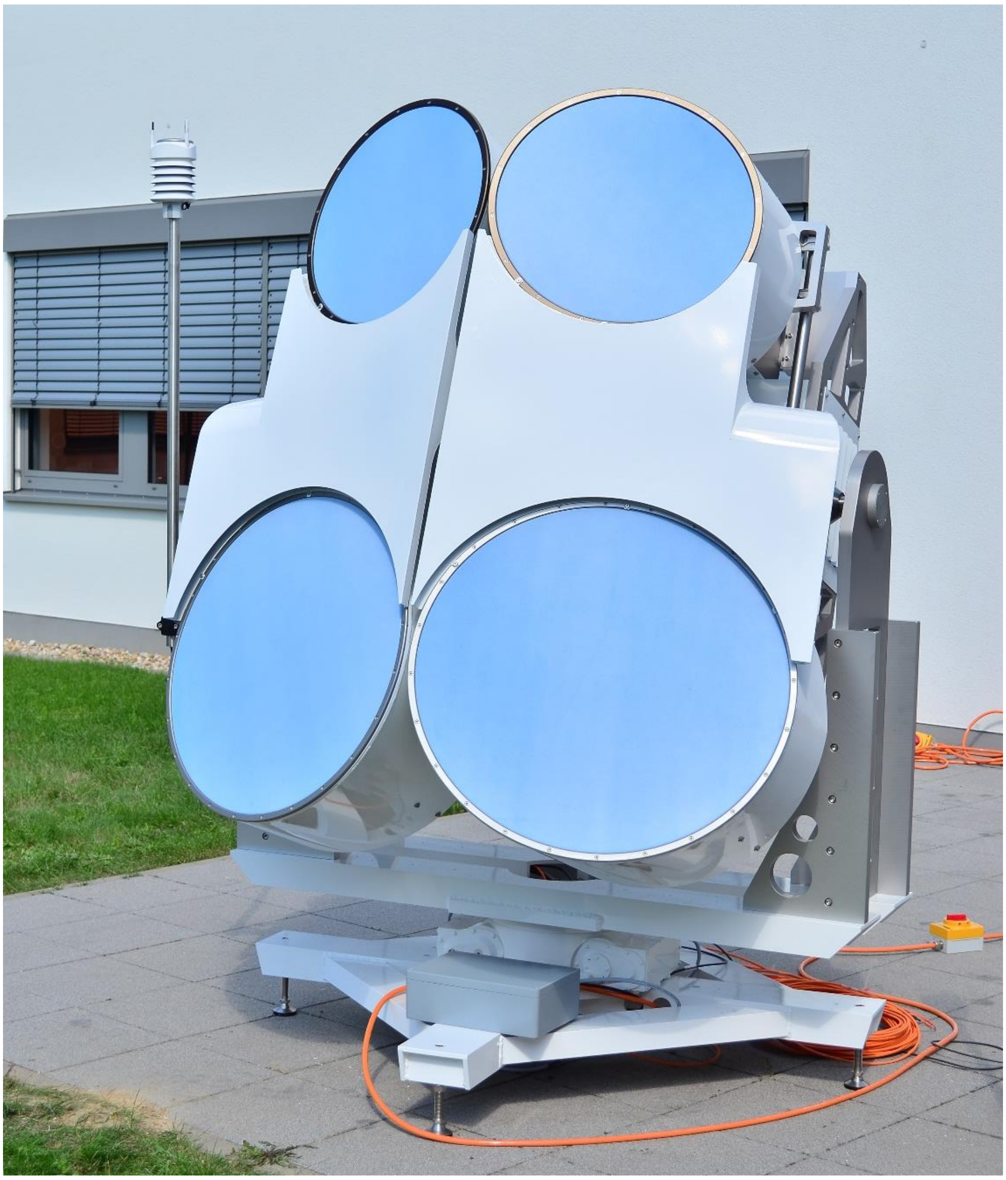
RPG-FMCW-DP-KW
35 / 94 GHz Dual Frequency Cloud Doppler Radar
Instrument Installation Guide



Radiometer Physics
A Rohde & Schwarz Company

Document Change Log

Date	Issue/Rev	Change
21.10.2020	01/01	Release
31.10.2020	01/02	Add description of single radar configuration
25.01.2024	01/03	Correction power line requirements
26.01.2024	01/04	Removed Chapter “Calibration”, modifications in 2.1, updated dimensions
06.03.2024	01/05	Add chapter ”Maintenance”, standardization of terminology
14.08.2024	01/06	Corrections in “Instrument use”

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1 Safety Instructions

Instrument Use

The RPG-FMCW-Dual-Freq-35-94 radar is a microwave instrument for the detection of cloud particles. It emits continuous microwave power at 35 and 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.

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 a maximum of 13 Watts at K-Band and 1.5 Watts at W-Band (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 2.5 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 at least 2.5 m radius around the centre of the radar).

⚠

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, position scanner, and blower control) 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 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**.
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	-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	230 V AC, 50 to 60 Hz
Power consumption W-Band radar and blower are one phase 1, K-Band radar is on phase 2 Position Scanner is on phase 3	Instrument: average 900 W (K-Band) and 500 W (W-Band) 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)!
- 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.
- The radars and optional scanner are powered by 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.
- 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 by obstacles 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	94 GHz Radar: approx. 100 kg 35 GHz Radar: approx. 160 kg Blower: approx.180 kg El/Az Scanner: approx. 200 kg
Dimensions	Radar + Blower (W x D x H): 164 x 172 x 210 cm^3

For transportation and installation purposes, the radar can be unmounted from the blower and scanner units.
Because of the instruments weight of approx. 90 kg and 160 kg, they 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.

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:

- 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.

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).

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 for the 94 GHz system and 90 meters for the 35 GHz system**. In off-axis direction of ±1° the safety distance drops down to 4 m (side lobe) for the 94 GHz system and 9 m for the 35 GHz system.

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 90 m! This requirement can be easily fulfilled by a deployment on high buildings or platforms.

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.

Further Information

If further technical support is required, please contact:

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

Tel: 0049-2225-99981-0

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

2 Instrument Installation

The RPG-FMCW-Dual-Freq-35-94 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) rain mitigation system, a set of power and data cables, two Ethernet-to-Fibre signal converters, an external calibration target and target table, 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.

2.1 Scanner Setup and Radar Installation

Unpacked scanner of the dual frequency 35 / 94 GHz cloud radars.

The scanner is usually delivered in a single wooden box. The blower without air guides is already installed on the scanner. Unloading the scanner requires a fork lifter since the weight is about 360 kg (scanner + preinstalled blower unit).
The 0° position of the scanner (marked by the orange arrow) has to be oriented towards the north direction. A coarse adjustment by using a compass is sufficient because the azimuth fine adjustment is later performed by software during a solar scan.
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 scanner should be handled by a fork lifter.

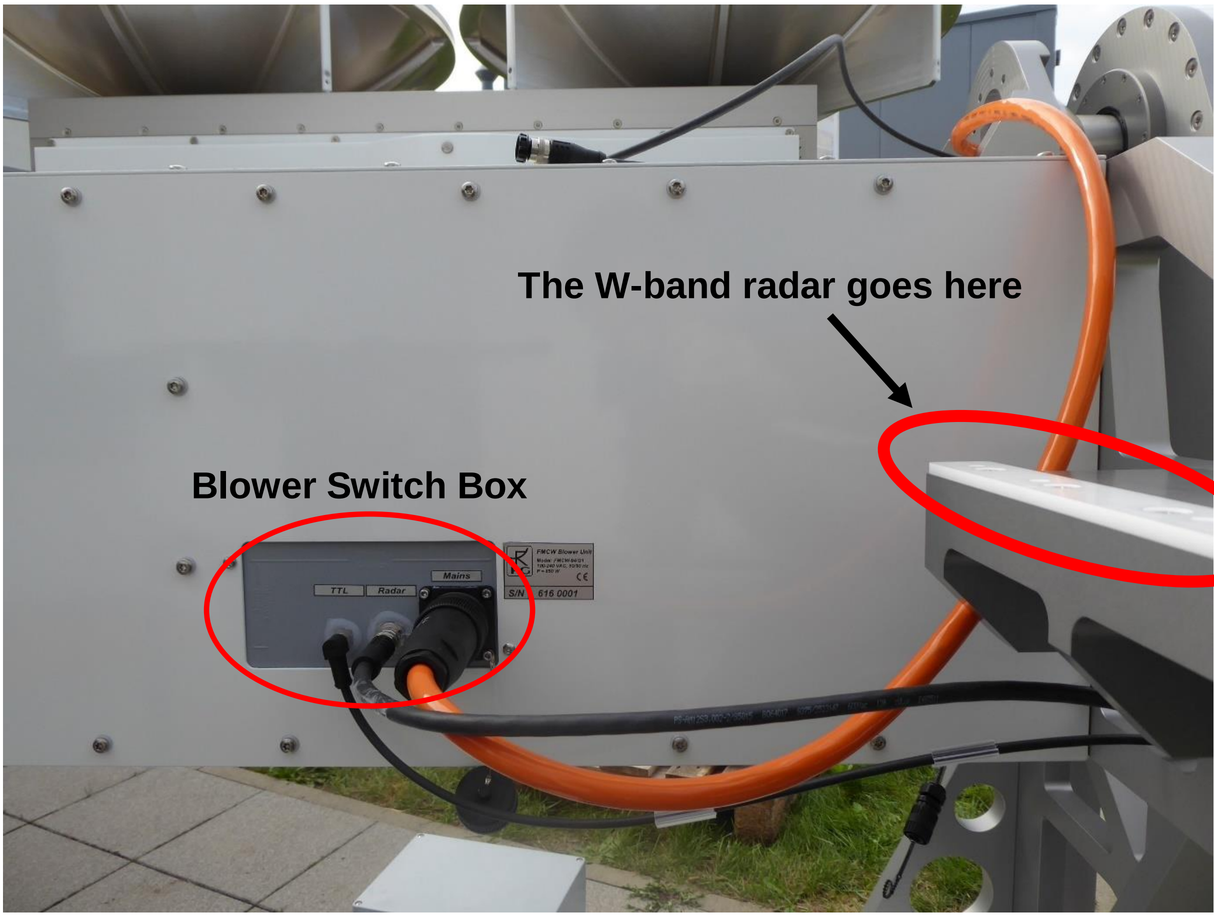
Turn the scanner in azimuth until the arrow is pointing to north direction.

Unpack the W-band radar from its flight case and load it on a fork lifter. Use the handles to get the radar out of the flight case (4 people are required!):

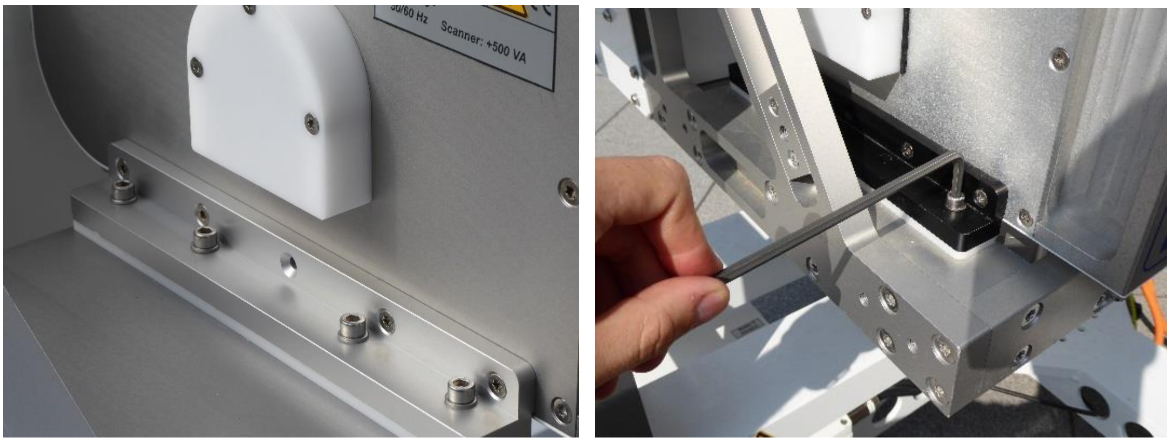


Do not lay the radar directly on the ground. On the bottom side of the radar body a cooler is sticking out and the metal housing may be deformed by the radar weight and block the fans inside from moving. This, in turn, may lead to overheating of the radar PC during operation.

Position the W-band radar body on the scanner. The radar body is finally sitting on the white hard-plastic sliding bars. The radar side with the connectors must point to the **RIGHT**.
The W-band radar is the Master unit and (the K-band radar is the Slave), meaning it will control the K-band radar during measurements. This is why the W-band radar is connected to the GPS clock, the weather station, the blower switch and the scanner controller while the K-band radar is not.

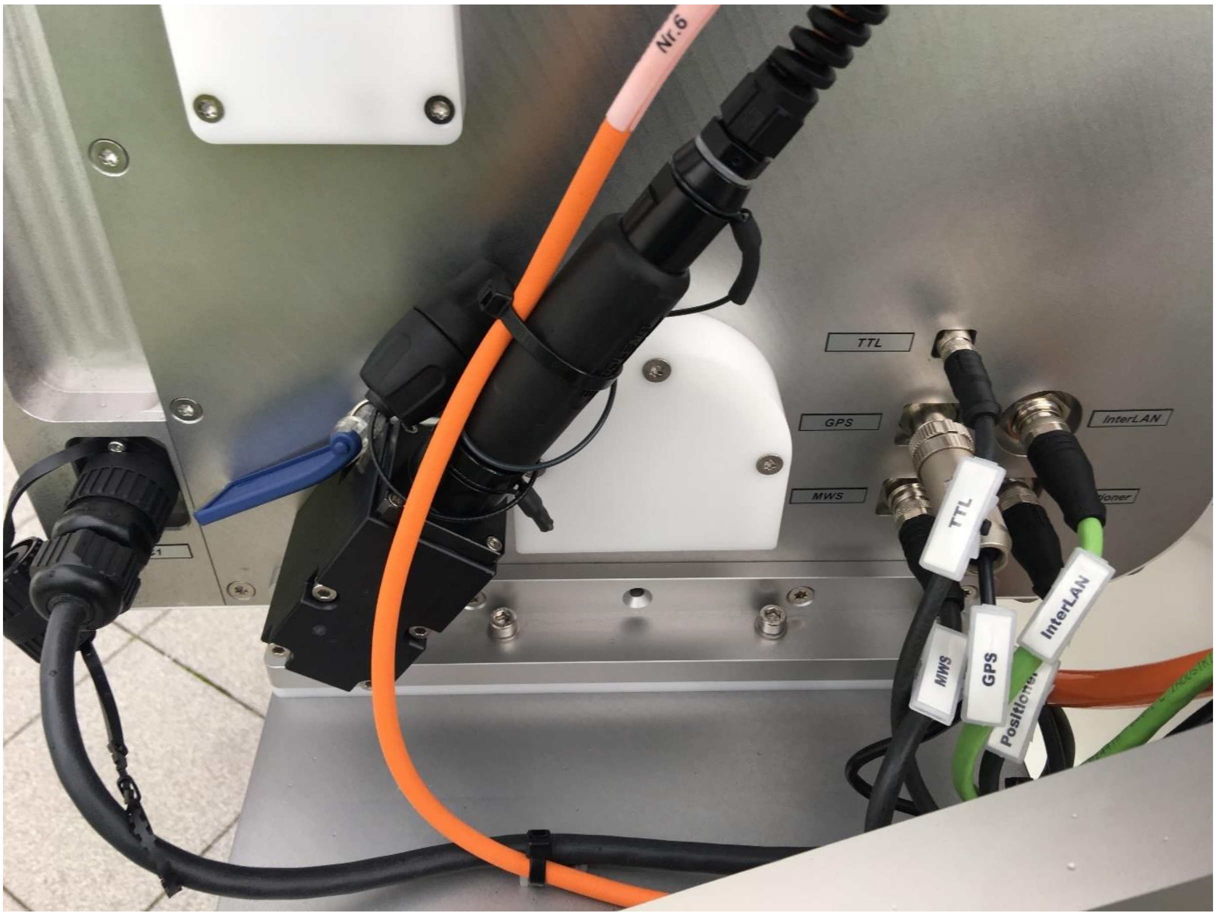


Make sure that no cables are lying on the radar mounting surfaces while lowering the radar onto the white plastic sliding bars.



Use Allan key to tighten the screws.

Mount the radar body to the scanner with four M6 x 35 screws on each side.
Then connect the cables. Use the 90° wrenches (from the tool box) to tighten the connectors.
The cables have labels that have to match the labels on the radar housing.



Please do not apply strong force when srewing the connectors onto the sockets and also do not use pliers. This may lead to damages of the connector pins.

Connect the protection caps with each other, so that water cannot penetrate into them. Also use cable ties to attach the loose cables to the scanner frame:

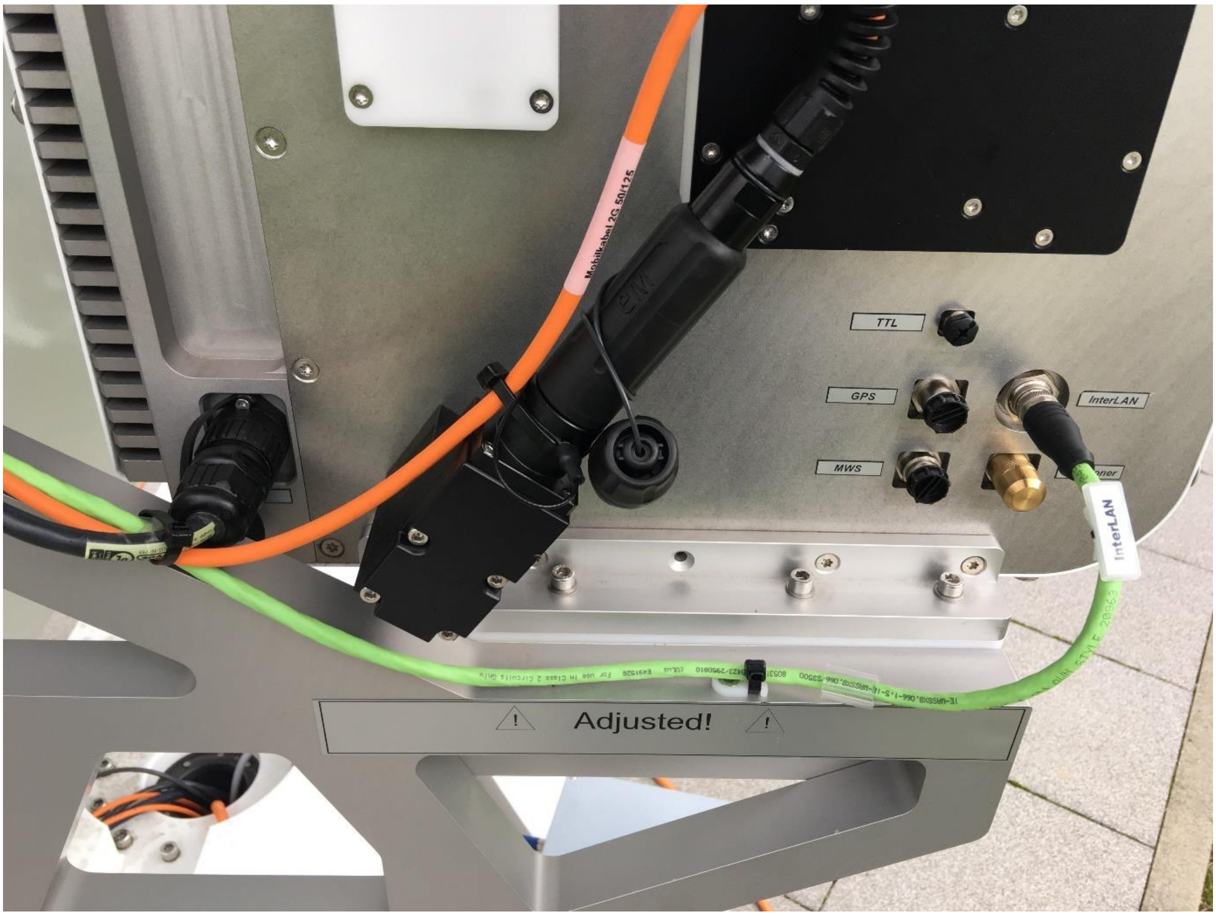




Now take the K-Band radar out of its flight case. The radar weight is about 150 kg, so that it should be carried and handled by a folk lifter. The procedure is simplified if the two sidelobe suppression cylinders are dismounted:

The connectors must point to the **LEFT** when lowering the radar onto the scanner, thus the opposite as for the W-band radar.

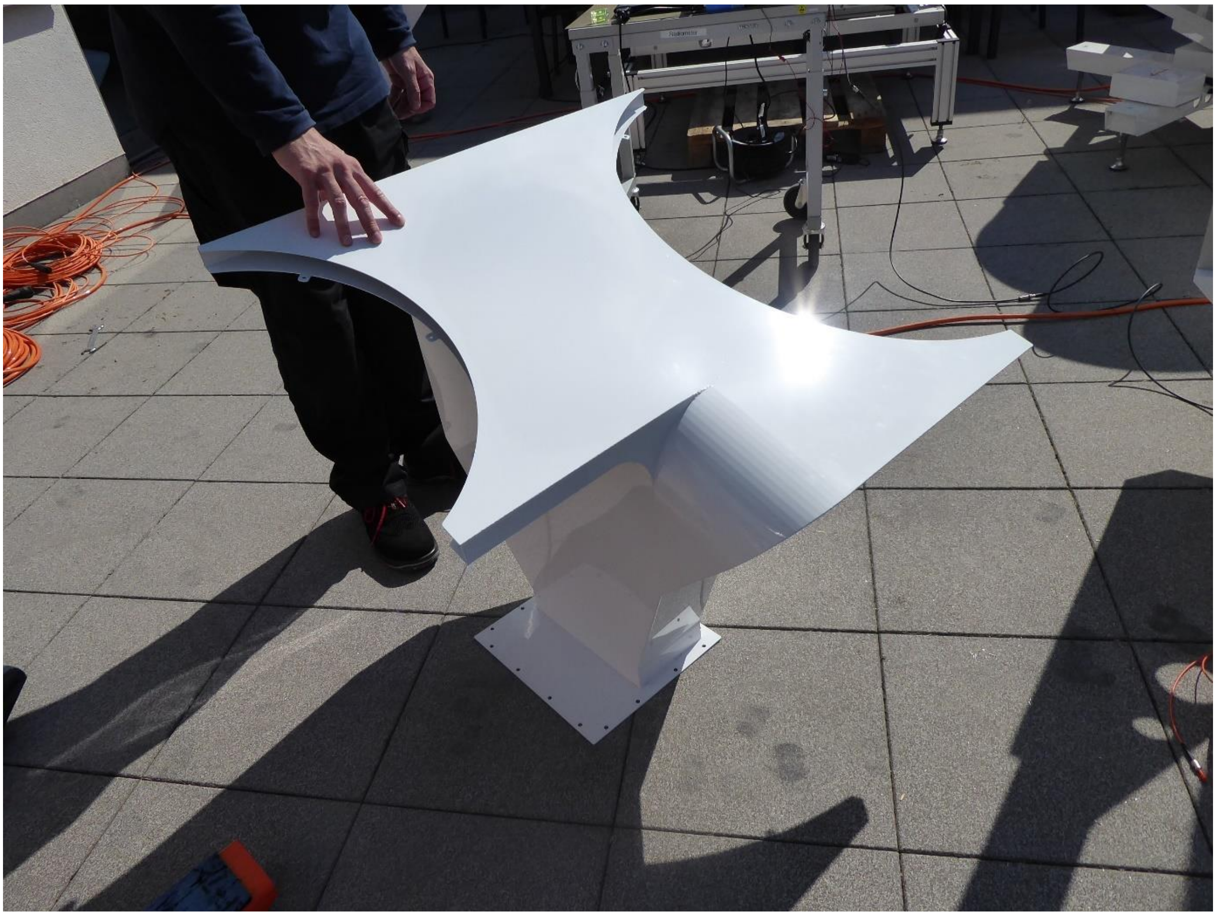
Fasten the K-band radar the same way as done with the W-band radar. Use a total of M6 x 35 screwes and tighten them properly. Then connect the InterLAN, power and data cables. Make sure that all non-connected sockets on the radar's side wall are protected with plastic caps:



Proper cable connections of the K-band radar.

Now re-install the K-band radar's sidelobe suppression cylinders and fix them with 8 screws each:

Install the blower air guides and tighten the flange screws:



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.

2.2 Power and Data Connections

In a dual frequency radar system, each radar has its own data cable (fibre optics cable) being connected independently to a single Host-PC (for instance via an EtherNet switch), while the power lines for both instruments are wired inside the scanner and are combined to a single 3 phase CEE (3 x 16 Amps, 220 Volts) connector:

The phases are distributed as follows:

Phase 1: W-band radar and blower unit
Phase 2: K-band radar
Phase 3: scanner

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

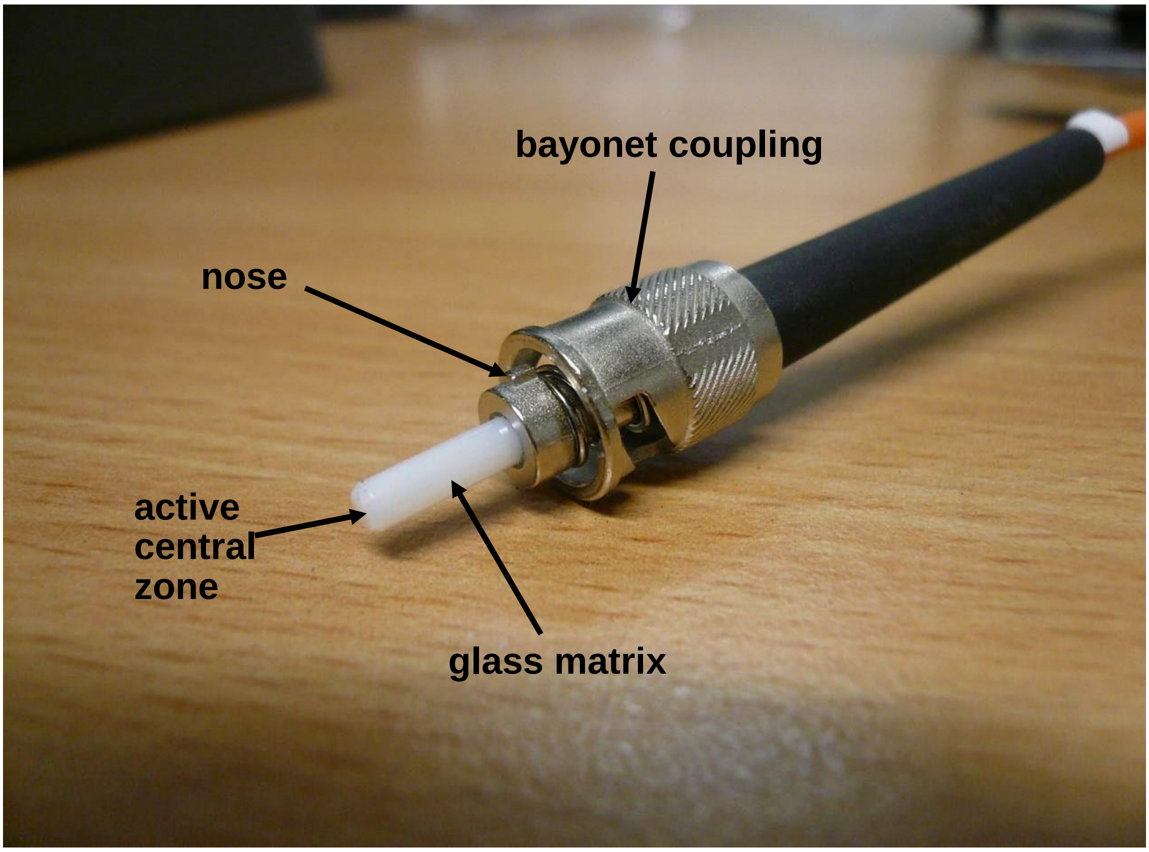
Connection of the power cable to the scanner.

Once the CEE connector is under power (also make sure the safety switch is in ON-position), turn on the power switches of both radars:
Turn the key on the radar body clockwise to the “on” position:

Secure the dual frequency radar system with a protection fence as described in the Safety chapter 1. The scanner is very powerful and may injure people standing too close to it, when moving.

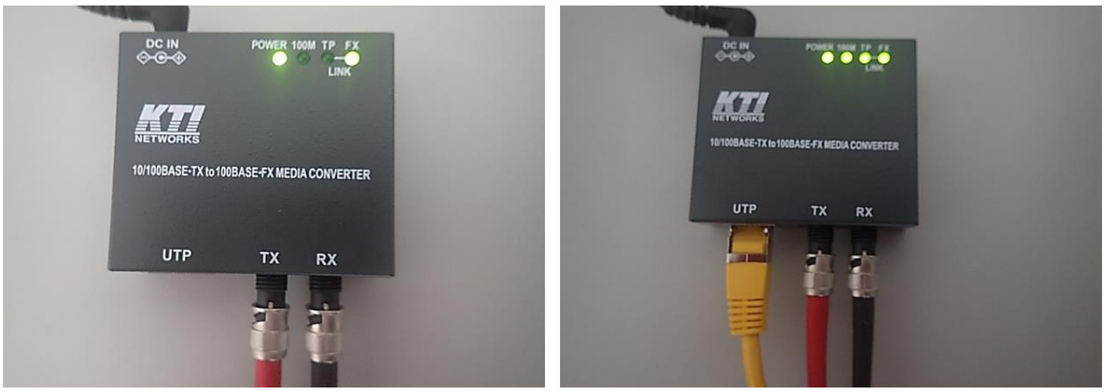
Each of the two data cables ends with two pig-tails equipped with bayonet couplings. Each data cable must be connected to its own fibre-to-LAN Ethernet converter.
Connect the end of the fiber cable to a MOXA Fiber-to-LAN-TCP/IP converter as indicated below. Each of the two lines end has a nose, which 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 and power supply.Connect the converter's power supply to a power line (110 to 220 Volts AC). When the power cable and the two fiber lines are connected, the power LED and FX LED turn on. Make sure that the TX fiber line (red) gets connected to the TX converter output and the RX fiber line (blue) to the RX converter input. 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). If everything is properly connected, all four converter control LEDs are on / blinking. If not, try to swap the two fibre cables (swap TX with RX).



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

This finishes the hardware installation procedure.

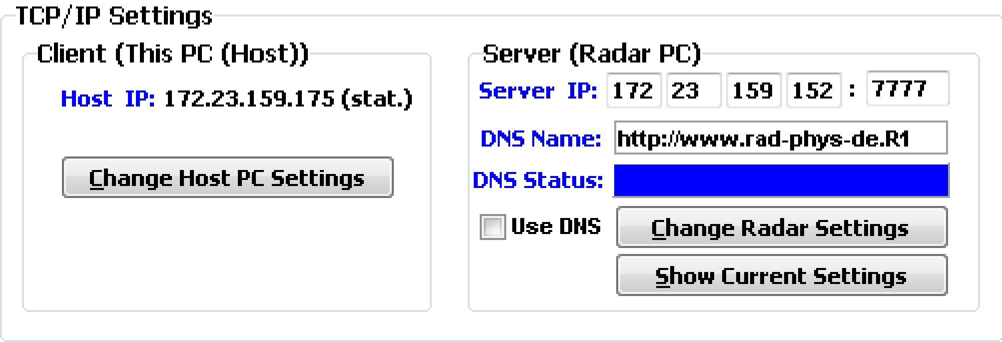
3 Software Installation on Host-PC

The two radars are coupled to each other by inter-connecting them with the green InterLAN cable. When InterLAN detection is enabled on both radars (see below), the radar software scans the InterLAN Ethernet port for another radar connected to it. If the W-band radar detects another radar on the InterLAN line, it automatically configures itself as the Master instrument. If the K-band radar detects another radar on the InterLAN port, it automatically configures itself as the Slave instrument.

During measurements, the Master radar synchronizes sampling and automatic calibrations of the Slave radar. This way, not only do the radar beams match precisely in direction, also the sampling is matched in time and range resolution.

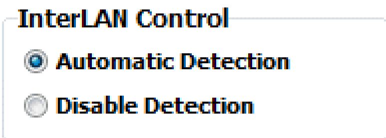
When installing the Host-PC application, create two folders on your PC, one for each radar. Name these folders whatever you like, for instance FMCW-35 and FMCW-94. Copy the application into both folders and run it. The Host application will create a number of sub-folders for internal use.

Each radar has its own IP address to be entered in each of the two Host-PC processes (inside the **Server (Radar PC)** box, **System Control** tag):



When the radars and the Host-PC are connected to the same network with matching sub-net masks, the Host will connect to both instruments.

In order to activate the InterLAN detection on both radars, select the **System Control** tag on both Host-PC applications and check the **Automatic Detection** radio-button within the **InterLAN Control** box.

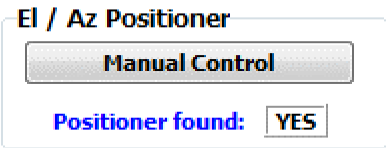


The radars will then automatically scan their InterLAN ports, every time the radar software is started.

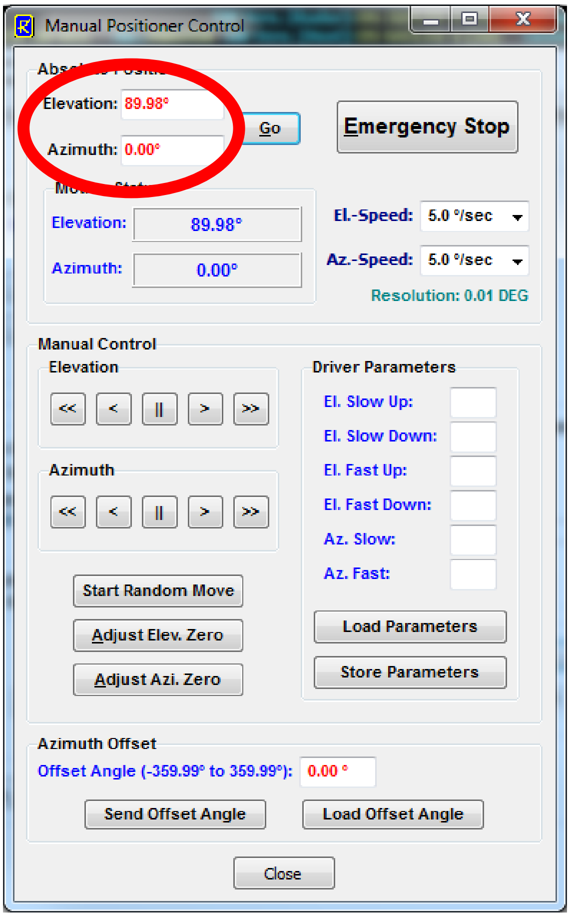
4 Adjustments

4.1 Horizontal Scanner Adjustment

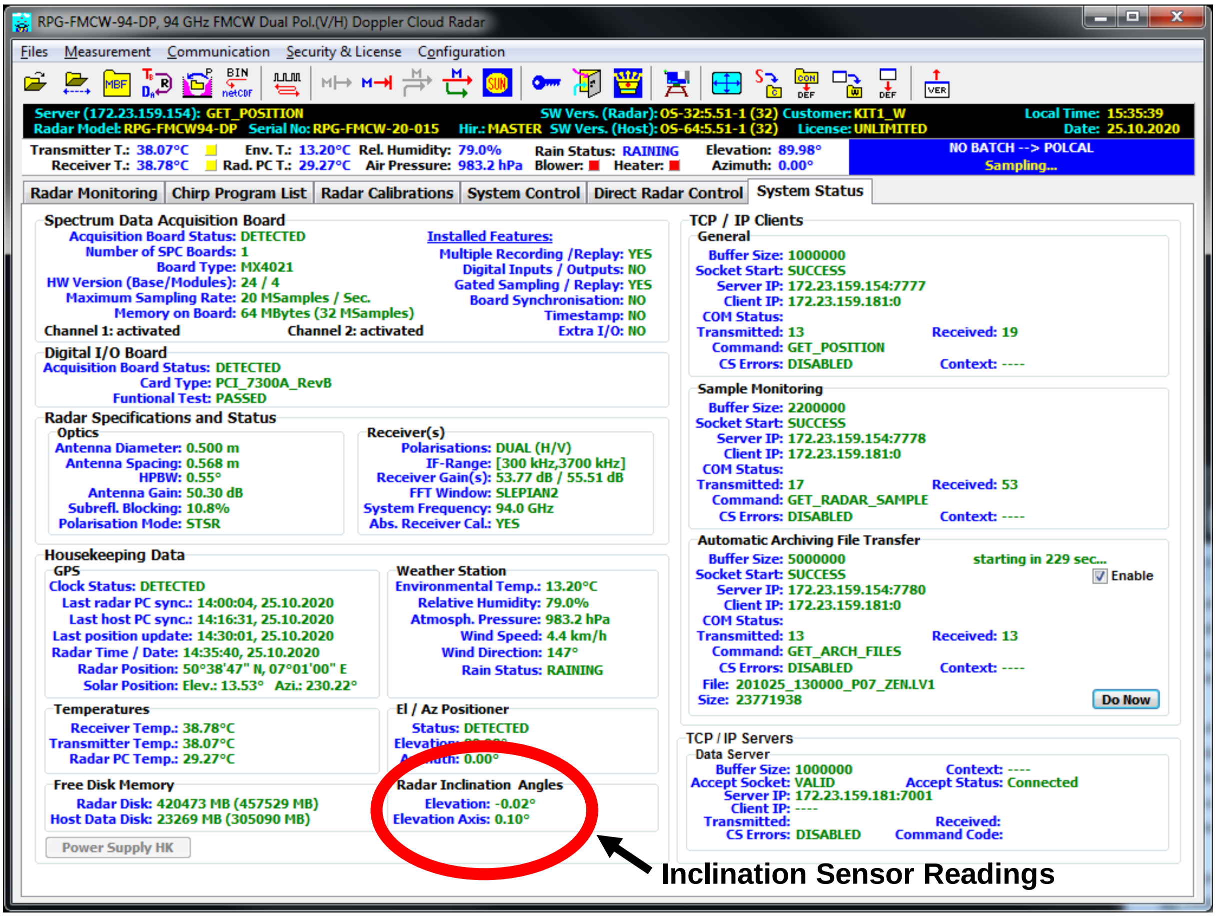
In order to allow for precise scanning, the positioner needs to be horizontally aligned. Both radars include a two axis inclination sensor attached to their optical reference plates inside the radar bodies. One sensor axis is oriented along the elevation axis and measures the elevation axis tilt relative to the horizontal direction. The other sensor axis measures the elevation relative to zenith in the range [-10°,…,+10°].
For the horizontal alignment, two azimuth directions should be used: 0° and 90°. Turn the azimuth to 0°. In order to do so, enter the W-bands Host-PC application and select the **System Control** tag. If the W-band radar has been connected successfully to the scanner's controller, the entry within the **El / Az Positioner** box looks like this:



Click the **Manual Control** button to open the scanner's manual operation menu:



Enter the numbers in red and click on **Go**. The scanner should move to zero azimuth direction. Then switch to the **System Status** tag:



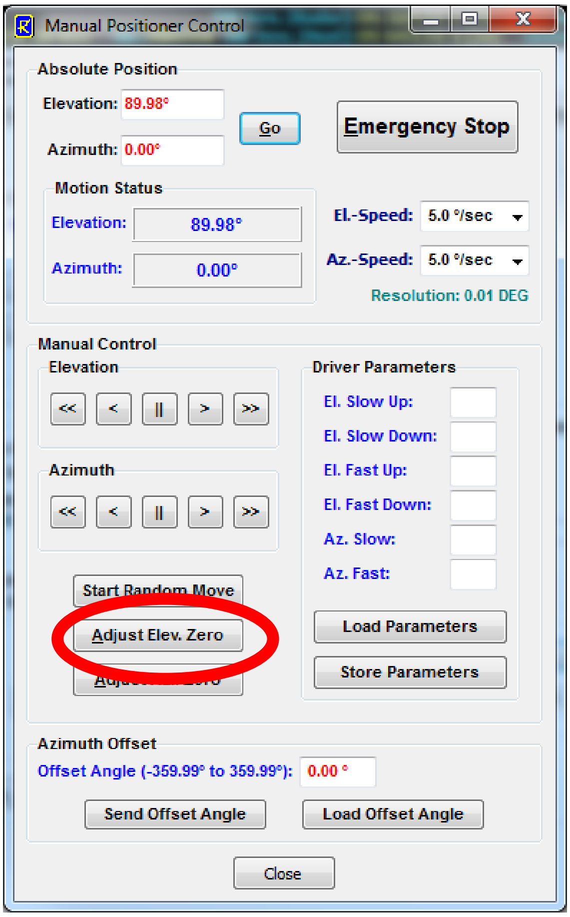
The elevation axis tilt is shown within the **Radar Inclination Angles** box.
Now take a M24 wrench and adjust one of the two feet of the scanner's basement leg that is running in parallel to the radar's elevation axis until the **Elevation Axis** reading is zero.

Use the elevation axis tilt reading for the horizontal alignment in both directions.

Move the azimuth to 90° and repeat the procedure with the other scanner base leg.
Repeat the whole procedure iteratively until the elevation axis tilt is somewhere in the range [-0.1°,…,+0.1°] in both directions. The horizontal alignment is then finished.

4.2 Elevation Scanner Adjustment

After the horizontal alignment, the scanner elevation can be adjusted. This is usually not required since the elevation zero had been already adjusted in the factory. However, if the elevation reading deviates more than 0.1° from zero while the scanner is pointing to zenith (90° elevation), the zero adjustment of the scanner's elevation should be performed.
By slightly changing the elevation angle (within the scanner manual control menu) from 90° to e.g. 90.1° or 89.9°, try to get the elevation reading of the inclination sensor close to zero.
As an example, let's assume you achieved a zero reading at an elevation angle of 89.9°. In this case, enter -0.1 in the elevation target edit box and click **Go**. The scanner will move to the correct zero now, even though it indicates this position to be -0.1°. Then click the **Adjust Elev. Zero** button:

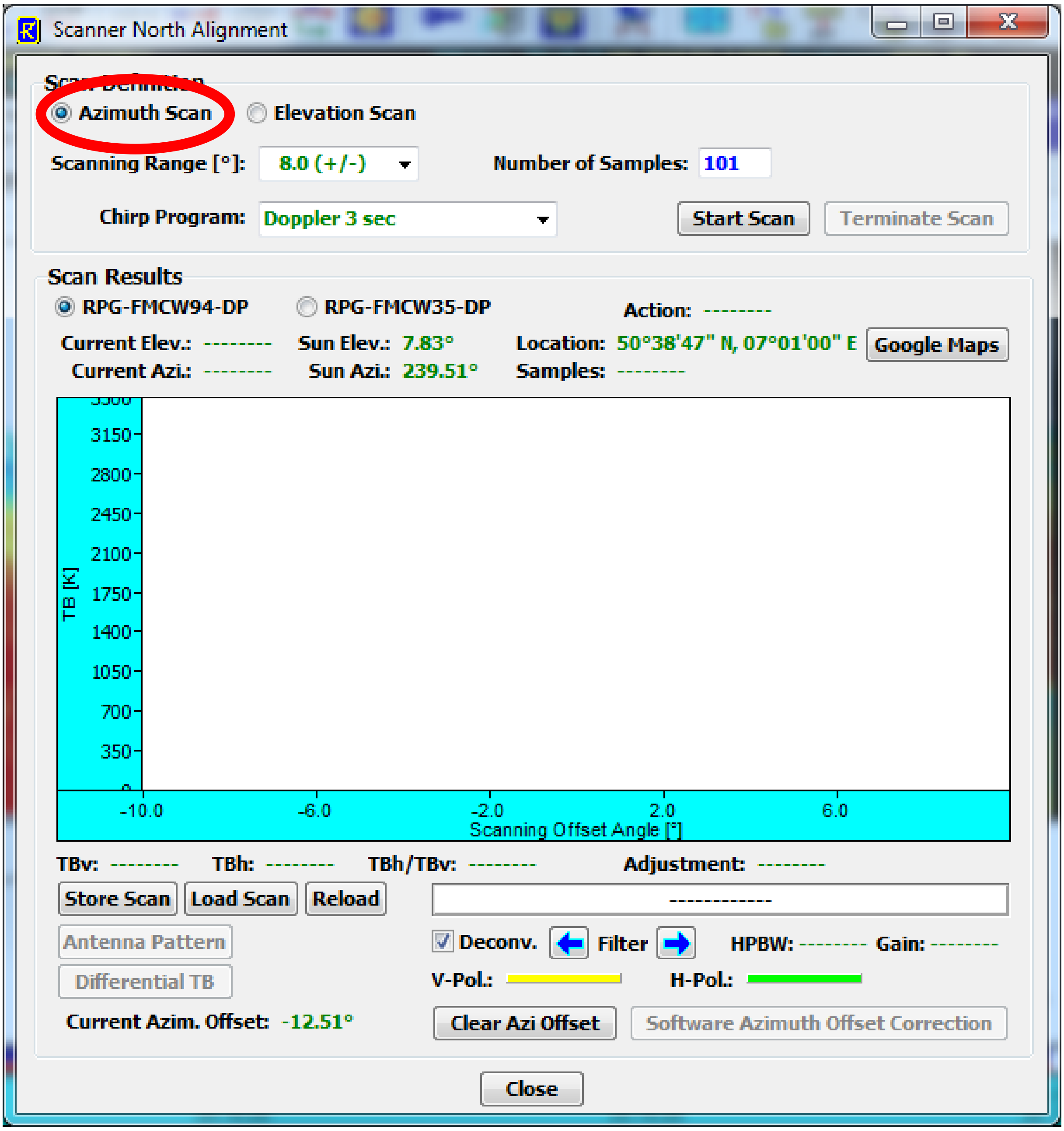


The scanner's elevation zero is now set to the old -0.1° position. When you return to 90° elevation, the inclination sensor's elevation reading should be close to zero now.

4.3 Azimuth Scanner Adjustment

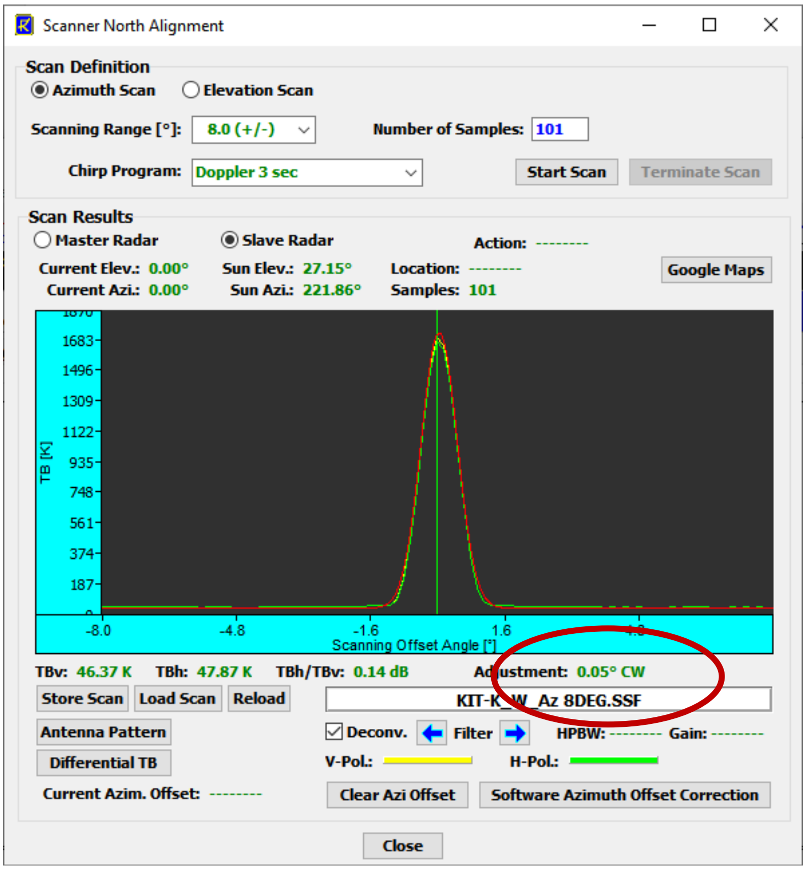
When the scanner is installed on its final location, the red arrow on one of its legs should point to north direction. A precise alignment in azimuth is not required at this stage (you may use a compass to determine the rough north direction), because the scanner azimuth is later fine adjusted in a solar scan procedure.

The Master radar controls the scanner, so that the solar scan has to be performed from the W-band radar Host-PC application (click the SUN button). During the scan, the W-band radar will also acquire the TB (brightness temperature) readings of the Slave (the K-band radar):



It should be clear that a solar scan is only possible during day time and without any obstacles in the direction of the sun. If the sun is at low elevation, only azimuth scans should be used (as indicated above) because a scan in elevation would drastically change the airmass and therefore the atmospheric damping over the scan.

The user may choose any program for the scan he wants, but it is recommended to select a program with about 3 seconds sampling rate (like the “Doppler 3 sec” in our example). At the beginning, when the azimuth alignment uncertainty is large, the selected scanning range should be large, e.g. +/- 15°. Then start a scan (choose the number of samples to be 101, as indicated above). Then click **Start Scan**. The scanner will move to the direction of the sun, which the W-band radar determines from the GPS location and UTC time measured by the GPS clock. The scan starts at the position where the system expects the sun to be minus half of the scanning range. A completed scan may look like this:



The red ellipse marks the measured azimuth misalignment. In the example above, this misalignment is already very slow (0.05°). In general, the first scan will show much larger misalignments, in the order of 10°. With such a large misalignment, click the **Software Azimuth Offset Correction** button. The measured misalignment in azimuth is then stored on the W-band radar and will be automatically corrected in the future. A second scan after this correction will then lead to a precise centering of the solar peak in the middle of the diagram.

4.4 Single Radar Operation

The described system is usually operated in dual radar mode, meaning both radars are mounted to the scanner and the W-band radar is configured as the Master radar while the K-band radar is configured as the Slave radar.

In the case one of these radars needs servicing, it is possible to run the remaining radar alone. If the K-band radar shall be repaired or serviced while the W-band radar (the former Master) remains, the situation is simple: All cable connections to the W-band radar remain untouched while the K-band radar is disconnected from all cables attached to the scanner frame (before it is removed from the scanner). The counter balance weights replacing the K-band radar are mounted to the scanner frame and the open connectors are protected with plastic caps.

In the other case, that the W-band radar needs servicing, certain cable connections must be swapped from W-band to K-band.

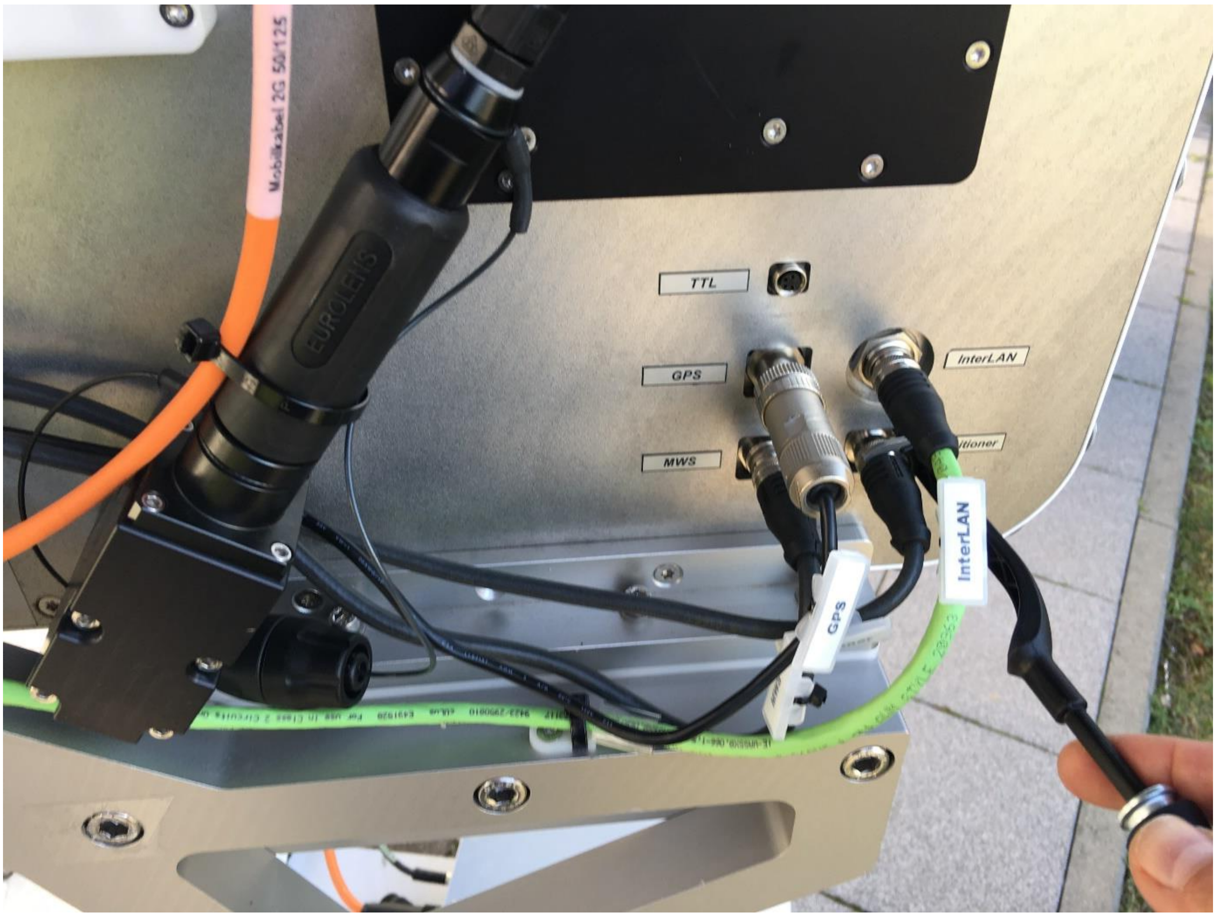
Step 1: Unsrew all connecting cables from the W-band radar. Use the 90° wrenches for that:

W-band radar sidewall with connecting cables.

Cut the cable ties that fix the cables named GPS / MWS / Positioner to the scanner frame and swap these cables to the K-band side. Then remove the protection caps on the K-band radar sidewall from the sockets named GPS / MWS / Positioner and connect the swapped cables. After tightening the connectors with the 90° wrench, apply cable ties to fix the swapped cables to the scanner frame.

The K-band radar is now able to use the weather station (MWS), the GPS clock and the scanner controller independently from a Master radar. Unplug also the InterLAN cable and keep it for later use when the W-band radar is back.

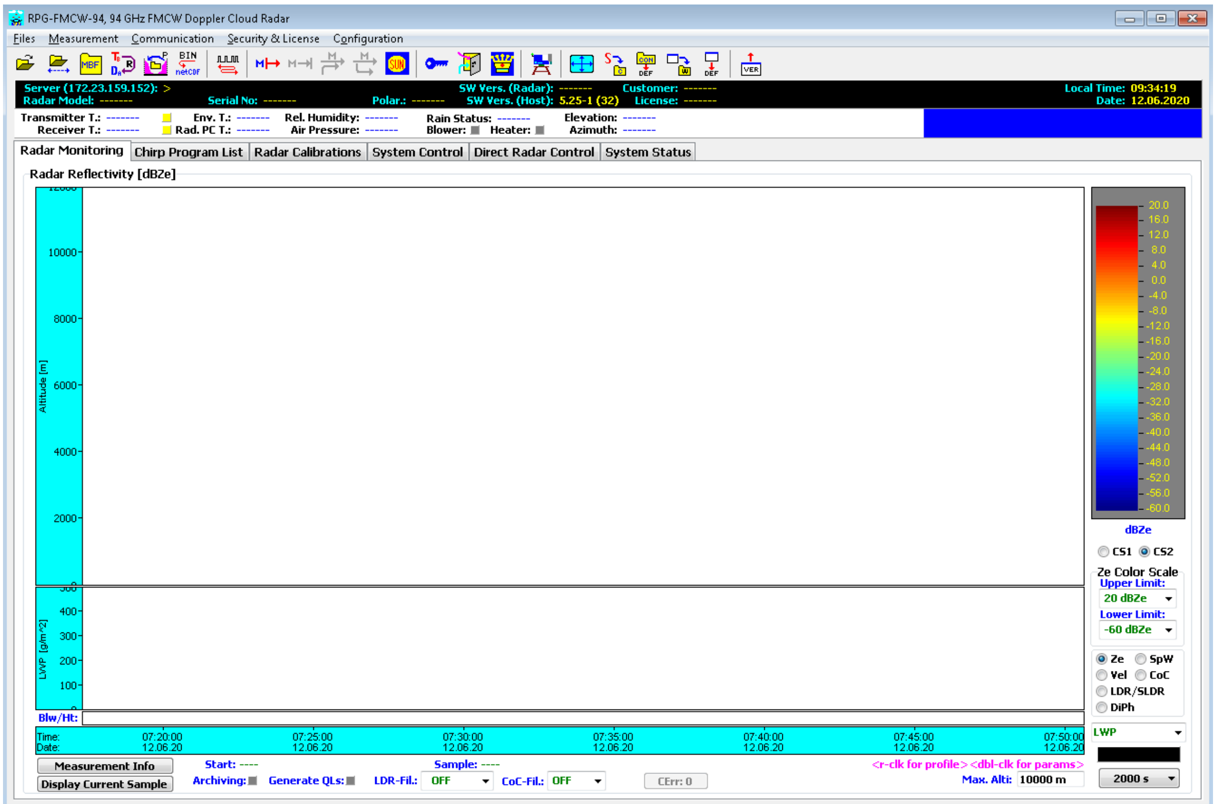
After all described connections have been established, power cycle (turn ON / OFF) the K-band radar. It will then configure itself as a single radar automatically.



K-band radar sidewall with swapped connecting cables.

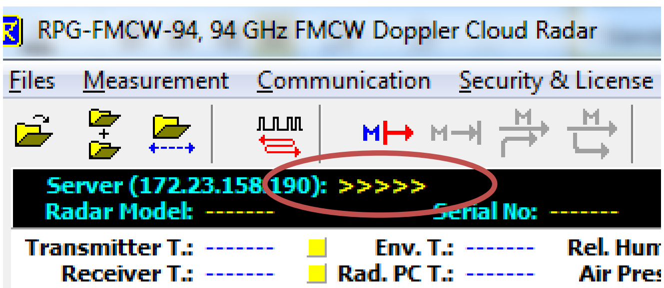
5 Running Measurements Quickstart

Start the host PC application with  from the desktop.

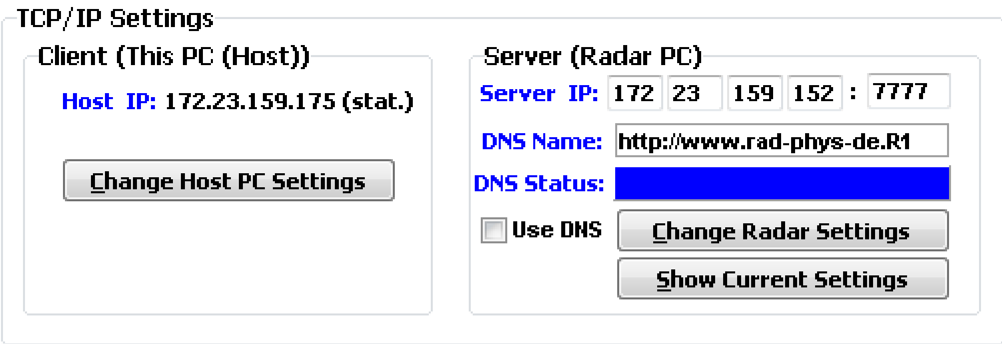


The screen is showing the ***Radar Monitoring*** tab. On top of the tab, environmental parameters (surface sensor data), position and blower status are displayed. The black panel summarizes the radar ID information, as model number, polarisation, customer code, software version and license status.

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:

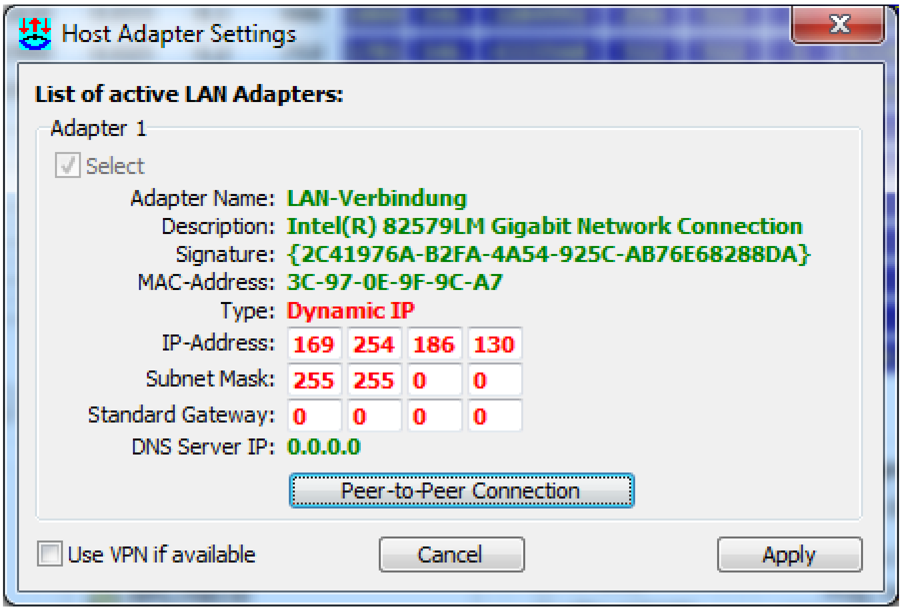


The Host assumes a radar (Server) with a certain IP connected to the network or directly connected (peer-to-peer connection). This IP is defined on the ***System Control*** tab in the ***TCP / IP*** box:



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).

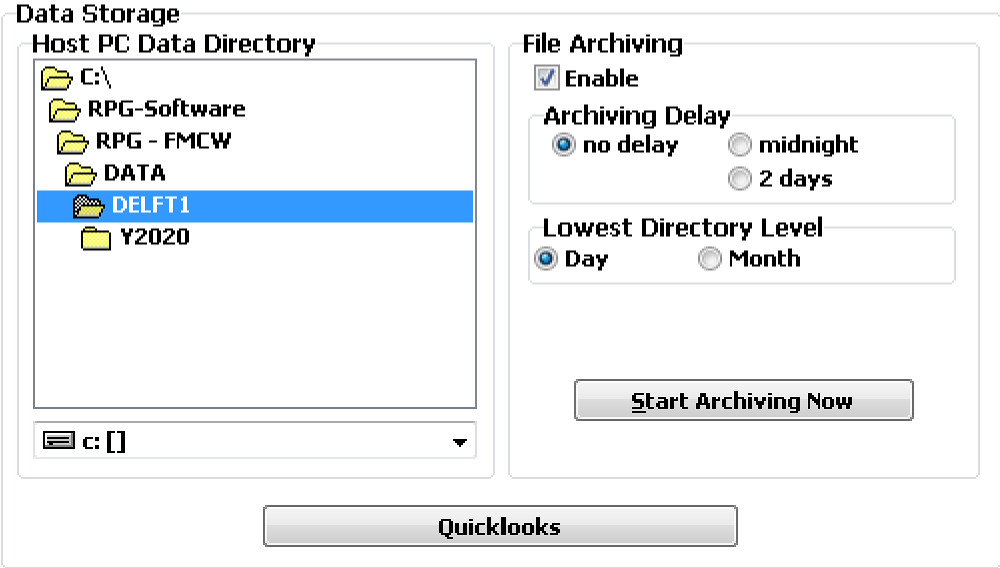
The H-PC IP settings may be changed from within the radar application when clicking ***Change Host PC Settings*** (you must run the host software with Administrator rights for this command):



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***.

5.1 Data Storage



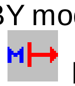
During measurements the recorded radar data is automatically stored in binary format to the directory selected in the ***Host PC Data Directory*** box.

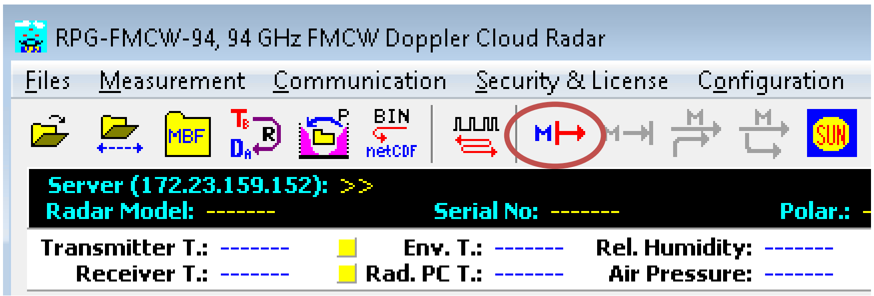
If other formats are required, they may be selected in ***Additional File Formats***. These other formats are stored to the same data directory as the binary files.

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.

5.2 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.

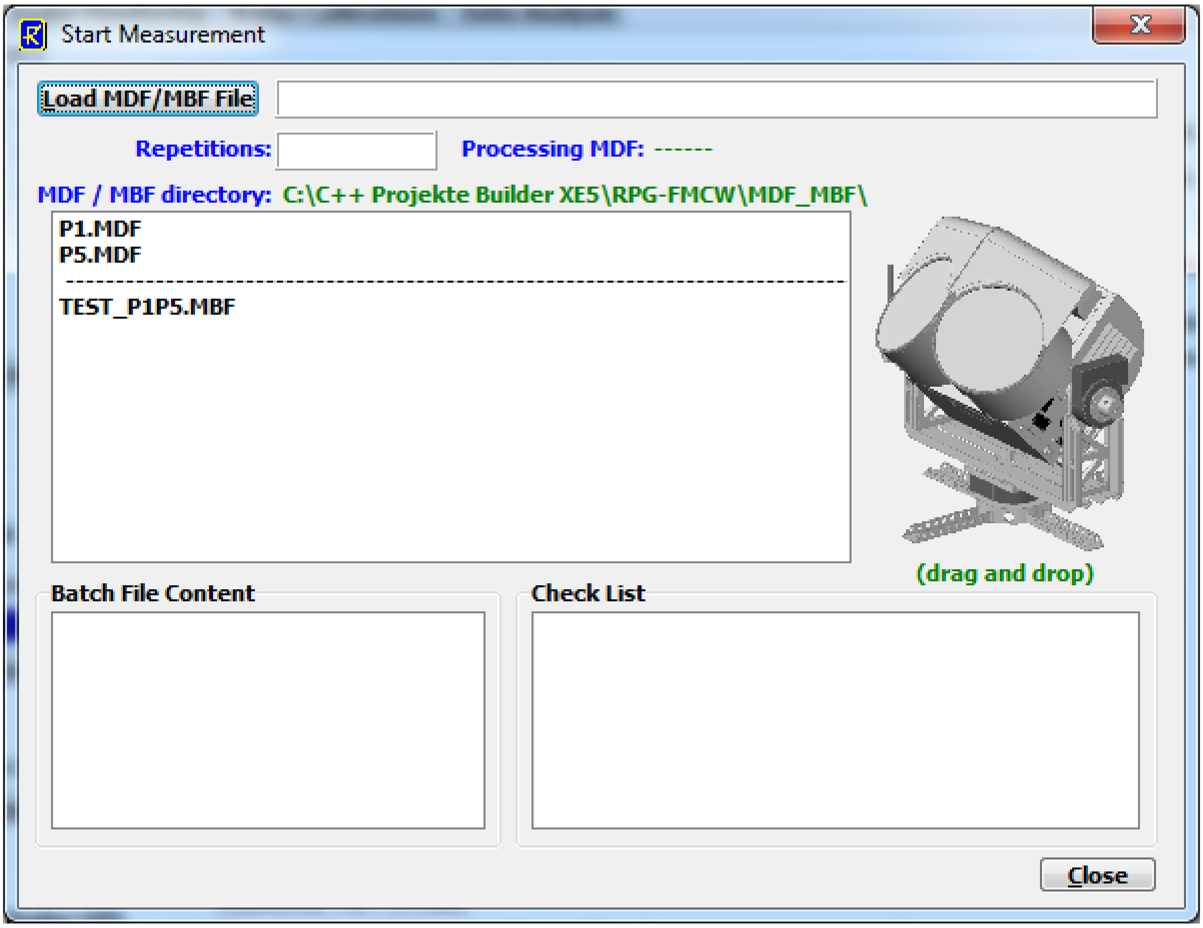
When a host successfully connects to the radar and the radar is in STANDBY mode, the radar is ready to start a measurement. This status is indicated by the enabled  button in the application's shortcut panel:



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.

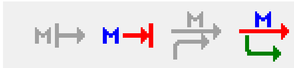
When the consistency check of a MDF is finished, the test result is displayed in the ***Check List***. The batch can only be sent to the radiometer if all consistency checks have finished with the status OK. Then the MBF is transmitted automatically.

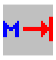
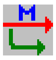
The H-PC 'remembers' the directory where MDFs and MBFs are stored from a previous ***Load MDF/MBF File*** command. This directory is listed in green. In the MDF / MBF list, MDFs are separated from MBFs by a dashed line. Dragging a file from the list and dropping it on the radar image on the right (or 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.

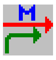
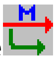
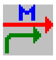


Measurement Launcher.

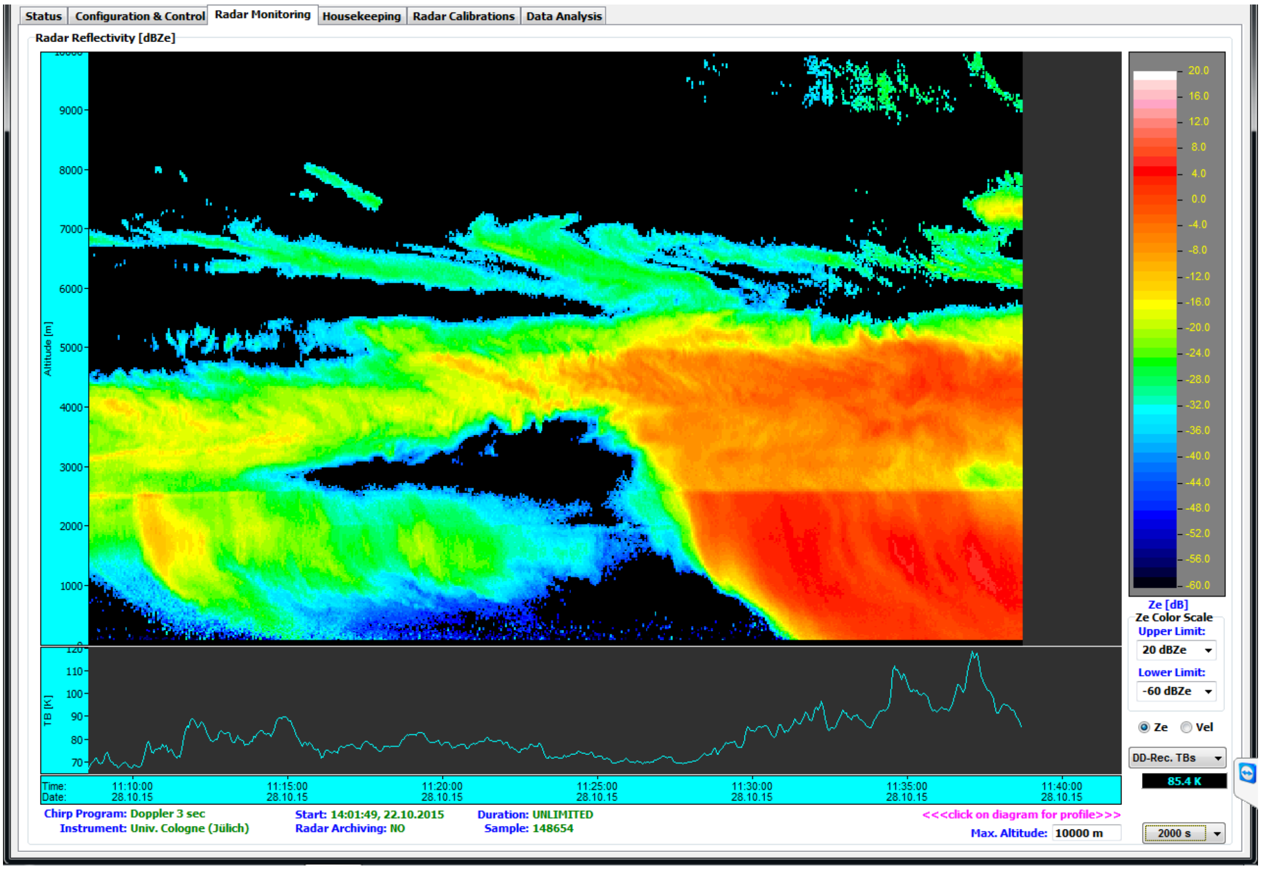
Once a measurement has been launched, the control buttons in the shortcut panel change in the following way:



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.

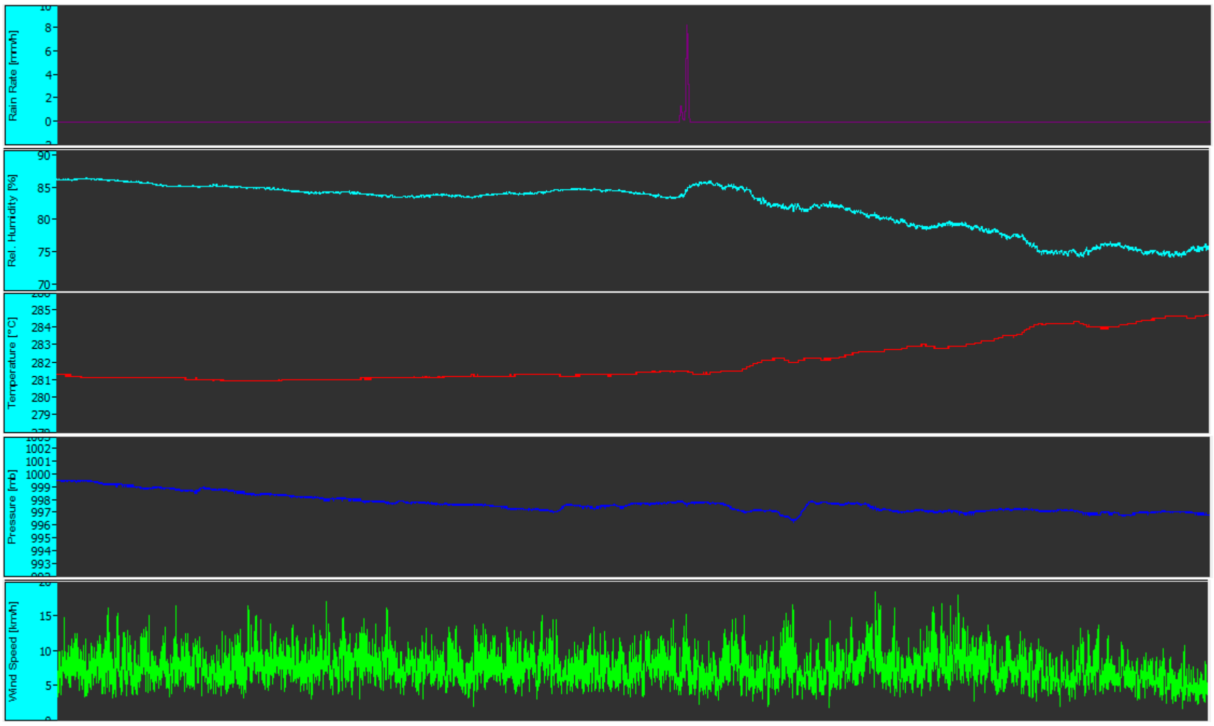
The radar profiles are displayed in the register page ***Radar Monitoring*** which acts as a real time display. In the main graphics area a color coded time series of reflectivity, mean velocity, spectral width, and polarimetric variables are shown. Radio buttons ***Ze, Vel, SpW, CoC, LDR/SLDR, DiPh***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



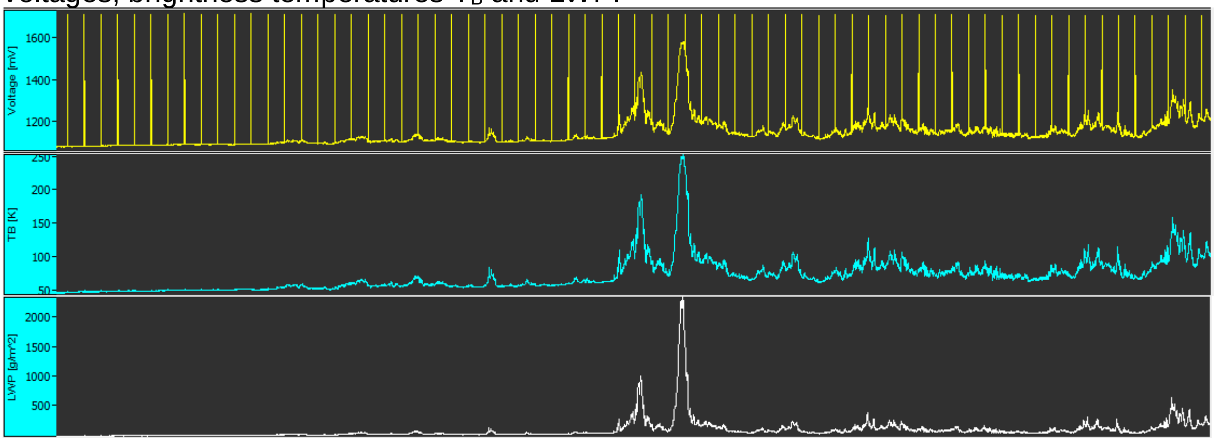
***Radar Monitoring* register page.**

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.

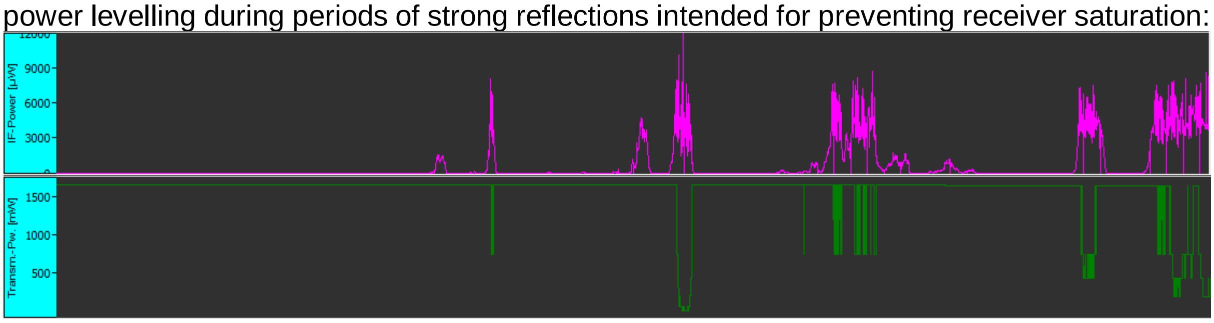
The radar is equipped with a weather station, providing information about environmental temperature, rel. humidity, barometric pressure, wind speed / direction and rain / snow rate:



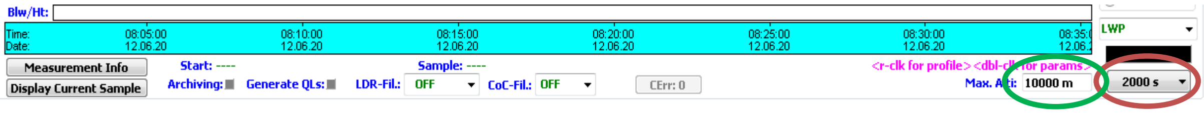
Another time series group is related to the direct detection passive channel at 89 GHz, which is intended for deriving LWP. Implemented are the DDR (Direct Detection Receiver) detector voltages, brightness temperatures T_B and LWP:



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 series time span 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.

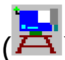


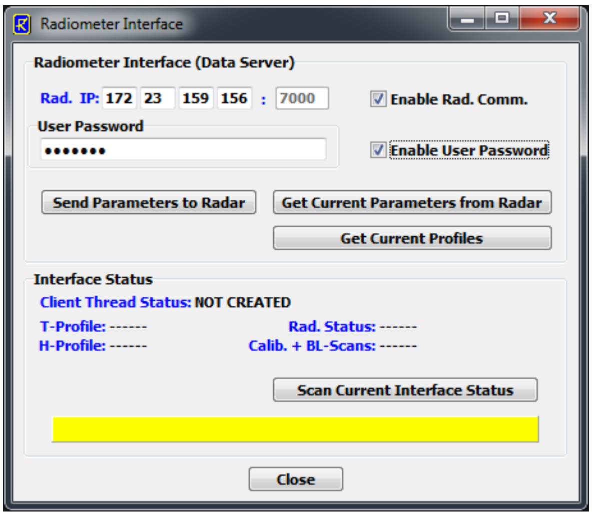
5.3 Connecting Radar to RPG-Radiometers

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 staton’s surface parameters.

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

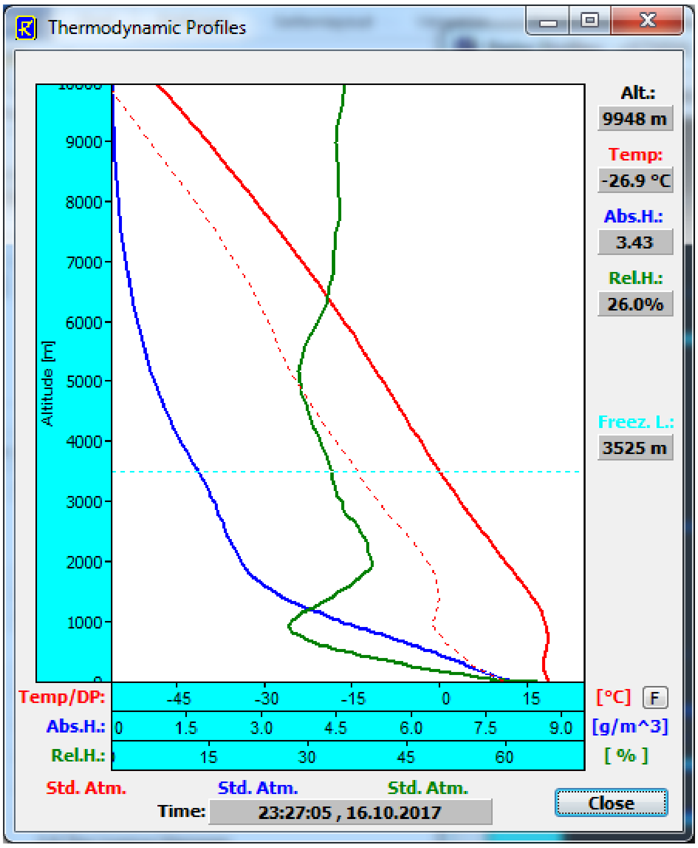
In order to establish a connection between the radar and a passive radiometer like the RPG-HATPRO, interface parameters need to be defined. This is accomplished by starting the ***Radiometer Interfacing*** menu ():



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:

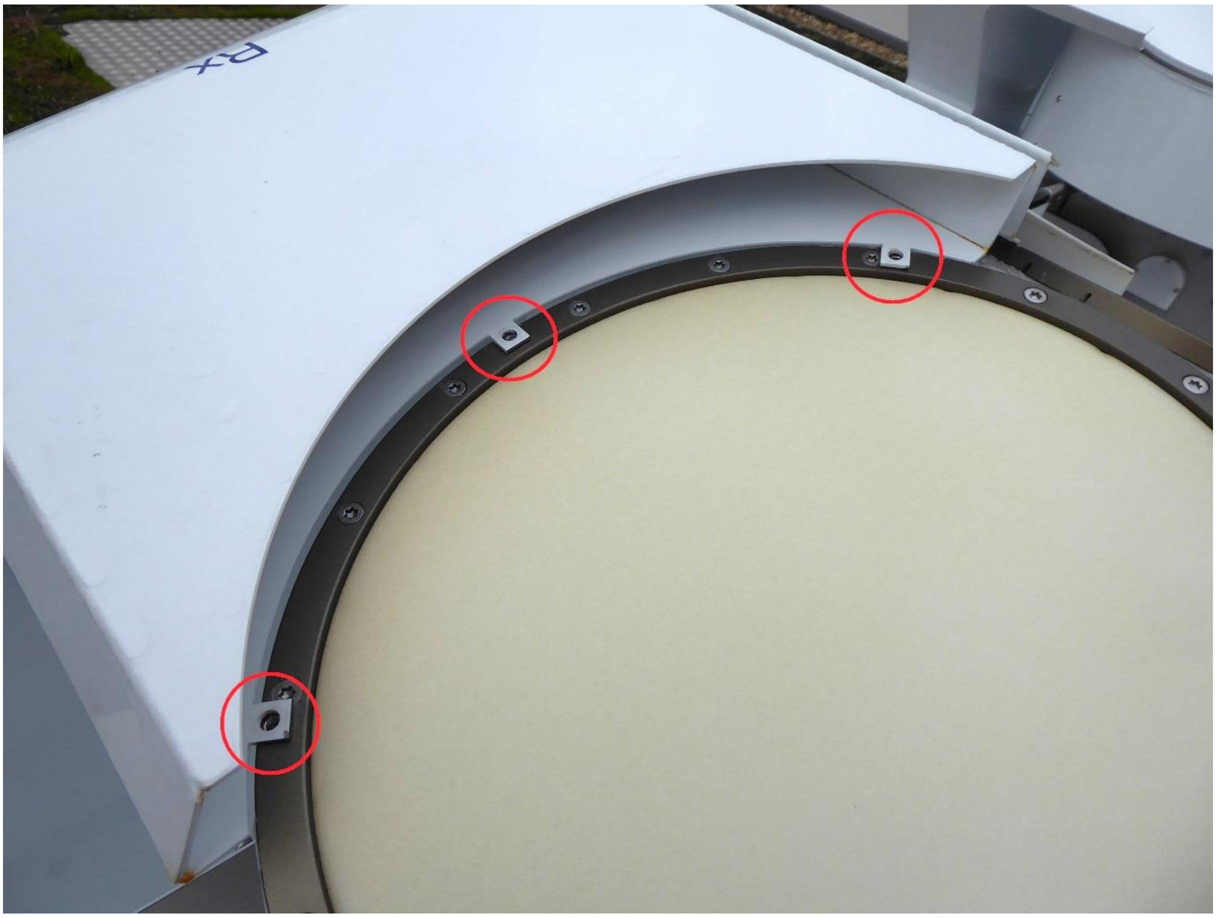
- temperature profile (in red)
- dew point profile (in dotted red)
- absolute humidity profiles (in blue)
- relative humidity profile (in green)

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.

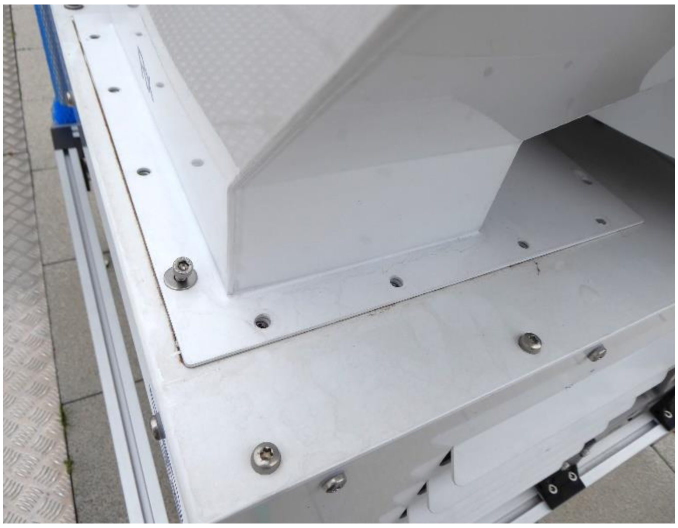
6 Maintenance

6.1 Changing the radome sheets

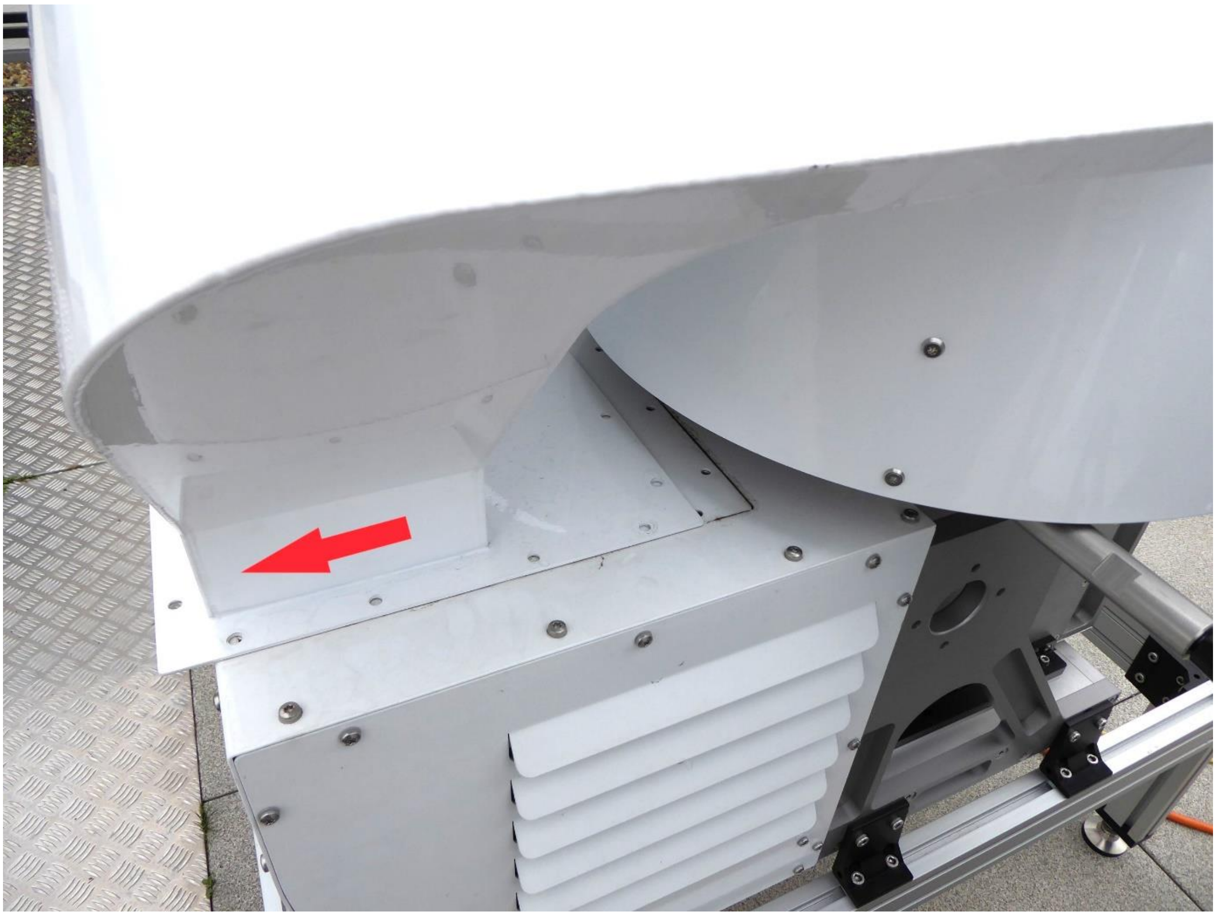
Remove 6 screws tightening the air-guides to the radome-holding cylinders, 3 on the transmitter and 3 on the receiver side. (This step is only required for older radars.)



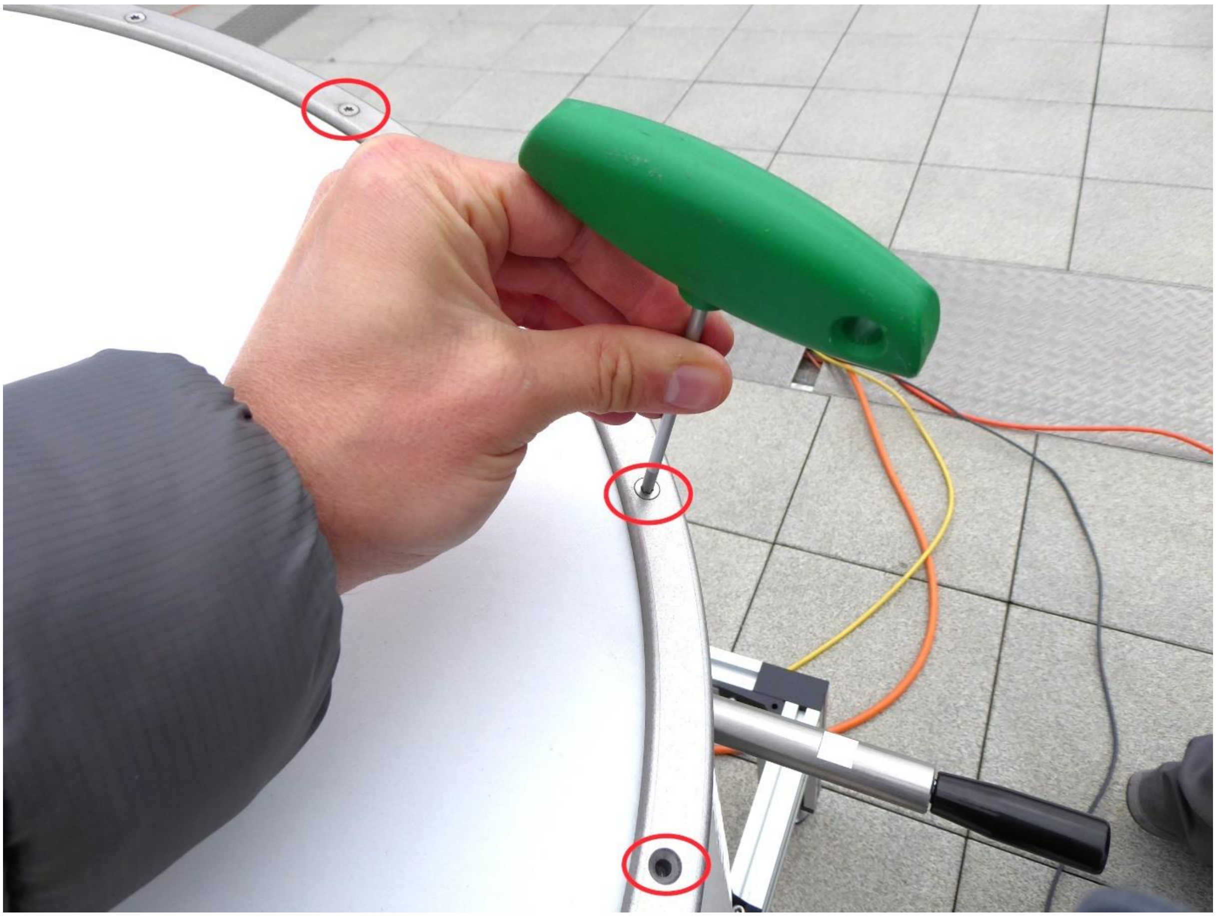
Remove all the screws holding both air-guides.



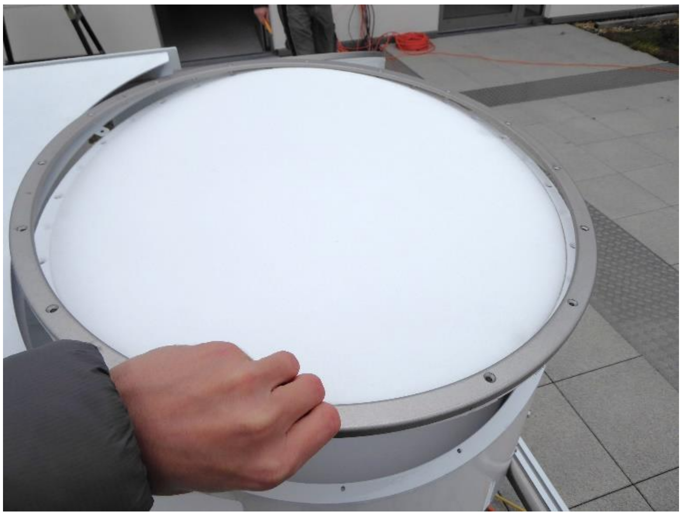
Move the both air-guides a bit to a side.



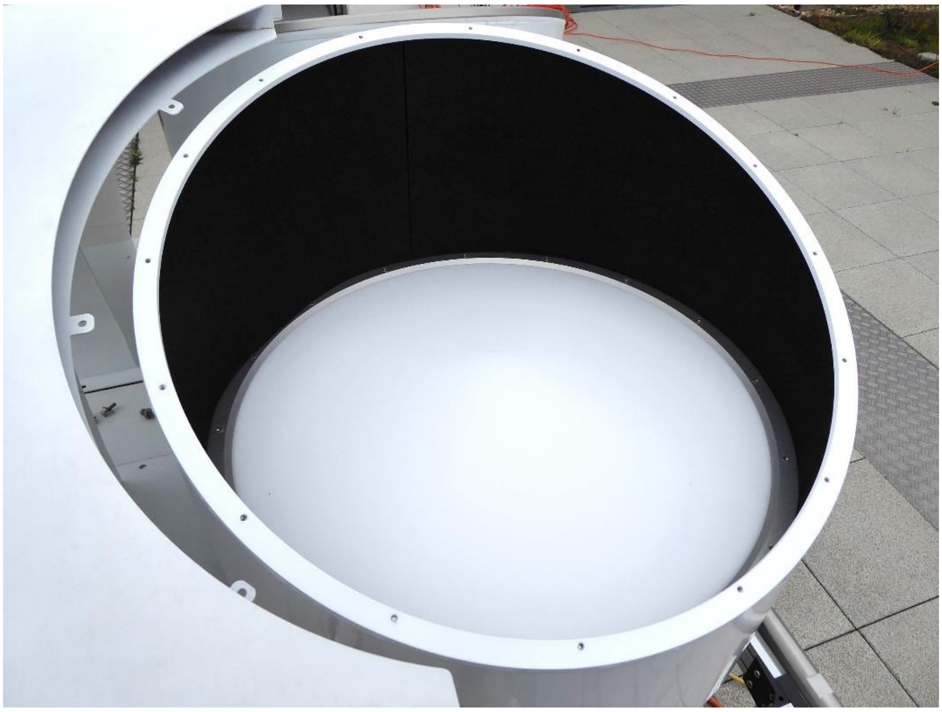
Unscrew all 16 screws holding the radome.



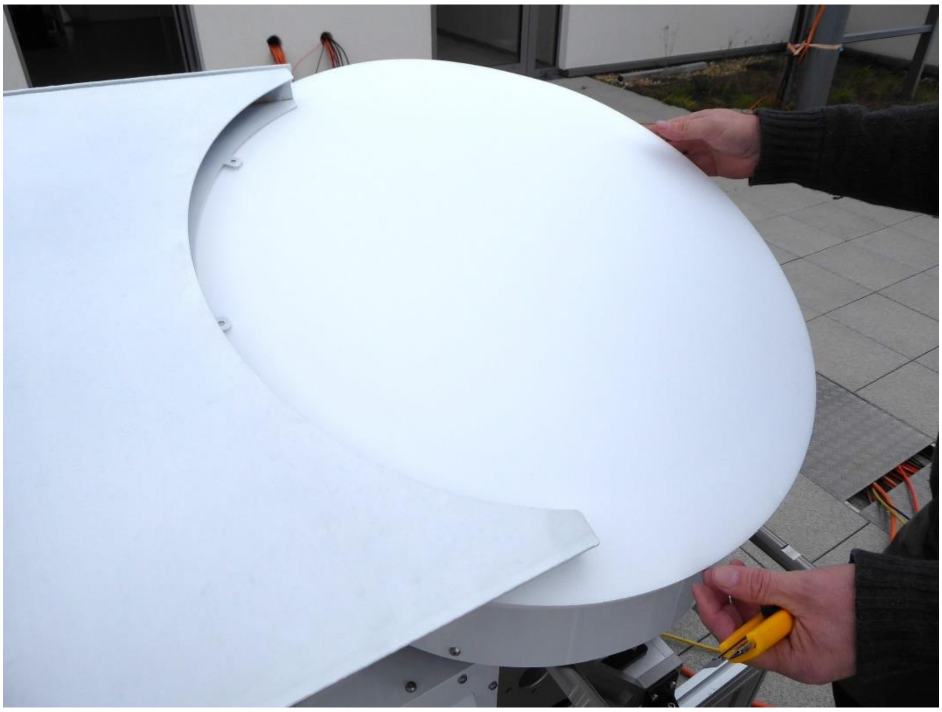
Remove the metal ring and the old radome material.



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

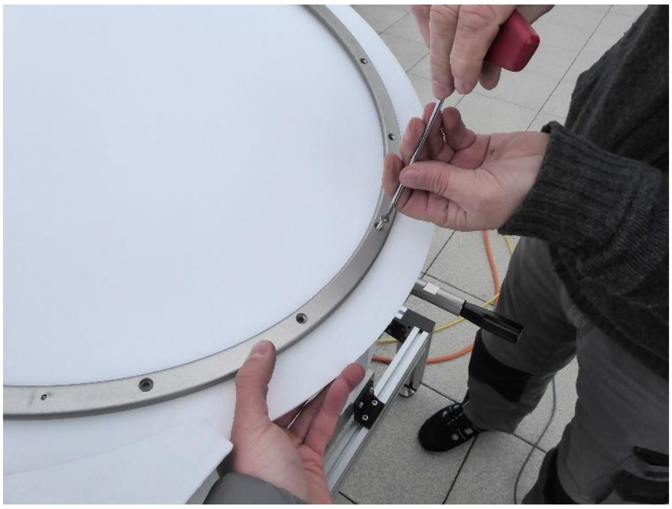


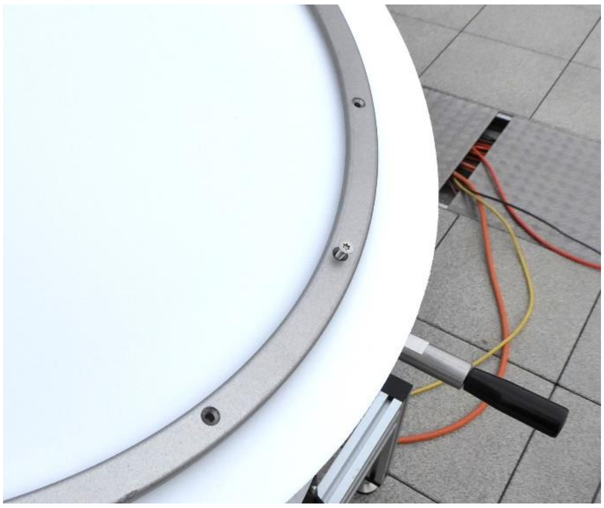
Put a new radome sheet on the cylinder. Make sure the coated (rough) side is facing upwards.



Put the metal ring on the radome sheet.

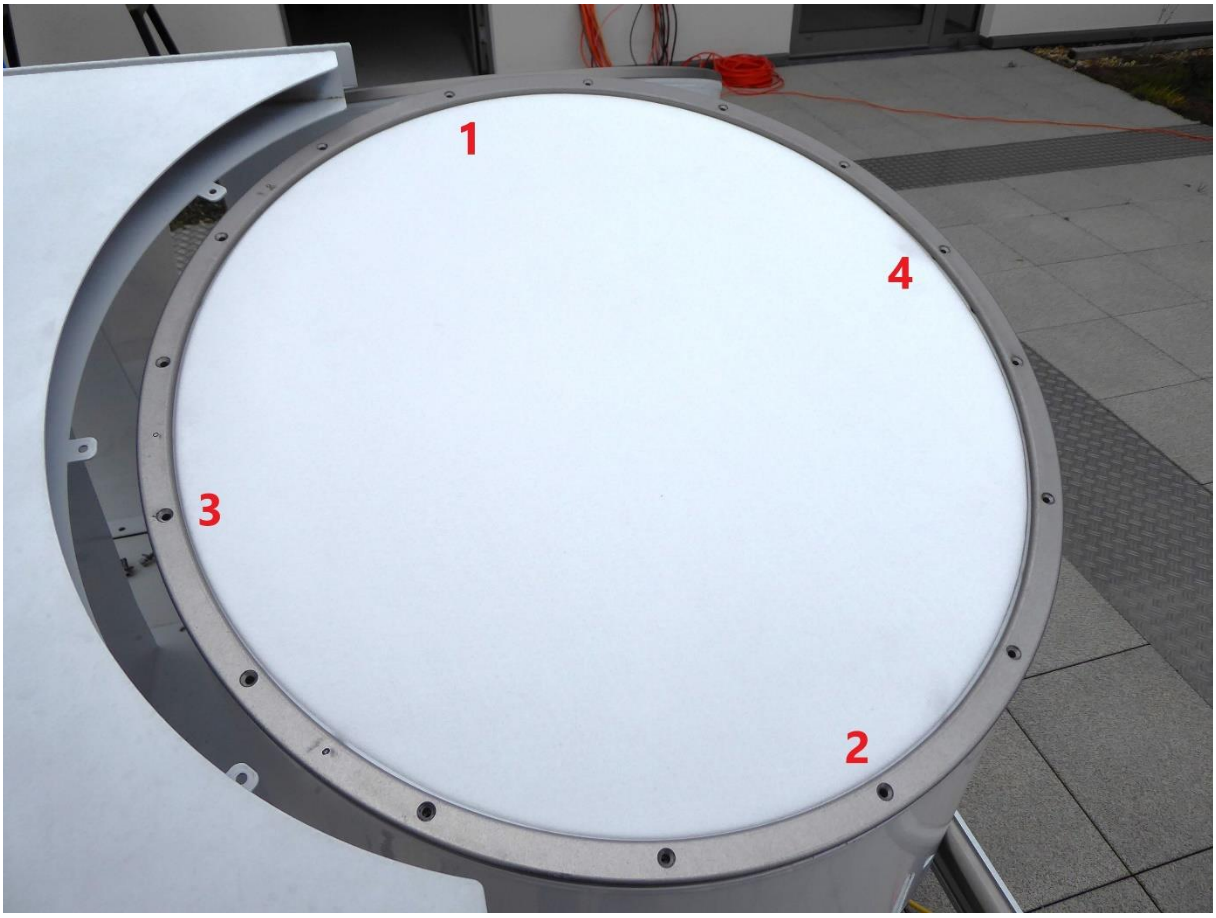
Punch the radome material with one screw through one of the ring holes and screw it down lightly.



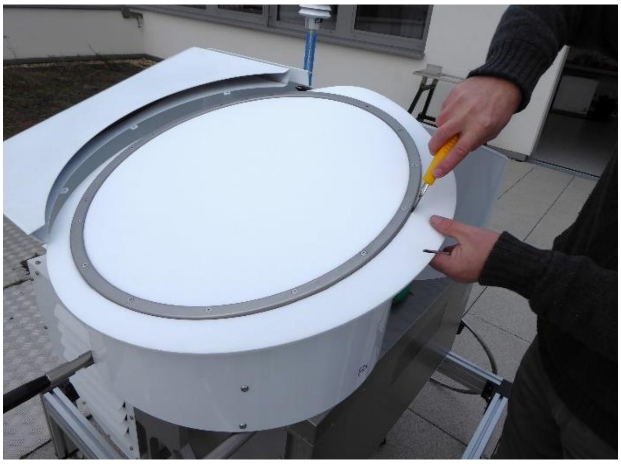


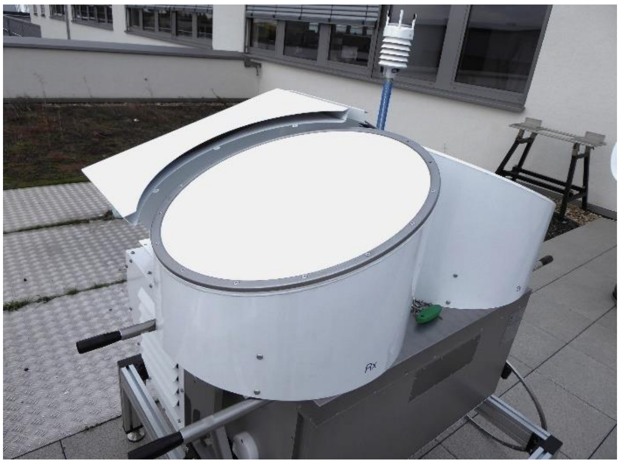
Do the same at the opposite side of the ring. Please do not pull the material at all.

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.





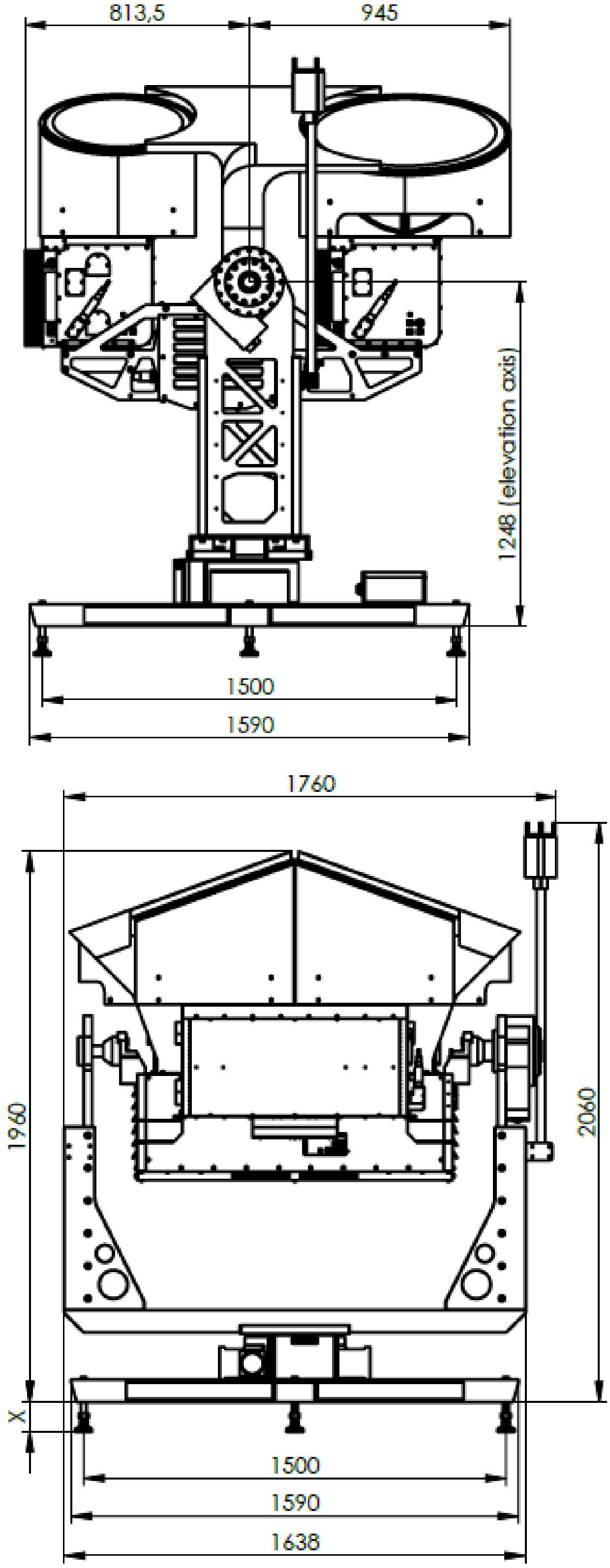
Repeat the steps for the other antenna and reinstall the air guides.

7 Instrument Specifications

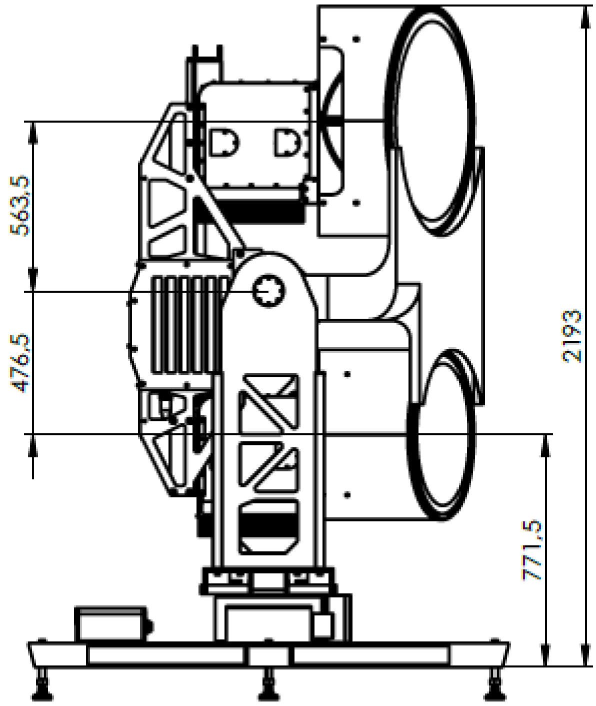
Parameter	Specification
Frequencies	35 GHz, bandwidth up to ± 100 MHz 94 GHz, bandwidth up to ± 100 MHz
Transmitter Power	K-band: 10 W typical (solid state amplifier) W-band: 1.5 W typical (solid state amplifier)
Antenna Type	K-band: Bi-static Cassegrain with 700 mm aperture W-band:Bi-static Cassegrain with 500 mm aperture
Antenna Gain	K-band:47.6±0.3 dB W-band:51.4±0.3 dB
Beam Width	K-band:0.84±0.03° FWHM W-band:0.56±0.03° FWHM
Polarisation	V (optional V / H)
Passive Channel Noise Figure	4.5 dB
Dynamic Range (Sensitivity)	K-band:-44 to +35 dBZ @ 5km distance / 30 m resolution / 10 s sampling time W-band:-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 ≥ 0.5 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	35 / 89 GHz for integral liquid water (LWP) detection (200 MHz / 2 GHz BW)
Control connection	TCP/IP connectivity via fibre 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

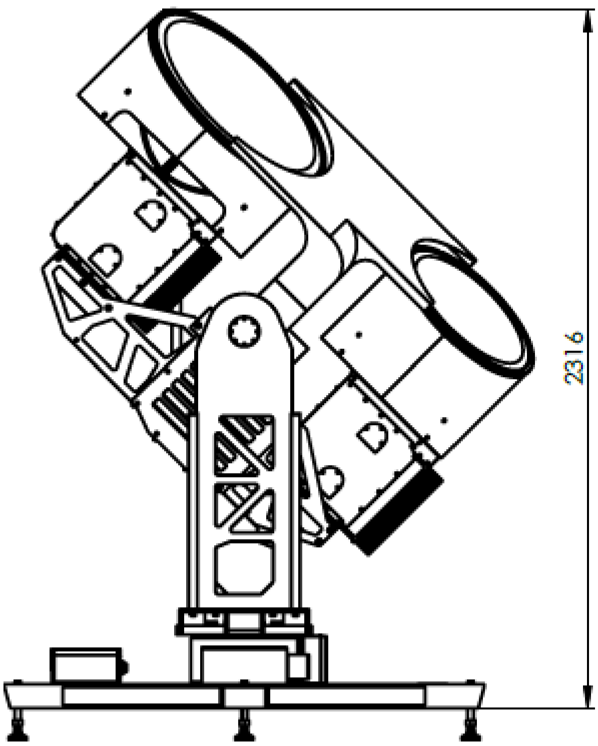
Data products	Raw spectra, Spectral polarimetric parameters, Reflectivity, Mean Doppler velocity, Doppler width, Skewness, Kurtosis, Differential reflectivity, Differential phase shift, Correlation coefficient.
Data Formats	proprietary binary netCDF (conformity with CF convention)
Mitigation system for rain/fog/dew	Strong dew blower (4000 m^3/h), radomes with hydrophobic coating
Additional sensors	Automatic weather station
Scanning	Scanner unit for full sky scanning capability with maximum angular velocity of 6 °/sec in azimuth and elevation
Weight	K-band: Radar main body: 160 kg W-band: Radar main body: 100 kg Blower: 160 kg Scanner: 200 kg Air guides: 25 kg
Maximum Power Consumption	K-band: Radar 1100 W, W-band: Radar 700 W, Blower 750 W, Scanner: 800 W, 230 V AC, 50-60 Hz

8 Instrument Dimensions



X max. height ~ 160 (levelling feets)


563,5
476,5
2193
771,5


2316