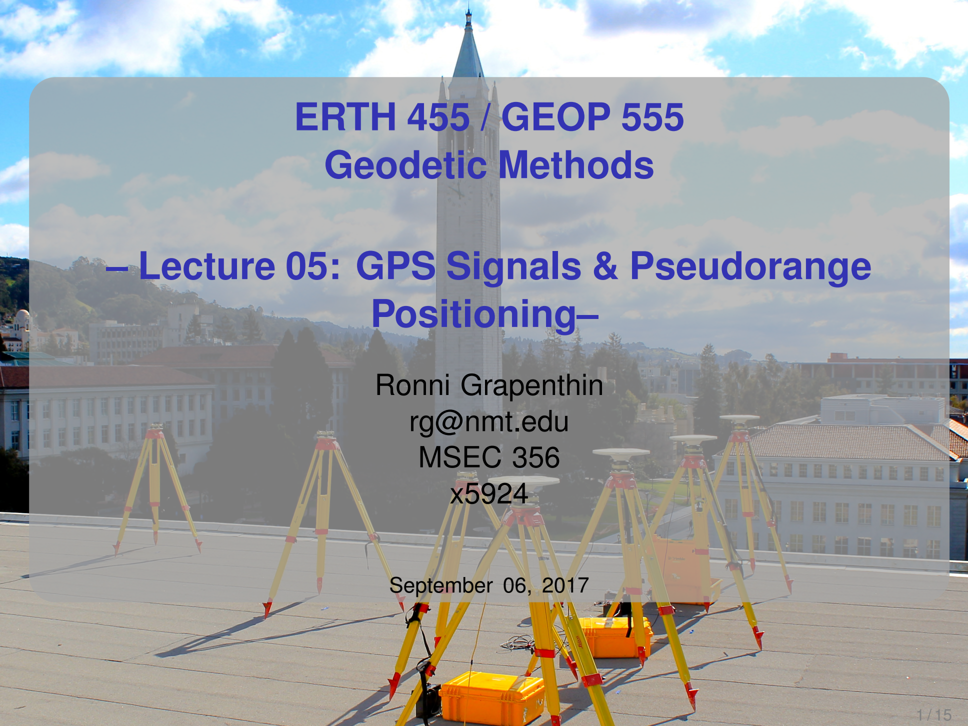


ERTH 455 / GEOP 555
Geodetic Methods

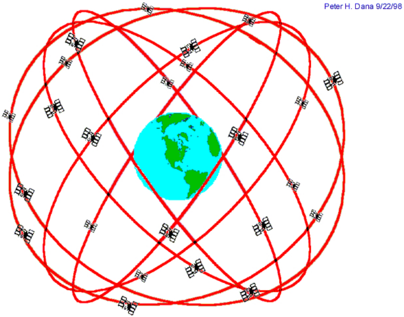
– Lecture 05: GPS Signals & Pseudorange Positioning–

Ronni Grapenthin
rg@nmt.edu
MSEC 356
x5924

September 06, 2017

System Architecture: Space Segment

- Baseline constellation 24 satellites, 6 orbital planes, 55° inclined
- Period $\approx$ 12 hours, stationary ground tracks
- Currently 32 satellites operational
- Constellation Status / Outages: `http://www.navcen.uscg.gov/`
- E.g. `http://navcen.uscg.gov/?Do=constellationStatus`



GPS Nominal Constellation
24 Satellites in 6 Orbital Planes
4 Satellites in each Plane
20,200 km Altitudes, 55 Degree Inclination

Signals

- continuous transmission on 2 L-band radio frequencies: Link 1 (L1), Link 2 (L2) (for legacy GPS)
- L1 (f_{L1} = 1575.42 MHz): 1 signal for civil users, 1 for military
- L2 (f_{L2} =1227.60 MHz): 1 signal military
- L3 (1381.05 MHz): classified – associated w/ Nuclear Detonation Detection System
- L4 (1379.913 MHz): classified – no transmission, maybe additional ionosphere correction in future
- L5 (1176.45 MHz): (future) Safety of Life; civilian use

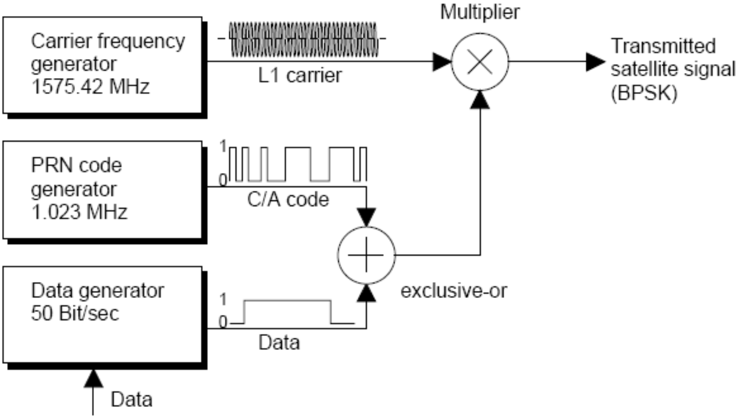
Signals: Structure

Detailed in Interface Specification (IS-GPS-200D):

`http://www.navcen.uscg.gov/pdf/IS-GPS-200D.pdf`

- *Carrier:* sinusoidal signal with $f_{L1,2}$, derives from 10.23 MHz atomic clock
- *Ranging Code:* pseudo-random noise (PRN) sequences unique to satellite
  - orthogonal to each other: no interference on same frequency
  - uncorrelated with itself, autocorrelation is zero unless perfect overlap
  - civilian: “Coarse/aquisition codes” (C/A codes) on L1
  - **C/A:** 1023 bits (chips), repeated each millisecond
  - each C/A chip $\approx 1\mu$s, chip width $\approx$300 m
  - military use, hence “Precision codes” (P(Y) is encrypted P-code) on L1,L2
  - **P-codes** extremely long PRN, part of master code
  - repeats after 1 week: C/A code for easier locking
- *Navigation Data:* satellite health, position, velocity, clock bias parameters, almanac (information/status on several/all satellites)

Signals: Structure



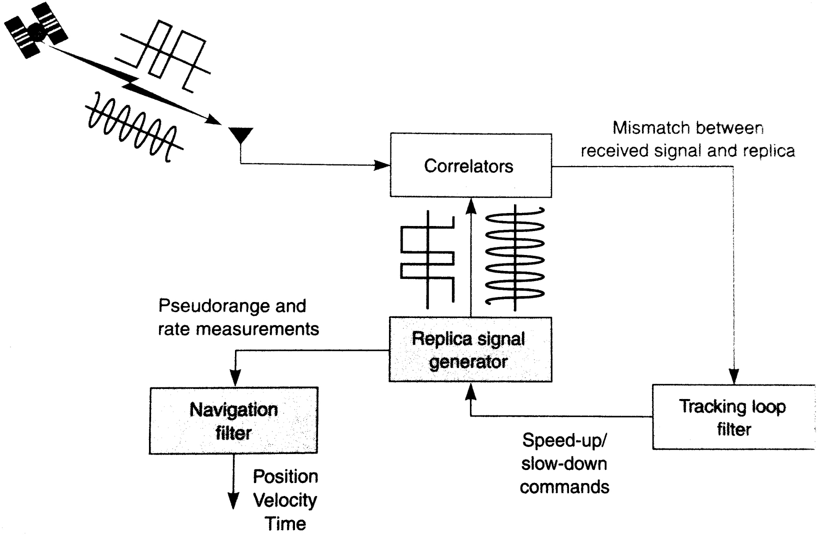
from: `http://www.ni.com/tutorial/7139/en/`

Receivers: Signal Acquisition and Tracking

Receiver tasks:

- capture radio signals transmitted by satellites
- separate individual satellites
- measure signal transit time (crude)
- decode navigation message: gives satellite position, velocity, clock

Receivers



Mismatch between received signal and replica

Correlators

Pseudorange and rate measurements

Replica signal generator

Navigation filter

Tracking loop filter

Speed-up/ slow-down commands

Position
Velocity
Time

Misra and Enge, 2011, GPS–Signals, Measurements, and Performance

Signal – Modernization: L2C

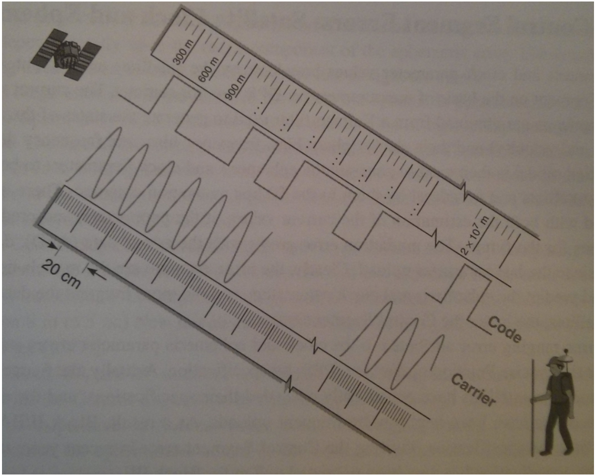
- added to L2
- initially replication of C/A intended
- 2 PRN codes (CM, CL; moderate and long codes)
- navigation data carried by CM
- CL is data-free: better correlation, multi-path mitigation, interference resistance

Signals – Modernization: L5

- for safety-of-life applications
- 2 signal components in phase quadrature, one w/ nav data (I5), one without (Q5)
- longer, faster than C/A, L2C: better correlation properties
- transmitted at higher power
- L1L5 combination will give better precision, robustness than current L1L2

Measurement Models

- Code Phase Measurement (today)
- Carrier Phase Measurement



Misra and Enge, 2011, GPS–Signals, Measurements, and Performance

Position Estimation w/ Pseudoranges

- Positioning by (pseudo-)ranging
- range: geometric distance between satellite and receiver
- pseudorange: includes distance, clock error effects, path delays

Position Estimation w/ Pseudoranges

- Positioning by (pseudo-)ranging
- range: geometric distance between satellite and receiver
- pseudorange: includes distance, clock error effects, path delays

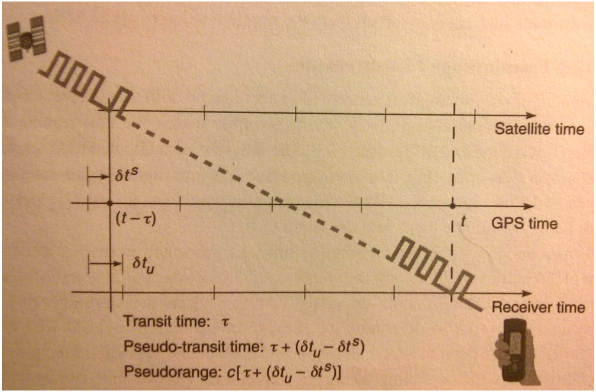
$$\rho = r + c(\delta t_u - \delta t^s) + I + T + \epsilon$$

ρ - pseudorange
r - true range to satellite
c - speed of light
δt_u - receiver clock bias
δt^s - satellite clock bias
I, T - Ionospheric and tropospheric delays
ϵ - unmodeled effects, measurement errors, etc.

Position Estimation w/ Pseudoranges

- Want range, get pseudorange: noisy and biased
- quality of range estimate depends on ability to deal with biases, errors
- more on those later!

Pseudorange Measurement Model

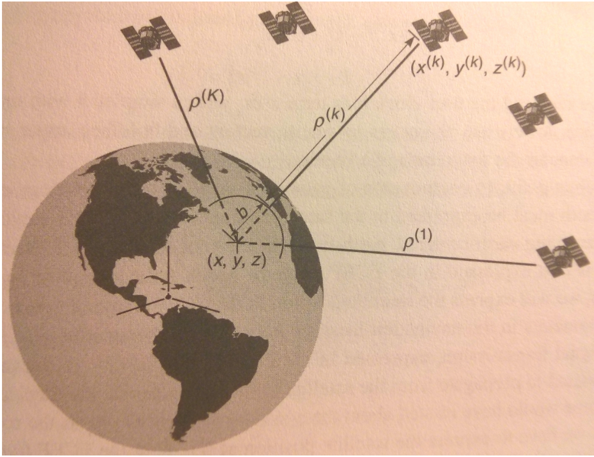


Misra and Enge, 2011, GPS–Signals, Measurements, and Performance

- need to deal with receiver t_u, satellite clocks t_s, and GPS time (t)
- τ - travel time of specific code
- PRN correlation shift gives estimate of τ
- receiver: $t_u = t + \delta t_u \ldots |\delta t_u| \leq 1\,\text{ms}$ ($\approx 300\,\text{km}$)
- satellite: $t^s = t + \delta t^s \ldots |\delta t^s|$ small (atomic clock)

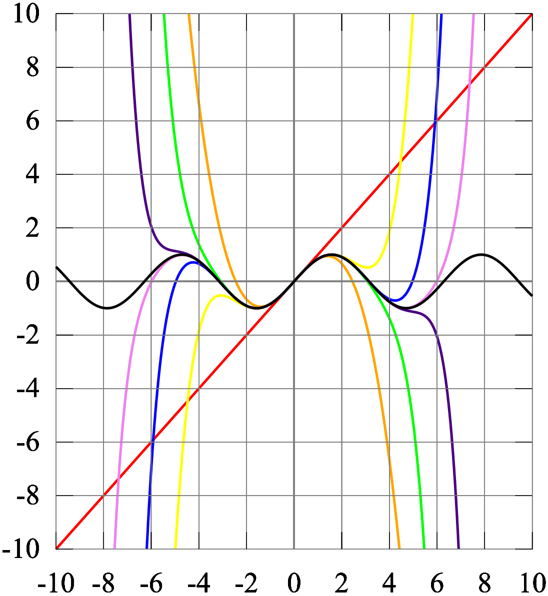
Pseudorange Measurement Model

Derivation in notes . . .



Misra and Enge, 2011, GPS–Signals, Measurements, and Performance

Taylor expansion



sin(x) and its Taylor approximations; *source wikipedia*