# 15 GLOBAL NAVIGATION SATELLITE SYSTEMS—KINEMATIC SURVEYS

Asterisks (*) indicate problems that have partial answers given in Appendix G.

**15.1*** What are the two types of kinematic survey?

<u>**Post-processed kinematic (PPK) and Real-time kinematic (RTK)**</u>

**15.2** What advantages does a PPK survey have over an RTK survey?

From Section 15.4, paragraph 4: "Data latency is not a problem in PPK surveys since the data is post-processed. Other advantages of PPK surveys are (1) that precise ephemeris can be combined with the observational data to remove errors in the broadcast ephemeris and (2) the base station coordinates can be resolved after the fieldwork is complete." Plus also the reduce amount of equipment needed in the field since a radio is not required.

**15.3** What advantages does an RTK survey have over a PPK survey?

From Section 15.4, last paragraph: "The advantages of RTK surveys over PPK surveys are the reduction in office time, and the ability to verify observations in the field. When using RTK, the data can also be downloaded immediately into a GIS (see Chapter 28) or an existing surveying project. This increases the overall productivity of the survey."

**15.4** Define data latency.

From Section 15.1, last paragraph: "Since observations from the base receiver must be transmitted, received, and processed at the rover, any motion by the rover during this time will cause errors in its computed position. The errors caused by this time difference, known as *data latency*, tend to be small, and are generally adequate for the lower-accuracy surveys previously cited."

**15.5** What items should be included in planning for a kinematic survey?

From Section 15.2: There are several including high solar activity, multipathing, canopy restrictions, and high PDOP.

**15.6*** How much error in horizontal position occurs if the antenna is mounted on a 2.000 m pole that is 10 min out of level?

<u>**5.8 mm**</u>; (10'*π/180)2.000

**15.7** Do Problem 15.6, but this time assume the level is 5 min out of level.

<u>**2.9 mm**</u>; (5'*π/180)2.000

**15.8** How much error in vertical position occurs with the situation described in Problem 15.6?

**0.008 mm** $2 - 2\cos 10'$

**15.9** How much error in the vertical position occurs if the GNSS antenna is mounted on a 2.25 m pole that is 5 min out of level?

0.002 mm; $2.25 - 2.25\cos 5'$

**15.10*** Why should the radio antenna at the base station be mounted as high as possible?

From Section 15.4, paragraph 6: "Mounting the radio antenna high can increase the range of the base radio."

**15.11** Why should periods of high solar activity be avoided in a GNSS survey?

From Section 15.2: "During periods of high solar activity, the errors due to ionospheric refraction can be large. Since the ionosphere will remain charged for extensive periods of time, there will be some days when a satellite survey simply should not be attempted. In periods of very high solar activity, radio signals from the satellites may be interrupted. Additionally during these periods, radio communication between the base and roving receivers in an RTK survey may be compromised."

**15.12** How can the solution of the integer ambiguities be checked in a GNSS survey?

From Section 15.3, last paragraph: "Prudent surveyors will check the OTF solution for the ambiguities. To do this, a control baseline is established immediately after the ambiguities have been resolved. This baseline is established using the initial ambiguity solution. The receiver is then "dumped," which is a process of losing lock on all the satellites by inverting the receiver. The OTF method is then allowed to resolve the ambiguities for each satellite again. Once this is accomplished, the baseline established previously is checked. The two solutions should match within the accuracy of the survey, which should be less than 3 cm typically. If the baseline does not check, a second dump of the receiver can be performed to check either of the previous solutions. If none of these attempts produce a suitable check on the baseline, other conditions such as canopy restrictions, multipathing, high solar activity, and so on should be investigated before the survey is attempted. Once satisfied with the solution, the surveyor can use this baseline to re-establish the ambiguities as necessary. This process ensures the same solution for the ambiguities during the entire project."

**15.13** Which of the following features should be surveyed using the stop-and-go method.

**(a)** Centerline of a highway curve

**(b)** Light pole

**(c)** Stop sign

**(d)** Grade points in a topographic survey

**b and c**

**15.14** What are autonomous coordinates?

From Section 15.6, paragraph 2: "When no reference station is available for the base, it can be started using *autonomous* coordinates. These coordinates are simply the code-based solution for the position of the receiver, which is only good to several feet in accuracy."

**15.15** Why can a PPK survey start with an autonomous position for the base receiver?

From Section 15.6, paragraph 2: "Once in the office, the data from the base can be used to correctly determine its position at the time of the survey using static surveying post-processing. The NGS provides the *Online Positioning User Service* (OPUS)[4] for this use. Additionally, OPUS will provide the base station coordinates in the local NAD83 coordinate system. To achieve the maximum accuracy from the standard OPUS service, the base station must continuously collect data for a minimum of two hours. During this time, the surveyor can proceed with the PPK survey. If dual-frequency or GNSS receivers are used in the survey, the NGS provides a rapid static OPUS (RS-OPUS) service that can determine the position of a receiver with as little as 15 min of data. During post-processing, the autonomous coordinates for the base can be replaced by the OPUS or post-processed coordinates. The software then moves the rover coordinates to agree with the base station's new coordinates." Or simply because it is post-processed.

**15.16** What is VRS?

From Section 15.7, paragraph 2: "Using the known positions of the base receivers and their observational data, the central processor models errors in the satellite ephemerides, range errors caused by ionospheric and tropospheric refraction, and the geometric integrity of the network stations. *Virtual reference station* (VRS) and *spatial correction parameter* (*FKP*) are examples of two methods used in modeling these errors."

**15.17** List the advantages of using a real-time network.

1. Mathematically: "Using the known positions of the base receivers and their observational data, the central processor models errors in the satellite ephemerides, range errors caused by ionospheric and tropospheric refraction, and the geometric integrity of the network stations."
2. Also it removes the need for a base station and thus doubles the productivity of a firm with the same hardware or reduces the cost of equipment used in a GNSS survey.

**15.18*** What frequencies found in RTK radios require licensure?

**<u>450 - 470 MHz.</u>** From Section 15.3: "In North America and in other areas of the world, frequencies in the range of 150–174 MHz in the VHF radio spectrum, and from 450–470 MHz in the UHF radio spectrum can be used for RTK transmissions." and from Section 15.6, paragraph 2: "The Federal Communications Commission (FCC) does not require a license for radios that broadcast in the range from 157 – 174 MHz. However, all other frequencies given in Section 15.4 do require a FCC license"

**15.19** What is site calibration of a survey?

From Section 15.9: It is the process of transforming satellite-derived coordinates into some local reference frame.

**15.20** Why is it important to site calibration a survey?

From Section 15.9, paragraph 2: "The current rendition of the WGS 84 reference frame (used in broadcast ephemeris) closely approximates ITRF 2000. The difference in the origins of the NAD 83 and ITRF 2000 data is about 2.2 m. Thus when performing a stakeout survey, the coordinates for stations produced by receivers can differ significantly from coordinates of the same stations in the regional reference frame that were used to perform the engineering design."

**15.21** What are the preferred locations of local control for a localization of the GNSS survey?

From Section 15.9: “As shown in Figure 15.5, it is important when performing these transformations to have control on the exterior and surrounding the project area to avoid extrapolation errors. It is also important to include control coordinates on key features.”

**15.22** What three surveying elements are needed in machine guidance and control?

From Section 15.10:

1. Digital terrain model
2. Sufficient horizontal and vertical control to support machine control in all areas of project and during all phases of the project.
3. Site calibration parameters for localization of project.

**15.23** A 3-mi stretch of road has numerous canopy restrictions. What is the minimum number control stations required to support machine control in this part of the road if a robotic total station is used?

**16 control stations**. From Section 15.9: Robotic total stations have a working radius of 1000 ft. Thus 3(5280)/1000 = 15.8 stations

**15.24** How are robotic total station used in machine guidance and control?

From Section 15.10: To fill in areas with canopy restrictions and to provide finish grades.

**15.25** How are finished grades determined in machine guidance and control?

From Section 15.10: By either robotic total stations, or laser levels.

**15.26** What factors may determine the best location for a base station in a RTK survey?

From Section 15.3, paragraph 7: "Several factors may determine the “best” location for the base station in a RTK survey. Since the range of the radio can be increased with increasing height of the radio antenna, it is advantageous to locate the base station on a local high point. Additionally, since the base station in an RTK survey requires the most equipment, it is also preferable to place the base station in an easily accessible location."

**15.27** What are the differences between the true kinematic and pseudokinematic methods?

From Section 15. : “”

**15.28*** How many total pseudoranges observations will be observed using a 1-sec epoch rate for a total of 3 min with 12 usable satellites?

**<u>2160</u>**; 60 obs/min(3 min)12 sats

**15.29** How many pseudoranges observations will be observed using a 5-sec epoch rate for a total of 3 min with 16 usable satellites?

**<u>576</u>**; 12 obs/min(3 min)16 sats

**15.30** The baseline vector between the base and roving receivers is 1000 m long. What is the estimated uncertainty in the length of the baseline vectors if a RTK-GPS survey is performed?

1 - 2 cm + 2 ppm yields a range of **<u>1 cm to 2 cm</u>**

**15.31** Why should periods of PDOP spikes be avoided in a kinematic survey?

Section 15.1, last paragraph: "Other factors that limit the positioning accuracy of kinematic surveys are its susceptibility to errors such as DOP spikes, atmospheric and ionospheric refraction, multipathing, and obstructions to satellite signals. For example if a kinematic survey collected data during the time of the PDOP spikes shown in Figure 14.3, the resulting positions during this time would be of considerably lower quality than those collected at other times of the day."

**15.32** Why should fixed height tripods or rods be used in a kinematic survey?

From Section 15.4, first paragraph: "In any case, the advantages of fixed-height rods and tripods in all GNSS surveys are that they minimize measurement errors in the height of the receiver and help avoid operator caused obstructions."