Radiometer Physics
A Rohde & Schwarz Company

Remote Sensing for Weather and Climate

FMCW Cloud Radars

Radiometer Physics GmbH (RPG) has developed a line of polarimetric solid-state radars operating at 94 and 35 GHz for continuous cloud and precipitation observations.

- Accurate absolute calibration, hardware monitoring
- High spatial, temporal, and Doppler resolution
- Built-in passive radiometric channel for LWP estimation
- Rain mitigation system for keeping the radomes dry
- Data products: full spectra, moments, spectral polarimetry
- Optional scanning unit for volumetric processing
- Automated data exchange with RPG radiometers
- Turbulence, wind shear, fog, and cloud observations
- Particle size distribution, rain intensity, ice microphysics

Profiling Radiometers

The RPG-HATPRO (Humidity And Temperature PROfiler) is becoming the radiometer of choice for meteorological networks and forecasting systems all around the world.

- 14 channels (22 to 31 GHz, 51 to 58 GHz, 183 GHz optional)
- Superior direct detection technology: EMI / EMC, parallel
- Network suitable, control + data flow via Ethernet
- Data products: IWV, LWP, T + RH profiles, stability indices
- Better boundary layer T-profiling than radio-soundings
- Full-sky scanning (350 directions in less than 5 minutes)
- Ground-based: complementing the satellite view!
- All-weather proof, reliable, robust… proven!

Scintillometers

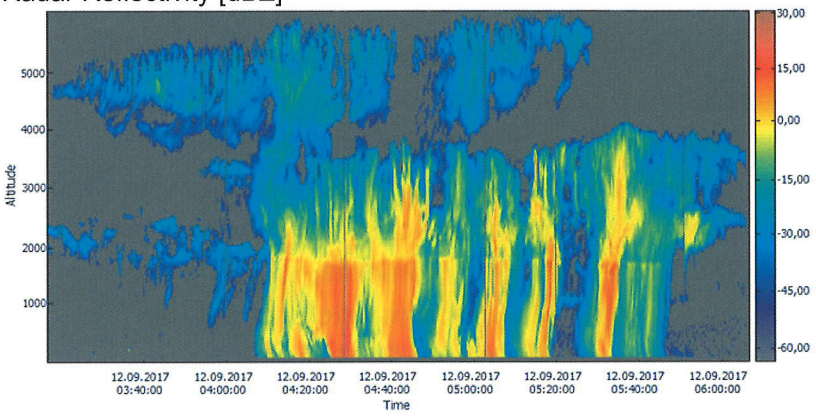
RPG is the only commercial supplier for scintillometers observing in the microwave spectral region.

- Microwave scintillometer RPG-MWSC operates at 160 GHz
- Synchronous observation of sensible and latent heat fluxes (combined with optical Large Aperture Scintillometer)
- Designed for automated networks
- Network suitable, control + data flow via Ethernet

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

04/2018
+49 (0) 2225 99981 – 0
www.radiometer-physics.de
remotesensing-sales@radiometer-physics.de

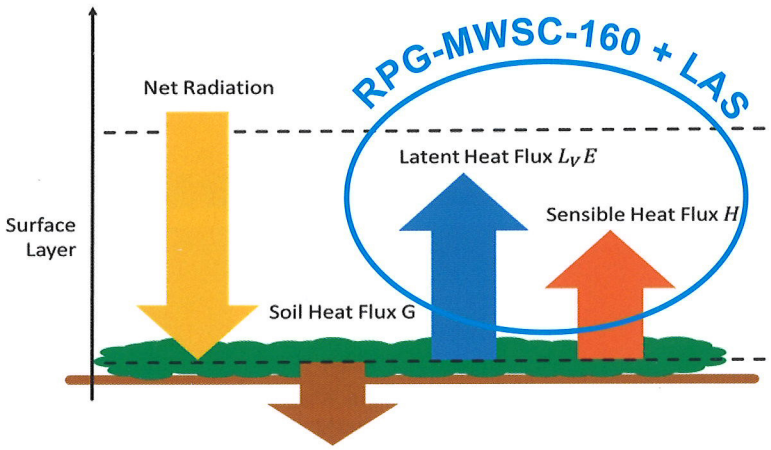
RPG-FMCW-94



Scan the code for more information

Parameter	Specification
Centre frequency	94 GHz (λ=3.19 mm) ± 100 MHz typical
Transmitter power	1.5 W typical (solid state amplifier)
Antenna type	Bi-static Cassegrain with 500 mm aperture
Antenna gain	50.1 dB
Beam width	0.56° FWHM
Polarisation	V (optional V & H)
Typical dynamic range (sensitivity) with 1.5 W transmitter @ 10 s sampling time	-50 dBz to +20 dBz (at 5 km height / 30 m resolution)
Ranging	50 m to 12 km typical, 15 km maximum
Vertical resolution	Typ. 15-30 m (down to 1 m is possible for a limited altitude range)
Calibrations (automatic)	Transmitter power monitoring and receiver Dicke switching for gain drift compensation (radar and passive channel)
Calibrations (maintenance)	Liquid nitrogen receiver calibration
Calibration verification	External reference sphere
Sampling rate (full profiles)	Adjustable: ≥1 second
Doppler range	± 9 m/s unambiguous velocity range (0-2500 m), ± 4.2 m/s above
Passive channels	89 GHz for integral LWP detection
Mitigation system for rain/fog/dew	Strong dew blower (approx. 4000 m³/h), radomes with hydrophobic coating
Integrated weather station	Vaisala® WXT-536
Scanning	Scanner unit for full sky scanning capability with maximum angular velocity of 6 °/s in azimuth and elevation
Dimensions and weight	150 x 90 x 140 cm³; 300 kg

RPG-MWSC-160

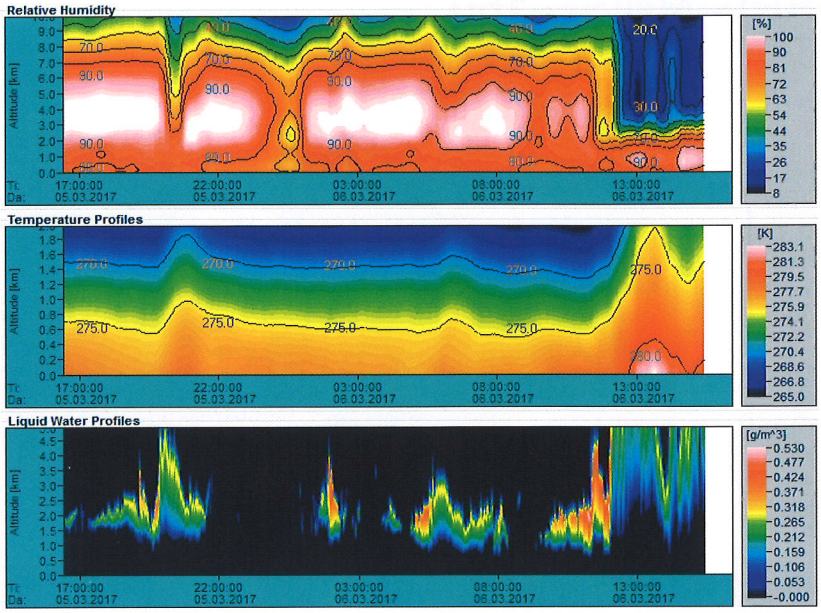


Scan the code for more information

Parameter		Specification
Frequency		160.8 GHz (λ=1.86 mm)
Radiated power		maximum power: < 25 mW, 50 dB attenuator
Antenna type		Cassegrain with 300 mm aperture
Antenna gain		52 dB
Beam width		0.45° FWHM
Power supply		10.8 – 13.2 V DC
Power consumption		maximum 60 W (per unit), 20 W typical (receiver), 15 W typical (transmitter)
Output data	Level 0	• 1 kHz digital raw data for RPG-MWSC-160 and LAS • housekeeping data
	Level 1	• (co)variances of the combined optical / microwave system.
	Level 2	• structure parameters C_n^2 • sensible and latent heat fluxes H, $L_V E$
Type of installation		Line of sight Tx/Rx system (transmit / receive)
Baseline length		500 m to 10 km
Dimension and weight		36 x 36 x 48 cm³ (receiver and transmitter), 12 kg receiver, 10 kg transmitter

RPG-HATPRO-G5

Scan the code for more information



Parameter	Specification
Channel centre frequencies	• K-Band: 7 channels in 22.24 – 31.4 GHz range • V-Band: 7 channels in 51.26 – 58.0 GHz range
Absolute calibration	with internal ambient & external cold load
Absolute Tb accuracy	±0.15 K
Radiometric resolution	K-Band: 0.07 K RMS, V-Band: 0.07 – 0.15 K RMS (@ 1 second integration time)
Internal calibration	• gain: with internal noise standard • gain + system noise: ambient temperature target + noise standard • abs. cal. of humidity profiler: sky tipping calibration
Receiver thermal stabilization	Stability better than 0.03 K over full operating temperature range
Rain / fog mitigation system	Blower system (130 Watts), hydrophobic coated microwave transparent window, 1.8 kW heater preventing dew formation
Optical resolution	HPBW (frequency dependent): 3.0° - 4.2° for water vapour, 1.8° - 2.2° for temperature profiler
Pointing range / resolution	Elevation: 0° to 180° (0.1° steps), full s/w control Azimuth (optional): 0° to 360° (0.1° steps), full s/w control
Operating temperature range	-30°C to +45°C
Available Level 2 products	IWV, LWP, stability indices, path delay, attenuation spectrum, TB spectrum, cloud base height, boundary layer height, IWV and LWP 2D maps, profiles of temperature, liquid water content, absolute and relative humidity
Available output formats	NetCDF, ASCII, BUFR, RAOB®
Power consumption	< 120 Watts average, 350 Watts peak for warming-up (without dew blower heater), blower: 130 Watts maximum

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

04/2018
+49 (0) 2225 99981 – 0
www.radiometer-physics.de
remotesensing-sales@radiometer-physics.de

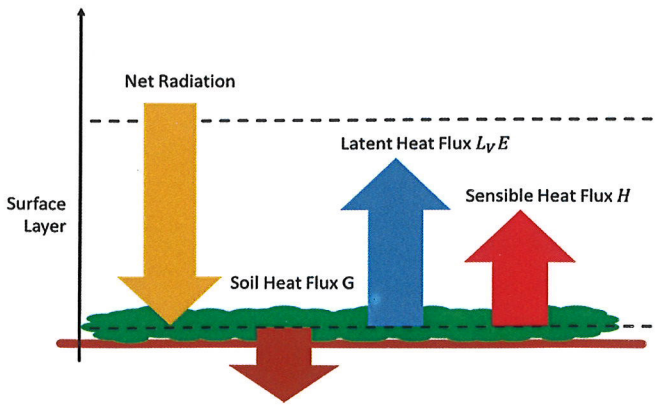
RPG-MWSC-160

Radiometer Physics GmbH (RPG) offers the only commercially available microwave scintillometer RPG-MWSC-160. It is designed for combined operation with an optical Large Aperture Scintillometer (LAS) to simultaneously observe sensible and latent heat fluxes.

Applications

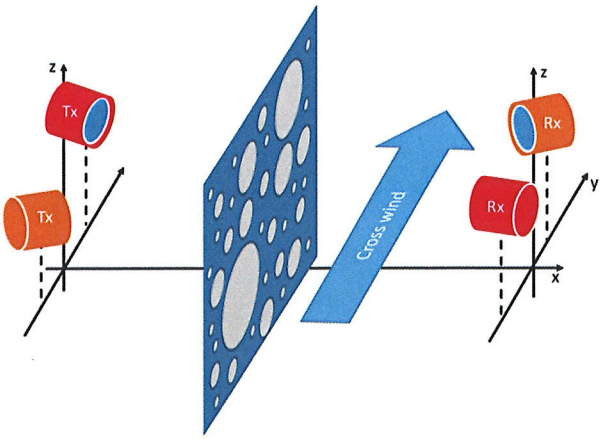
Measurement of sensible heat flux H and evapotranspiration (latent heat flux $L_v E$) significant for:

- Irrigation
- Water management
- Hydrology
- Forest fire warning
- Weather forecasting
- Radiation budget studies



Concept

- Transmit / receive system
  - Transmitter: continuous signal
  - Receiver: observes fluctuations
- Information Content: Turbulence modulates the refractive index of air, leading to intensity fluctuations
- Combination of microwave (RPG-MWSC-160) and infrared signal (LAS) frequencies allows simultaneous determination of sensible and latent heat fluxes.

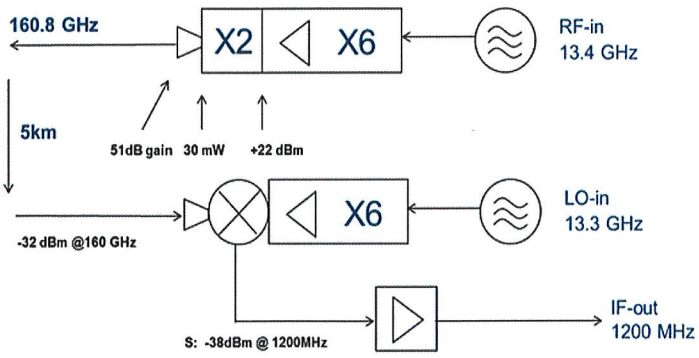


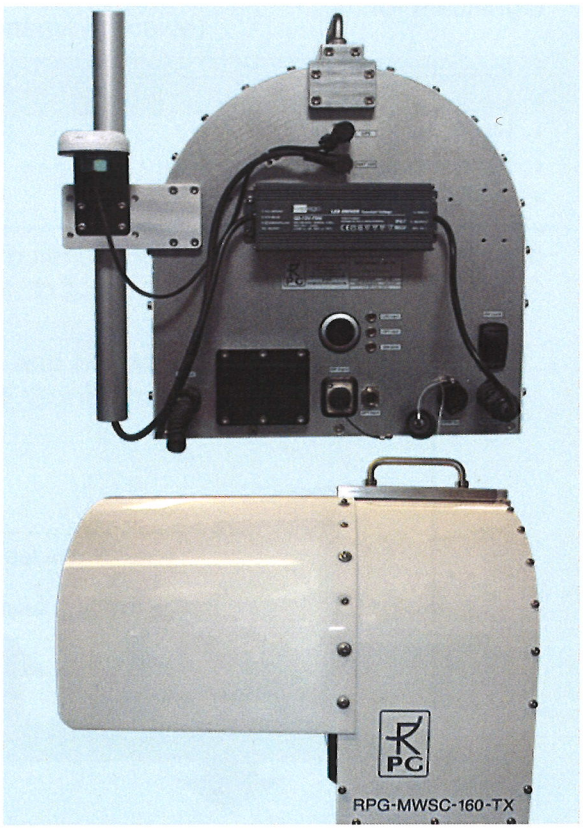
*Setup of combined **MWS** and **LAS** system with crossing signal beams. The turbulence field is shifted through the beams by the mean wind across the measurement path.*

Concept

The RPG-MWSC-160 prototype was developed by RPG and Wageningen University (The Netherlands) within the OMS (Optical and Microwave Scintillation) project. The RPG-MWSC-160 uses hardware developments from space projects.

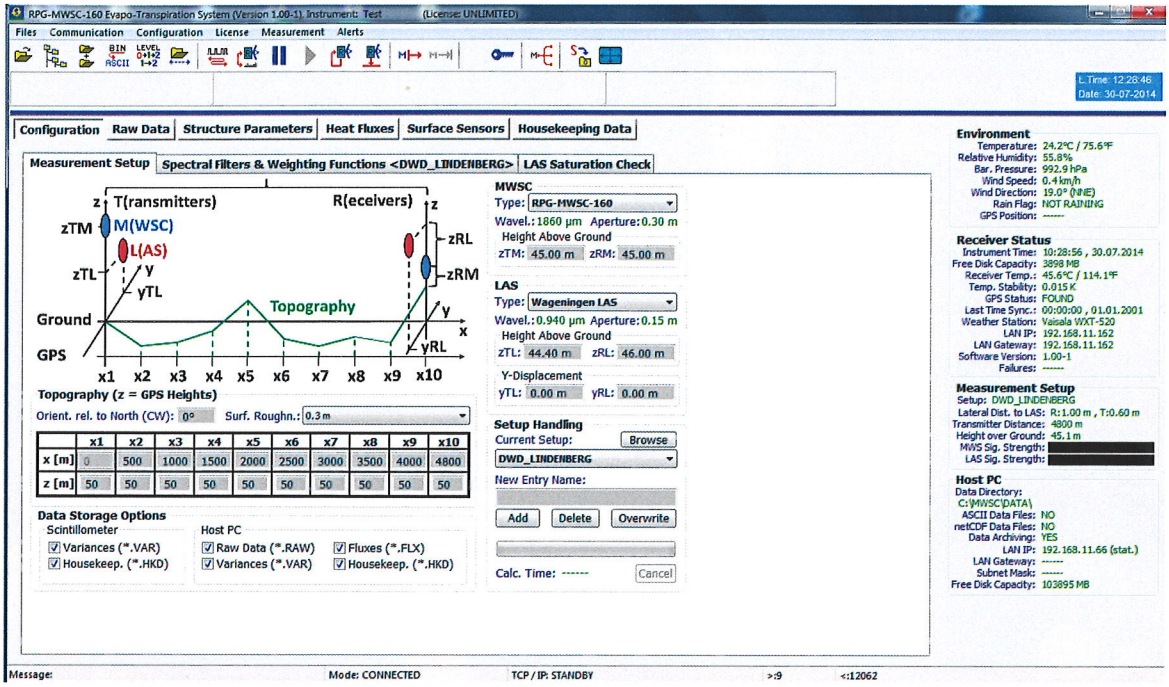
- High frequency (160.8 GHz) for good co-spectrum with LAS
- Large aperture (300 mm) provides small beam width
- Tuneable power level (up to 25 mW) allows path lengths between 500 m and 10 km
- Low weight (~10 kg)
- Low power consumption (~20W)



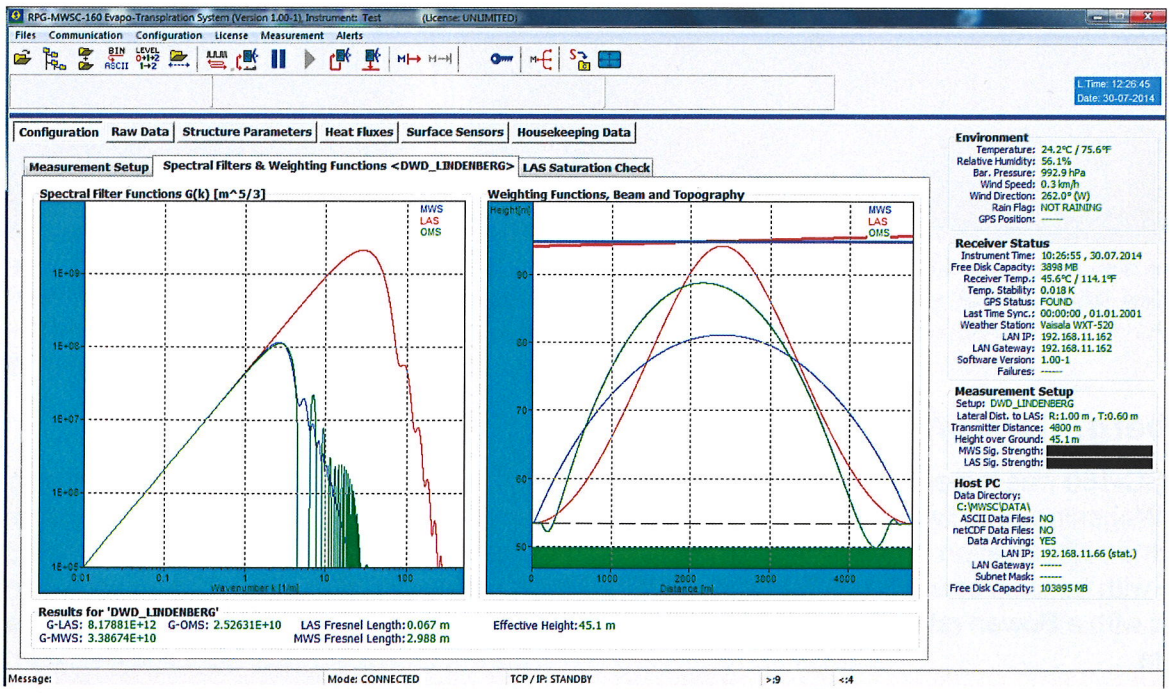


Operating Software

The RPG-MWSC-160 comes with a comprehensive operating software package *[2]*, which processes the synchronously digitized microwave and optical raw signals. The complete data processing from raw signals to heat fluxes is performed in **real-time**. All data products are continuously displayed on the screen and automatically stored.



User interface for setup of a combined optical / microwave system.



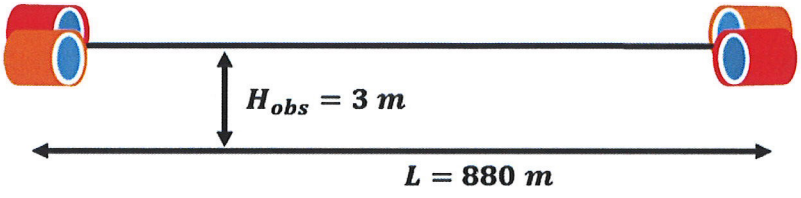
***Left**: Spectral weighting functions [1]. **Right**: Path weighting functions and effective height.*

Field Observations

The RPG-MWSC-160 was successfully operated in combination with different optical LAS systems within two comprehensive field campaigns in Sonora (Mexico) and Lindenberg (Germany).

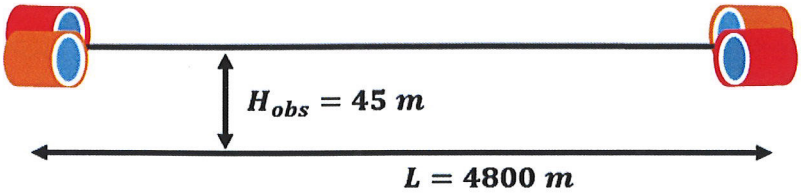
Sonora, Mexico

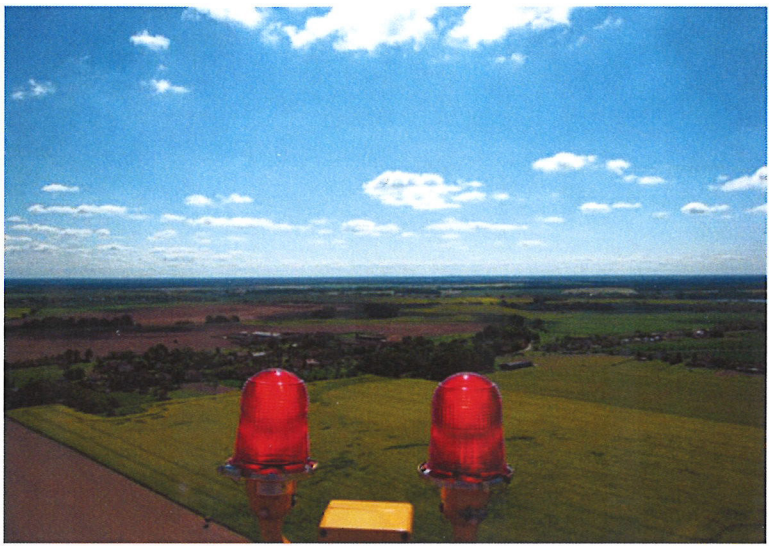
RPG-MWSC-160 was operated in combination with two different LAS systems across an irrigated sub-tropical crop field in Sonora (Mexico). The experiment was characterized by short path length and low observation height over a flat and homogeneous surface. During the day, Bowen ratios were usually smaller than 1, i.e. the latent heat flux is dominating.

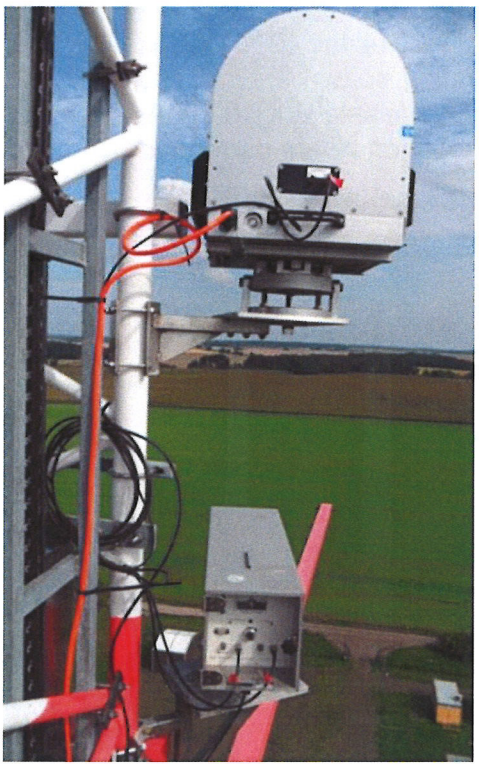


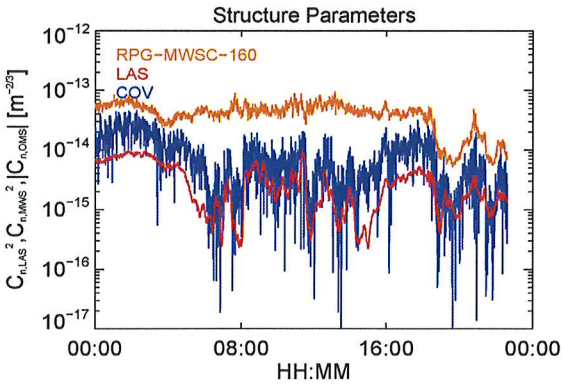
Lindenberg, Germany

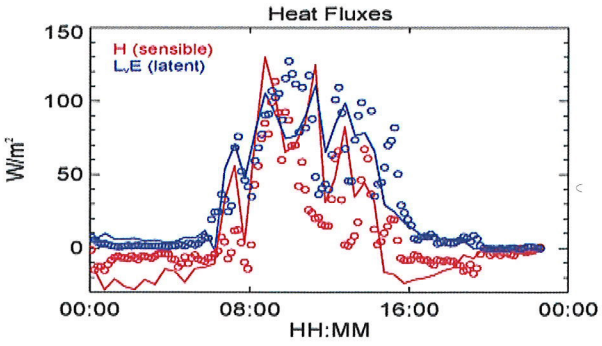
RPG-MWSC-160 was tested in mid-latitude continental climate. It was operated in combination with two LAS systems (Wageningen University and Scintec BLS900) over a long signal path between two measurement towers with an observation height of approximately 45 m. The setup was characterized by inhomogeneous landscape with patches of woodland, lakes, and crops. The combined scintillometer measurements registered heat fluxes with a Bowen ratio around 1. Measurements were in good agreement with Eddy-Covariance (EC) station data.







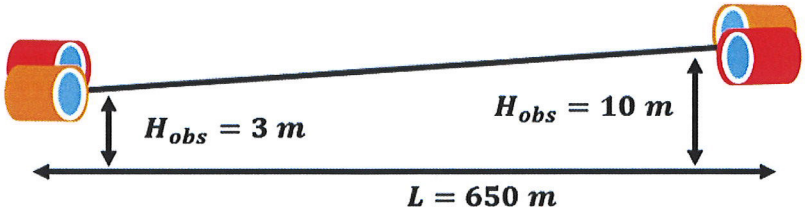


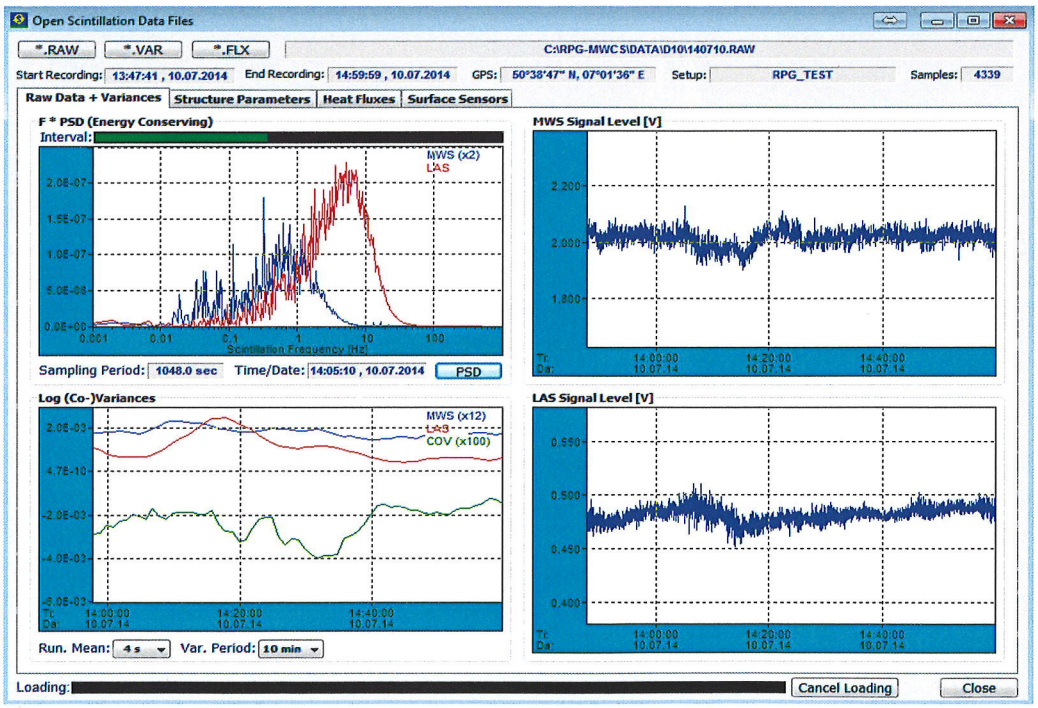


*Measurement time series for a long path over heterogeneous landscape (September 8, 2013, Germany). Left: refractive index structure parameters for **RPG-MWSC-160**, optical **LAS**, and for the signal covariance (**COV**) of both instruments (combined optical / microwave method, Lüdi et al. [1]). Right: estimates of path integrated **sensible heat flux** H and **latent heat flux** L_vE. Circles give measurements from an Eddy Covariance station (EC).*

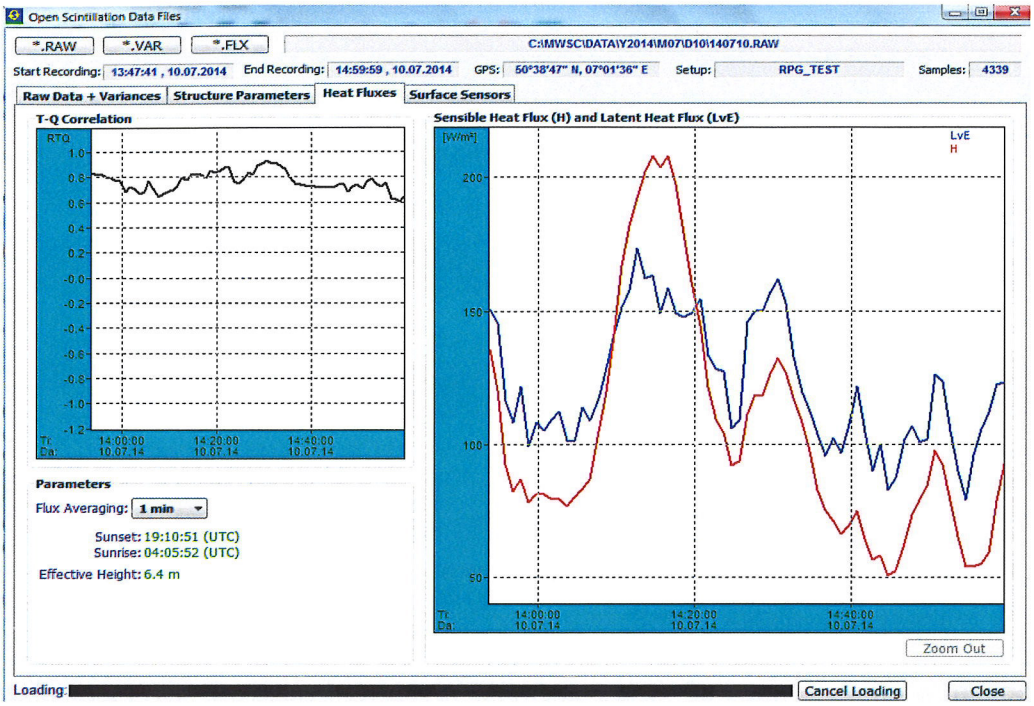
Meckenheim, Germany

In July 2014 the RPG-MWSC-160 was tested in combination with a LAS (Kipp&Zonen Mk-II) and RPG's operating software. Data processing included surface sensor data from the integrated external weather station (Vaisala WXT 520). A one hour time series of heat fluxes under variable cloudiness is given below. Observations were performed over a dry rapeseed field.





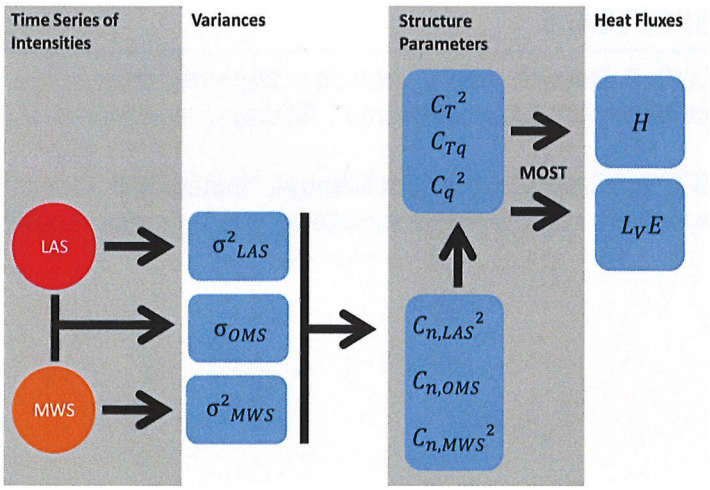
Power spectra, raw signals and variances are continuously displayed.



Data Processing

- Data Processing following *Lüdi et al. [1]* (see instrument manual *[2]* for details):
  - Calculate signal MWS and LAS variances and covariance between the signals
  - Triple of variances ⇒ structure parameters of refractive index (C_n^2).
  - Read surface sensors from integrated weather station.
  - Apply Monin-Obukhov Similarity Theory (MOST) ⇒ Heat fluxes H and L_vE.

- Available data formats:
  - Signal (co)variances
  - Structure parameters
  - Correlation coefficient R_{TQ}
  - **Heat fluxes** H, L_vE .
  - Weather station data
  - Housekeeping data



Specifications

Parameter		Specification
Frequency		160.8 GHz (λ=1.86 mm)
Radiated power		maximum power: typ. 25 mW, 50 dB attenuator
Antenna type		Cassegrain with 300 m aperture
Antenna gain		52 dB
Beam Width		0.45° FWHM
Detection bandwidth		10 kHz
Sensitivity		2.0 x 10^{-5} (resolved intensity fluctuations dI/I)
Temperature stability		< 0.03 K (two-stage control)
Power supply		120 VDC
Power consumption		max. 50 W (per unit), 20 W typical (receiver), 15 W typical (transmitter)
Output Data	Level 0	• 1 kHz digital raw data for RPG-MWSC-160 and LAS • housekeeping data
	Level 1	(co)variances of the combined optical / microwave system.
	Level 2	• structre parameters C_n^2 • sensible and latent heat fluxes H, L_vE
Type of installation		Line of sight Tx/Rx system (transmit / receive)
Baseline length		500 m to 10 km

References

[1] A. Lüdi, F. Beyrich, and C. Mätzler, “Determination of the Turbulent Temperature–Humidity Correlation from Scintillometric Measurements”, *Bound.-Layer Meteorol.*, vol. 117, no. 3, pp. 525–550, Dec. 2005.

[2] RPG-MWSC-160-Instrument Manual, “Installation, Operation and Software Guide”, RPG Radiometer Physics GmbH, http://www.radiometer-physics.de/download/PDF/Scintillometer/RPG_MWSC_TN.pdf

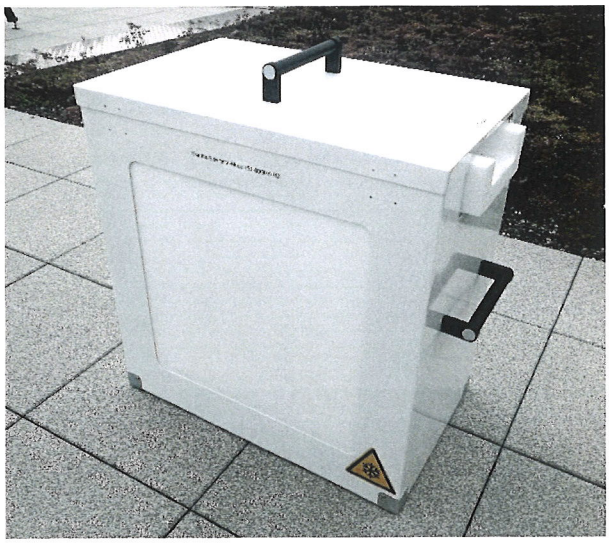
Radiometer Physics
A Rohde & Schwarz Company

The New Precision LN2 Calibration Target PT-V1
for RPG radiometers

Introduction

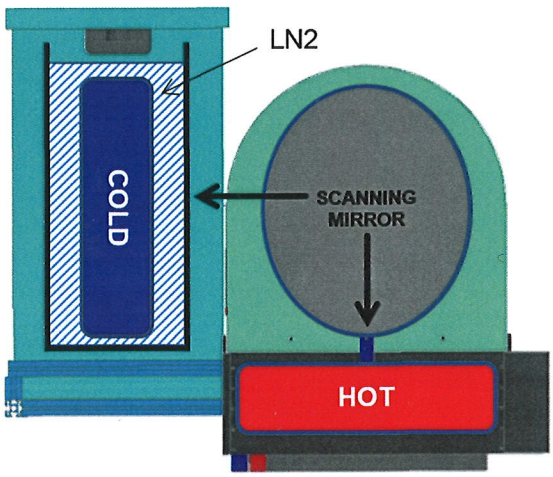
A major progress has been achieved in radiometer calibration accuracy and repeatability. RPG has developed a novel liquid nitrogen (LN2) cooled high-precision calibration target (PT-V1).

The new target effectively eliminates reflections and standing wave contributions during the calibration process. The PT-V1 improves the absolute calibration for all generations of RPG standard radiometers. In combination with a generation 5 instrument (G5), an absolute accuracy of ±0.1 K and a calibration repeatability of better than 25 mK is achieved.



Absolute Calibration of RPG Radiometers

The optical path of the new precision target PT-V1 has changed compared to the previously used cold targets. The blackbody absorber is now oriented vertically instead of horizontally. The insulating container is made of a material which is 100% transparent for microwave signals below 200 GHz. This container is cased in a protection housing with handles for carrying and lifting the target. The target has two observation windows – one for each receiver. Both windows use anti-reflection coatings, which are sensitive to polarization. Each window is optimized to the polarization plane of the corresponding receiver (V / H).



Improvements

The old calibration targets suffered from the fact that the microwave beam is partially reflected by the air/liquid interface, leading to a not exactly quantifiable impact on brightness temperatures observations on the cold target. Additionally, the reflective component was modulated by a standing wave that built up between target and receivers while LN2 was evaporating from the target container. Both effects have been observed with the previous generation of the cold calibration target and required to apply corrections by the operating software. The residual uncertainty of these corrections motivated a new target design, which completely eliminates reflections at the cold target and - as a

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

09/2016
+49 (0) 2225 99981 – 0
www.radiometer-physics.de
remotesensing-sales@radiometer-physics.de

consequence - also prevents the built-up of standing waves. The suppression of reflections on the liquid surface works only perfectly well for microwave signals of a certain polarization. Within RPG radiometers, the main beam is optically split by a wire grid and then distributed to the two receivers, resulting in orthogonal polarizations for both receivers. The new PT-V1 calibration target offers two windows optimized for each polarization. During an absolute calibration, the target is turned once from one side to the other while the calibration routine is integrating on receiver 1 or receiver 2.

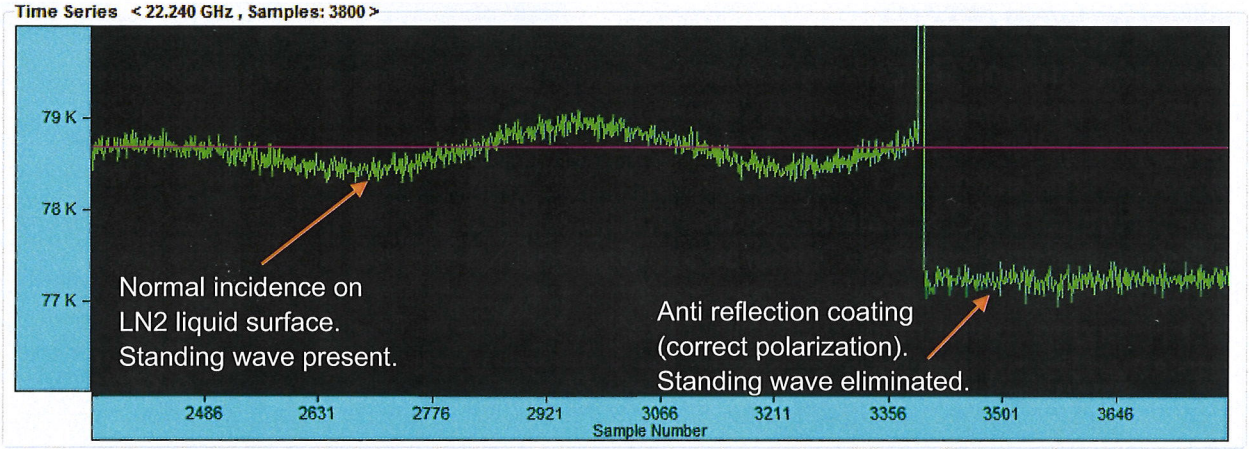


Fig. 1: Comparison of a 22.24 GHz brightness temperature time series measured on an old target with normal incidence and the new PT-V1 target.

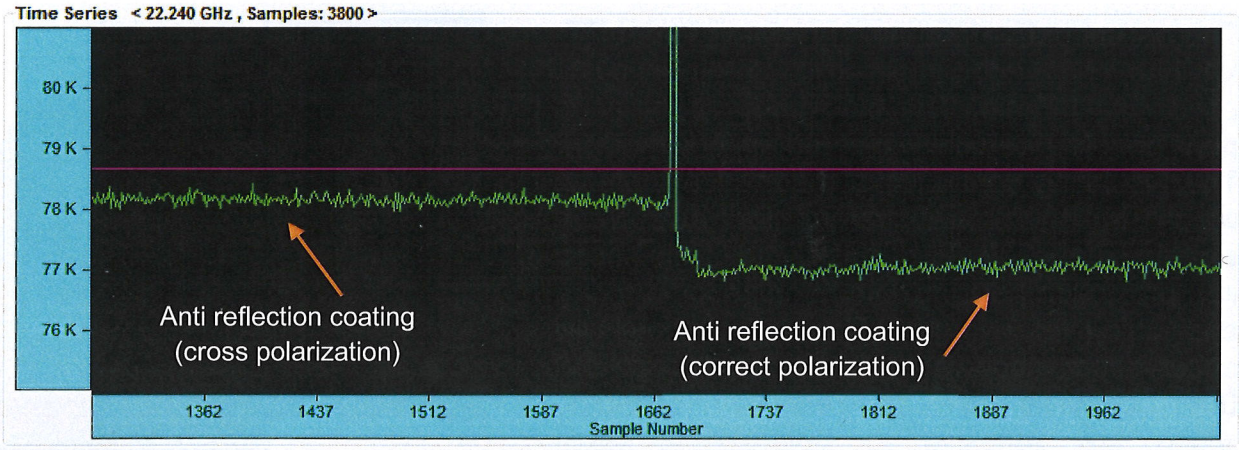


Fig. 2: Effect of different polarizations incidence to the PT-V1 anti reflection coating.

The new precision target is equipped with an insulation lid to avoid a fast wind induced LN2 evaporation and the entrainment of oxygen from the outside air. A small channel in the insulation container provides the LN2 gas exhaust which also effectively prevents the outside air from entering the target.

Summary

- Major progress in radiometer calibration accuracy (±0.1 K) and repeatability (25 mK)
- Effective elimination of reflections and standing waves at the air/LN2
- An insulation lid avoids rapid evaporation of LN2 and the entrainment of environmental oxygen.

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

09/2016
+49 (0) 2225 99981 – 0
www.radiometer-physics.de
remotesensing-sales@radiometer-physics.de

Radiometer Physics
A Rohde & Schwarz Company

Novel Product Line FMCW Cloud Radars

Zenith Polarimetric Doppler Cloud Radar[1]

High-tech low-cost solution for synergistic ground-based and airborne platforms

Evaluation of high resolution regional models

New scanner compatible design

Ka, W, G-band configurations

Calibration of meteorological radars, including airborne and spaceborne systems

Microphysical retrievals

Scanning Polarimetric Doppler Cloud Radar[1]

Fog nowcast

Ice shape and orientation

Rain drop size distribution

Boundary layer characterization

Lightning detection

Solar scan antenna measurements

Propagation effects for satellite links

Qualitatively new precipitation estimation

Weather nowcast

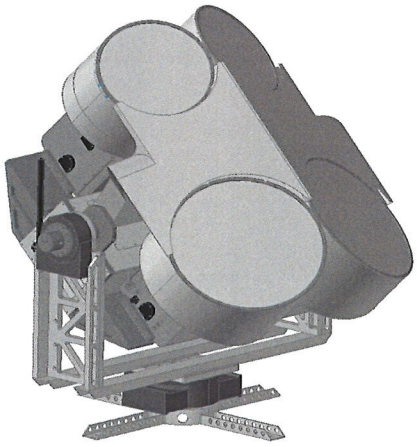
Wind retrieval

Hydrometeor classification

Dual Frequncy 35/94 GHz Polarimetric Doppler Cloud Radar[2] (available from 2018)

Advanced detection of supercooled liquid

Accurate profiling of liquid water content



Improved ice characterization

Attenuation-based precipitation estimation

[1] Single polariazation version is available upon request

[2] Zenith configuration can be implemented.

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

09/2017

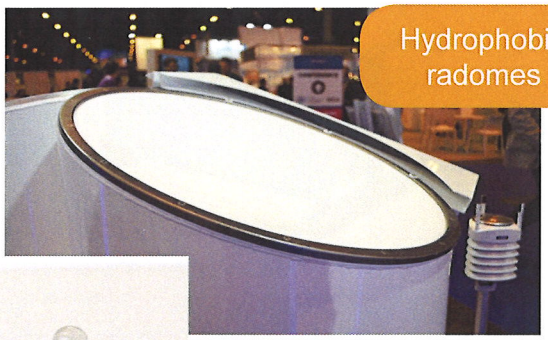
+49 (0) 2225 99981 – 0
www.radiometer-physics.de
remotesensing-sales@radiometer-physics.de

Radiometer Physics
A Rohde & Schwarz Company

Novel Product Line
FMCW Cloud Radars

Advantages

- ±0.5 dBZ calibration accuracy
- Embedded passive channel
- Company based production chain
- Small form factor
- High electromagnetic compatibility
- Perfect thermal insulation ±0.5K
- No high voltages
- Low cost

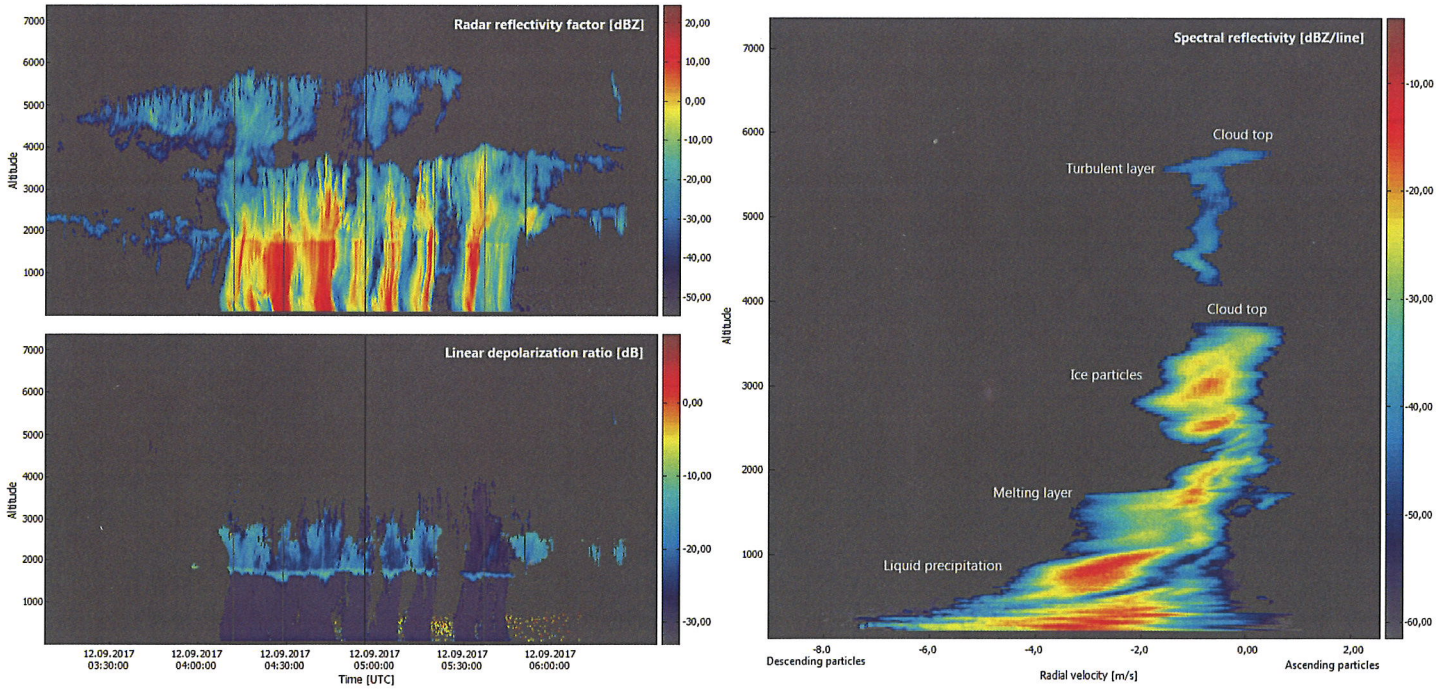


Hydrophobic radomes

Drone-based calibration verification

- High Doppler resolution (1.7 cm/s)
- Powerful rain mitigation system
- High range resolution
- High sensitivity
- Small blind zone
- Stable signal shape
- Low noise temperature
- Integrated weather station

Measurement Example (W-band radar, LDR-mode)



For more details and observations please refer to the extended brochure.

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

09/2017
+49 (0) 2225 99981 – 0
www.radiometer-physics.de
remotesensing-sales@radiometer-physics.de