INTRODUCTION
Antenna changes at GNSS reference stations frequently produce discontinuities in their coordinate time series, especially in the height component. These coordinate shifts are mainly caused by changes of carrier-phase multipath effects and also, but usually to a smaller extend, by errors in the antenna phase centre corrections. A monitoring method was developed and successfully tested, which requires additional GNSS observations from a local, temporary reference station. Changes of carrier-phase measurement errors due to the antenna exchange are determined and stored in L1 and L2 phase maps. These phase maps can be used to correct for the changes (Wanninger 2009). This technique is not able to remove all multipath effects or all remaining antenna phase centre offsets but only differences between old and new antennas. It enables a smooth transition from old to new antennas and thus avoids discontinuities in the coordinate time series and alterations of the geodetic reference frame.

The results of 13 antenna changes in the network of continuously operating reference stations (CORS) of the State Office for Surveying and Geoinformation Rhineland-Palatinate were published in Wanninger et al. (2008). In the meantime the antenna changes have been completed and thus another 4 controlled antenna changes could be added to the analysis.

SUMMARY & RECOMMENDATIONS
The approach of controlled antenna changes requires additional GNSS observations from a local, temporary reference station. Any changes in carrier phase multipath effects and also errors of antenna phase centre corrections are determined and stored in L1 and L2 phase maps. These corrections can either be applied in a reprocessing to the observation data obtained before the antenna change or in real-time processing to the observations data observed after the antenna change.

17 controlled antenna changes were performed in the CORS network of Rhineland-Palatinate. At several stations apparent height shifts of more than 1 cm were observed in ionospheric-free coordinate solutions. Applying the observation corrections stored in L1 and L2 phase maps removes these discontinuities.

The described technique is recommended for all planned antenna changes at reference stations. If a GNSS reference station antenna fails unexpectedly and needs a replacement, it is recommended to exchange it with an antenna of the same kind and retain the same antenna height. In order to keep the local multipath effects unchanged, GNSS stations with a high relevance for maintaining the geodetic reference frame should be equipped with two sets of GNSS equipment. Then, if one antenna must be replaced the second system can serve as reference for a controlled antenna change as described in this paper.

Further Reading


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**VERIFICATION – TIME SERIES**

Coordinate solution (L0+T) for Daun in the network of surrounding stations (Prüm, Mayen, Bernkastel-Kues) without (left) and with (right) application of phase maps.

**APPARENT SHIFTS OF HEIGHT COORDINATES**

Examples of L1 and L2 phase maps containing azimuth-elevation dependent observation corrections.

**OBSERVATION CORRECTIONS**

L1 fixed solution – short baseline, carrier-phases, ambiguities fixed
L2 fixed solution – as above but L2, seldom used in practice
L0 fixed solution – as above but ionospheric-free linear combination
L0+T fixed solution – ionospheric-free plus estimation of tropospheric zenith delays
L0+T float solution – as above but no ambiguities fixed, standard PPP solution

**ANTENNA CHANGE METHODS**

(A) without any additional observations, most commonly used at CORS
(B) procedure recommended by the International GNSS Service (IGS) for its stations
(C) proposed method

**ANTENNA CHANGES**

- Choke-ring antenna, rotatable, type D/M with or without radome
- Large groundplane, no choke rings
- Choke-ring antenna, type D/M

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**REFERENCES**


**Lambert Wanninger**, **Christian Rost**, **Volker Frevert** and **Martin Fettke**

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**T E C H N I S C H E U N I V E R S I T Ä T D R E S D E N**