Exam Satellite Navigation AE4-E08
Monday January 28, 2008, 14:00-17.00, Kluyverweg 1, Room E

Question 1 - Abbreviations

Explain in 1-2 sentences the following abbreviations

a. PRN
b. PDOP
c. RTCM SC-104
d. IGS
e. WAAS
f. RINEX
g. TEC
h. RAIM
i. UERE (or UERA)
j. WGS-84

Question 2 – Anti-Spoofing

Monday January 31st, 1994, at 0:00Z, Anti-Spoofing (A-S) was enabled on GPS satellites

a. Explain what Anti-Spoofing is and how it is implemented on GPS.
b. What is the main effect of Anti-Spoofing for ordinary users of GPS?
c. Please quantify the effect of Anti-Spoofing on the positioning accuracy (using mass-market and semi-professional receivers, exclude high-end geodetic receivers).
d. Is the effect on the positioning accuracy for GPS the same for 2001, 2007 and 2012? Please explain.
e. How do semi-professional and aviation receivers mitigate the negative effects of Anti-Spoofing?
f. How do high-end dual-frequency geodetic receivers deal with Anti-Spoofing?
g. Anti-Spoofing (A-S) should not be confused with Selective-Availability (S/A). Please explain what Selective-Availability was and the effect it had on positioning.
h. Is Anti-Spoofing implemented on GLONASS? Will Anti-Spoofing be implemented on Galileo and modernized GPS?

Question 3 – Multipath

a. What is multipath, on what does it depend, and how large it can be?
b. What is the effect of multipath on the receiver positions? Which characteristic may convince us that it is indeed multipath?
c. Is there a difference between code- and carrier-phase multipath?
d. Explain how code-multipath can be monitored with dual frequency GPS receivers using geometry free linear combinations.
e. Is multipath on a certain location the same for any receiver? Please explain.
f. What can you do to prevent or reduce multipath.

Question 4 - Subsidence monitoring for an offshore platform

The company you work for got a contract to monitor the subsidence of an offshore platform 300 km from the nearest coast. The main deliverable is the coordinates of the baseline vector, between a GPS receiver on the platform and a GPS receiver on-shore, computed on a daily basis (i.e. using a 24 hour period). The required standard deviation for the coordinates is 5 mm in the horizontal and 8 mm in the vertical component. The sample rate of the receiver is 30 seconds[1].

a. You will be using the ionosphere free linear combination. Give the ionosphere free linear combination of the L1 and L2 phase observations.
b. Considering the problem at hand, which parameters do you have to estimate and how often do you have to estimate them?
c. Give the system of observation equations for a single epoch *k* using the single difference ionosphere free linear combination of phase measurements, using the parameters of question b).
d. Sketch symbolically the structure of the system of observation equations for epochs *k=0,1,..,N-1* for the ionosphere free linear combination of phase observations. You may assume that the tropospheric zenith delay T_{12} can be represented by a single parameter for the duration of 1 hour.
e. Give a formula or table for the number of observations, unknowns and redundancy (number of observations, minus number of unknowns, plus rank-defect) of the system in question d).
f. In order to compute a solution for the station coordinates we use the so-called 'double difference' method. Rewrite the system of observation equations in question c), but now using 'double' instead of 'single' differences.
g. Answer question d) and e) again in case of 'double differences'.
h. Give the co-variance matrix of the 'double difference' phase observations. You may assume that the original phase observations have equal standard deviation and are uncorrelated.
i. Is the expected value for the double difference phase ambiguity of the ionosphere free linear combination an *integer* number? Please explain.
j. Discuss methods for finding the integer values of the L1 and L2 double difference ambiguities in the present case.
k. What is the effect of the satellite orbit and clock errors on the computed position vector? What is your source of satellite orbits for the problem at hand?

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[1] The linearized observation equation for relative positioning with GPS phase measurements is

$$E\{\Delta \underline{P}_{12}^{s}\} = -\mathbf{e}_2^{s*}\Delta\mathbf{x}_{12} + c\Delta\delta t_{12} + \gamma_i I_{12}^{s} + M(e_2^{s})\Delta T_{12} + \lambda\Delta A_{12}^{s}$$

With $P_{12}^{s} = P_2^{s} - P_1^{s}$ the so-called single difference phase observation, and $\mathbf{x}_{12} = \mathbf{x}_2 - \mathbf{x}_1$ the unknown position vector, $\delta t_{12} = \delta t_2 - \delta t_1$ the unknown differential receiver clock error, I_{12}^{s} the unknown differential ionospheric delay in the direction of the satellite with γ_i a signal dependent factor (-1.0 for L1-phase and -1.6469 for L2-phase), T_{12} the unknown differential troposphere delay in the zenith direction and $M(e_2^{s})$ a known elevation dependent mapping function, $A_{12}^{s} = A_2^{s} - A_1^{s}$ the unknown single difference phase ambiguity. All quantities refer to the time of observation t_k, with *k=0,1,…,N-1* and *N* equal to the number of observation epochs, and $t_k - t_{k-1}$ a constant time interval of 30 seconds in the receiver time system. At every epoch both receivers observe simultaneously the same m_k satellites

Question 5 – Ambiguity resolution

a. Why are double difference phase ambiguities integers? Please explain.
b. What is ambiguity resolution? Why is ambiguity resolution so important?
c. Please explain the LAMBDA method for ambiguity resolution.
d. What is the main difference of the LAMBDA method versus most other methods of ambiguity resolution (i.e. what is the key element of LAMBDA)?
e. If you may choose between using a single or dual frequency receiver for fast & precise relative GNSS positioning over short baselines, which receiver would you choose and why?

End of exam