1. **In vertical datum, geoid is considered as reference. What is "geoid"? (5 pt.)**

Answer: **Geoid** is the surface of fixed equigravitational potential value which coincides on average with mean sea level

2. **What is "Orthometric height"? (5 pt.)**

Answer: **Orthometric height** is the height of a position normal to the geoid. It is often also considered to be the height above mean sea level

3. **a) How many zones are there in Universal Transverse Mercator (UTM)? What is the longitude of each zone?**
   b) What is the civil UTM coordinate notation? (5 pt.)

Answer:

a) 60 zones, 6°
b) Zone number North/South – Easting – Northing

4. **What is multipath? What causes it? (5 pt.)**

Answer: Multipath propagation means that a signal reaches the receiving antenna on various paths with different lengths and different degree of attenuation. Multipath results from a combination of reflection, diffraction and scattering.

5. **What is the difference between analog and digital modulation? (5 pt.)**

Answer: In analog modulation the added information is analog and in digital modulation the added information is digital.

6. **Name four indoor navigation methods? (5 pt.)**
   Answer:
   WLAN Positioning, RFID Positioning, Infrared-based Systems and Ultrasound-based Systems

7. **a) What is the wave length of a sinusoidal electromagnetic signal with the form $g(t) = 2\sin\left(12.57 \times 10^6 t + \frac{\pi}{8}\right)$? (5 pt.)**

   b) After how many periods the signal travels 18.6 km? (5 pt.)

   c) If an acoustic signal with the same frequency is traveling in air what will be the wavelength? (consider the propagation speed of sound in air to be: $340\ {}^{m}/_{s}$) (5 pt.)

   Answer:

   a) $\lambda = \frac{v}{f} = \frac{3\times10^8}{\frac{12.57\times10^6}{2\pi}} = 150\ m$

b) $n = \frac{d}{\lambda} = \frac{18600}{150} = 124$

c) $\lambda = \frac{v}{f} = \frac{340}{\frac{12.57\times10^6}{2\pi}} = 170\ \mu m$

8. If the bandwidth of a baseband signal is 20.46 MHz, what should be the minimum sampling frequency of the signal to be able to reconstruct it? (5 pt.)

Answer: $f_s \geq 2B = 40.92\ MHz$

9. A 100 W transmitter is transmitting a 200 MHz radio signals with an omnidirectional antenna. What is the received power at 2 km? (5 pt.)

Answer:

$\lambda = \frac{v}{f} = \frac{3\times10^8}{200\times10^6} = 1.5\ m$

$P_r = \frac{\lambda^2 P_t}{(4\pi d)^2} = \frac{1.5^2\times100}{(4\pi\times2\times10^3)^2} = 356\ nW = 3.56\times10^{-7}\ W$

10. To determine the position of the target in two dimensional Cartesian coordinate system, we measure the distances of the target from 4 reference points. The reference points are located at: $\boldsymbol{P_1(0,\ 0)}$, $\boldsymbol{P_2(6,\ 0)}$, $\boldsymbol{P_3(7,\ 4)}$ and $\boldsymbol{P_4(-2,\ 6)}$. The measured distances are not accurate (pseudorange): $\boldsymbol{d_1 = 4.3}$, $\boldsymbol{d_2 = 4.4}$, $\boldsymbol{d_3 = 4.5}$ and $\boldsymbol{d_4 = 6.0}$.

a) What estimation technique can be used to estimate the position? (2 pt.)

b) Write the proper range measurement equations. (6 pt.)

c) Create a set of linear equations from the range measurement equations (hint: subtract the first equation from the other equations and write in the matrix form: $\boldsymbol{A\cdot P_e = b}$) (6 pt.)

d) Find the coordinates of the target. (6 pt.)

Answer:

a) Least squares estimation

b)

$$4.3^2 = x^2 + y^2$$
$$4.4^2 = (x-6)^2 + y^2$$
$$4.5^2 = (x-7)^2 + (y-4)^2$$
$$6.0^2 = (x+2)^2 + (y-6)^2$$

c)

$$-6x = -17.565$$
$$-7x - 4y = -31.62$$
$$2x - 6y = -11.245$$
$$A = \begin{bmatrix} -6 & 0 \\ -7 & -4 \\ 2 & -6 \end{bmatrix},\ b = \begin{bmatrix} -17.565 \\ -31.62 \\ -11.245 \end{bmatrix}$$

d) $P_e = \begin{bmatrix} x_e \\ y_e \end{bmatrix} = (A^T \cdot A)^{-1} \cdot A^T \cdot b = \begin{bmatrix} 2.9 \\ 2.83 \end{bmatrix}$

11. The target starts moving from the origin at time $t_0 = 0$ along the x axis with the constant acceleration, a_x. The accelerometer output shows $a_x = 20\ {}^{m}/_{s^2}$.

a) What is the x coordinate of the target at $t_1 = 10s$ based on the accelerometer output? (3 pt.)

b) If accelerometer has a bias value of $a_{bias} = 2\ {}^{m}/_{s^2}$ what is the coordinate error at $t_1 = 10s$? (5 pt.)

c) If in addition to bias, the accelerometer has a drift of $a_{drift} = 0.012\ {}^{m}/_{s^3}$. What is the error due to drift at $t_1 = 10s$? (7 pt.)

Answer:

a) $x = \frac{1}{2} a_x \Delta t^2 + v_0 \Delta t + x_0 = \frac{1}{2} 20 \times 100 + 0 + 0 = 1000\ m$

b) $a_{true} = a_x - a_{bias} = 18\ {}^{m}/_{s^2}$

$x = \frac{1}{2} a_{true} \Delta t^2 + v_0 \Delta t + x_0 = \frac{1}{2} 18 \times 100 + 0 + 0 = 900\ m$

$\Delta x = 1000 - 900 = 100\ m$

c) $a(t) = a_{true} + a_{drift} t$

$x = \iint_{t_0}^{t_1} a(t)\ dt^2 = \frac{1}{6} a_{drift} t^3 + \frac{1}{2} a_{true} t^2 + v_0 t + x_0 \Big]_{t_0}^{t_1} = 902\ m$

$\Delta x = 902 - 900 = 2\ m$

12. For our project we selected the u-Blox MAX-7 series GPS receiver. From its datasheet find the following parameters: (10 pt.)

a. Power consumption @ 3.0 V

b. Operation temperature range

c. GPS Positioning accuracy

d. Time to first fix (TTFF) cold start

e. GPS tracking sensitivity

f. GLONASS cold start sensitivity

g. Interface protocols

h. Package dimensions

i. Which model is suitable for 2.0 V power supply?

j. Which model uses Temperature controlled crystal oscillator (TCXO)?

Answer:

a) 51 mW

b) -40°C to +85°C

c) 2.5 m CEP

d) GPS: 29 s, GLONASS: 30 s

e) -162 dBm

f) -140 dBm
g) NMEA, UBX Binary, RTCM
h) 9.7x10.1x205 mm
i) MAX-7C
j) MAX-7Q