Introduction

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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.

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To get tools and skills to process and analyze GNSS data. To implement algorithms for satellite navigation.
An intuitive approach to GNSS positioning
Assume that a ship with a clock perfectly synchronised to the one in the lighthouse is receiving these signals in a time that is not an exact multiple of 10 minutes, for example 20 seconds later \( t = n \times 10m + 20s \).

Suppose that a lighthouse is emitting acoustic signals at regular intervals of 10 minutes and intense enough to be heard some kilometres away.
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With a single lighthouse, possible solutions lie on a circle of radius $\rho$.

With two lighthouses, the possible solutions are reduced to two.
The **ranges** are measured by **traveling** time of the acoustic signal from the lighthouses to the ship. Synchronism errors in clocks (lighthouses and ship) affect accuracy.
How GNSS Works

Satellites broadcast orbit and clock data

→ Satellite coordinates and clock offset

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
One of the solutions is not on the Earth surface.
How GNSS Works
How GNSS Works

Lesson 1:
GPS measurements and its combinations

Measurements: Ranges
“Pseudoranges” are computed from the traveling time sat-rec
Several error sources affect these measurements

Receiver location

travel time x speed of light
Lesson 2: GPS Orbits and clocks

Satellite location

Satellite coordinates and clock offsets are computed from the navigation message:
(orbit.f)

Measurements:
Ranges
"Pseudoranges" are computed from the traveling time sat-rec
Several error sources affect these measurements

Receiver location

GPS NAVIGATION DATA FORMAT

TLM  ONE WORD = 30 BITS, 24 DATA, 6 PARITY
TELEMETRY WORD  8-BIT PREAMBLE  DATA  PARITY
HOW  17-BIT TIME OF WEEK  DATA  PARITY
HANOVER WORD

SV CLOCK CORRECTION DATA

ONE DATA FRAME

25 PAGES OF SUBFRAME 4 AND 5 = 12.5 MINUTES
1500 BITS, 30 SECONDS

SV EPHEMERIS DATA (I)

2

TLM
HOW

SV EPHEMERIS DATA (II)

3

TLM
HOW

OTHER DATA (IONO, UTC, ETC)

4

TLM
HOW

ALMANAC DATA FOR ALL SYS

5

TLM
HOW

How GNSS Works

Master of Science in GNSS

@ J. Sanz & J.M. Juan
How GNSS Works

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

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

And the navigation equations are built

\[
\begin{align*}
\Delta x_i &= \frac{x_{io} - x^1}{\rho^1_{io}} + \sum_{k=2}^n \frac{x_{io} - x^k}{\rho^k_{io}} \\
\Delta y_i &= \frac{y_{io} - y^1}{\rho^1_{io}} + \sum_{k=2}^n \frac{y_{io} - y^k}{\rho^k_{io}} \\
\Delta z_i &= \frac{z_{io} - z^1}{\rho^1_{io}} + \sum_{k=2}^n \frac{z_{io} - z^k}{\rho^k_{io}} \\
\end{align*}
\]

**Navigation equations**
The geometric problem is linearized, and Weighted Least Mean Squares or Kalman filter are used to compute the solution.
How GNSS Works

Lessons 4, 5, 6:

- Code and Carrier phase
- Differential positioning.
- Floating/fixed ambiguities
References


Thank you!
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