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WHITE PAPER

SI Traceability of Calibration for Distance Measurement

Vaisala Lidar Ceilometer CL61

Calibration is important

Accurate calibration is fundamental to the high measurement accuracy of Vaisala Lidar Ceilometer CL61.
CL61 distance measurement is calibrated against a reference that is traceable to international standards (SI units).
Calibration uncertainty is comprehensively analyzed and regularly verified by independent laboratory measurements.
Accurate height measurements ensure the correct height coordinates for measured atmospheric variables.

1 SI traceability chain

The Vaisala Ceilometer CL61 units are individually calibrated at the Vaisala factory. Figure 1 illustrates the traceability chain of distance measurement calibration to International System of Units (SI). The working standard is a reference fiber optic delay-line. Traceability of the standard to SI units is established through an unbroken chain of documented time delay calibrations by National Metrology Institute (VTT-MIKES, Finland).

The calibration certificate provides details on the reference fiber optic delay-line. The working standard is calibrated regularly by VTT-MIKES.
To guarantee consistent quality of calibration, process instrument changes are managed according to ISO 9001:2015 Quality Management System and the ISO 10012:2003 normative reference. The uncertainty of the calibration is determined according to JCGM 100:2008 (Evaluation of measurement data — Guide to the expression of uncertainty in measurement).

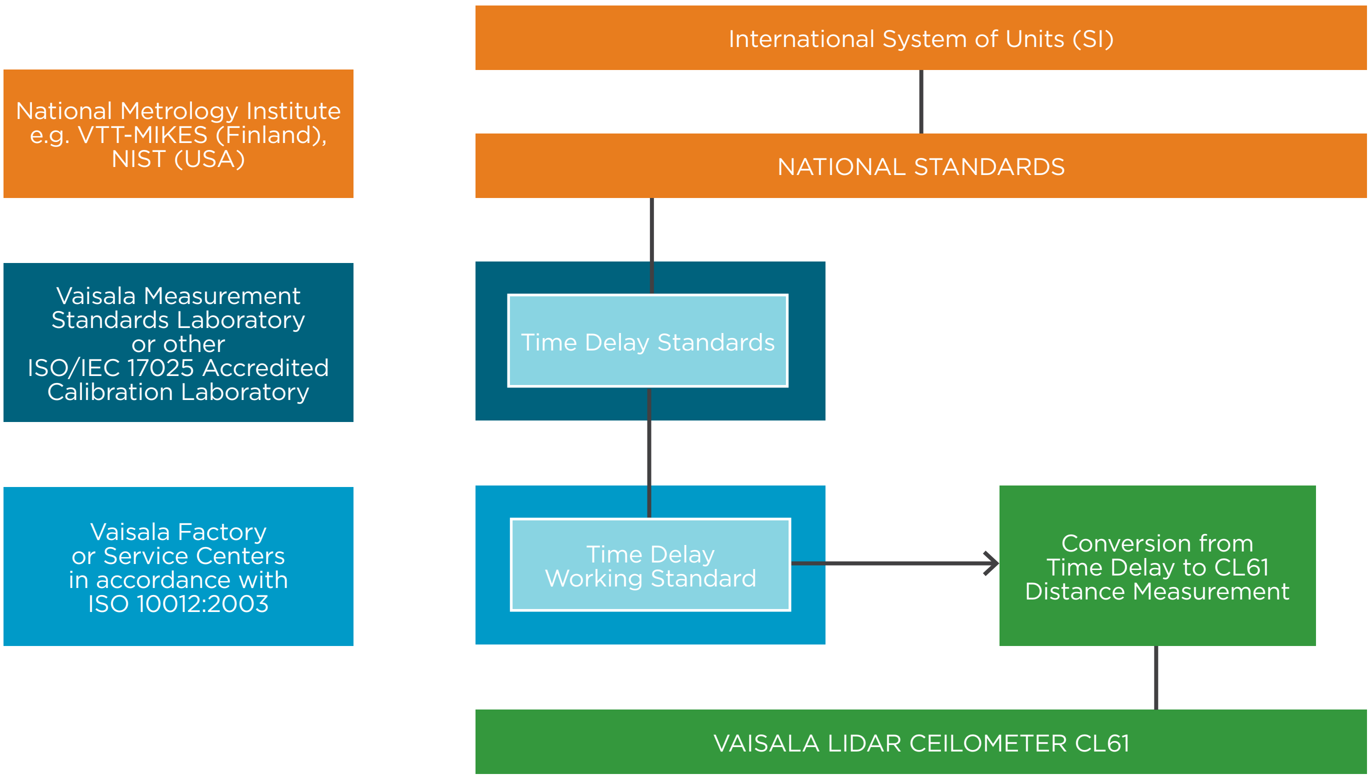

Figure 1. SI traceability chain for Vaisala Lidar Ceilometer CL61 distance measurement

2 Calibration process

CL61 distance measurement is calibrated using time of flight measurements with a reference fiber optic delay-line. Figure 2 illustrates the setup. The delay-line is built with parallel branches to measure travel time along shorter and longer optical lengths. The time of flight is determined as the time difference between a peak response from a triggered laser pulse and a peak response from the received laser pulse. Time of flight measurements are converted into distance measurements using the approximation v = 3.00e+8 ms-1 for the speed-of-light in the air.

Calibration uncertainty analysis considers several sources of uncertainty, including the following essential points:

- Temperature sensitivity of the reference
- Wavelength sensitivity of the reference
- Short-term stability (random component)
- Sampling clock uncertainty
- Peak location estimation uncertainty

The calibration certificate provides detailed information on the reference, calibration uncertainty, and calibration test result. During the calibration process, the measurement results of each CL61 unit are examined and saved to the calibration database. All data gathered during the manufacturing and calibration processes is traceable and a link between the serial number and the process data is established.

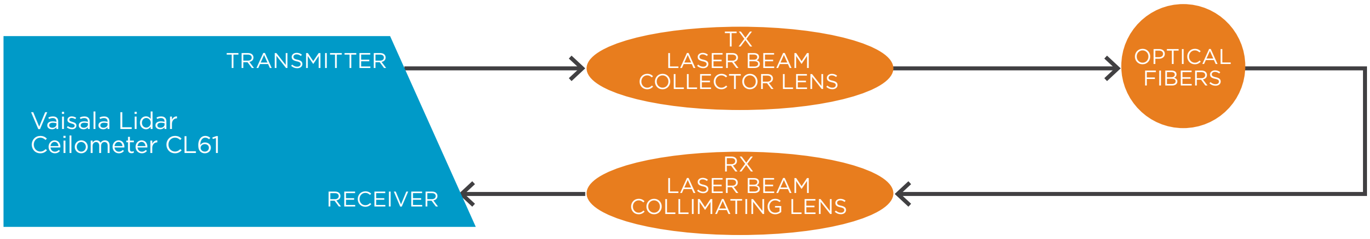

Figure 2. Calibration of Vaisala Lidar Ceilometer CL61 distance measurement

3 Calibration result and CL61 measurements

Calibration ensures that CL61 correctly records the time of flight as laser pulse propagates to a target and back to the receiver, i.e. basic lidar operation principle. The calibration setup mimics a field test where the ceilometer is pointed at a known hard target at a known distance. However, to avoid many of the uncertainties related to field experiments, the test is designed to be performed in controlled indoor conditions.

The calibrated time of flight measurement is converted into distance measurement, which is the basic coordinate of all CL61 measurement products. For backscatter profiles, calibration ensures that each value corresponds to the correct range coordinate.

For cloud base heights, a well-defined distance measurement is fundamental; however, compared to hard target detection, cloud algorithms contain more complex logic and related additional uncertainties. They estimate the cloud base in the continuous cloud volume, which is not a hard target, following application requirements.

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