GNSS positioning

DIY Oceanography BZH

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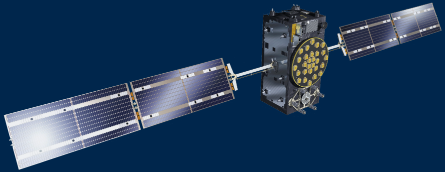

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Outline

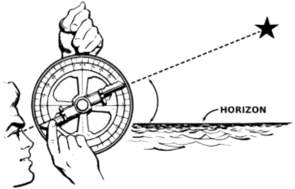
1. GNSS principles
2. Positioning methods
3. Devices

This presentation is based on Bosser, 2015

GNSS principles

How to calculate a position on Earth?

Ancestral techniques	Conventional techniques	Space techniques
Using stars	*Using georeferenced points and topography*	*Using satellites and stars*

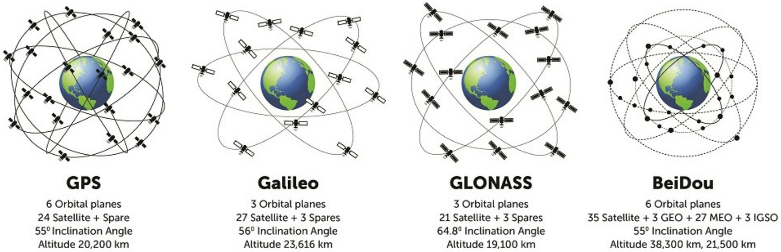


In the 1970s, searching for positioning techniques $\pm$ accurate (10-meters to cm), all over the globe, weather independent, not too expensive...

From GPS to GNSS

The GPS (Global Positioning System), launched in the early 1980s, was succeeded by the GNSS.

⇒ **GNSS** (Global Navigation Satellite System): Positioning system based on signals emitted from satellites orbiting the Earth and providing global coverage.



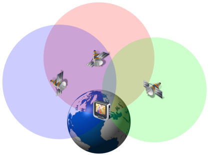
Source: spacenews.com

How does it work ?

- GNSS satellites know and emit their positions.
- Receivers receive the satellite's position and **deduce their distance** from it by measuring the propagation delay.
- Accurate propagation delay measurements require perfect time synchronization between all the satellites and with the receivers.

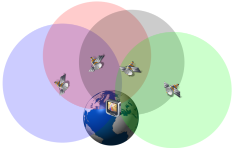
  $\Rightarrow$ Estimation of a **clock error parameter** to account for receiver and satellite clocks **desynchronization**.

Trilateration



3 unknowns (X,Y,Z) $\rightarrow$ Need of 3 satellites

Mutlilateration



4 unknowns (X,Y,Z, δt_r) $\rightarrow$ Need of 4 satellites

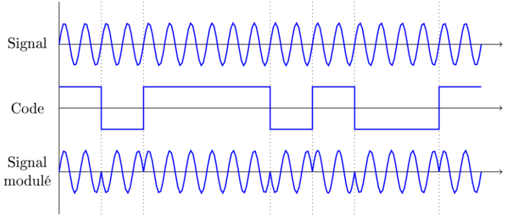
GNSS signal

- Signal emitted in band L: $\sim$ 1200 - 1600 MHz, i.e., a wavelength of about 20 cm.

Some examples :

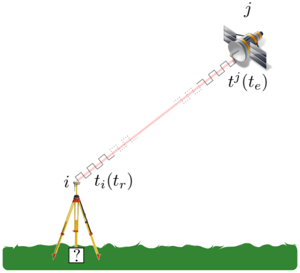
- *GPS: 2 frequencies, a third is setting up (1207 - 1602 MHz)*
- *GLONASS: 2 frequencies, a third is setting up (1207 - 1602 MHz)*
- *Galileo: 4 frequencies (1176 - 1575 MHz)*
- *BeiDou: 4 frequencies (1191 - 1575 MHz)*

- Information transferred using **phase modulation of carrier wave**, realized using **positioning code** and **navigation message**.



Code or carrier-based measurements

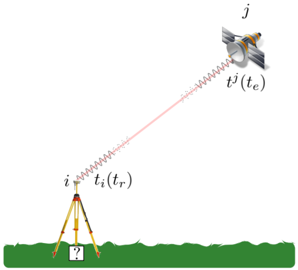
Code



Synchronization code generated by satellites

- Native GNSS measurement for positioning
- Accuracy: from 50 cm to 5 m

Carrier-based



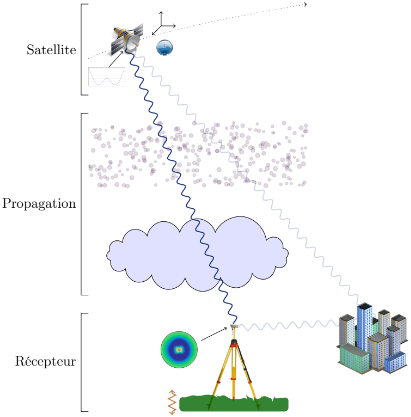
Phase difference measurement

- Performed on the different carriers
- Accuracy: a few mm ... **modulo one ambiguity**

Error budget on GNSS measurements

- **At the satellite level**
  - Satellite orbit and clock → From m to 5mm
  - Satellite phase center
- **During the signal propagation**
  - Ionosphere → From meters to mm
  - Troposphere → From 1m to 2-10mm
- **At the receiver and ground antenna level**
  - Multipath → From 1m to 2-15mm
  - Antenna phase center
  - Ground motion → From 50cm to 1mm
  - Jamming and spoofing

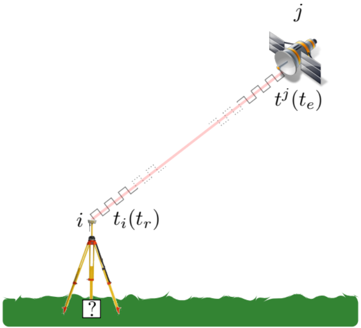
⇒ Correction using models, external data, observation process (spatial errors)



Positioning methods

Types of measurements

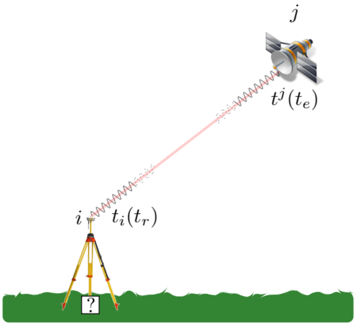
Code



⊕ Low-cost receiver, computation simplicity

⊖ Metric observation quality

Phase

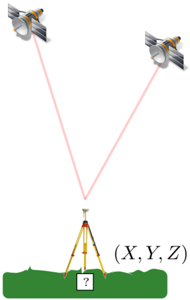


⊕ Observable quality

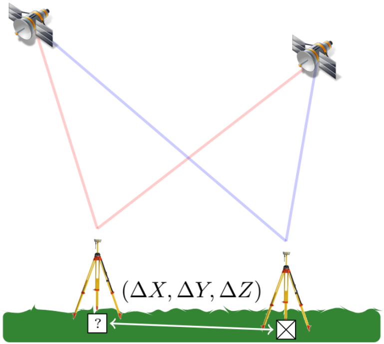
⊖ Advanced and expansive receivers

Modes of measurements

Absolute



Relative



⊕ Autonomous and direct positioning

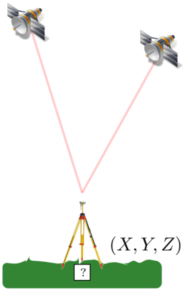
⊖ Require accurate errors modelling

⊕ Reduction of spatial correlated errors (atmosphere) satellite systematisms (orbit, clocks)

⊖ Requires a nearby station, communication link

Latency

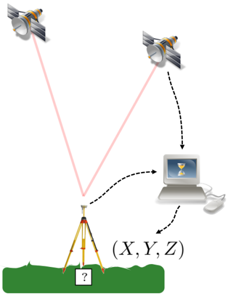
Real-time



⊕ Instantaneous

⊖ Medium/poor quality instant products

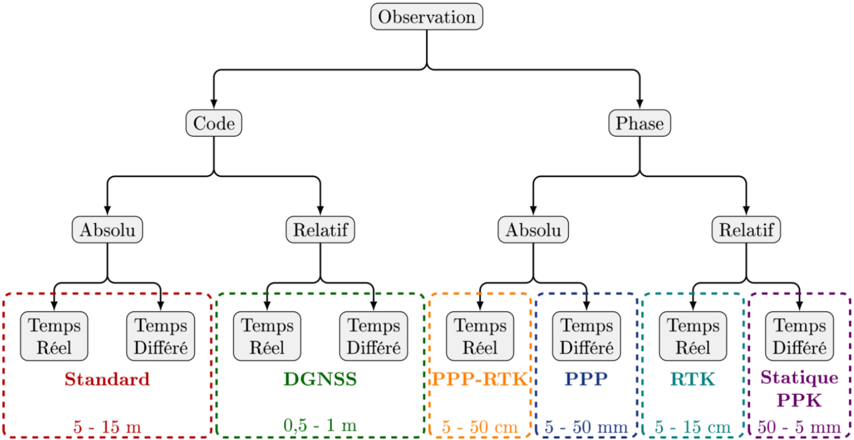
Post-processed



⊕ Refined product

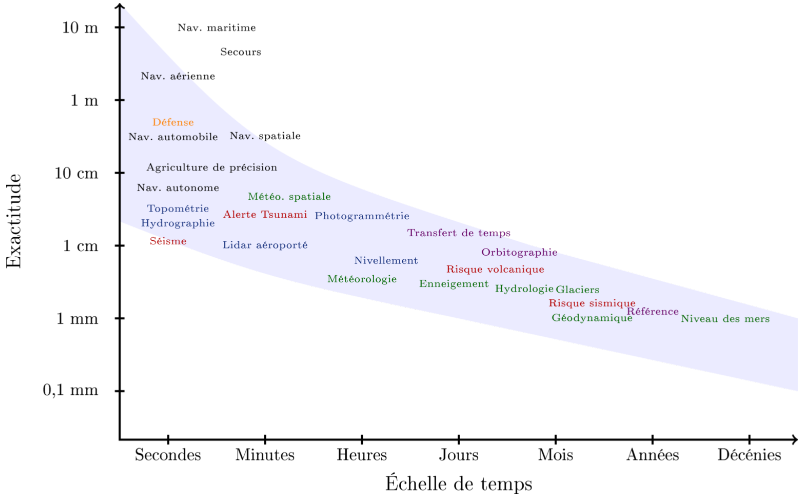
⊖ Long delay for positioning with ultimate accuracy (14 days)

Summary



Some applications : Marine navigation assistance / USV guiding / GNSS buoy / Permanent station

Accuracy and applications

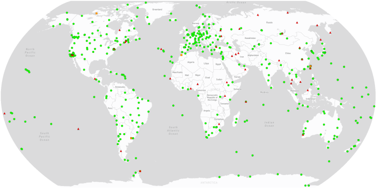


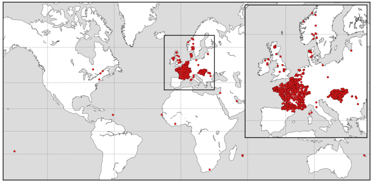
GNSS permanent stations networks

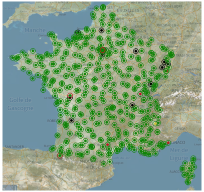
Networks of permanent stations have been developed to support these applications:

- Management of GNSS infrastructures (satellites, signals, etc.).
- Estimation of products required for precise positioning (orbits, reference frame, etc.).
- Surface monitoring (eathquake, volcano, landslide)
- Real time applications (RTK)
- Archiving and providing access to the data.

→ Public (IGS, RGP), private (Teria, Satinfo, Orpheon), open & collaborative (Centipede-RTK).







Devices

Acquisition systems

General public	Professional		
Géonavigateur (« GPS »)	**Topographic systems**	**Geodesic systems**	
		Antenna	*Receiver*
 *Garmin®*  *TomTom®* 	 *Leica GPS1200®*  *Spectra SP80®*	 *Trimble Zephyr 2®*  *Leica AR20® Choke-Ring*	 *Trimble Net R9®*  *Leica GR25®*
Hiking, route navigation	Survey, mobile mapping, reference point positionning, implantation	Survey, permanent GNSS stations, geodesic studies	
< 200€	8 000/10 000 € (*complete system*)	800 – 3 000 €	10 000 €

Low-cost devices

			Main characteristics	Performance	Cost
Receivers	*simpleRTK2B Budget* platform based on U-blox ZED-F9P receiver		→ Multifrequency, multiconstellation → Multiband (L1, L2, E5b) → Update rate: 1Hz > 10Hz → Output in UBX format	From meter to cm level precision (standard or RTK)	~170 €
	simpleRTK3B Budget platform based on Unicore UM980		→ Multifrequency, multiconstellation → Multiband (L1, L2, L5) → Update rate: 1Hz > 50Hz → Output in Unicore format, NMEA, RTCM v3 → **Galileo HAS**	From meter to mm level precision (standard or RTK)	~230€
	simpleRTK3B Pro platform based on Septentrio Mosaic-X5		→ Multifrequency, multiconstellation → Multiband (L1, L2, E5b) → Update rate: 1Hz > 100Hz → Output: SBF, NMEA, RINEX, …	From meter to mm level precision (standard or RTK)	~580€
Antennas	U-blox, ANN-MB		→ Multi-band (L1, L2/E5b/B2I) → Multiconstellation → 82.0 x 60.0 x 22.5mm → Weight: 173g	-	~55€
	AS-ANT2B-OEM-L1L2-02SMA-00		→ Multi-band (L1, L2/E5b/B2I) → Multiconstellation → Maximum length: 76mm → Weight: 80g	-	55-60€
	AS-ANT2B-CAL-L1L2-15SMA-00		→ Multi-band (L1, L2/E5b/B2I) → Multiconstellation → Maximum length: 152mm → Weight: 400g → **Calibration file available**	-	~150€

⇒ Low-cost retailers : ardusimple, drotek

How to meet your needs?

- **Metric precision**
  - Standard (SPP) positioning (real-time)
  - Very low-cost receivers/antennas ($\sim$ 10 euros) or Smartphone + logger
- **Centimetric precision**
  - RTK (real-time), PPK / PPP-PPK (post-processing) for a static or moving antenna
  - Low-cost or survey/geodetic devices, with logger (embedded)
- **Sub-centimetric precision:**
  - Static antenna only
  - Post-processing methods : static relative or precise point positioning
  - Low-cost or geodetic devices
- Additional requirements for post-processing:
  - Logging of GNSS raw data
  - Post-processing software (e.g. RTKlib, PRIDE PPP-AR)

References

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- An accessible book on GNSS : *GNSS - Global Navigation Satellite Systems* by Hofmann-Wellenhof, B. ; Lichtenegger, H. & Wasle, E., 2008
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