The ITRF/Galileo Interface

C. Boucher

The paper investigates the various aspects of the relations between ITRF and the Galileo system: Specific issues include:

- The adoption of ITRS as spatial reference system for Galileo, through the Galileo TRF realization (GTRF)
- The use of Galileo as additional system for the future determinations of ITRF
- The role of existing organizations in the implementation of this interface, in particular IGS and IERS
- The liability requirements for ITRF as part of the Galileo quality control

It also presents for discussion, short term proposals of actions, in particular to be undertaken in the IGS Working group on GNSS.

Time and Frequency Transfer Using GNSS

P. Defraigne, C. Bruyninx, A. Moudrak, F. Roosbeek

Since several years, GPS is used at the Royal Observatory of Belgium (ROB) for time and frequency transfer applications. Software for code and/or carrier-phase data analysis has been developed and allowed to detect the sensitivities and limitations of the methods. We have also extended the analysis to GLONASS and demonstrated that the satellite-dependent hardware delays are the main factors degrading the accuracy of the time transfer links.

Presently, we perform all-in-view time transfer and contribute to the TAI by applying our in-house developed RINEX-CGGTTS conversion software on the code data form our Ashtech Z-XII3T GPS receiver. We are also routinely using the Bernese to compute the time links between BRUS and all the EPN stations equipped with an Ashtech Z-XII3T receiver. In order to anticipate the renewal of the time transfer equipment, we started to test different geodetic GPS receivers (the PolaRx2, developed by Septentrio (Belgium), and the LegacyE from Topcon) to investigate their suitability for time transfer applications. In the light of these results, the perspectives and improvements we expect for time and frequency transfer with the upcoming GALILEO and modernized GPS signals and their combination will be presented. In particular, we assess - with the help of simulated GPS and Galileo observations - the satellite visibility and the accuracy of the Common View time transfer for selected links, and discuss possibilities of employing guaranteed Galileo services for time and frequency transfer. These results were obtained in cooperation with German Aerospace Center (DLR) which is involved into the work on Galileo design and has developed a GNSS simulation software.

GPS/GLONASS Antennas and Ground Planes: Size and Weight Reduction Perspectives

D. Tatarnikov, V. Filippov, I. Soutiaguine, A. Astahov, A. Stepanenko

Antenna ground plane (GP) plays the major role in reduction of multipath coming from underneath the antenna. User equipment size and weight reduction continues to be important challenge of GNSS development while antenna GP is still the biggest and most of times the heaviest part of the system.

Different types of GP are considered: flat (plane), impedance (Choke Rings), resistive, vertical structures. Theoretical treatment, computational results and basic limitations for broadband GPS/GLONASS/GALILEO operation are provided. Results of size reduction (up to the order of several centimeter) multi-system antenna developments while keeping high level of multipath protection are discussed.

Field tests with small GP antennas show perspectives of the approach. Analysis shows that “superderictivity” phenomena might become the biggest concern for further broadband GPS/GLONASS and possible GALILEO small size multipath-protected antennas.

The IGLOS Pilot Project – Transitioning an Experiment into an Operational Service

J. Slater, R. Weber, E. Fragner

With a constellation of 11 satellites as of December 2003, GLONASS provides a significant complement to the GPS constellation, providing opportunities for enhanced navigation and positioning accuracy, atmospheric modeling, time transfer, and earth orientation estimation. Since 1998, when the IGEX-98 campaign was conducted, there has been a continuously operating global network of GLONASS tracking stations. Subsequently, the IGS made some modifications to its operations to integrate GLONASS stations and GLONASS orbit computation into the IGS standard operations.

Four organizations routinely compute precise GLONASS orbits, and combined orbits are generated as well. Time standardization, reference frames, RINEX file formats, and station logs are some of the areas that have been addressed to handle GLONASS and GPS in the same operations. This has been a very successful endeavor, although some problems still exist including delays in production of precise orbits, the uneven global distribution of stations, and uncertainty regarding the long-term viability of GLONASS.

GNSS Analysis at CODE

S. Schaer, U. Hugentobler, R. Dach, M. Meindl, H. Bock, C. Urschl, G. Beutler

Since the beginning of May 2003, the CODE analysis center has been computing a rapid orbit product for both the GPS and the GLONASS satellite constellation. In the meantime, this is also the case with respect to our final product (since 8 June 2003) as well as our ultra-rapid orbit product (officially since 30 July 2003). GPS and GLONASS orbits are generated at the same time in a rigorous GNSS analysis. We will give an overview of our GNSS analysis activities and discuss issues we consider relevant for a combined analysis of two or more navigation satellite systems.

C/A Code Biases in High-end Receivers

A. Simsky, J.-M. Sleewaegen

Systematic biases of C/A code pseudoranges (average differences C/A- P1) include satellite-side and receiver-side components. Satellite-dependent biases, similar in nature to well known time group delays, are monitored and tabulated by a few IGS data processing groups including CODE, the IGS data processing center of the University of Bern. Additional receiver-side bias is normally a hardware-related PRN-independent constant.

We found, however that some high-end receivers produce anomalous meter-level PRN-dependent biases when multipath-mitigating code tracking is used. Anomalies have been detected by computing average C/A-P1 code differentials of collected GPS observation data and comparing them to standard values recommended by CODE. Anomalous biases up to 1.65m occur for PRNs 7,8,15,17,21 and 24. The analysis reported in this paper reveals the reason for this anomaly: the affected PRNs have the peculiarity that their autocorrelation peaks exhibit slight deviations from the ideal triangle. When multipath mitigation is enabled, this distortion is mistaken as multipath and induces the bias.

This anomaly can not only affect IGS processing, but all bias-sensitive applications, such as reference stations: it is shown by live examples that code-based DGPS or WAAS positioning may show meter-level deviations when multipath mitigation is active in the receiver. However, once these anomalous biases are known and understood, they can be easily compensated either in the receiver or in post-processing.

It is also shown that the accuracy of standalone positioning by GPS receivers is improved when C/A code pseudoranges are corrected for all the required biases, including normal CODE-recommended C/A-P1 delays and above-mentioned receiver-side PRN-dependent biases related to the multipath mitigation.

GLONASS Analysis for IGS

H. Habrich, P. Neumaier, K. Fischer

The Federal Agency of Cartography and Geodesy analyses combined GPS/GLONASS data of a global network of observing stations since the beginning of the IGEX experiment in 1998. Significant milestones in the geometry of the tracking network, development of GLONASS receivers, constellation of GLONASS satellites and improvements of the analysis strategy became visible during that period of 6 years. The weekly analysis products include precise GLONASS satellite orbits, station coordinates, transformation parameters between PZ-90 and ITRF and the difference of the GPS- and GLONASS system time. The system time differences could be compared to the results of other analysis centres, e.g. ESA, and to the publications of the BIPM. The precise knowledge of such numbers is a prerequisite for a complete combination of GNSS systems (GPS, GLONASS or GALILEO), e.g., if the analysis procedure solves for phase ambiguities between satellites of different systems. Recent results are not precise enough for the latter application. In our approach we solve for GLONASS satellite orbits but use orbits from IGS for the GPS satellites. We have demonstrated, that we could use the IGS rapid orbits in our analysis without significant impact on our products. This allows to submit our weekly GLONASS orbits before the generation of the IGS final orbits. We plan to continue with the analysis of GLONASS data, to expand our products by satellite clock estimates and to observe the possibility to add GALILIEO observations to the analysis.

Impact of Galileo on Geodetic Positioning Applications

H. van der Marel, S. Verhagen, P. Joosten

The impact of Galileo, the proposed European satellite navigation system, on geodetic positioning and zenith delay estimation is investigated. Galileo and the modernized GPS system will provide more and better signals on both existing and new frequencies, resulting in improved observations. In particular, the so-called ionosphere free linear combination will be improved: the new signals on L5 result in a 24% improvement in precision if used instead of L2, or 30% if all three frequencies are used, under the restrictive assumption that the carrier phase observations have the same accuracy as GPS. This means that possible improvements in tracking-performance of the new signals have not been taken into account yet, which could result in an additional improvement.

The main improvement comes from having additional satellites. When the receiver tracks both GPS and Galileo, the precision in height for, for example, a mid-latitude station is improved by about 63-75% if only the effect of additional satellites is taken into account. This is beyond what can be expected from just doubling the number of satellites. These numbers are derived for quite a conservative situation, in which the station position, satellite clock errors, independent GPS and Galileo receiver clock errors, tropospheric delays and the initial phase ambiguities for every satellite are estimated. The improved redundancy in case of a dual GNSS constellation will also make it possible to introduce additional parameters to reduce (systematic) errors, and the improved accuracy will make new applications possible. For instance, the precision of troposphere parameters is improved considerably with the use of GPS and Galileo, especially for moving receivers, thus making it possible to collect water vapor

information for meteorologists from ships and buoys on the oceans where observations of water vapor have always been sparse.

Finally, the increased number of satellites and new signals also result in an improvement in ambiguity resolution.