

Navigation: GPS

SYST 460/560

Background

- GPS is an artificial “star” used for navigation
- Reliable and accurate means for position fixing
 - All times
 - All points on earth
- Reliable – 99.999% of the time

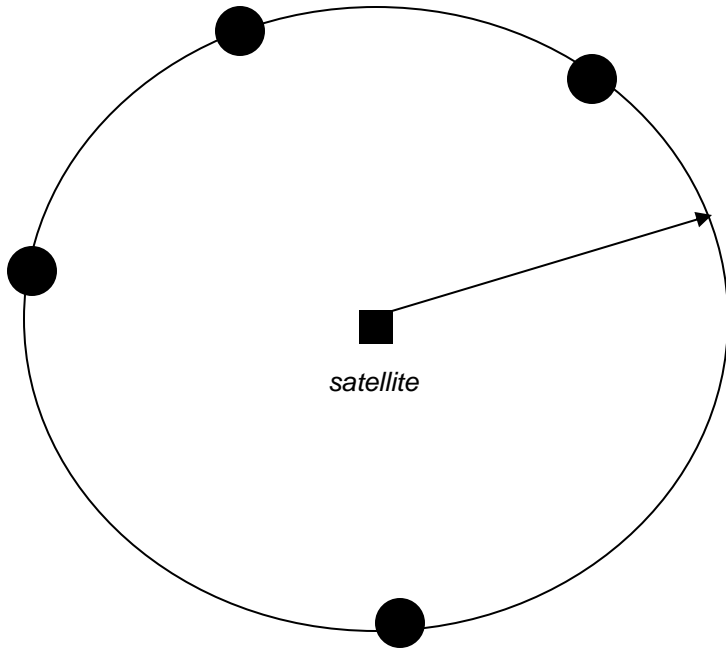
Concept

- Satellites
 - In an orbit with radius of approx 25km
 - Not geostationary
 - Carries an atomic clock and broadcasts time
- Receivers
 - has a clock

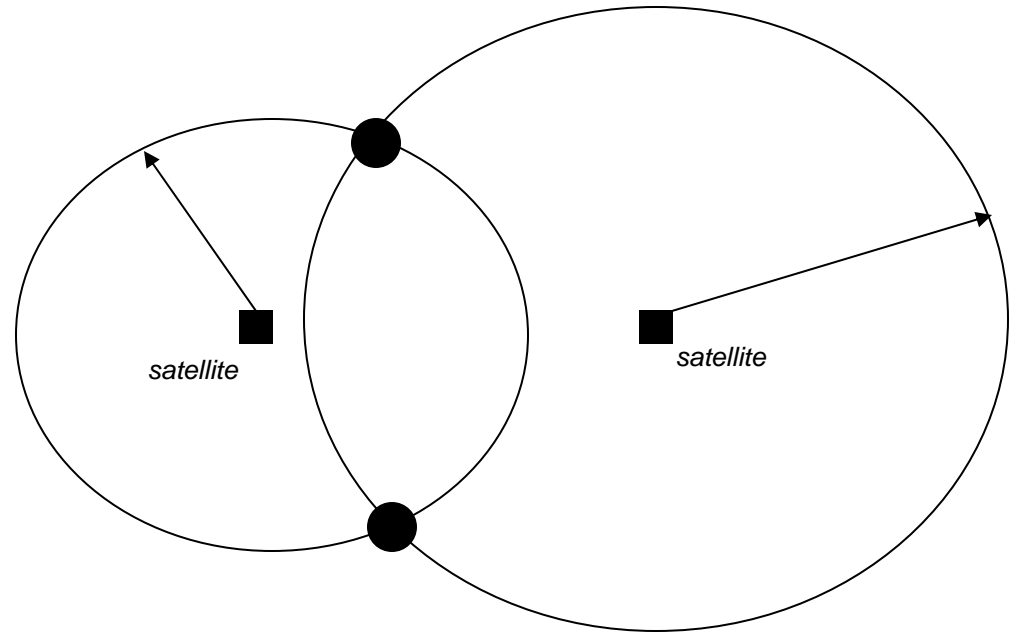
Computing Position

- Receiver
 - Compares broadcast time with it's own time
 - Computes how long took signal to travel from satellite
 - Distance = Velocity X Time Difference
 - Velocity = speed of light
 - Distance known as psuedo-range (due to errors)

Computing Position



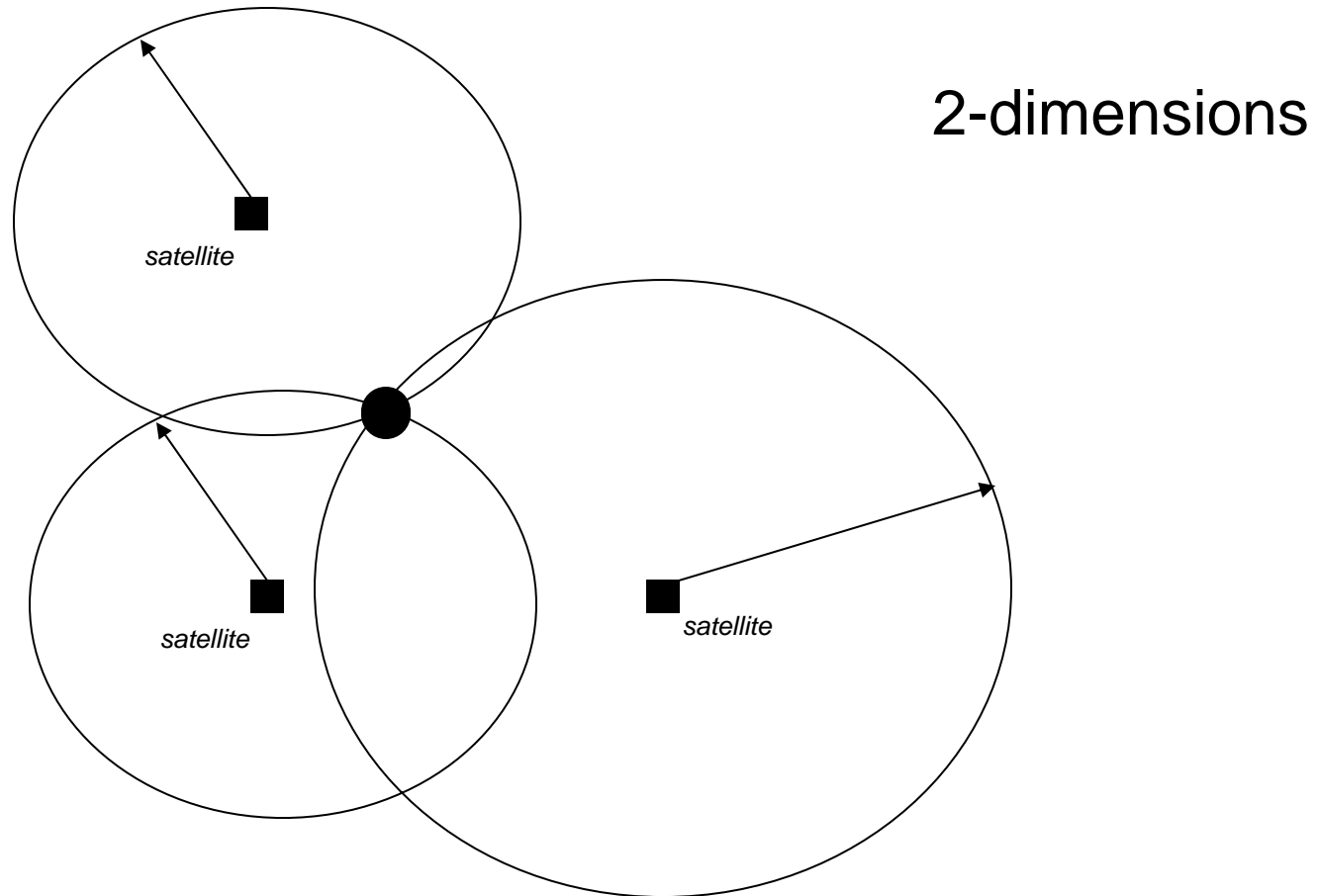
Reading of distance from 1
satellite \rightarrow n possible position



Reading of distance from 2
satellites \rightarrow 2 possible positions

2-dimensions

Computing Position



Reading from 3 satellites \rightarrow 1 possible positions

Computing Position

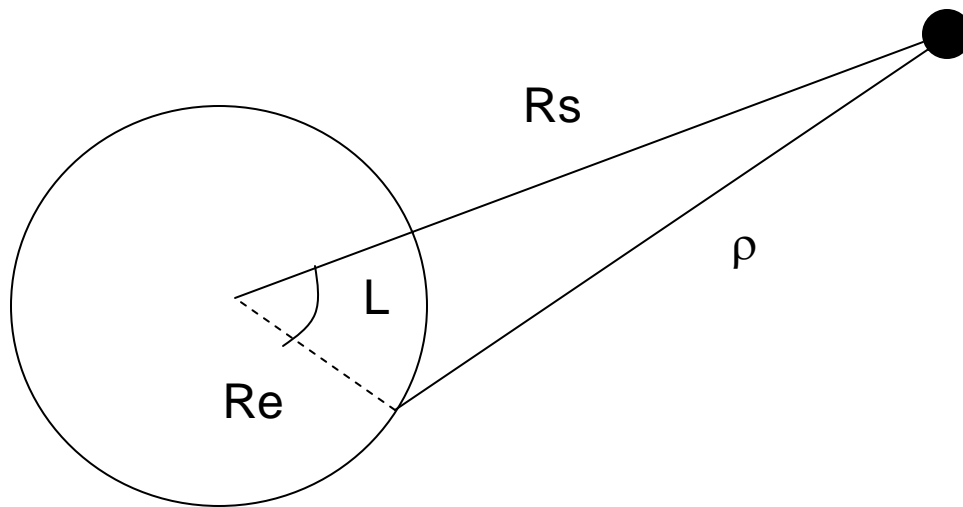
- 4 psuedo-ranges provides 3-dimensional position centered at Earth's atmosphere
 - (x, y, z)

How long does it take a GPS Signal to Reach the Receiver

- Altitude of satellite = H
- ρ = psuedo-range
- R_e = Radius of earth = 3438 nm
- R_s = radius of orbit of satellite = 13,700 nm
- Law of Cosines

$$\rho^2 = R_e^2 + R_s^2 - 2R_eR_s\cos L$$

How long does it take a GPS Signal to Reach the Receiver



How long does it take a GPS Signal to Reach the Receiver

Co-Altitude Psuedo-range

0°	10249
10°	10318
30°	10847
50°	11775
70°	12922

- When psuedo-range = 12,000 nm = 21,900km
 - Speed of light = 299,800 km/second
 - Time for satellite signal to reach receiver =
 $21,900\text{km}/299,800 \text{ km/second} = 0.073 \text{ seconds}$

Sources of Error

- Error: Satellite atomic clock failure
- Guard: Receiver Autonomous Integrity Monitoring (RAIM)
 - More than 5 satellites
 - Compute position from sets of 4 satellites
 - ABCD, ABCE, ABDE, ACDE, BCDE
 - Position computation from all 5 within some tolerance – position is OK

Source of Error

- Error: Ionospheric
 - Layer of charged particles in atmosphere (ionosphere)
 - Particles change speed of signal (affects pseudo-range)
- Solution: Ground controllers measure ionospheric delay and include as part of the time message sent by satellites

Sources of Error

- Error: Intentional Interference
 - Military jamming
- Solution: Read Notice to Airmen (NOTAM)