Introduction

Contact: jaume.sanz@upc.edu
Web site: http://www.gage.upc.edu
Specific Objectives:

- To learn about **GNSS observables** (code and phase), their characteristics, properties, combinations and applications.

- To learn how to **calculate satellites orbits and clocks** from navigation message. To know the achievable precision.

- To learn how to **model pseudodistance** for code and phase measurements. This includes calculation of: 1) Coordinates at emission epoch, 2) Ionospheric delay (Klobuchar model), 3) Tropospheric delay, 4) relativistic correction, 5) clocks offsets and satellite instrumental delays, 6) phase wind-up, etc.

- To learn how to **set and solve the navigation equation system** using least-squares or Kalman filter (algorithm level).

- To know how to use phase differential positioning: Floating and fixing ambiguities.

- To learn Carrier Phase Ambiguity Fixing techniques.

---

To get tools and skills to process and analyze GNSS data. To implement algorithms for satellite navigation.
An intuitive approach to GNSS positioning
A ship determines its location from a set on lighthouses that send an acoustic signal at a known time.

Knowing the emission time “t0” in the lighthouse and the reception time “t1” in the ship, the traveling time “t1-t0”, and the geometric range “ρ=v(t1-t0)” may be computed.

With only one lighthouse there is a whole circumference of possible locations
A ship determines its location from a set on lighthouses that send an acoustic signal at a known time.

With two lighthouses there are two possible solutions. But, one of them is not on the sea!
A ship determines its location from a set on lighthouses that send an acoustic signal at a known time.

With three lighthouses a single solution is found.
Errors in the clocks (lighthouses and ship) synchronism affects the accuracy.

The ranges are measured by means the traveling time of the acoustic signal from the lighthouses to the ship. Thence, the synchronism errors between the lighthouses and ship clocks will degrade the positioning accuracy.

True range or Geometric range

Pseudorange or apparent distance due to the error clocks
**SUMMARY:** The positioning system is based on:
- To know the coordinates of the lighthouses
- To know the ranges from the ship to the lighthouses
- To solve a geometric problem.

**NOTE:** the ranges are measured by means the traveling time of the acoustic signal from the lighthouses to the ship.
Thence, the synchronism errors between the lighthouses and ship clocks will degrade the positioning accuracy.

True range or Geometric range

Pseudorange or apparent distance due to the error clock
Satellites broadcast orbit and clock data

→ Satellite coordinates and clock offset

Satellite coordinates

Lighthouses coordinates

Receiver measures traveling time from satellite to receiver

→ Pseudorange (P)

Lighthouses-ship ranges.

Thence, the receiver coordinates are found solving a geometrical problem: from sat. coordinates and ranges.
How GNSS Works

One of the solutions is not on the Earth surface.
Lesson 1:
GPS measurements and its combinations

Measurements: Ranges

“Pseudoranges” are computed from the traveling time sat-rec
Several error sources affect these measurements
Lesson 2: GPS Orbits and clocks

Satellite location

Satellite coordinates and clock offsets are computed from the navigation message:

(orbit.f)

Satellite location

Receiver location

How GNSS Works

GPS NAVIGATION DATA FORMAT

P H DANA 10/82

TLM

TELEMETRY WORD

ONE WORD = 30 BITS, 24 DATA, 6 PARITY

8-BIT PREAMBLE

DATA

PARITY

HOW

HANOVER WORD

17-BIT TIME OF WEEK

DATA

PARITY

Measurements:

Ranges

"Pseudoranges" are computed from the traveling time sat-rec

Several error sources affect these measurements

SV CLOCK CORRECTION DATA

ONE DATA FRAME

25 PAGES OF SUBFRAME 4 AND 5 = 12.5 MINUTES

SV EPHEMERIS DATA (I)

SV EPHEMERIS DATA (II)

OTHER DATA (IONO, UTC, ETC)

ALMANAC DATA FOR ALL SVS

ONE = 300 BITS, 6 SECONDS

@ J. Sanz & J.M. Juan

Master of Science in GNSS
Lesson 3:
GPS measurements modeling (code)

Atmospheric propag., relativistic effects, clocks and instrum. delays are modeled and removed.

And the navigation equations are built.
Lesson 3: Solving the navigation Equations

Navigation equations

The geometric problem is linearized, and Weighted Least Mean Squares or Kalman filter are used to compute the solution.

MODEL:

Atmospheric propag., relativistic effects, clocks and instrum. delays are modeled and removed.

And the navigation equations are built

\[
\begin{bmatrix}
\frac{x_{io} - x}{\rho_{io}} & \frac{y_{io} - y}{\rho_{io}} & \frac{z_{io} - z}{\rho_{io}} \\
\frac{x_{io} - x^2}{\rho_{io}^2} & \frac{y_{io} - y^2}{\rho_{io}^2} & \frac{z_{io} - z^2}{\rho_{io}^2} \\
\vdots & \vdots & \vdots \\
\frac{x_{io} - x^n}{\rho_{io}^n} & \frac{y_{io} - y^n}{\rho_{io}^n} & \frac{z_{io} - z^n}{\rho_{io}^n}
\end{bmatrix}
\begin{bmatrix}
\Delta x_i \\
\Delta y_i \\
\Delta z_i \\
cd t_i
\end{bmatrix}
\]
How GNSS Works

Lessons 4, 5, 6:
- Code and Carrier phase
- Differential positioning
- Floating/fixing ambiguities
References


Thank you!