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Nuisance Effects in GNSS

L. WANNINGER[1], S. SCHÖN[2]

Introduction

Observations of the signals from satellites of one of the GNSS (the US-American GPS, the Russian GLONASS, the future European Galileo and quite a few planned regional systems) are influenced by several factors which adversely affect the accuracy and reliability of the positioning results. The most important influences are ionospheric and tropospheric propagation delays, multipath from the surroundings of the receiving antenna, and antenna phase centre variations (PCV) of both the receiving and the transmitting antennae (cf. SEEBER 2003).

Ionospheric and tropospheric propagation delays can be reduced considerably by relative GNSS using a single reference station or even better a network of reference stations surrounding the observation site. Multipath and PCV, however, are station and antenna dependent effects. They are dealt with in the measurement procedure or by calibration.

During the past four years a considerable amount of research work has been carried out in the field of nuisance effects affecting GNSS observations. A selection of key publications is given in the text. A more extensive list is included in the references.

Ionospheric propagation delay

First-order effects of the ionospheric propagation delay are successfully removed by using dual-frequency observations (ionosphere-free linear combination). Higher-order effects are typically ~0-2 cm at zenith, larger for lower elevated satellites, but at the same time smaller for relative positioning applications. Nevertheless, corrections for the higher-effects can easily be obtained and may improve positioning results (FRITSCHE et al. 2005, MAINUL HOQUE, JAKOWSKI 2007).

Relative ionospheric propagation delays influences the reliability and success rate of ambiguity resolution even in case of dual-frequency observations. The pre-processing of the observation data of networks of reference stations does not only provide improved ionospheric real-time correction models but can also produce valuable information on the size of ionospheric residuals which will affect baseline processing (CHEN et al. 2003, WANNINGER 2004).

Tropospheric propagation delay

There are several approaches to reduce the influence of tropospheric propagation delays which mainly affect the height component of the positioning results: application of standard tropospheric corrections, relative positioning, estimation of tropospheric delays as additional unknowns etc. In practice these approaches are combined to yield precise positioning results.

Research work dealt with standard tropospheric models for Galileo (PÓSFAY, 2003, KRUEGER et al. 2004), comparison of tropospheric mapping functions (VEY et al. 2006) and radiometric measurements for validation studies (HÄFELE et al. 2004). Tropospheric modelling based on GNSS observations from moving platforms has been studied by SCHÜLER (2006a).

Multipath mitigation

The ability to discriminate between direct and reflected signal in the measurement process largely depends on the signal characteristics. New signals structures were analysed regarding their multipath performance in order to select appropriate signals for the Galileo system (IRSIGLER et al. 2004, PANY et al. 2005, ÁVILA-RODRIGUEZ et al. 2006).

An alternative approach for permanent stations or identical antenna set-ups is multipath calibration. Calibration of carrier-phase multipath effects caused by signals reflected in close vicinity (… 10-20 cm) of the antenna has been performed by WÜBBENA et al. 2006b. In-situ multipath calibration of an antenna and its surroundings has been published by DILSSNER et al. (2006).

Uncorrected multipath effects may cause an apparent height shift of up to approx. 1 cm in case of an antenna exchange. This phenomena has been observed e.g. in the German SAPOS network of permanent GPS-stations (KLEIN, KLETTE 2005, WANNINGER et al. 2006). It illustrates the unresolved difficulties precise height determination still faces.

Antenna phase centre variations

Many research groups contributed to a better understanding of the antenna phase centre variations (PCV) of both the receiving antennae and the transmitting antennae on-board the GNSS satellites. Receiving antennae are calibrated either in the field using the original GNSS signals (MENGE

[1] Lambert Wanninger: TU Dresden, Geodätisches Institut, D-01062 Dresden, Germany, e-mail lambert.wanninger@tu-dresden.de

[2] Steffen Schön: Leibniz Universität Hannover, Institut für Erdmessung, Schneiderberg 50, D-30167 Hannover, Germany, e-mail schoen@ife.uni-hannover.de

2003, WÜBBENA et al. 2006a) or in an anechoic chamber using artificial signals (CAMPBELL et al. 2004, GÖRRES et al. 2006, BECKER et al. 2006).

The data processing of regional or global GNSS-networks made use of so called relative PCV corrections until recently. Although it had been shown for several years that absolute corrections would be required (MENGE 2003, VÖLKSEN 2005) it lasted until 2006 to change the processing procedures of these large-scale networks. The processing of these networks also requires PCV corrections of the GNSS satellites. These corrections are estimated from the ground observations as additional unknowns in the adjustment procedure (SCHMID et al. 2003, SCHMID et al. 2005).

References

AVILA-RODRIGUEZ J.-A., PANY T., HEIN G.: *Bounds on Signal Performance Regarding Multipath-Estimating Discriminators*, Proc.ION-GNSS 2006

BECKER M., KIRCHNER M., HÄFELE P., SÖHNE W., WEBER G.: *Near Real-Time Tropospheric Signal Delay from EPN and German Permanent GPS Sites.* Proc. EUREF Symposium 2003, Toledo

BECKER M., GÖRRES B., ZEIMETZ P., SCHÖNEMANN E.: *New results of absolute antenna calibrations and related problems.* IGS Workshop May 2006a, Darmstadt

BECKER M., SCHÖNEMANN E., ZEIMETZ P.: *Gelöste und ungelöste Probleme der Antennenkalibrierung.* DVW-Schriftenreihe, No 49 (2006b), 189-208

BISCHOFF W., HECK B., HOWIND J., TEUSCH A.: *A procedure for testing the assumption of homoscedasticity in least squares residuals: a case study of GPS carrier-phase observations.* J Geodesy, 78 (2005), 397-404

BISCHOFF W., HECK B., HOWIND J., TEUSCH A.: *A procedure for estimating the variance function of linear models: a case study of GPS carrier-phase observations.* J Geodesy, 79 (2006), 694-704

CAMPBELL J., GÖRRES B., SIEMES M., WIRSCH J., BECKER M.: *Zur Genauigkeit der GPS Antennenkalibrierung auf der Grundlage von Labormessungen und deren Vergleich mit anderen Verfahren*, Allgemeine Vermessungs-Nachrichten (AVN), 111 (2004), 2-11

CHEN X., LANDAU H. VOLLATH U.: *New Tools for Network RTK Integrity Monitoring.* Proc. of ION-GPS/GNSS 2003, 1355-1361

DILSSNER F., SEEBER G., SCHMITZ M., WÜBBENA G., TOSO G., MAEUSLI D.: *Characterisation of GOCE SSTI Antennas.* Zeitschrift für Geodäsie, Geoinformation und Landmanagement (zfv), 131 (2006), 61-71

FRITSCHE M., DIETRICH R., KNÖFEL C., RÜLKE A., VEY S., ROTHACHER M., STEIGENBERGER P.: *Impact of higher-order ionospheric terms on GPS estimates.* Geophysical Research Letters, 32 (2005), doi 10.1029/2005GL024342

GÖRRES B., CAMPBELL J., SIEMES M., BECKER M.: *New anechoic chamber results and comparison with field and robot techniques.* IGS Workshop & Symposium 2004, Berne, published on CD

GÖRRES B., CAMPBELL J., BECKER M., SIEMES M.: *Absolute calibration of GPS Antennas: Laboratory results and comparison with field and robot techniques.* GPS Solutions 10 (2006), 136-145

HÄFELE P., MARTIN L., BECKER M., BROCKMANN E., MORLAND J., NYEKI S., MÄTZLER C., KIRCHNER M.: *Impact of Radiometric Water Vapor Measurements on Troposphere and Height Estimates by GPS.* Proc. ION GNSS 2004, 2289-2302

HOWIND J.: *Analyse des stochastischen Modells von GPS-Trägerphasenbeobachtungen.* Deutsche Geodätische Kommission (DGK), C-584 (2005)

IRSIGLER M., EISSFELLER B.: *Comparison of Multipath Mitigation Techniques with Consideration of Future Signal Structures*, Proc. ION-GPS 2003

IRSIGLER M., HEIN G., EISSFELLER B.: *Multipath Performance Analysis for Future GNSS Signals*, Proc., ION NTM 2004

IRSIGLER M., HEIN G.: *Development of a Real Time Multipath Monitor Based on Multi-Correlator Observations*, Proc. ION-GNSS 2005

IRSIGLER M., ÁVILA-RODRIGUEZ J.-A., HEIN G.: *Criteria for GNSS Multipath Performance Assessment*, Proc. ION GNSS 2005

KLEIN G., KLETTE M.: *Monitoring der SAPOS-Stationen in Bayern.* Mitteilungen des DVW Bayern, 2005, 401-424

KNÖPFLER A., MAYER M., NUCKELT A., HECK B., SCHMITT G.: *Untersuchungen zum Einfluss von Antennenkalibrierwerten auf die Prozessierung regionaler GPS-Netze.* Universität Karlsruhe, Schriftenreihe des Studiengangs Geodäsie und Geoinformatik der Universität Karlsruhe, 2007/1 (2007)

KOLB P.F., CHEN X., VOLLATH U.: *A New Method to Model the Ionosphere Across Local Area Networks.* Proc. of ION-GNSS 2005, 705-711

KRUEGER E., SCHÜLER T., HEIN G., MARTELLUCCI A., BLARZINO G.: *Galileo Tropospheric Correction Approaches Developed Within GSTB-V1*, Proc. ENC-GNSS 2004

KRUEGER E., SCHÜLER T., ARBESSER-RASTBURG B.: *The Standard Tropospheric Correction Model for the European Satellite Navigation System Galileo.* Proc. General Assembly URSI 2005

LUO X., MAYER M., HECK B.: *Quantifizierung verschiedener Einflussfaktoren in GNSS-Residuen.* Zeitschrift für Geodäsie, Geoinformation und Landmanagement (zfv), 132 (2007), 97-107

MAINUL HOQUE M., JAKOWSKI N.: *Higher order ionospheric effects in precise GNSS positioning.* J Geod, 81 (2007), 259-268, doi 10.1007/s00190-006-0106-0

MENGE F.: *Zur Kalibrierung der Phasenzentrumsvariationen von GPS-Antennen für die hochpräzise Positionsbestimmung.* Wissenschaftliche Arbeiten Fachrichtung Vermessungswesen an der Universität Hannover, Nr. 247, 2003

PANY T.: *Tropospheric GPS Slant Delays at Very Low Elevations, Proc.* Int. Workshop GPS Meteorology, Tsukuba (2003)

PANY T., FÖRSTER F., EISSFELLER B.: *Real-Time Processing and Multipath Mitigation of High-Bandwidth L1/L2 GPS Signals with a PC-Based Software Receiver*, Proc. ION-GNSS 2004

PANY T., IRSIGLER M., EISSFELLER B.: *S-Curve Shaping: A New Method for Optimum Discriminator Based Code Multipath Mitigation*, Proc ION-GNSS 2005

PANY T., IRSIGLER M., EISSFELLER B.: *Optimum Coherent Discriminator Based Code Multipath Mitigation by S-Curve Shaping for BOC(n,*n) and BPSK Signals, Proc. ENC-GNSS 2005

PÓSFAY A., KRUEGER E., SCHÜLER T., HEIN G.: *Tropospheric Delay Modelling for the European Spase Agency's Galileo Testbed: Methods of Improvement and First Results*, Proc. ION NTM 2003, 817-825

PÓSFAY A.: *Tropospheric Zenith Wet and Hydrostatic Delay Models for the ESA Galileo Testbed: Models Based on*

Meteorological Measurements and a Blind Model, Proc. ION-GPS/GNSS 2003

SCHMID R., ROTHACHER M.: *Estimation of elevation-dependent satellite antenna phase center variations of GPS satellites.* J Geod 77 (2003), 440-446, doi 10.1007/s00190-003-0339-0

SCHMID R., MADER G., HERRING T.: *From relative to absolute antenna phase center corrections.* IGS Workshop & Symposium 2004, Berne, 209-219

SCHMID R., ROTHACHER M., THALLER D., STEIGENBERGER P.: *Absolute phase center corrections of satellite and receiver antennas: Impact on global GPS solutions and estimation of azimuthal phase center variations of the satellite antenna* . GPS Solutions 9 (2005), 283-293, doi 10.1007/s10291-005-0134-x

SCHMID R., STEIGENBERGER P., GENDT G., GE M., ROTHACHER M.: *Generation of a consistent absolute phase center correction model for GPS receiver and satellite antennas.* J Geod (2007), doi 10.1007/s00190-007-0148-y

SCHÖN S.: *Affine distortion of small GPS networks with large height differences.* GPS Solutions, 11 (2007), 107–117, doi 10.1007/s10291-006-0042-8

SCHÖN S., DILSSNER F.: *Challenges for GNSS-based high precision positioning – some geodetic aspects.* Proceedings of the 4th Workshop on Positioning, Navigation and Communication 2007 (WPNC07), 229-237

SCHÖN S., KUTTERER H.: *Uncertainty in GPS Networks due to Remaining Systematic Errors: The Interval Approach.* J Geod 80(3) (2006), 150-162, doi 10.1007/s00190-006-0042-z

SCHÜLER T.: *GNSS Meteorology on Moving Platforms*, Inside GNSS, 1-4 (2006a), 56-60

SCHÜLER T.: *Impact of systematic errors on precise long-baseline kinematic GPS positioning*, GPS Solutions, 10 (2006b), 108-125, doi 10.1007/s10291-005-0012-6

SEEBER G.: *Satellite Geodesy*, 2nd ed., W. deGruyter, Berlin, 2003

VEY S., DIETRICH R., FRITSCHE M., RÜLKE A., ROTHACHER M., STEIGENBERGER P.: *Influence of mapping function parameters on global GPS network analyses: Comparisons between NMF and IMF.* Geophysical Research Letters, 33 (2006), doi 10.1029/2005GL024361

VOLLATH U., BROCKMANN E., CHEN X.: *Troposphere: Signal or Noise?* Proc. ION-GPS/GNSS 2003, 1709-1717

VÖLKSEN C.: *The Importance of Correct Antenna Calibration Models for the EUREF Permanent Network.* Proc. EUREF Symposium 2005, Vienna

WANNINGER L.: *Ionospheric Disturbance Indices for RTK and Network RTK Positioning.* Proc. ION GNSS 2004, 2849-2854

WANNINGER L., ROST CH., HARTLIEB G., KÖHR M.: *Zur Problematik des Antennenwechsels auf GNSS-Referenzstationen.* Zeitschrift für Geodäsie, Geoinformation und Landmanagement (zfv), 131 (2006), 171-175

WÜBBENA G., SCHMITZ M., BOETTCHER G., SCHUMANN C.: *Absolute GNSS Antenna Calibration with a Robot: Repeatability of Phase Variations, Calibration of GLONASS and Determination of Carrier-to-Noise Pattern.* Proc. IGS Workshop 2006a, Darmstadt

WÜBBENA G., SCHMITZ M., BOETTCHER G.: *Near-field Effects on GNSS Sites: Analysis using Absolute Robot Calibrations and Procedures to Determine Corrections.* Proc. IGS Workshop 2006b, Darmstadt

ZEIMETZ P., KUHLMANN H.: *Systematic effects in absolute chamber calibration of GPS antennas.* Geomatica, 60 (2006), 267-275