GPS Recvier

1.5 GHz
19cm

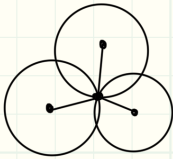AMP Mixing A/D | IF Supply | PLL / DLL | decoder | SV PNT | Nav. Filter → PVT

— Multiplying 2 1.5 GHz $\sim \ast \sqcap\sqcup$
  - 1 is 3.0 GHz
  - 2 is 0 Hz (DC)
  ↳ goal is to lower frequency (use LPF on 1)

— PLL: Phase lock loop
— DLL: delay lock loop

$$\sin(\omega_n t) \ast \sin(\omega_{mix} t)$$
$$= \frac{1}{2}\sin((\omega_n + \omega_{mix})t) + \frac{1}{2}((\omega_n - \omega_{mix})t)$$

LPF

11/13/23
Radio Navigation

Trilateration

Triangulation

30°   15°

— AoA

— ToA $(c = 3 \times 10^8 \frac{m}{s})$
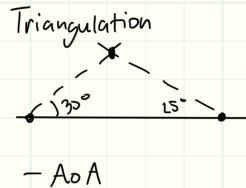 $\Delta t \ast c = range$
  ↳ clocks must be synced
  * if accurate to 1ms, range error = 3×10^5
  * $\Delta t = 1ns \rightarrow 0.3m$

~ Need 4 satellites (5 to start)
— with 3 satellites (don't calc. altitude)

$$r^2 = (X_u - X_{sv})^2 + (y_u - y_{sv})^2$$

Positioning Types
— Triangulation (AoA)
— Trilateration (ToA)
— Hyperbolic (TDoA)
— Doppler (FDoA)
  ↳ (change in freq. due to ΔV)

GPS
1) Active or (Passive)
  ↳ no reciever (user) limit
2) Doppler, hyperbolic, (trilateration)
  ↳ passive ranging system
3) Pulsed or Continuous Wave (CW) signal
  ↳ less energy   ↳ continuous tracking
  ↳ more powerful signal
  ↳ each sv dump at different times

— GPS became first widespread use of CDMA
  (code divide multiple access)

4) Frequency?
  ↳ L-Band (1-2 GHz)
    — $f\uparrow \Rightarrow \downarrow$ ionosphere error, $\uparrow$ space loss
      ~ multi-frequency (reduce ionosphere error)

5) Altitude
  — LEO (<2000 km)   only visible for 10-20 min (100-200 sv)   stronger signal
  — MEO (5000-20000 km)
  — GEO (36000 km)   see more earth
    → "fixed" in sky

  ↳ selected 24+ MEO satellites
    ↳ provides worldwide coverage
    ↳ 12 hr orbits (-4 min)

Tech Challenges
1) development of stable clocks
2) stable and predictable orbits
3) Spread spectrum signals
4) integrated circuits

Overview
• SPS — standard positioning system (civilian)
• PPS — precise positioning system (DoD)

• System Architecture
1) Space Segment
2) Control Segment → 7 monitoring stations (sv clocks & orbits)
3) User Segment
    — Hawaii
    — Colorado Springs (Master)
Master { — Cape Canaveral
    — Ascension Island
    — Diego Garcia
    — Kwajalein
    — National Geospatial

GPS uses its own Coordinate & Time System
↳ developed new "global" coordinate system
  - WGS 84
↳ own time → GPS time
  - offset from UTC

Satellites (SVs)
- broadcast RF signal with coded ranging signal and data
- Data → satellite clock corrections
  satellite position (as $f(t)$)
  satellite and system health

Statistics

$$\bar{X} = E\{x\}$$
  ↳ mean is the expectation of some variable