Developments in Absolute Field Calibration of GPS Antennas and Absolute Site Dependent Multipath

G. Wübbena, M. Schmitz

Geo++®
Gesellschaft für satellitengestützte geodätische und navigatorische Technologien mbH
D−30827 Garbsen, Germany
www.geopp.de

G. Seeber, V. Böder, F. Menge

Institut für Erdmessung (IfE),
Universität Hannover
D−30167 Hannover, Germany
www.ife.uni−hannover.de

1. Introduction

Antenna phase variations (PCV) and multipath (MP) are site dependent errors on GPS stations, which can have a magnitude of several centimeters. Neglecting these errors can cause severe problems in ambiguity resolution, but also for estimation of distance dependent errors (e.g. troposphere) and coordinates.

Geo++® and IfE have developed an operational procedure to determine the absolute PCV of an antenna in a field calibration completely independent from any multipath effects. Subsequently, it is now possible to separate between PCV and MP error components. Currently, a procedure is under investigation, which gives absolute carrier phase multipath and can be used for absolute site multipath calibration.

Absolute PCV Field Calibration

Absolute PCV Corrections for Antennas

Absolute PCV Field Calibration:

- antenna is inclined and rotated around a nominal mean phase center
- PCVs from subsequent observations are free of MP (short−time observations)
- spherical harmonics used to model PCV

Characteristics:

- independent from geography and local site
- not affected by reference antenna
- elevation and azimuth dependent PCV
- high precision and repeatability
- duration of calibration is some hours

- pre−requisite for Absolute Multipath Calibration

2. Absolute Multipath Calibration/Basic Concepts

verification of Absolute Multipath Calibration using two robots and one antenna/site to be MP calibrated

1st: separate MP:

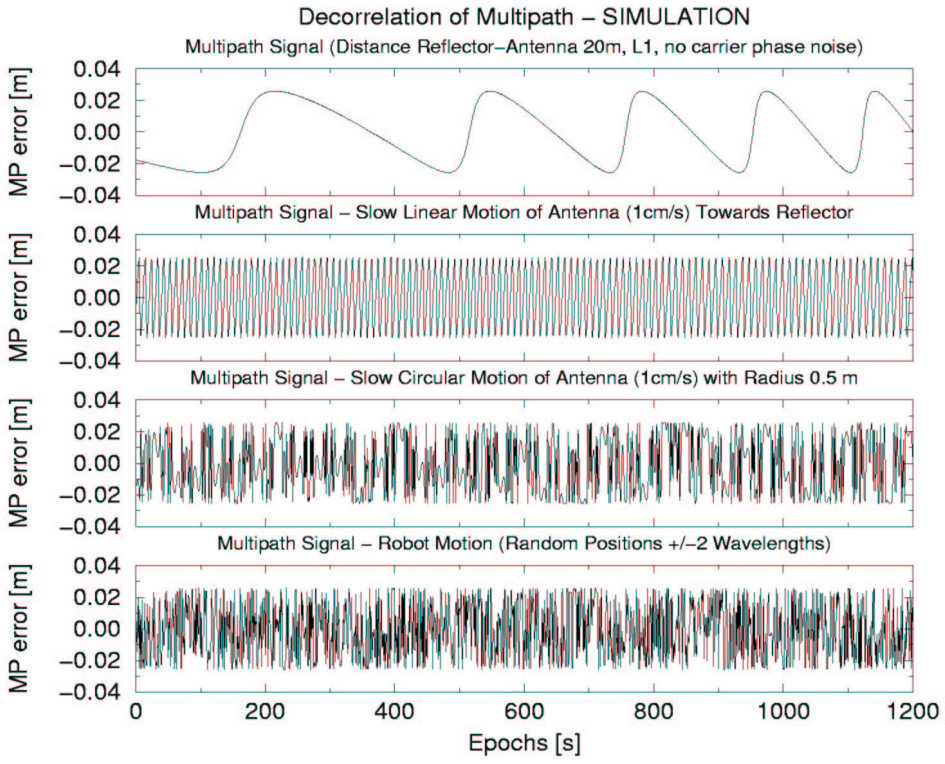
- separation of PCV and MP by applying absolute antenna PCV correction

2nd: separate Absolute MP:

- "decorrelation" of MP through fast and pseudo−random movements of antenna by a robot
- multipath is "randomized" or "noisified" through fast movements within a radius of two wavelengths

Simulation showing the decorrelation of MP through movements of an antenna:

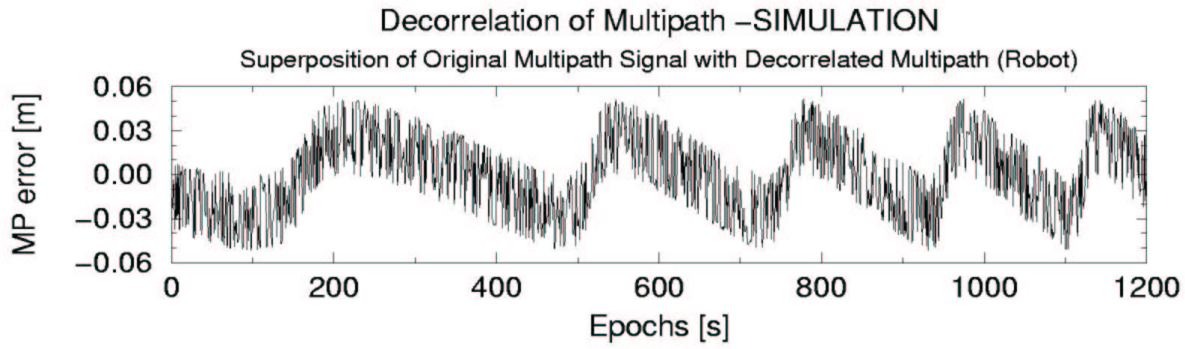
- static multipath
- multipath from small linear motion towards reflector (1 cm/s)
- multipath from slow circular motion (1 cm/s, 0.5 m radius)
- multipath from actual pseudo−random motion of robot (random positions within +/− two wavelengths)



decorrelation of MP with simulated data

Simulation of single difference between moving and static antenna:

- superposition of original static multipath and decorrelated multipath of moving robot
- low−pass filtering gives static multipath of one single station (absolute)

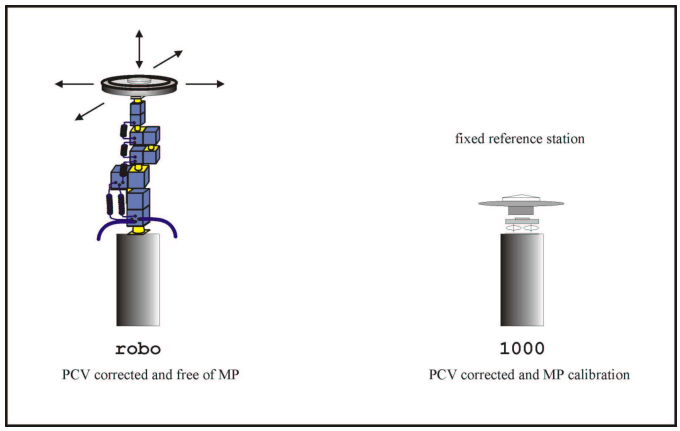


simulation of observation difference between moving and static station

3. Measurement Procedure and Multipath Adjustment/Representation

Measurement:

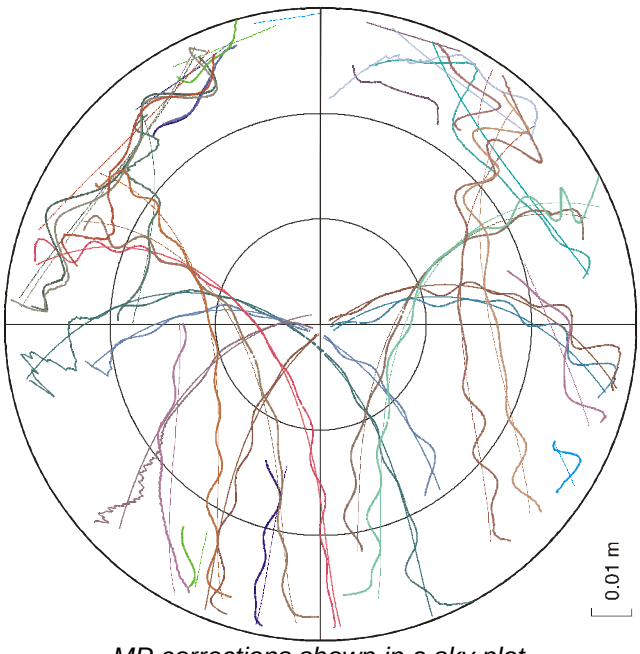
- station of interest is observed in static mode with associated antenna mount and antenna (in situ)
- robot with moving antenna is temporary reference station during calibration
- PCV are corrected for both antennas
- observations on the robot are corrected by the eccentricity vector to a nominal fixed point
- continuous pseudo−random motion within +/− two wavelength around fixed point in all directions
- over short distance single differences between antennas on the robot and on static station contain systematic MP of the static station and "noisified" MP of robot station



moving antenna on robot (decorrelated MP) and static antenna (MP calibrated)

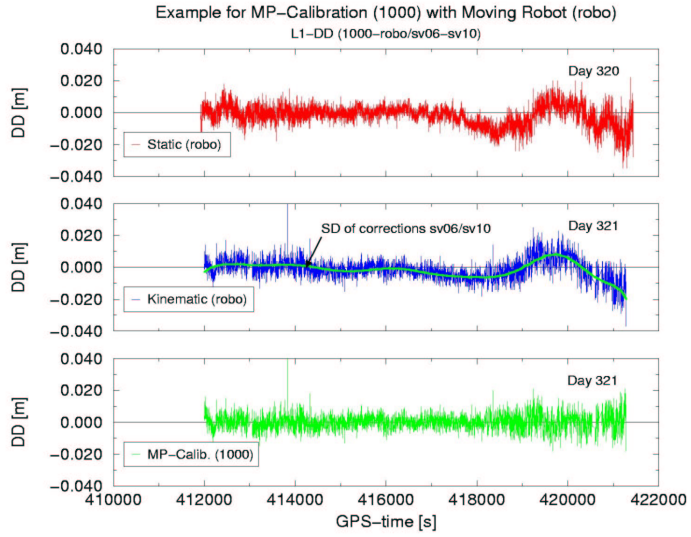
Adjustment/Representation:

- modeling of MP corrections using azimuth and elevation
- currently adjustment using spherical harmonics (limitation)
- currently storage of corrections using the Geo++ antenna file format, which utilizes the correction in the same way as PCV corrections



MP corrections shown in a sky plot

4. First Results after Applying MP Corrections



original DD of two stations, decorrelated stations and superimposed correction; corrected DD

Analysis of Double Differences (DD):

- example of absolute multipath
- original DD of two static stations
- uncorrected DD with absolute multipath signal from one station and „noisified“ MP from moving robot station; actually low−pass filtered MP correction superimposed
- corrected DD without multipath signal

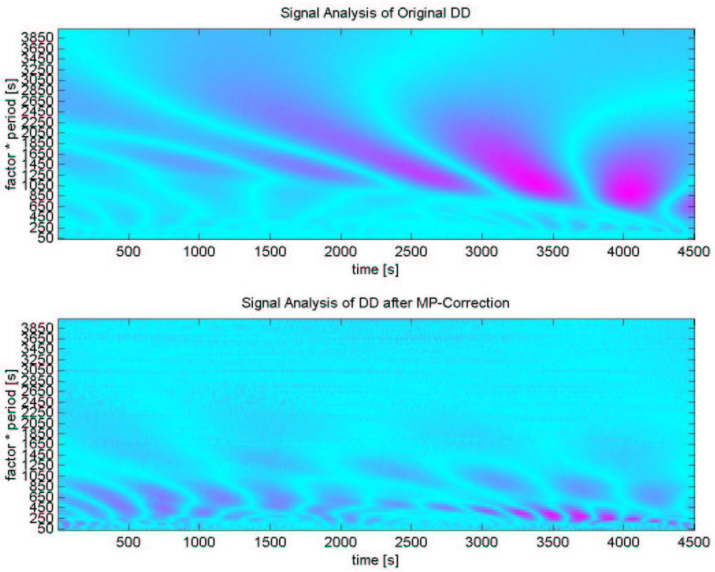
Selected DD with standard deviation:

- before and after correction
- moving average of 60 s

- reduction of noise in DD in both cases

satellites		*02−11*	*03−19*	*06−10*	*19−31*
uncorrected s [mm]	(1)	6.9	6.9	6.7	8.2
corrected s [mm]	(2)	5.2	5.6	5.2	7.2
reduction (1)/(2) [%]	(3)	24.6	18.8	22.4	12.2
moving average (60 s) of DD s [mm]	(4)	2.1	2.5	1.9	3.2
reduction (1)/(4) [%]	(5)	69.1	63.8	71.6	61.0

selected DD with standard deviation

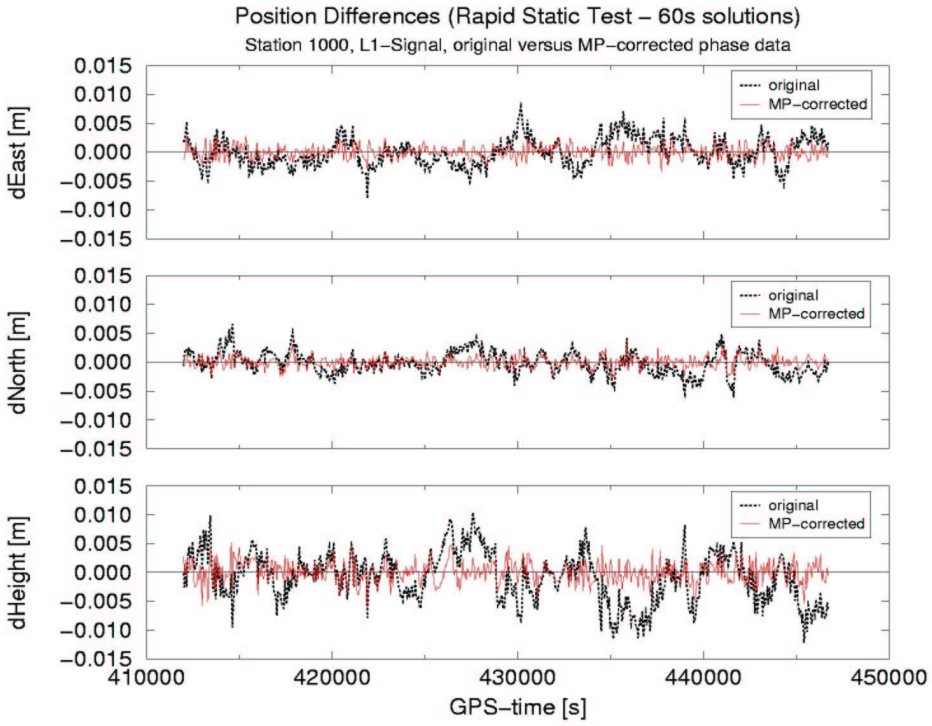


different relative color scale for graphs, which makes amplitudes not directly comparable

Wavelet Analysis of DD:

- verification of MP reduction
- low frequencies are reduced
- high frequencies remain

Analysis of Coordinates:



time series of 60 s−L1 coordinate estimations

Comparison of short−term coordinate estimation:

- reference station is antenna on robot
- MP corrected for static antenna
- 60 s blocks used for L1 coordinate estimation
- differences to known position

- reduction of noise for estimated coordinates

component		*north*	*east*	*height*
uncorrected s [mm]	(1)	2.44	1.93	4.29
corrected s [mm]	(2)	1.10	0.99	1.87
reduction (1)/(2) [%]	(3)	54.9	48.7	56.4

Outlook:

Hard− and software will be improved to enable faster and more effective measurements. Alternative models are investigated to substitute the spherical harmonics and to consider variation of multipath under changing environmental conditions (e.g. humidity on reflectors, SV orbit, snow). The absolute calibration of station dependent GPS error components will lead to improved global, regional and local reference station and RTK network services (e.g. IGS, SAPOS) as well as for precise GPS applications.

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