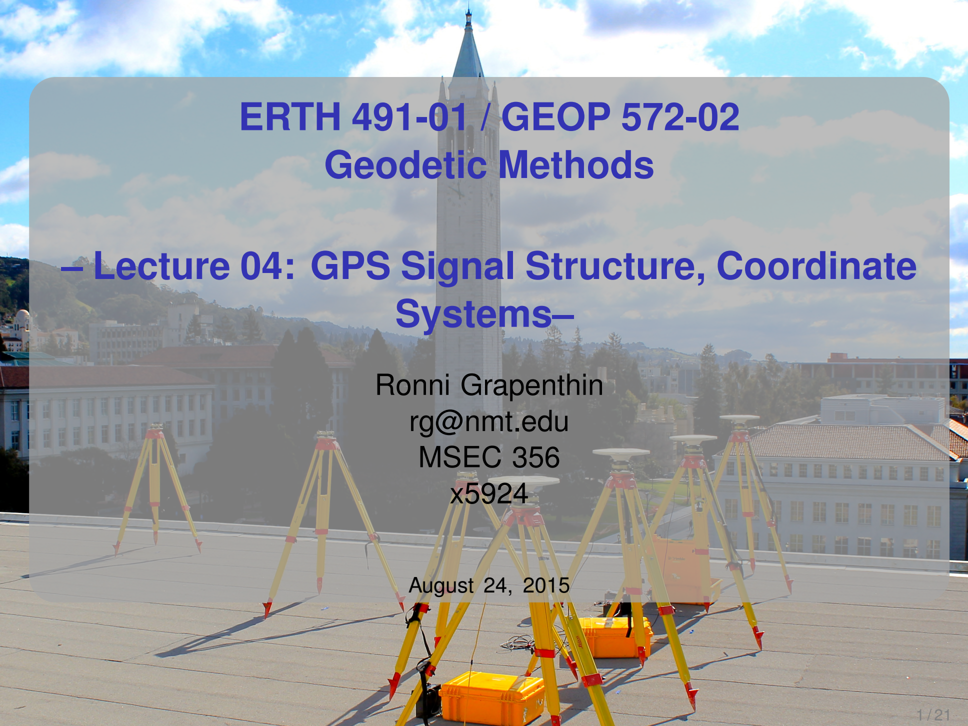


ERTH 491-01 / GEOP 572-02
Geodetic Methods

– Lecture 04: GPS Signal Structure, Coordinate Systems–

Ronni Grapenthin
rg@nmt.edu
MSEC 356
x5924

August 24, 2015

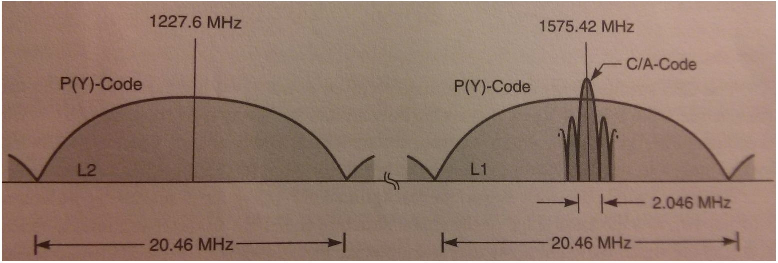
Signals: 2 signals one carrier????

Signals: 2 signals one carrier????

- C/A carrier generated by clock (in phase)
- P(Y) shift C/A carrier in phase by 90° (quadrature components)
- produces ‘orthogonal’ signals; receiver can separate these

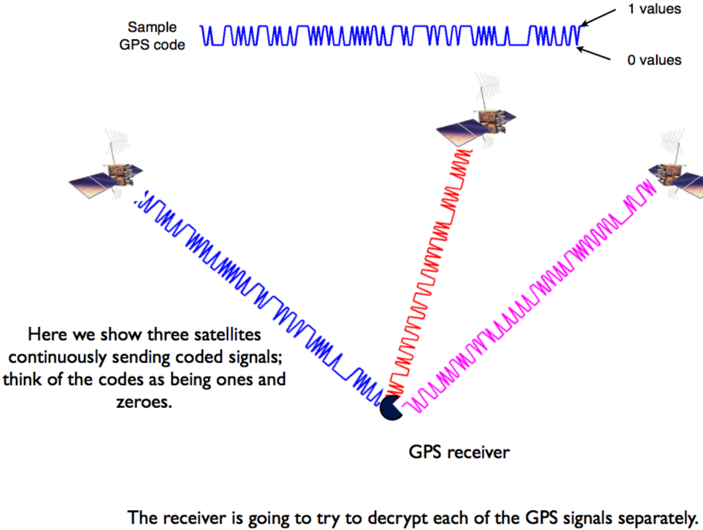
Signals: Magic – spread spectrum

- modulation spreads signal energy over wide band
- 2 MHz for C/A, 20 MHz for P(Y)
- power unchanged, spectral density below background RF
- if code known, receiver can 'de-spread' (cross-correlation)



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

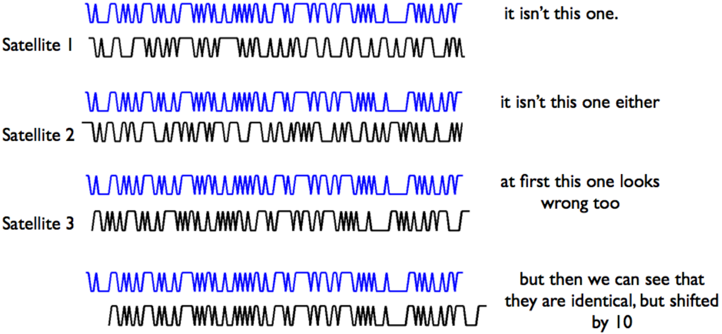
Signals: Magic – spread spectrum



from: *GPS Spotlight*, `http://xenon.colorado.edu/spotlight`

Signals: Magic – spread sectrum

Here the receiver compares the blue coded signal to all the known codes.



It is this time shift the receiver uses to figure out how far away the satellite 3 is from the receiver - and how big the radius is for that sphere.

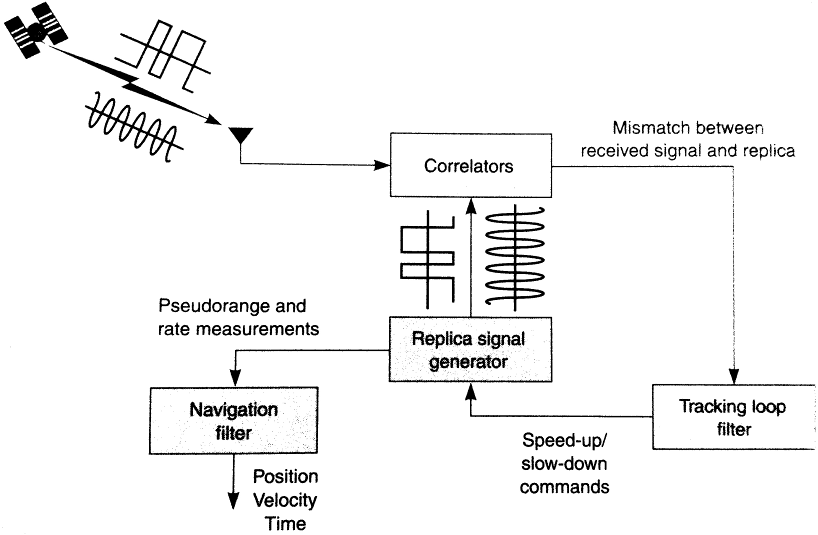
from: *GPS Spotlight*, `http://xenon.colorado.edu/spotlight`

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



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)
- multiplexed chip by chip: CL-CM-CL-CM-. . . ; half C/A chipping rate for each
- 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

Signals – Modernization: L1C

- pilot and data component like L2C
- some of same advantages
- enables Galileo L1 interoperability
- transmitted at higher power

Coordinate Systems 1/11

Now that you know what signals are coming from the satellites you can convert those into a position, right?

Coordinate Systems 1/11

Now that you know what signals are coming from the satellites you can convert those into a position, right?

But what's your coordinate system?

Coordinate Systems 2/11

- need 2 coordinate systems
- one in which user position is fixed – rotates with Earth
- another spaced-fixed/inertial to express satellite motion – Earth rotates
- transformations (rotations) link the coordinate systems

Coordinate Systems 3/11 – CTRS

Coordinate system in which user position is fixed:

- rotates with the Earth: conventional terrestrial reference system (CTRS)
- use cartesian coordinate system
- define origin at center of mass
- z-axis is axis of rotation
- x-axis goes through intersection of equatorial plane and reference median
- y-axis makes it right-handed

Coordinate Systems 3/11 – CTRS

Coordinate system in which user position is fixed:

- rotates with the Earth: conventional terrestrial reference system (CTRS)
- use cartesian coordinate system
- define origin at center of mass
- z-axis is axis of rotation
- x-axis goes through intersection of equatorial plane and reference median
- y-axis makes it right-handed

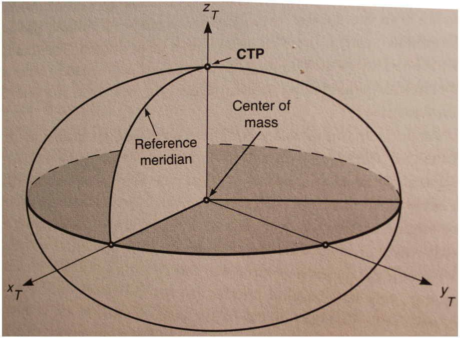
Easy, right?

Coordinate Systems 3/11 – CTRS

Coordinate system in which user position is fixed:

- rotates with the Earth: conventional terrestrial reference system (CTRS)
- use cartesian coordinate system
- define origin at center of mass
- z-axis is axis of rotation
- x-axis goes through intersection of equatorial plane and reference median
- y-axis makes it right-handed

Easy, right?



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

Coordinate Systems 4/11 – CTRS

What are potential issues?

Coordinate Systems 4/11 – CTRS

What are potential issues?

- *polar motion*: pole of rotation moves, roughly circular, several meters/year
- use conventional terrestrial pole (CTP) – average of polar motion between 1900-1905
- *center of mass*: where is it?

Coordinate Systems 4/11 – CTRS

What are potential issues?

- *polar motion*: pole of rotation moves, roughly circular, several meters/year
- use conventional terrestrial pole (CTP) – average of polar motion between 1900-1905
- *center of mass*: where is it?

Actually,

- CTRS is *realized* through a set of points
- need consistent coordinates from measurements
- measurements have errors
- *realize* coordinate frame that fits data best (e.g,least-squares)
- World Geodetic System 1984 (WGS84) one such realization
- GPS provides position in WGS84 ECEF coordinate frame (unless otherwise)

Coordinate Systems 5/11 – CIRS

Coordinate system which is space-fixed

- Earth within: conventional inertial reference system (CIRS)
- express forces, acceleration, velocity, position vectors
- inertial reference system defined as stationary / constant velocity in space
- define origin at center of mass
- z-axis is axis of rotation
- x-axis in equatorial plane pointing to vernal equinox (intersection of equatorial plane w/ plane of rotation around sun)
- y-axis makes it right-handed

Coordinate Systems 5/11 – CIRS

Coordinate system which is space-fixed

- Earth within: conventional inertial reference system (CIRS)
- express forces, acceleration, velocity, position vectors
- inertial reference system defined as stationary / constant velocity in space
- define origin at center of mass
- z-axis is axis of rotation
- x-axis in equatorial plane pointing to vernal equinox (intersection of equatorial plane w/ plane of rotation around sun)
- y-axis makes it right-handed

Again . . . easy, right?

Coordinate Systems 6/11 – CIRS

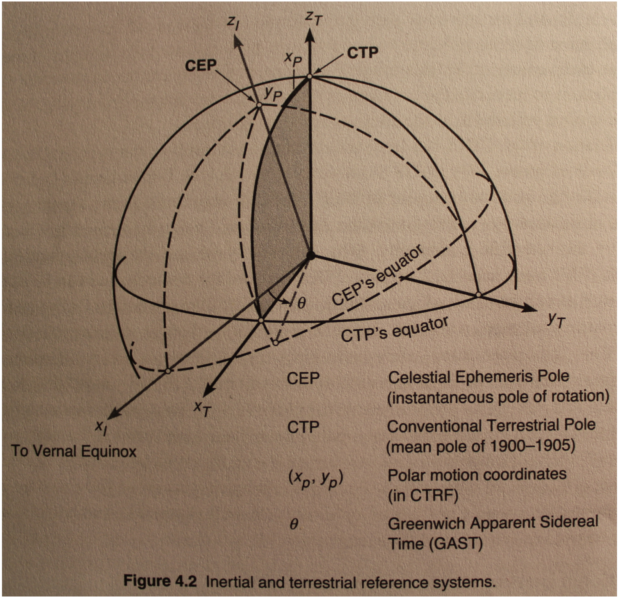


Figure 4.2 Inertial and terrestrial reference systems.

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

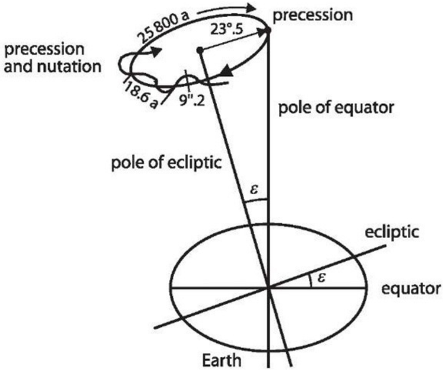
Coordinate Systems 7/11 – CIRS

What are potential issues?

Coordinate Systems 7/11 – CIRS

What are potential issues?

- *varying speed around sun*: think as inertial coord sys over short time
- *axis of rotation not fixed*: precession (26 kyrs), nutation (18.6 yrs)
- well understood – can be traced to any epoch



source: `http://what-when-how.com`

Coordinate Systems 8/11

Cartesian coordinates not intuitive to convey position
(Any guess where we are: X=-1353856.8945, Y=314830.6876,
Z=-6205742.1059)

- how about latitude, longitude, height?
- Earth is rough, need smooth model; easy to characterize: ellipsoid
- origin Earth's center of mass
- z-axis = axis of revolution of ellipsoid
- need to specify semi-major/minor axis (*a*,*b*), or flattening $f = (a - b)/a$
- WGS84: $a = 6378137.0m$, $1/f = 298.257223563$

- *geodetic latitude,* ϕ: angle in meridian plane, between equatorial plane and line that's normal to tangent at P
- *geodetic longitude,* λ: angle in equatorial plane, between reference meridian and meridian plane through P
- *geodetic height, h*: measured along normal to tangent at P; no physical meaning!

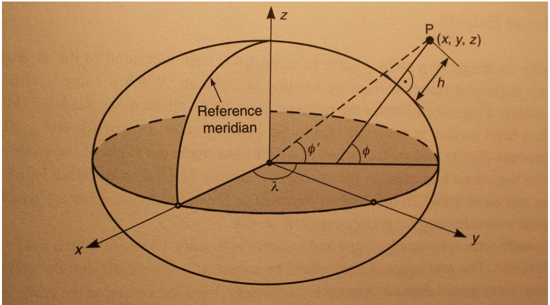


Figure 4.4 Cartesian (x, y, z) and ellipsoidal (ϕ, λ, h) coordinates. Geocentric latitude is denoted as ϕ'. We denote a right angle as ⊾.

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

Coordinate Systems 10/11 – HEIGHTS

- first definition of absolute height relative to mean sea level (MSL)
- recall previous slide: height measured along normal to level surface (tangent at P)
- perpendicular to gravity vector! . . . understanding gravity is important!
- all points with same value of gravity potential: *equipotential surface*
- equipotential surface with best fit to MSL is *geoid*
- orthometric height $H = h - N$, shown on topo maps.

Coordinate Systems 11/11 – HEIGHTS

- orthometric height $H = h - N$, shown on topo maps.

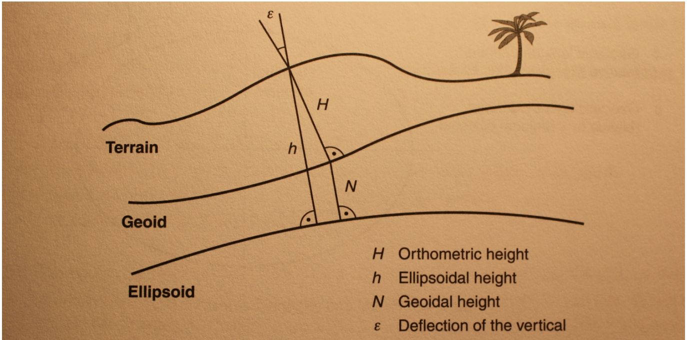


Figure 4.5 Geoid, geoidal height, and deflection of the vertical.

(i) determine the ellipsoidal coordinates (ϕ, λ, h) from GPS measurements,
(ii) determine the geoidal height from a data base, and subtract it from the ellipsoidal height h.

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