Absolute Receiver Antenna Calibrations with a Robot

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Motivation and Goal

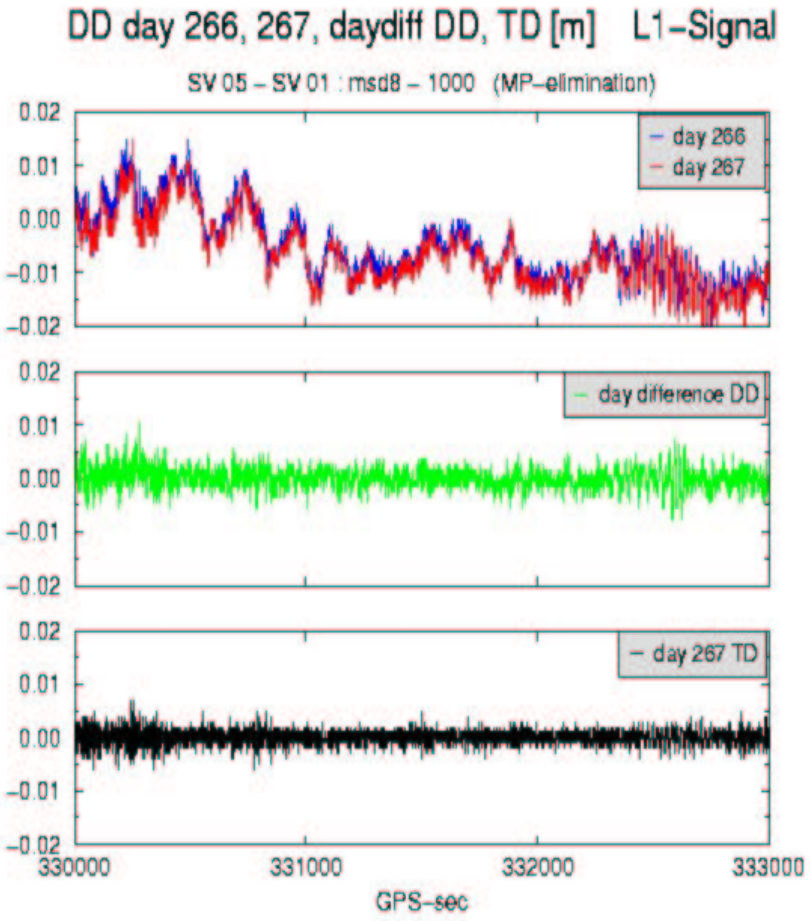
- problems with existing field calibration procedure
- problems with absolute chamber calibration results
- PCV urgently needed for mixed antenna type applications (e.g. RTK networks, engineering tasks)

- separation of multipath (MP) and phase variations (PCV)
- absolute PCV independent from reference antenna
- high resolution and precision for PCV
- site and location independent
- field procedure

Development of Absolute PCV Field Calibration

- siderial day differences (1992), first PCV calibrations (1992−1993)
- close cooperation with IfE (since 1995)
- spherical harmonics PCV model, post−processing with GEONAP (1995)
- development of antenna mounts (1996−2000)
- absolute calibrations and detailed analysis (1995−1999)
- automated absolute PCV field calibration in real−time using robot (2000)
- operational absolute PCV field calibration (since 2000)
  - publication of absolute PCV for AOAD/M_T (2000)
  - proposal of GPP_NULLANTENNA (2000)
  - absolute PCV supplied for analysis/verification/use (2000−2001)
  - Geo++ GNPCVDB antenna database (2001)

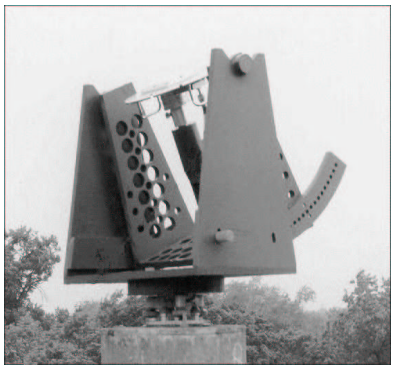
Development of Multipath Elimination Techniques and PCV Separation



- siderial differences in post−processing
  - first approach
  - observation on two days
  - same geometry/environment eliminates MP
- short−term differences in real−time
  - operational procedure
  - same MP for subsequent epochs eliminates MP
- PCV reintroduced by orientation changes (rotations and tilts)

Development of Automated Antenna Mount

- orientation changes of antenna required
- mount for rotating and tilting antenna
  - precise, fixed and stable rotation point
  - automation
  - operational procedure
- finally use of a robot
  - fast changes
  - automated robot guidance
  - real−time



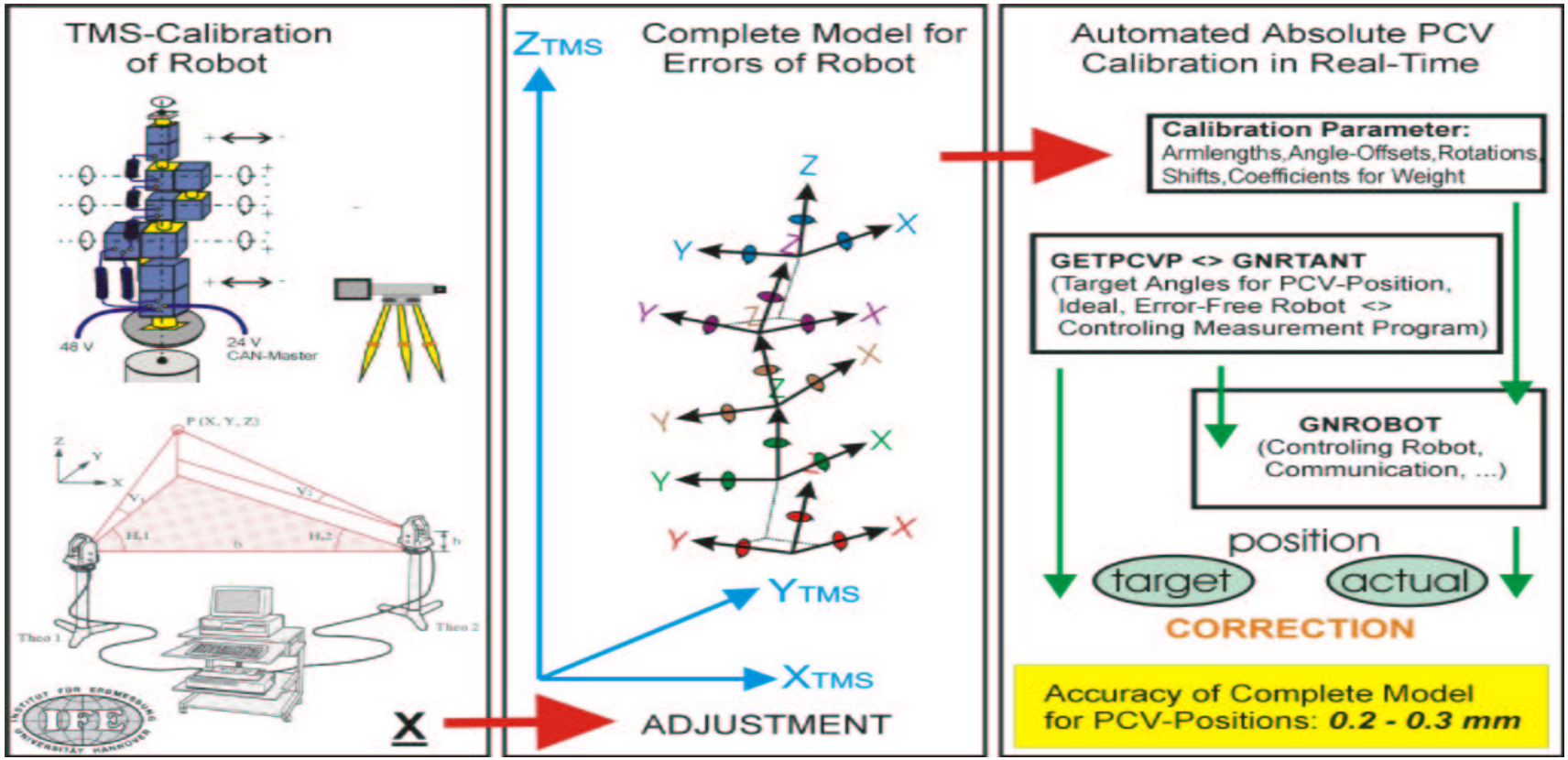
1996

1998

2000

Development of Robot Calibration Procedure

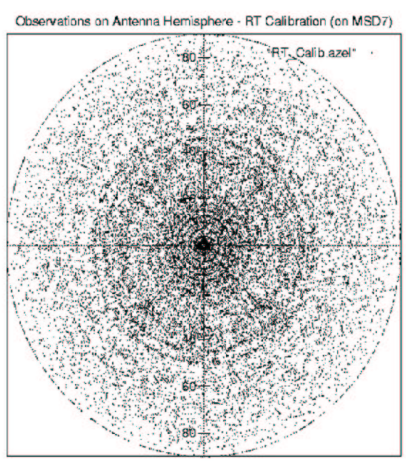
- corrections for robot required
- accuracy for antenna positions : 0.2 − 0.3 mm



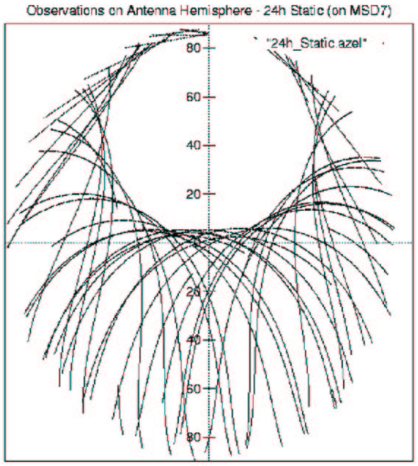
Details on Absolute PCV Field Calibration

- homogeneous coverage of antenna
  - 6000 − 8000 different positions
- dynamic robot guidance
  - depends on satellite constellation
  - optimizes observation time
- dynamic elevations mask
  - satellites with high elevation (>18°)
  - actual negative elevation (−5°) used

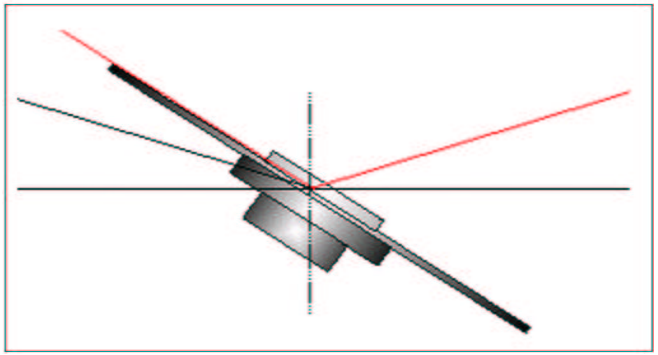
Coverage



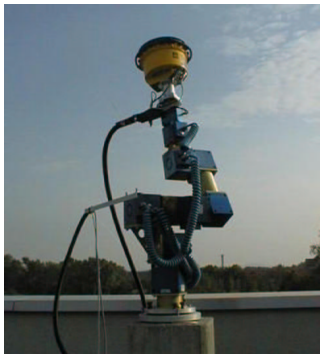
Absolute



Relative



Analysis of Operational Absolute PCV Field Calibrations

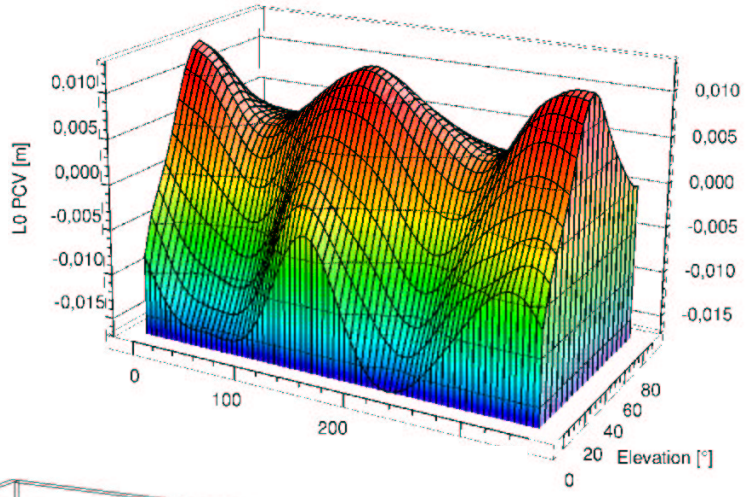


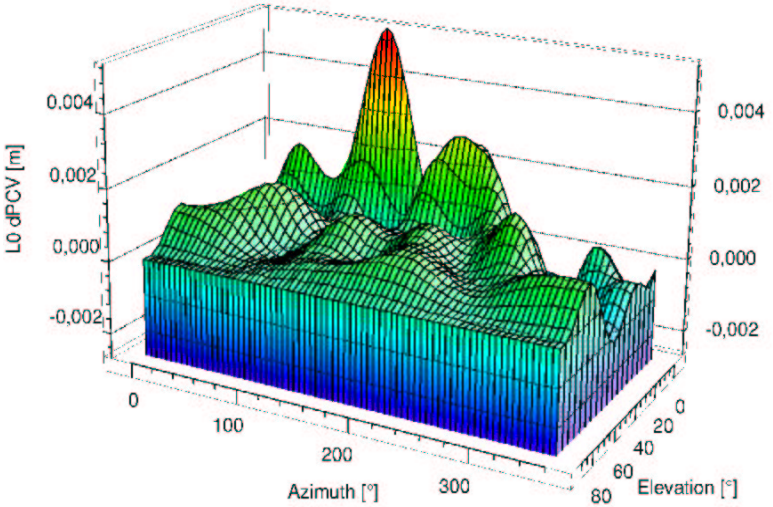
- ✔ different locations (Geo++, IfE)
- ✔ different times (days, seasons, ...)
- ✔ different weather (temperature, rain, snow, wind, ...)
- ✔ different robots (hardware, robot calibrations, performance, ...)
- ✔ different reference antennas (all major manufacturers)
- ✔ different GPS receivers (all major manufacturers)
- ✔ different north orientations
- ✔ different mounting on robot
- ✔ ...

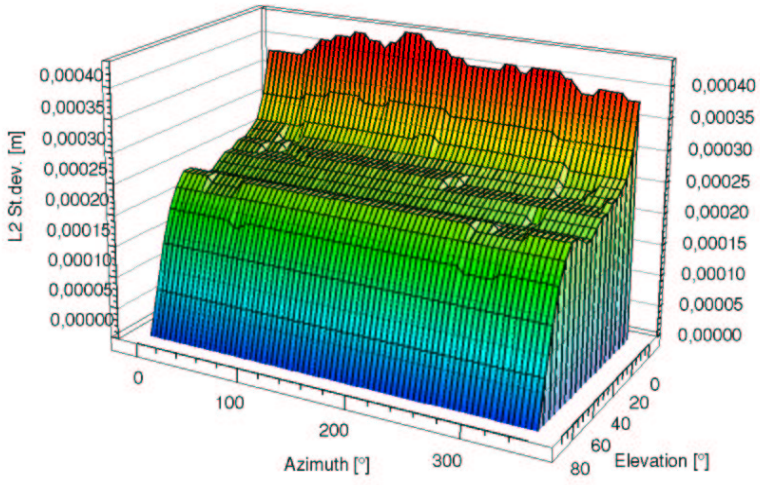
Repeatability and Accuracy of Absolute PCV Field Calibration

example LEIAT303

- absolute L0 PCV : −10 to 15 mm range
- std. dev. of L2 PCV : 0.2 to 0.4 mm range
- difference L0 PCV 5 month apart : 1 mm mean, except horizon







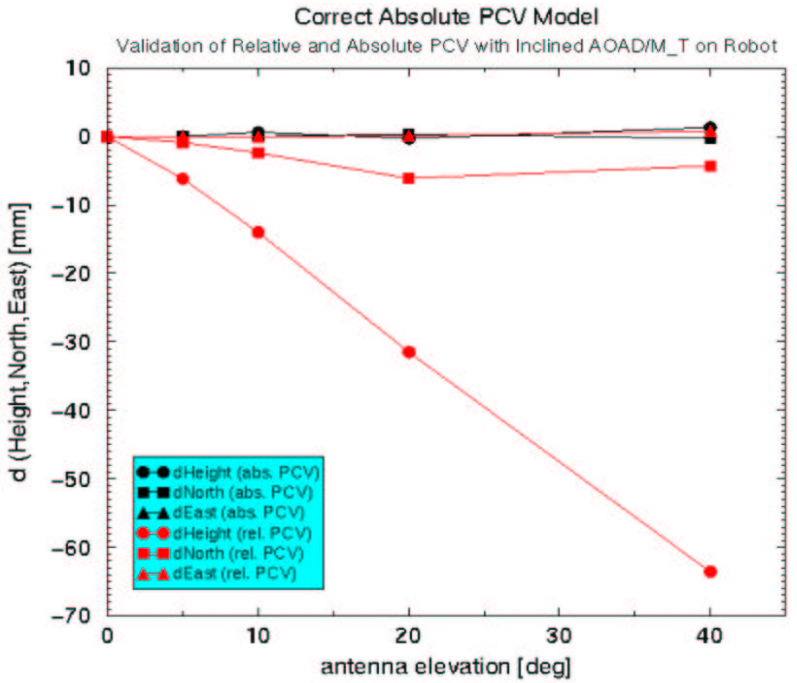
Characteristics of Absolute PCV Field Calibration

- absolute 3D offset
- absolute PCV
- PCV from (<) 0° to 90° elevation
- 0° to 360° azimuthal PCV
- simultaneous L1, L2 GPS and GLONASS PCV
- high resolution and precision
- free of multipath influence
- site and location independent

- at least two independent calibrations
- duration of several hours
- standard deviation 0.2−0.3 mm (1 sigma) for complete PCV (offset plus PCV)
- verification of accuracy through repeatability

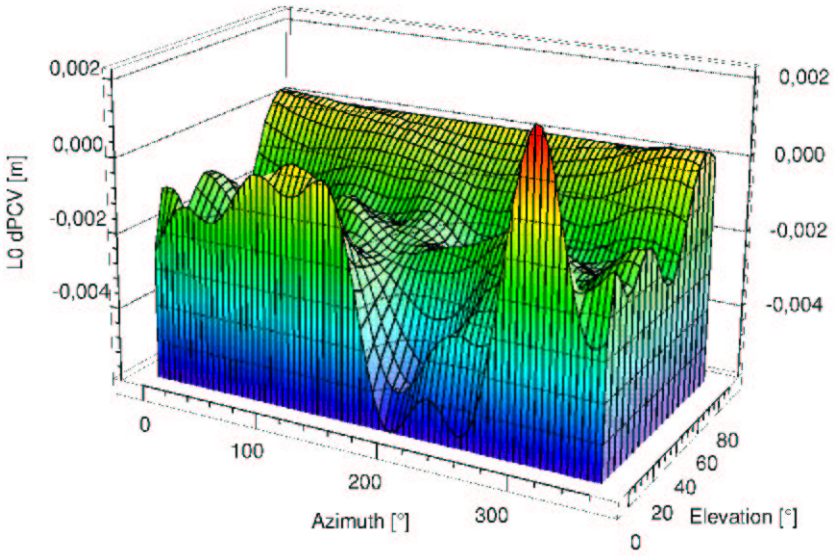
Verification of Absolute PCV

- concern “15 ppb scale” for global networks
- experiment simulating “large network”
  - inclined and rotated AOAD/M_T simulates geographical separation
  - no effects from atmosphere, orbits, satellite antenna using short baseline, true reference
- coordinates from 24 h data, L0 + tropospheric scale parameter
- proof by comparing absolute and relative PCV performance

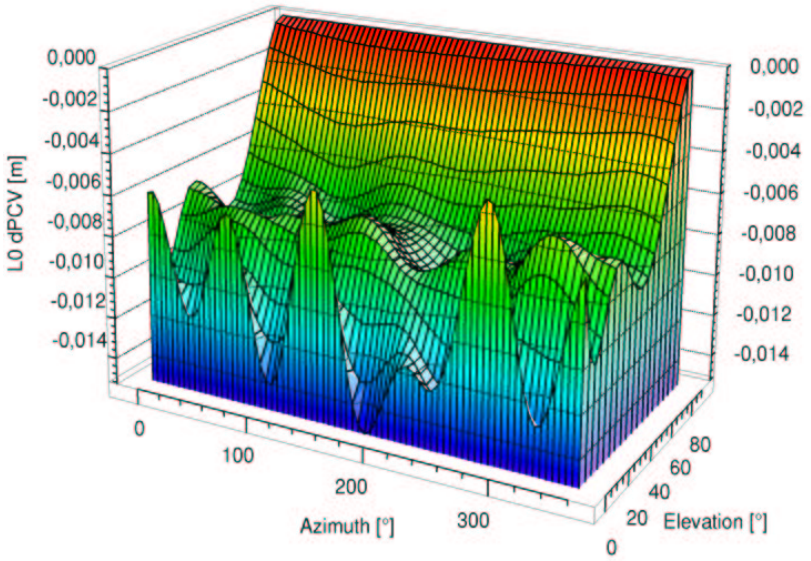


Effect of Radome Construction

- difference absolute L0 PCV LEIAT504 / LEIAT504 LEIS : −4 to 2 mm range



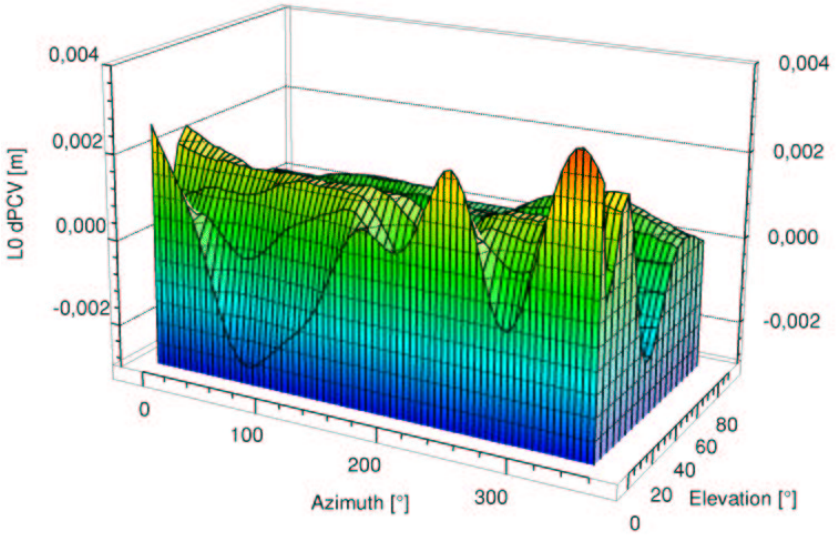
- difference absolute L0 PCV LEIAT504 / LEIAT504 SCIS : −14 mm range



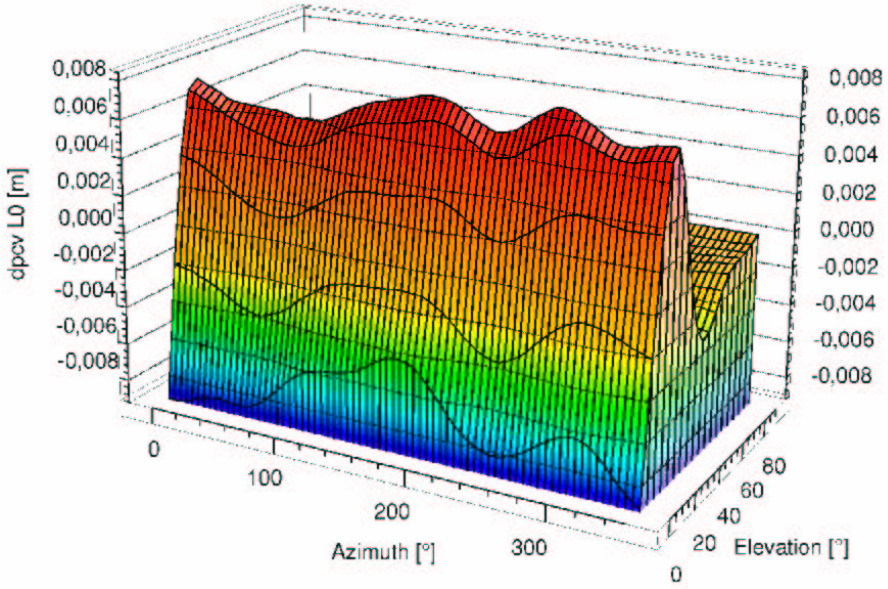
Effect of Radome Construction

Geo++®

- difference absolute L0 PCV ASH700936M_E/ASH700936M_E SNOW : −2 to 4 mm range



- difference absolute L0 PCV TRM29659.00/TRM29659.00 TCWD : −8 to 8 mm range



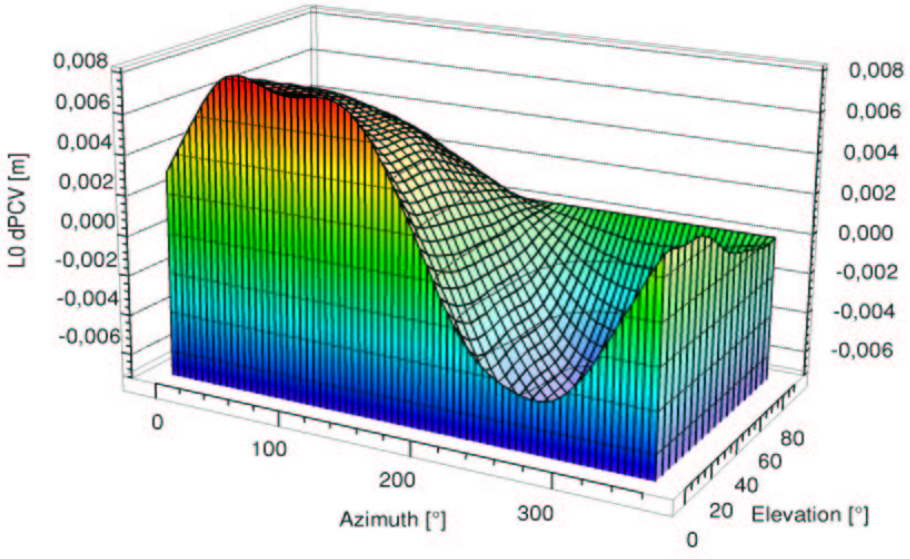
Individual or Type Mean PCV Correction

- individual calibration best choice
  - most antennas not accessible
  - option for new installations
- type mean suitable for other applications
  - simple procedure
  - uncertainty remains
- significant differences between antenna types observed
  - manufacturing series
  - assembling errors
  - outliers even for “Dorne Margolin Type” choke ring antenna

Example of Individual PCV Difference

- “Dorne Margolin Type” choke ring antenna
- best geodetic antenna type
- example of outlier
  - primarily L1 east offset
  - effect for L0 absolute PCV : −6 to 8 mm range
- different manufacturers
  - 1 outlier out of 10 antennas
  - 1 outlier out of 26 antennas

Typ −Individual Offset	*dNorth [mm]*	*dEast [mm]*	*dHeight [mm]*
L1	−0.2	−4.9	−1.0
L2	+0.1	+0.7	−0.1



Benefits of Absolute PCV Field Calibration and Correction

- high precision absolute PCV
- reliable azimuthal PCV
- separation of error components possible (e.g. station MP calibration, atmospheric parameter)
- unbiased absolute positioning
- mixed antenna type application possible (e.g. RTK networks)
- engineering application with inclined antennas (negative elevation)
- ...

Geo++ GNPCVDB Antenna Database

- type means from calibrated antennas
- rigorous adjustment using complete variance−covariance matrix of individual calibrations
- about 64 different antenna types (Dec. 2001)
  - 344 individual calibrated antennas
  - 1939 individual calibrations
- public information on e.g. PCV pattern shape, etc.
- license for access and use of absolute PCV
- http://gnpcvdb.geopp.de/

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- additional publications can be found under http://www.geopp.com/publikationen/lst_gpcv.htm