On the accuracy of absolute GNSS antenna calibration and the conception of a new Anechoic Chamber

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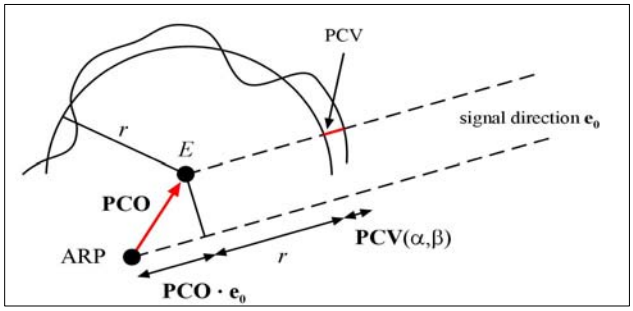
Antenna Model



Important for phase detection are especially :

1.: PCO: phase centre offset (up to 15 cm)

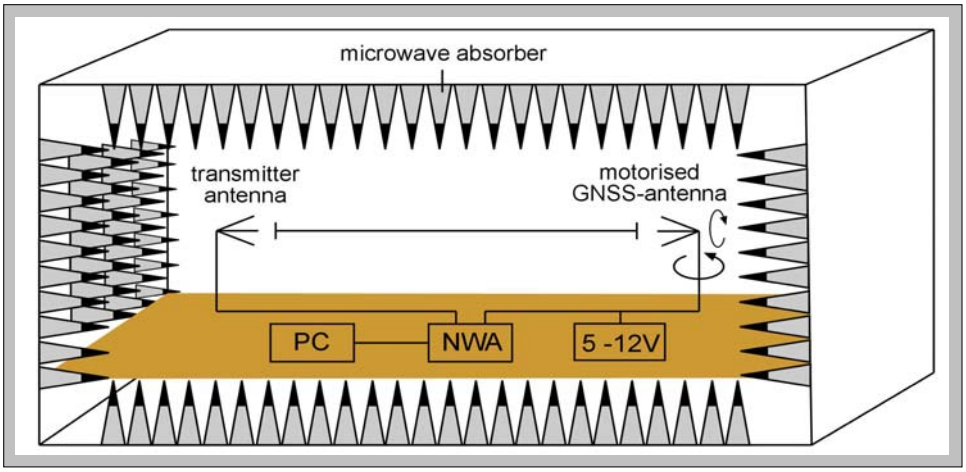
the exact position of the phase centre is unknown

2.: PCV: phase centre variations (up to 2 cm)

the phase centre is not a point in a mathematical sense

Result: the measured phase does not refer to the ARP and depends on the direction of the incoming signal

Calibration Setup



- NetworkAnalyser (NWA): measurement of the phase variations
- 2-axis-Positioner: rotation of the GNSS-antenna in order to change the direction of the incoming signal

Accuracy of Calibration

GNSS observation accuracy: 0.3mm – x cm (zenith to horizon)
Required antenna accuracy: 0.1mm – 1mm (zenith to horizon)

Important aspects concerning accuracy:

- Accuracy of the NetworkAnalyser
- Noise of the calibration setup
- Effects of temperature
- Effects of varying signal level
- ...

- Repeatability of the calibration results (Precision)
- Comparison with field calibration procedures (e.g. Geo++)
- Near-field effects, Sensitivity of the Setup

Repeatability

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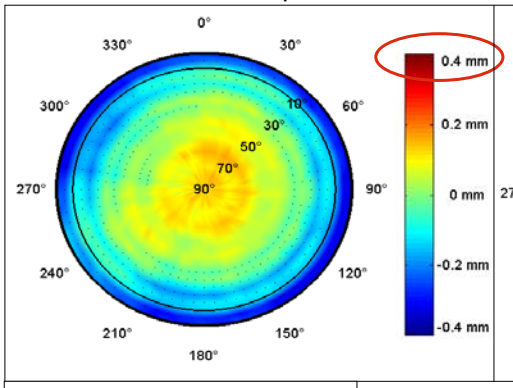
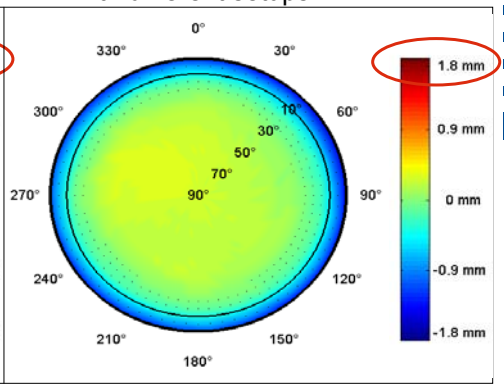
differences between two measurements

with identical setups:



with different setups:



Leica AX 1202GG antenna:

Typical differences for identical setups: +/- 0.3mm

Possible differences in the setup are:
- cable placement
- mounting of the antenna
- orientation of the transmitter

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Repeatability

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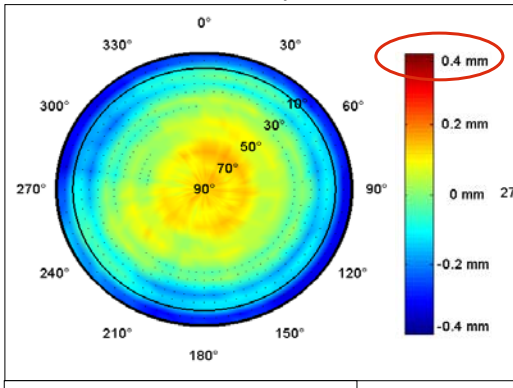
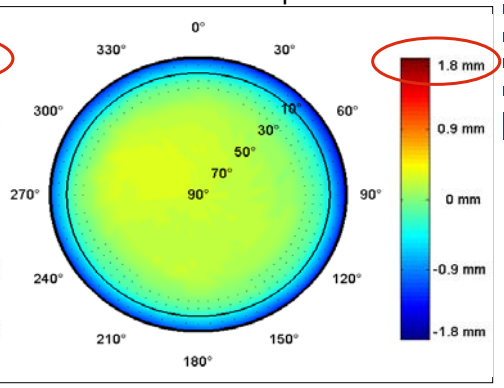
differences between two measurements

with identical setups

with different setups:





Leica AX 1202GG antenna:

Typical differences for identical setups: +/- 0.3mm

Elevation	0° - 5°	5° - 10°	10° - 15°	15° - 90°
Max. diff.	1.5 mm	1.0 mm	0.7 mm	0.3 mm

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Near-Field-Effects: one nice Example

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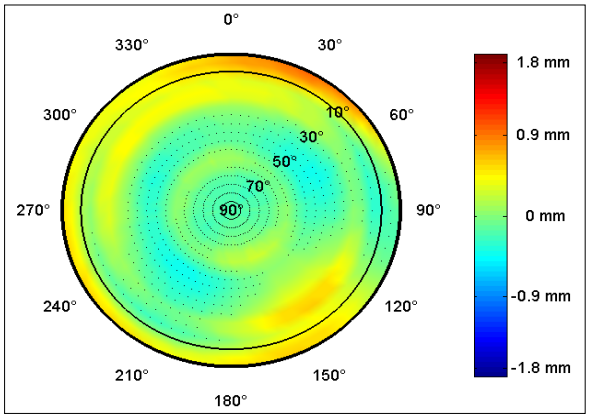
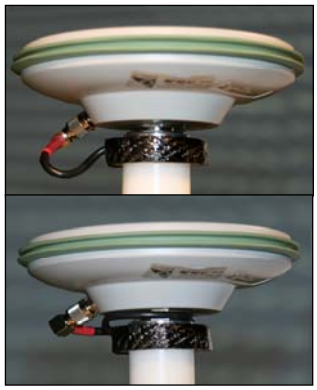


max. diff = 1.0 mm

min. diff. -0.4 mm



The effects of cable placement are 3 times larger than the repeatability without changes in setup.

Near-Field-Effects: Consequence

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consequences of the presented results:

- the near-field effects are large in relation to the repeatability
- to reach the required accuracy of up to 0.1mm
  – we have to solve the near-field problems –

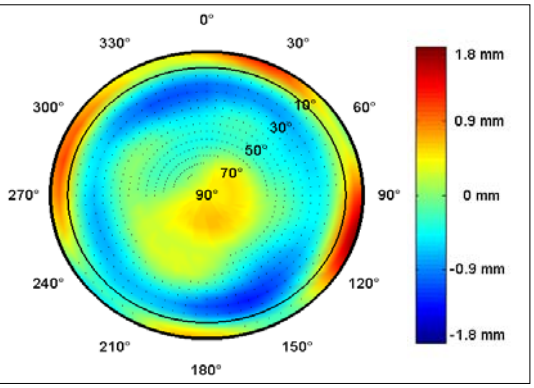
One solution (but very difficult to realize):

→ the antenna environment has to be similar for calibration and GNSS-measurements

Comparison with Field Procedure (here: Geo++)

Example: Trimble Zephyr Geodetic antenna (L1)

Elevation	Max. diff.
0° - 10°	± 1.8 mm
10° - 20°	± 1.0 mm
20° - 90°	± 0.5 mm



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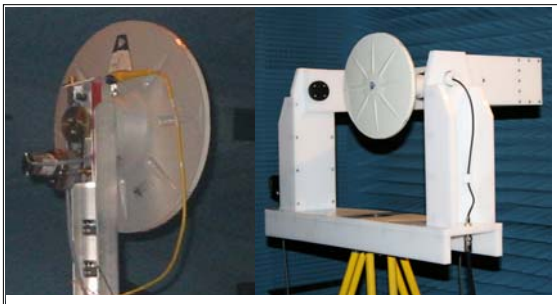
Deviations are only slightly higher than the effects of the near-field

→ Both procedures correspond well

For antennas without a good shielding, the maximal deviations increase

Comparison with Field Procedure (here: Geo++)



vs.

One remark:
signal level, noise, environment etc. are identical for all frequencies
→Calibration accuracy should be similar for L1 and L2

But: deviations for L2 are up to twice as large as for L1

Concept of the new Anechoic Chamber

The most important characteristic is the size of the chamber
- the larger the chamber the smaller the remaining errors but:
- the larger the chamber the higher the costs

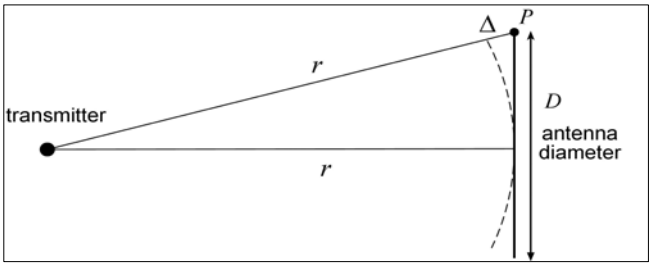
The acceptable remaining errors depend on the required accuracy

→ The chamber length depends on the required accuracy

Calibration on short Test Ranges

GNSS-Aplication: Distance Satellite – GNSS-antenna > 20 x 10^6 m
Calibration: Distance Transmitter – GNSS-antenna < 20 m

Problem: phase shift as a result of a short additional distance Δ at P



The effect Δ in a Point P depends on
- the length of the test range r
- the effective antenna diameter D

⇒ find min. test range

Calibration on short Test Ranges

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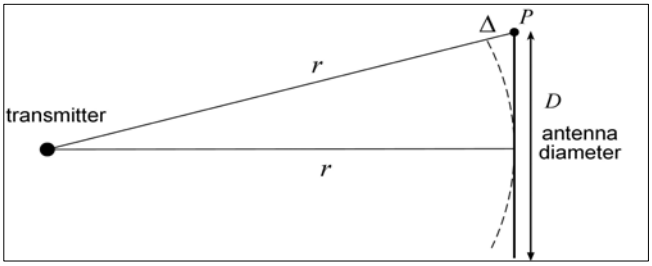


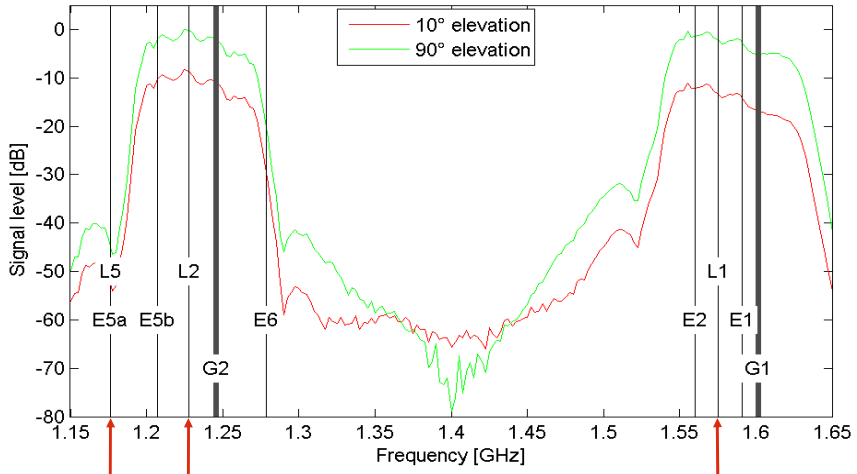
The effect Δ in a Point P depends on
- the length of the test range r
- the effective antenna diameter D

Antenna diameter depends on the wavelength/frequency

GNSS-Frequencies

calibration of a wide frequency spectrum: 1.15 – 1.65 GHz

(Leica AX 1202GG Antenna



λ ~ 25.48 cm λ ~ 24.45 cm wavelength λ ~ 19.05 cm

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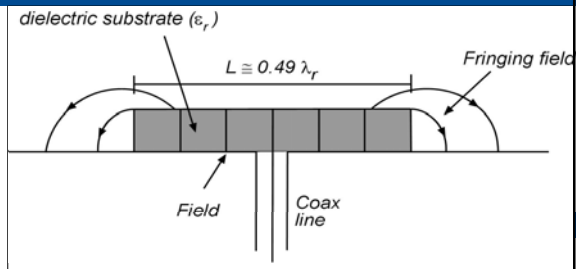
Calibration on short Test Ranges

Wavelength L5 ~ 25.5 cm

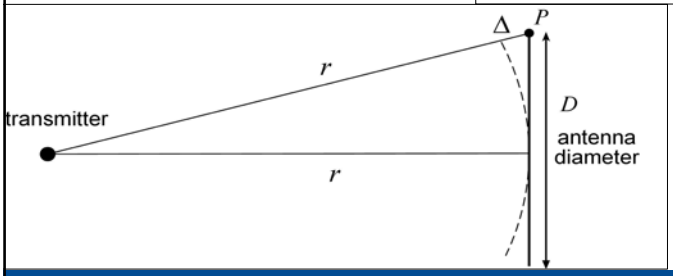
Resulting Diameter D=L=9 cm
(for many antenna types)

For a test range of 6m:
Δ= Δ(r,P) < 0.17mm

Effect on phase shift: < 0.1mm



$$L \approx 0.49 \frac{\lambda_0}{\sqrt{\varepsilon_r}} \quad with \quad \varepsilon_r \approx 2$$

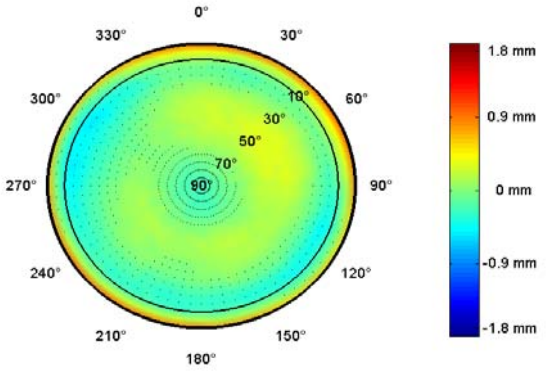


Improvement by measurements →

Calibration on short Test Ranges

Differences between calibrations with 6 and 20m test range

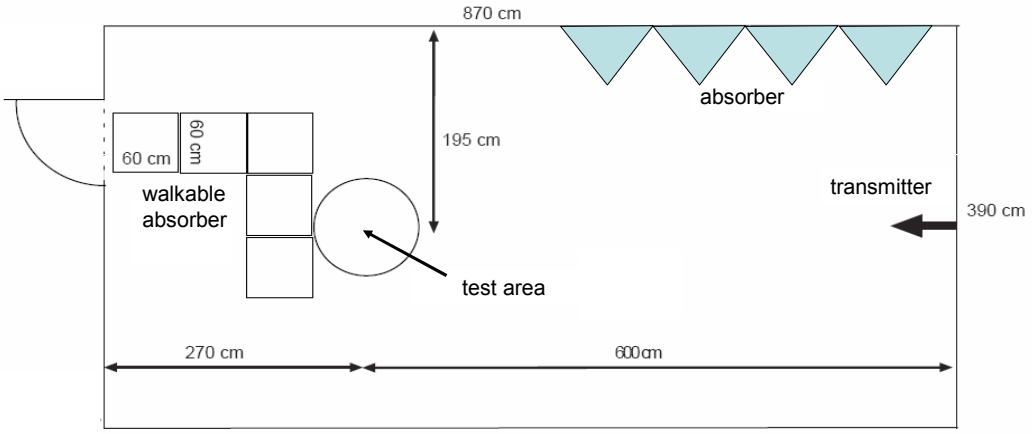
Elevation	Max. diff.
0° - 5°	± 1.0 mm
5° - 90°	± 0.5 mm



Changing test range includes changing the setup
(e.g. cable placement, position of the tripod)

→ The effect of the reduced test range is not visible

The new Anechoic Chamber in Bonn



The anechoic chamber is being constructed in cooperation with the Landesvermessungsamt NRW (surveying and mapping agency of North-Rhine Westphalia)

(Dis-)Advantages of the laboratory Procedure

Advantages:
- calibration of a wide frequency spectrum (no satellites necessary)
- the calibration procedure is very efficient (40-60 min)
- constant environments can be achieved

The main disadvantage:
- the test signal differs from the real GNSS-signal

Summary

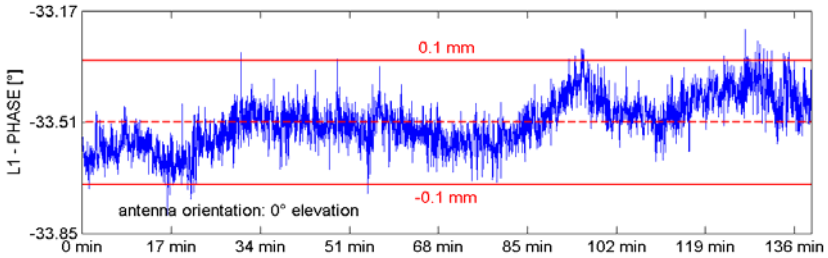
Near-field effects are currently the main problem

A test range of about 6m is suitable for typical GNSS-antennas

A new anechoic chamber is currently under construction
→ Possibility to extend investigations

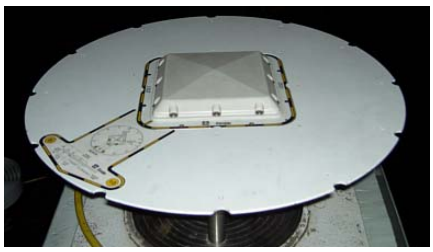
Thank You!

Noise and Systematic Effects



Different Antenna Types

Leica AX1202GG

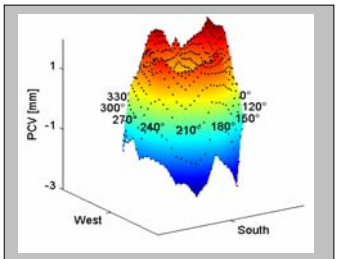


Trimble Compact +GP

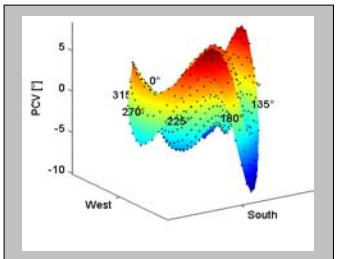
Leica AT504

Trimble Zephyr Geodetic

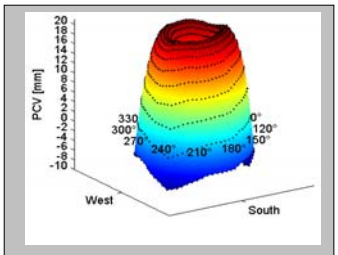
Corresponding Antenna Pattern



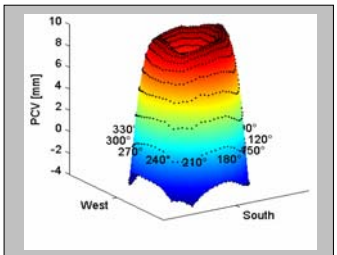
Leica AX 1202



k.A.



Leica AT 504



Trimble Zephyr Geodetic

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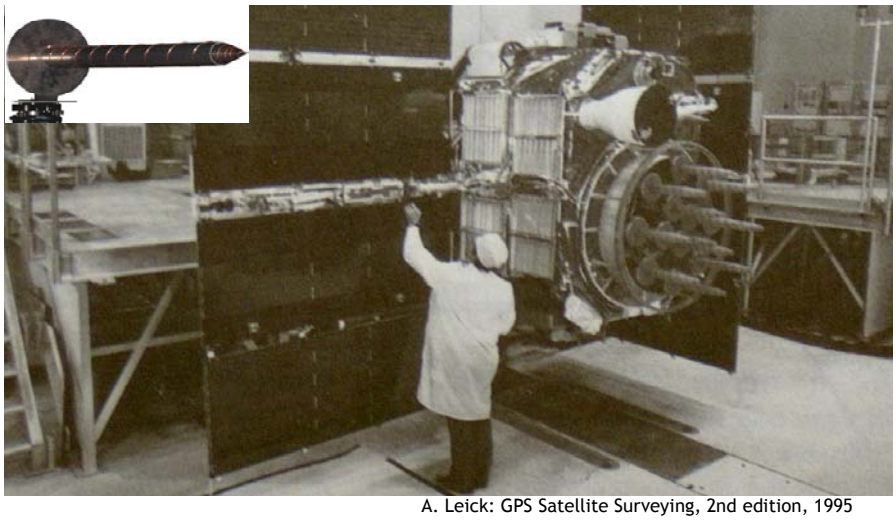
Transmitter & Satellite

Block II Satellite:



A. Leick: GPS Satellite Surveying, 2nd edition, 1995

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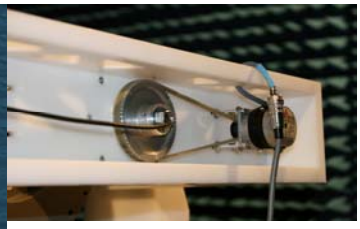
Positioner I & II

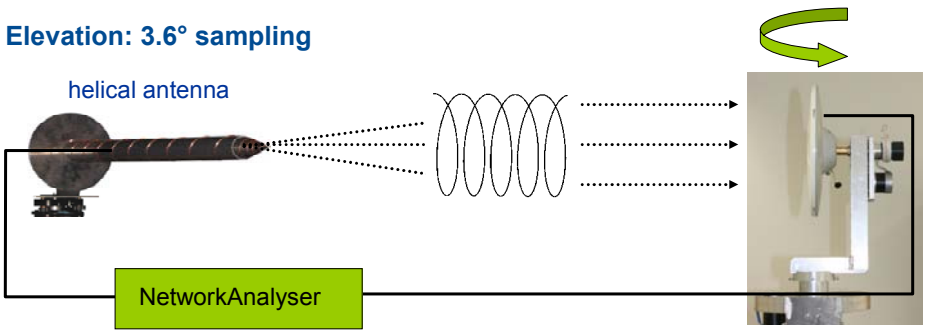


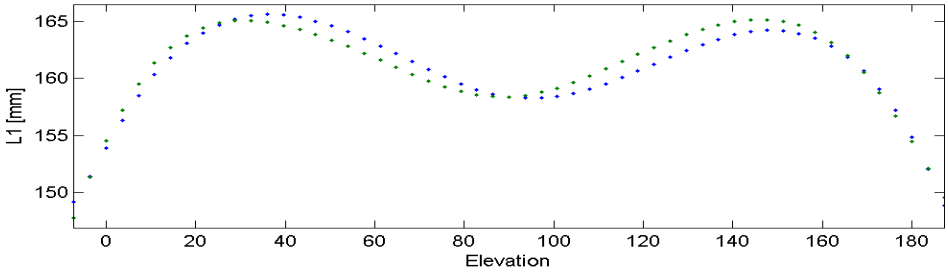
Positioner:

- Sampling: 0.9° Schritten (elevation & zimuth)
- Material: 1: aluminium
  2: polyethylen

Changing Signal Direction

Elevation: 3.6° sampling

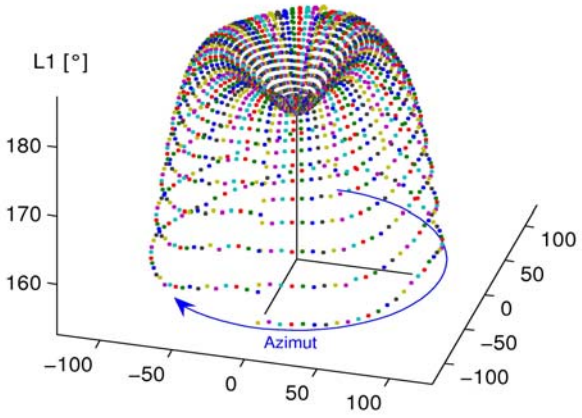




Changing Signal Direction

Elevation: 3.6° sampling

Azimut: 3.6° sampling



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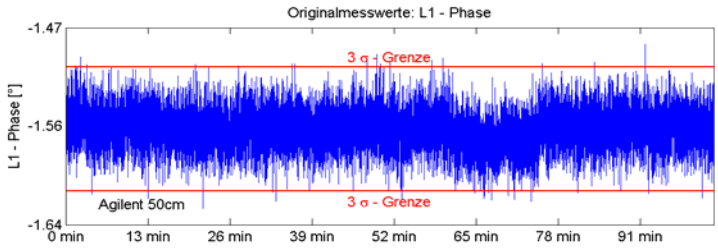
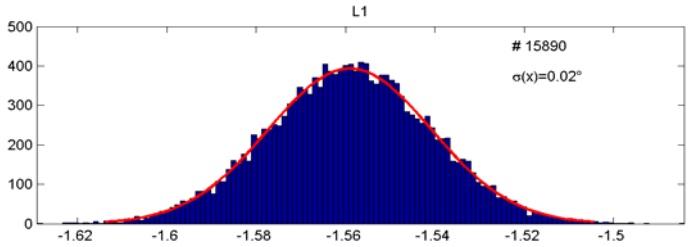
Network Analyser





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Network Analyser