed to withstand all kinds of weather and climate conditions. However, it is a good practice to prevent accumulations of dust, dirt, debris, salt (if located close to the sea), and other pollutants on the weather station, on the blower, on the radar housing, and on the radomes. Such cleaning is best done

* with pure fresh water (no chemical detergents, soap, solvent etc.)

* without applying mechanical force, especially to the microwave window

* just by watering and spraying gently to wash away the accumulated pollutants (and thus simulating a rain shower…)

The air inlets to the radar (cooler slits at sidewalls of main housing) and the inlet of the blower device need to stay clear from large scale size debris (leaves, spiderweb, insects, etc.).

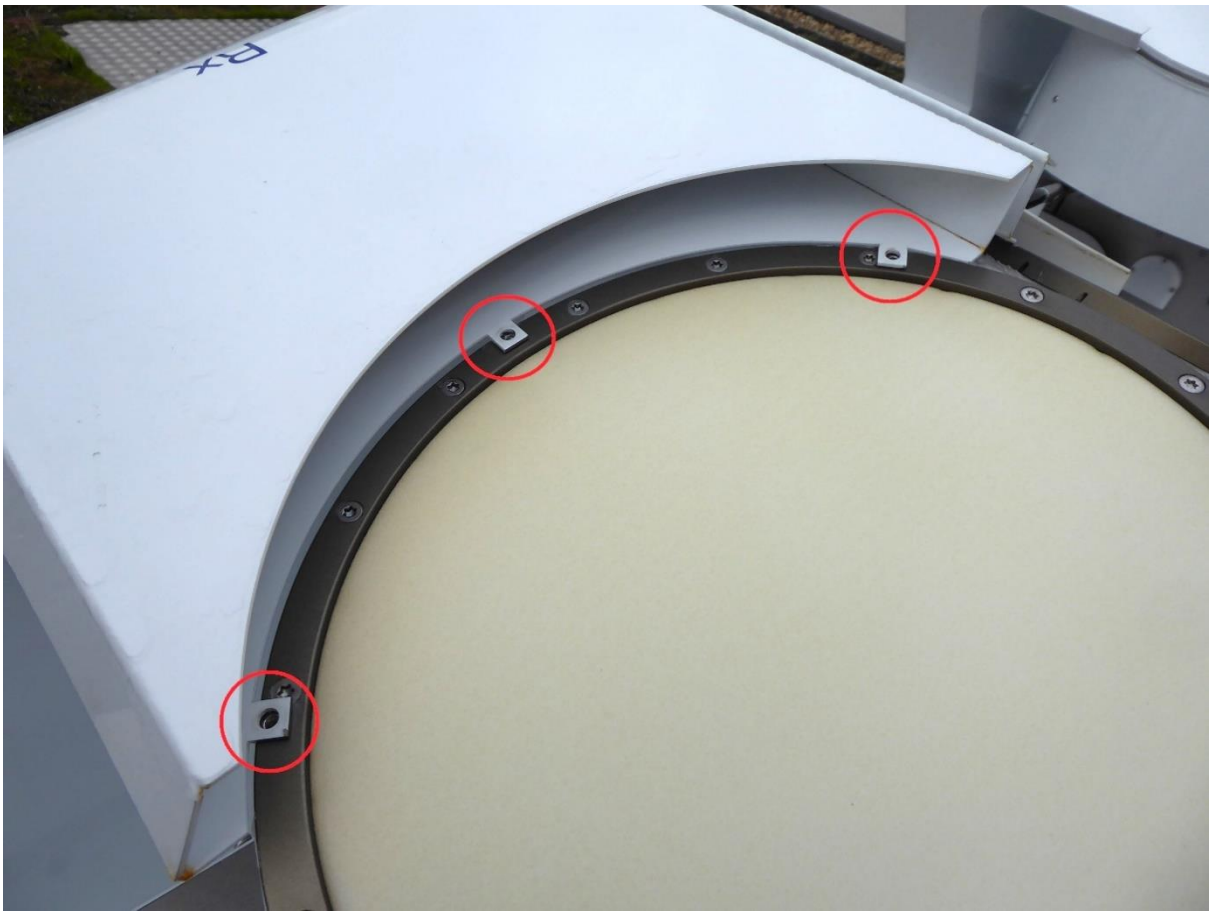
In areas with extreme snow amounts and ice-rain, the radar needs to be checked for snow/ice obstacles which would prevent the moveable parts (if any, depending on the selected options) from rotating. This affects the scanner.

All these cleaning activities need to be carried out according to the demand generated by the specific local environmental conditions. The intervals vary from twice a year (during the recommended calibrations) to weekly or daily (on ships).

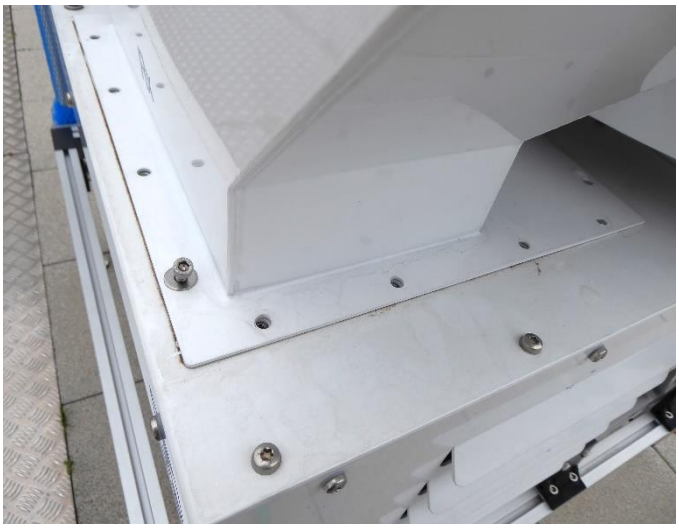
4.2 Exchange / Replacement of parts

4.2.1 Changing the radome sheets

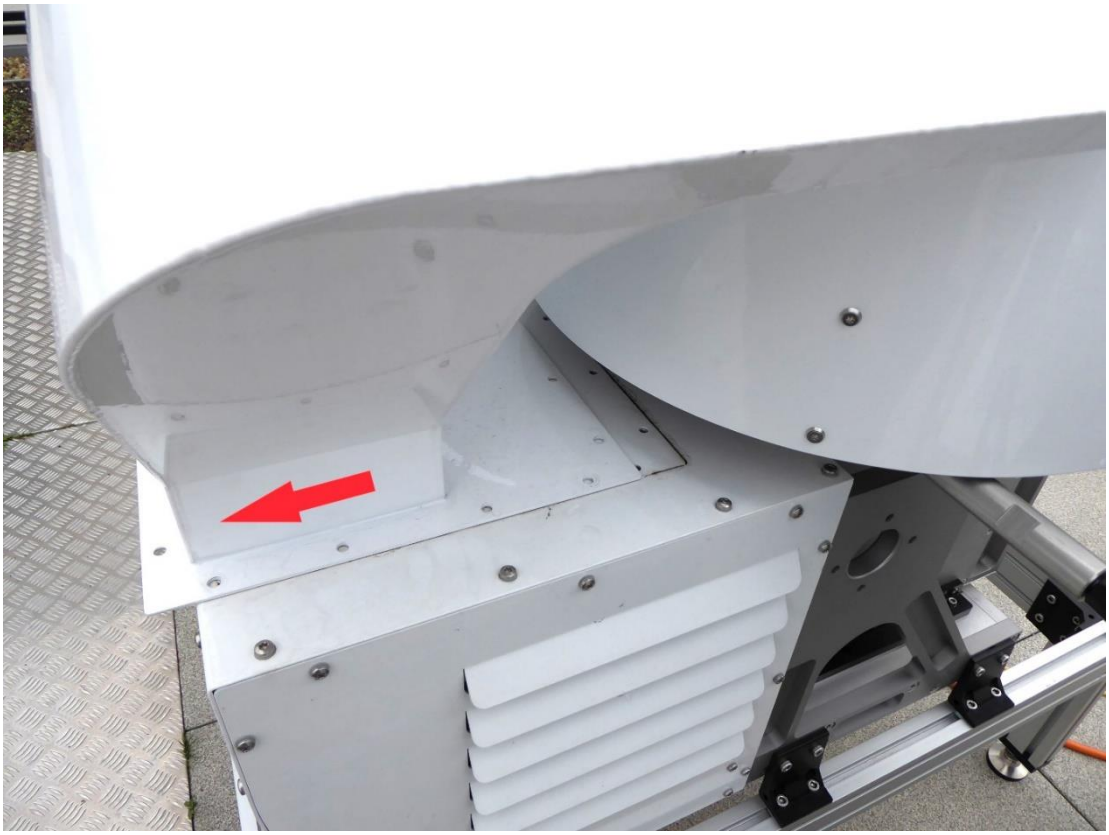
Remove 6 screws tightening the air-guides to the radome-holding cylinders, 3 on the transmitter and 3 on the receiver side. (This step is only required for older radars.)



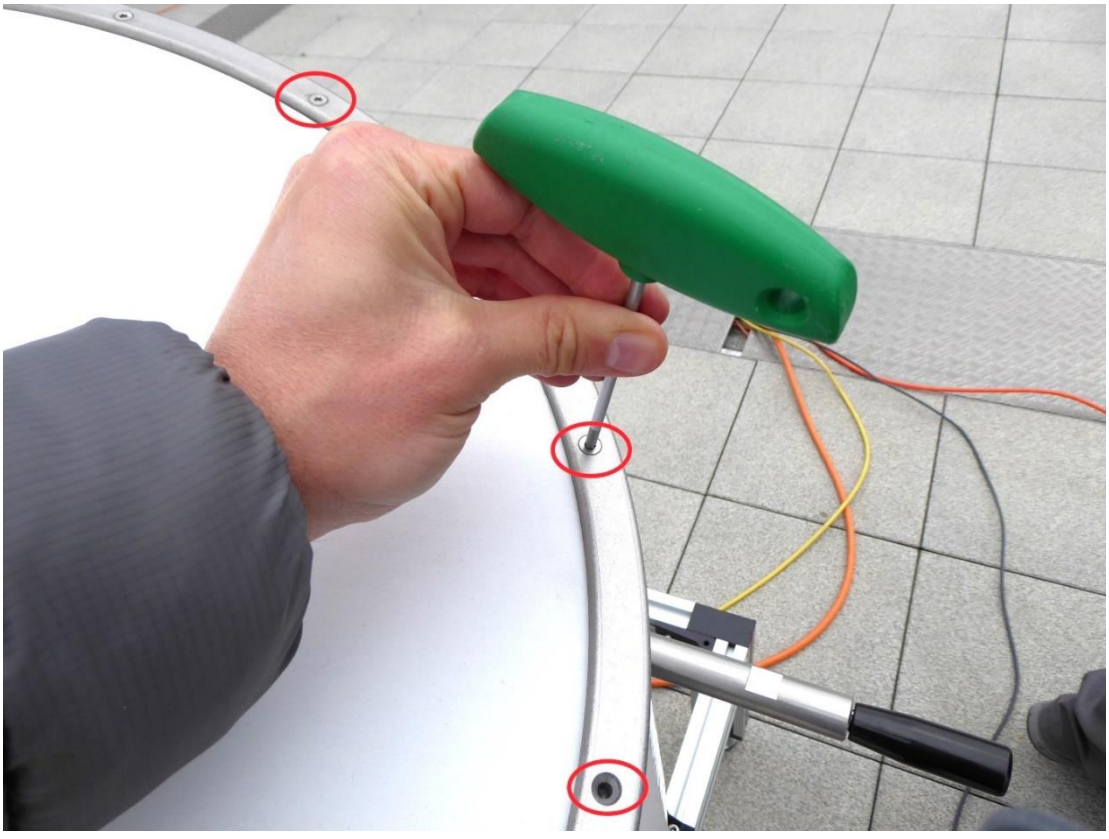
Remove all the screws holding both air-guides.



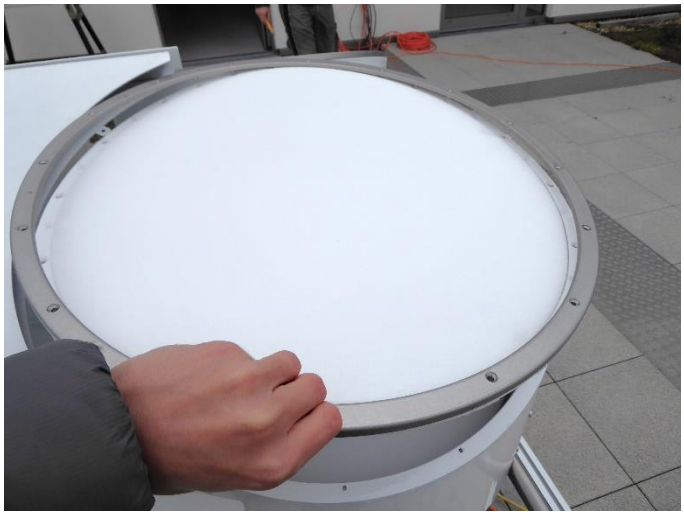
Move the both air-guides a bit to a side.



Unscrew all 16 screws holding the radome.



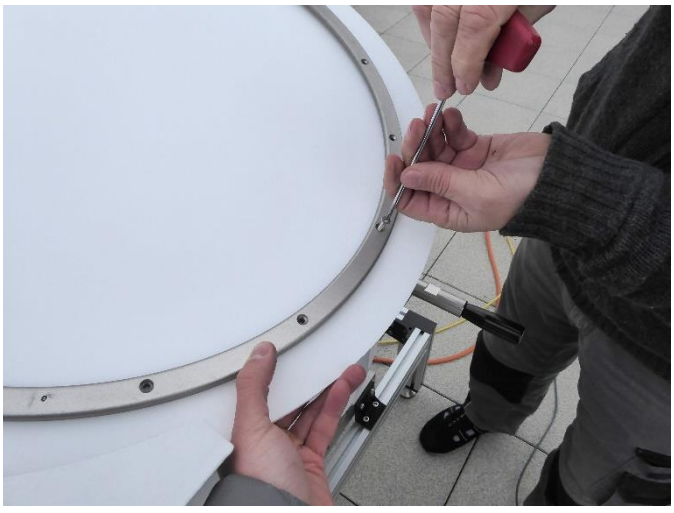
Remove the metal ring and the old radome material.

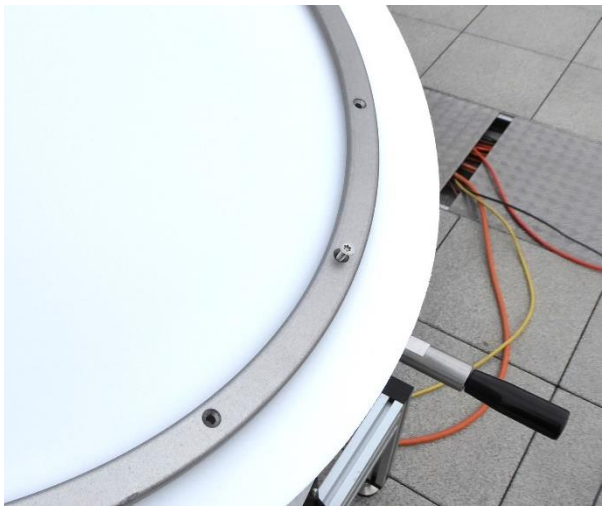


Make sure that the secondary (internal) radome is clean.

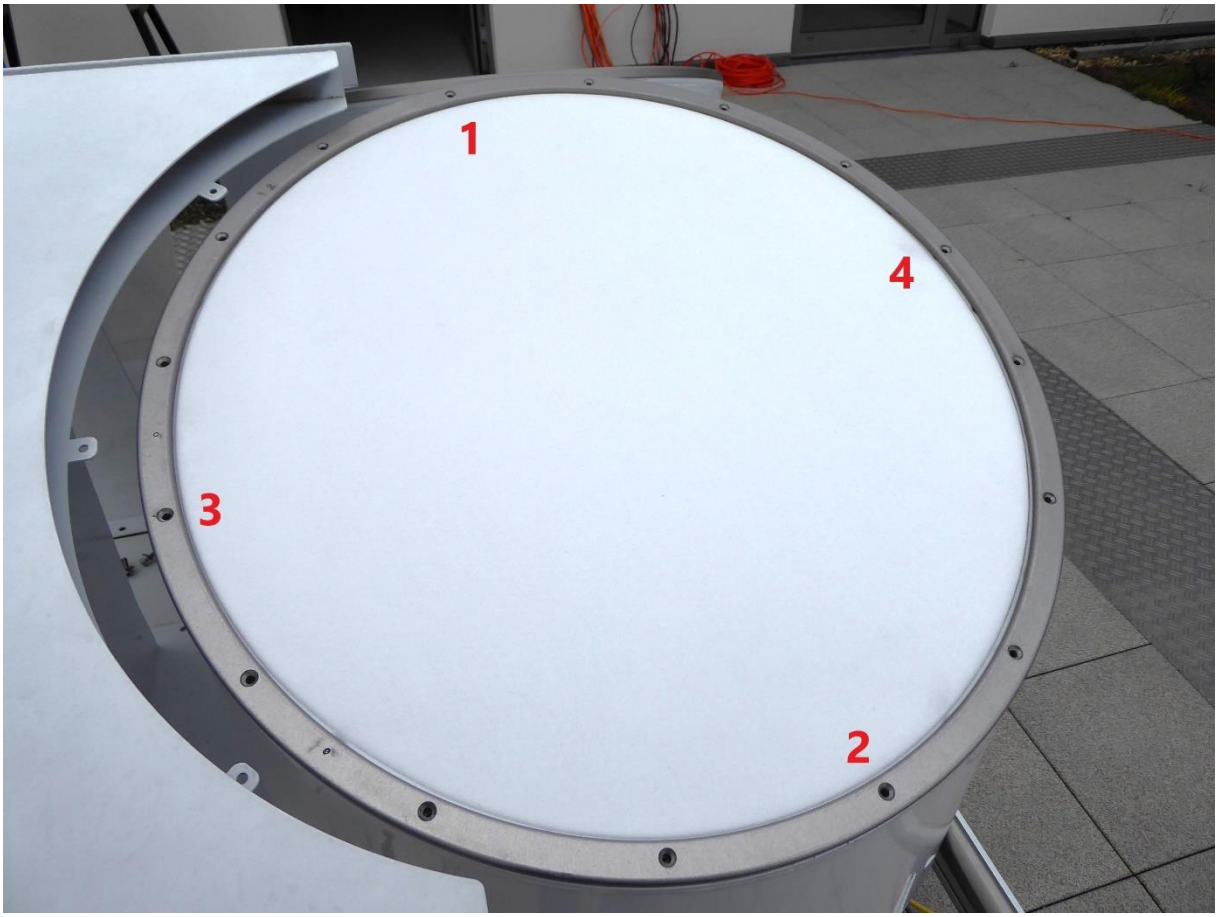
Put a new radome sheet on the cylinder. Make sure the coated (rough) side is facing upwards and put the metal ring on the radome sheet.

Punch the radome material with one screw through one of the ring holes and screw it down lightly.

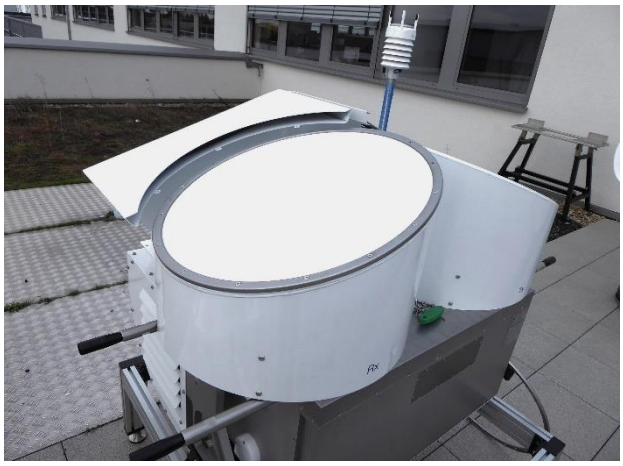




Do the same at the opposite side of the ring. Please do not pull the material at all. Insert all screws and tighten them, ensuring that the first 4 screws are orthogonal to each other.



When all the screws are tightened, cut off the material outside the ring with a sharp knife.



Repeat the steps for the other antenna and reinstall the air guides.

4.2.2 Vaisala weather station

4.2.2.1 Cleaning

To ensure the accuracy of measurement results, clean the transmitter when it gets contaminated. Remove leaves and other such particles from the precipitation sensor and clean the transmitter carefully with a soft, lint-free cloth moistened with mild detergent. Wipe with soft cloth or sponge and rinse with clean water.

Vaisala recommends that you clean the radiation shield once a year. Clean the radiation shield with a soft cloth. If the radiation shield looks worn and yellow, you can replace it with a radiation shield

4.2.2.2 Replacing PTU Module

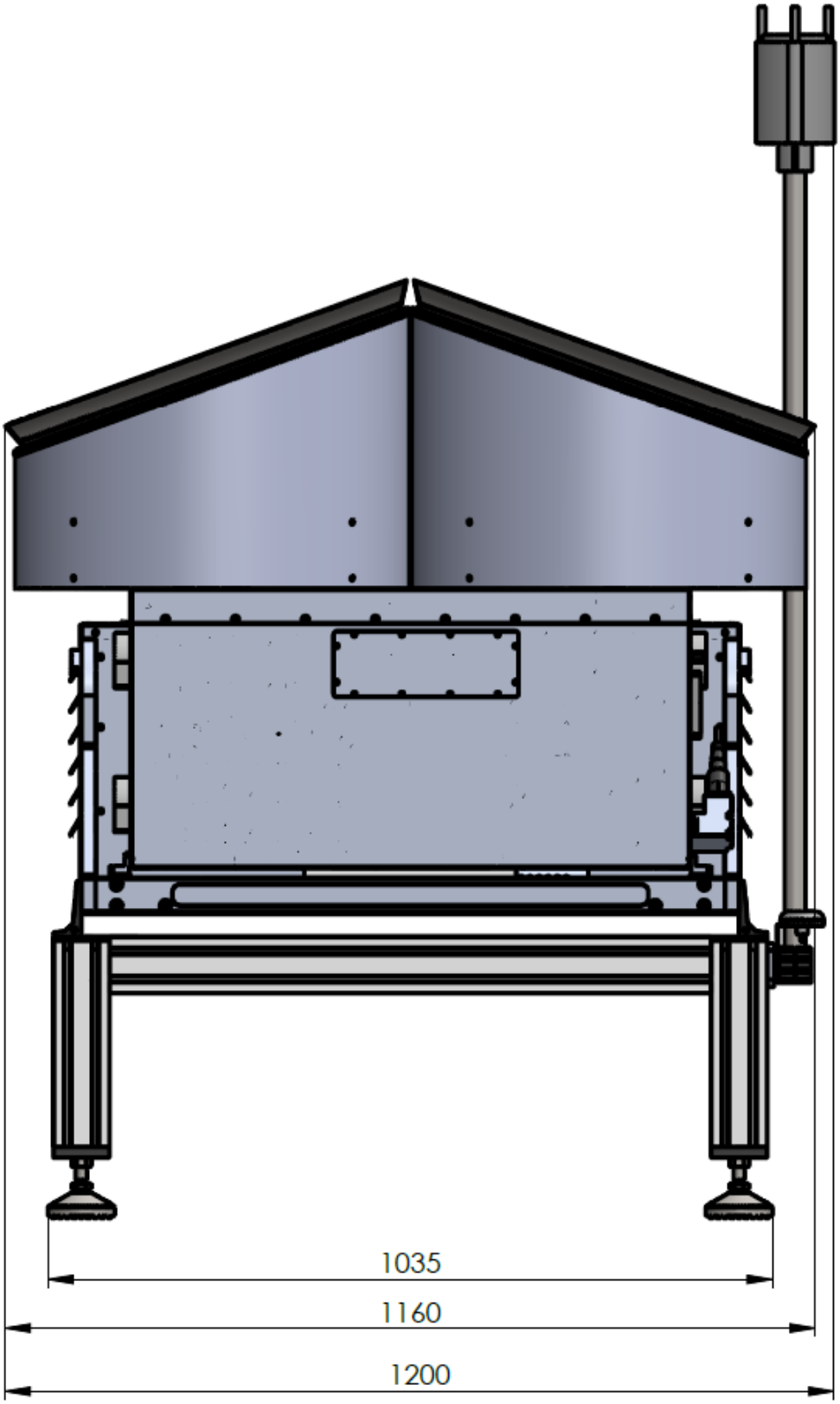
The PTU module contains separate sensors for pressure, temperature, and humidity measurement. Vaisala recommends changing the PTU module every two years. Follow the instructions contained in the Vaisala WXT530 Series user guide delivered with the radiometer. The PTU module shall be purchased directly from the manufacturer: https://store.vaisala.com

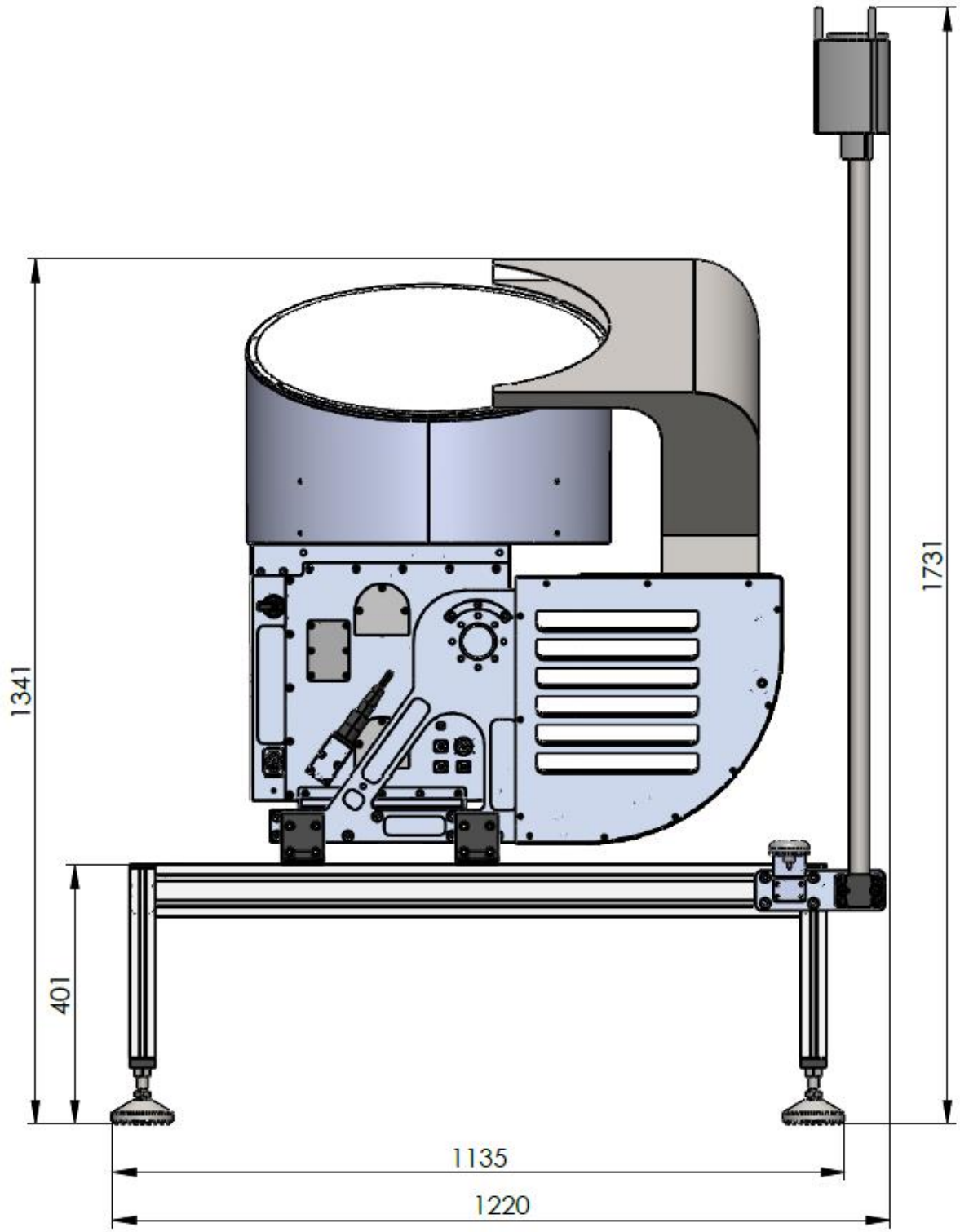
5 Instrument Specifications

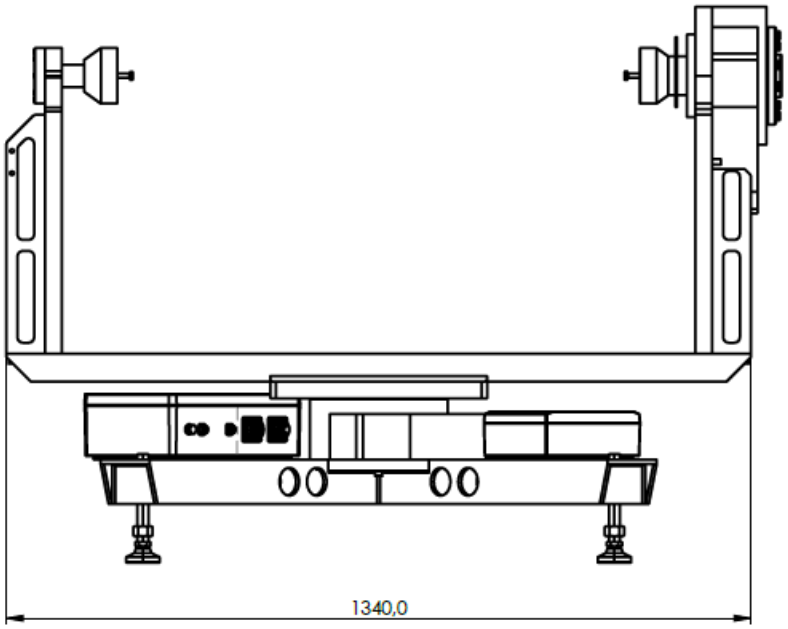
Parameter	Specification
Frequency	94 GHz (λ=3.2 mm), bandwidth up to ± 100 MHz
Transmitter Power	1.5 W (solid state amplifier)
Antenna Type	Bi-static Cassegrain with 500 mm aperture
Antenna Gain	50.1±0.3 dB
Beam Width	0.56±0.03° FWHM
Polarisation	V (optional V / H)
Passive Channel Noise Figure	4.5 dB
Dynamic Range (Sensitivity)	-46 to +20 dBZ @ 5km distance / 30 m resolution / 10 s sampling time
Ranging	50 m to 12 km typical, 18 km maximum
Vertical Resolution	15-30 m (down to 4 m for a limited distance range)
Calibration (automatic)	Transmitter power monitoring and receiver Dicke switching for gain drift compensation (radar and passive channels)
Calibration (maintenance)	Liquid nitrogen receiver calibration
End-to-end Calibration Verification	(1) Comparison with a disdrometer (2) Comparison with a calibrated radar
Calibration Accuracy	±1 dB
ADC Sampling Rate	11.45 MHz
IF Range	0.3 to 3.7 MHz
Sampling rate (full profiles)	Adjustable: typically ≥ 1 second
Doppler Resolution	±4 cm/s or better
Doppler Range	±9 m/s max (0-2500m), ±4.2 m/s above
Chirp Variations	3 typical, 5 possible, re-programmable
Passive Channels	89 GHz for integral liquid water (LWP) detection (2 GHz BW)
Control connection	TCP/IP connectivity via fiber optical data cable
Operation software	Real time visualization, real time data extraction, real time control (adaptive observation modes depending on context), data archiving, radar can be operated in stand-alone mode
Data products	Raw spectra, Spectral polarimetric parameters, Reflectivity, Mean Doppler velocity, Doppler width, Skewness, Kurtosis, Differential reflectivity, Differential phase shift, Correlation coefficient.
Data Formats	proprietary binary netCDF (conformity with CF convention)

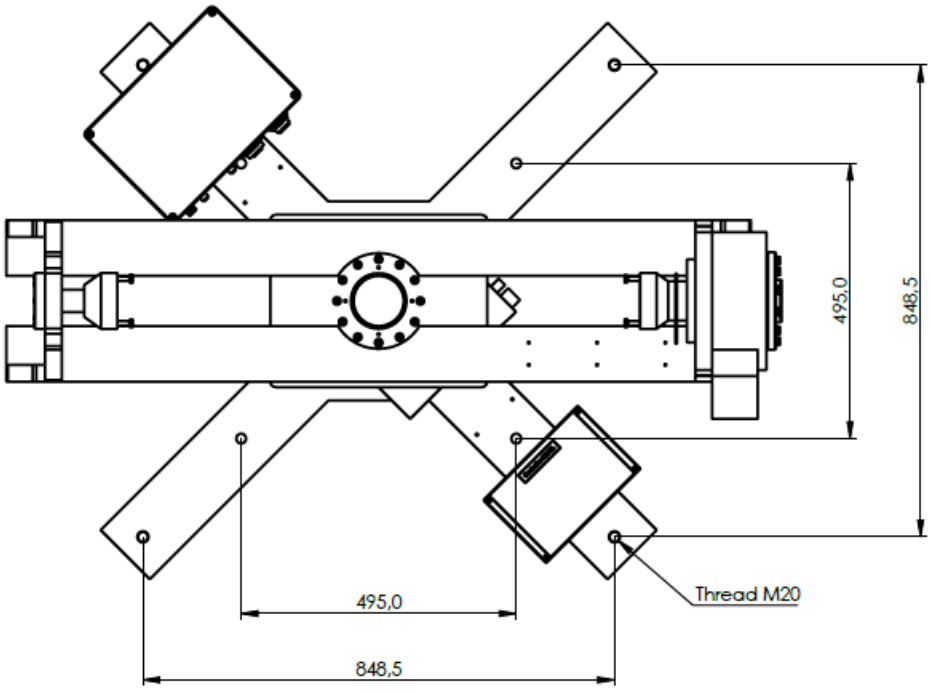
Mitigation system for rain/fog/dew	Strong dew blower (4000 m^3/h), radomes with hydrophobic coating
Additional sensors	Automatic weather station
Scanning (optional)	Scanner unit for full sky scanning capability with maximum angular velocity of 5 °/sec in azimuth and elevation
Weight	Radar main body: 90 kg Blower: 90 kg Table: 30 kg Air guides: 25 kg
Maximum Power Consumption	Radar 700 W, Blower 750 W, Scanner: 800 W, AC 230 V 3~ 16A 50-60 Hz

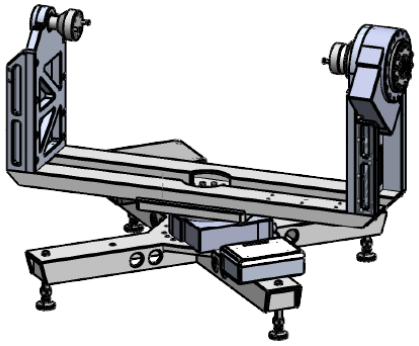
6 Instrument Dimensions




1731
1341
401
1135
1220







Scanner, dimensions of mounting holes.