Introduction

Currently station-dependent errors are intensively studied, which cover antenna phase variations, near-field effects on GNSS antennas and general multipath effects. Near-field effects affect the antenna reception characteristic and are caused within the close vicinity of the antenna. The effect basically belongs to the multipath errors. The characteristic of the near-field effect, however, differs fundamentally, so that a separation from the far-field multipath effects is feasible and meaningful. Near-field effects have a long periodic behavior that have no zero mean characteristic and are therefore caused by a systematic bias especially in the height component. Opposite to this, multipath far-field effects of phase measurements have a zero mean and can be eliminated or largely reduced with sufficient long observation times.

GNSS are generally weather independent with respect to the signal propagation in space. Rain, sleet or snow in the air between antenna and satellite will normally have no significant effect. Snow or ice, however, may accumulate on a GNSS antenna and absorb some of the GPS signals reaching the GPS antenna.

Multipath effects depend on the reflective properties of the environment and thus depend on weather conditions. With changing weather conditions a change in the position domain must theoretically be expected, if the acting errors are not effectively eliminated by the observation procedure or corrected in a sufficient way.

Motivation

What antenna setup should be used for precise GNSS applications?
- Dome Margolin type GNSS chocking antennas considered best choice
- Is there any effect when it comes to rainfall?
  - drop forming at the chokering because of adhesion and cohesion
  - solid water at the bottom of the chokering
- Is there any advantage in using a radome considering rainfall?
  - dry reception element and chokering from direct rain
  - water layer (or moisture) on radome

The different reflective properties of the environment on the stations at different weather conditions will individually affect the multipath influence. Consequently, changes in the characteristics of the receiving antenna occur which are visible in the position domain, when the differences are not considered in the processing.

The weather conditions over short distances in GNSS applications are generally comparable: it rains or it rains not on both stations. The situation is different in reference station networks. Already in RTK networks with intervals of 30 km in the spatial distribution of stations, but especially at intervals of several 100 km or more, exist completely different weather conditions on the GNSS stations. The same holds for extensive projects covering large areas (simultaneous use of a large number of receivers). An implicit elimination or reduction of similar acting error influences in differential GNSS processing is no longer valid due to the missing high correlation in such cases.

Analysis of a Sprinkled Antenna Site on a Short-Baseline

Setup of Experimental Investigations

- three static stations, 1 sec-data of 22 h length, JPS LEGACY receivers, observed on seven consecutive days (setup 1-7), basically comparable sidereal times
- two identical pillars and always the same equipment setups (0007 and 0011), ASHT700936D_M antennas either both with NONE or with SNOW radome
- permanent Geo++ reference station 1000 (control), ASHT700936E SNOW antenna with a single-sided pollution of radome, strong non-symmetrical near-field multipath
- reference coordinates from dry weather conditions for all stations (red or blue)
- "rain simulation" for one single antenna site (0007) or (0011) by using a lawn sprinkler with rainfall intensity of 21 mm/h
- natural rainfall on additional days for all stations (red or blue) with rainfall intensity of 3 to 4 mm/h at the rainy days
- four absolute antenna calibrations, combining all possible combinations of no radome, SNOW radome, dry weather and "rain simulation"

Hence, there is heavy rainfall in the controlled setup and moderate rainfall during the natural setup (5 mm moderate rainfall, 50 mm violent storms in Germany).

Analysis of Controlled Rainfall GNSS Measurements

In a dual frequency GNSS processing with tropospheric scale factor changing conditions for all stations (0007 and 0011), we can observe significant effects from rainfall identified on the coordinate determination of a permanent Geo++ reference station 1000 (ASH700936D_M).

Coordinate changes larger than 0.5 mm and due to near-field are indicated in blue.

<table>
<thead>
<tr>
<th>Setup</th>
<th>Change in coordinate [mm]</th>
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<tbody>
<tr>
<td>Reference</td>
<td>E</td>
</tr>
<tr>
<td>0007 NONE</td>
<td>-0.9</td>
</tr>
<tr>
<td>0007 SNOW</td>
<td>-1.4</td>
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<td>0011 NONE</td>
<td>-1.2</td>
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<tr>
<td>0011 SNOW</td>
<td>-1.8</td>
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Analysis of Controlled Rainfall during Absolute Antenna Calibration

The results of the absolute antenna calibration confirm the investigation of the static experiments. While comparing sprinkled and dry calibrations
- small PCV changes (significant compared to repeatability of individual antenna)
- especially change in height offset for the calibration without radome
- significant PCV changes up to 10 mm and change in height offset for the calibration with SNOW radome

Coordinate changes larger than 0.5 mm and due to near-field are indicated in red.

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<td>0007 SNOW</td>
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<td>0011 NONE</td>
<td>-1.0</td>
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<tr>
<td>0011 SNOW</td>
<td>-1.4</td>
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Summary

There are significant effects from rainfall identified on the coordinate determination of a 22 hour long sprinkled chocking antenna with radome. The influence of a heavy rain on the height component for the investigated antenna model Ashtech ASHT700936D_M SNOW is 3 to 4 mm. This means that systematic effects in precise height determination are present between antennas with and without radome or between antennas with radome in case of differences in local moisture and rain fall.

The additional, not controlled setups regarding rainfall confirm the identified coordinates changes. In addition the control station with strong not symmetrical reflectors in the near-field of the antenna reveals significant coordinates changes under changing weather conditions.

The detected changes are also found in other applications with shorter observation time. In the experiment, the more far-field multipath has been eliminated through long observation times. In case of short observation times the identified effects on antenna reception characteristics will be superimposed by multipath.

Further analysis is required (rain intensity, polluted water, different antennas and radomes, etc) to complete the findings.