Overview of GPS
Global Positioning System

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Outlines

- GPS overview
- Different segments
- GPS signal structure
- Absolute and relative positioning

Some references

- Duquenne et al., **2005**, GPS: localisation et navigation, Hermès édition, 2ème édition revue et augmentée, 330 pages.
- Herring, T., **2009**, Geodesy Treatise on Geophysics, ISBN 13 : 978-0-444-53460-6, Elsevier.
- Hofmann-Wellenhof B., Lichtenegger H., Wasle E., **2008**, GNSS - Global Navigation Satellite Systems, GPS, GLONASS, Galileo, and more, XXIX, 516 p. 95 illus., Springer, ISBN: 978-3-211-73012-6
- Strang, G. et K. Borre, **1997**, Linear algebra, geodesy, and GPS, Wellesley-Cambridge Press, 624pp.
- Xu G., **2000**, GPS: theory, algorithms and applications, Springer, 315p.
- Capderou M., **2011**, Satellites : de Kepler au GPS, Springer, 844 pp.
- van Diggelen F., **2009**, A-GPS : assisted GPS, GNSS, and SBAS.
- Kaplan E. D.& C. J. Hegarty, **2006**, Understanding GPS : principles and applications,

Other refs on the web

- site web de Peter Dana

http://www.colorado.edu/geography/gcraft/notes/gps/gps.html

- French Permanent GNSS network

http://rgp.ign.fr/

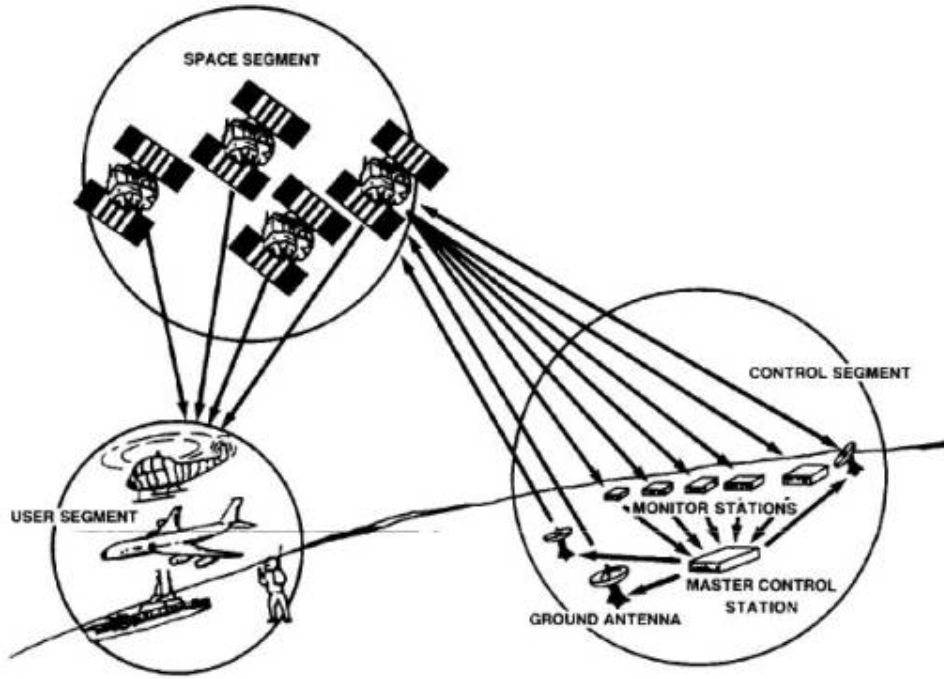
- IGS: International GNSS Service

http://igscb.jpl.nasa.gov/

- UNAVCO http://unavco.org

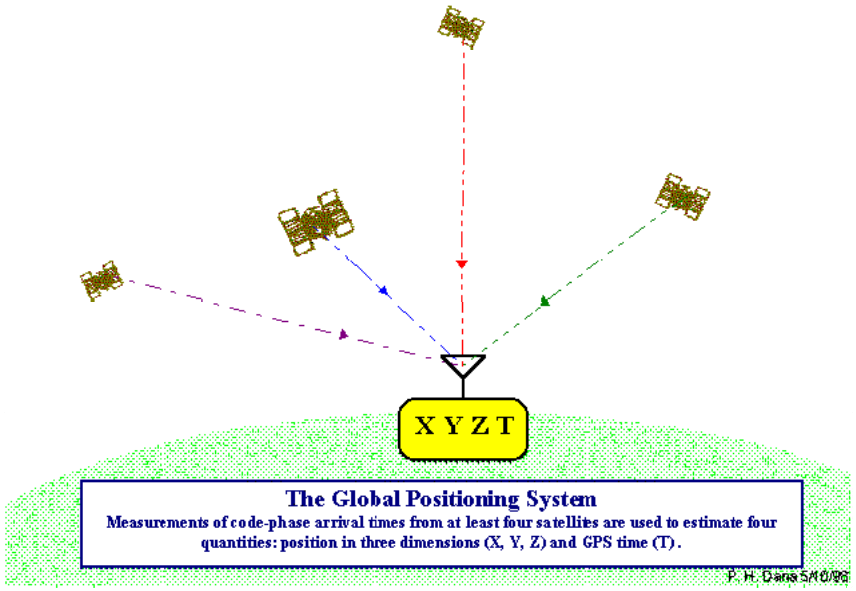
Global Positioning System

- Military system for navigation et positioning
- Position, velocity and time
  - Anytime
  - Everywhere
  - In a global reference system
- Different kind of precision
  - few mm to several meters
- 3 segments
  - Space segment
  - Control segment
  - User segment



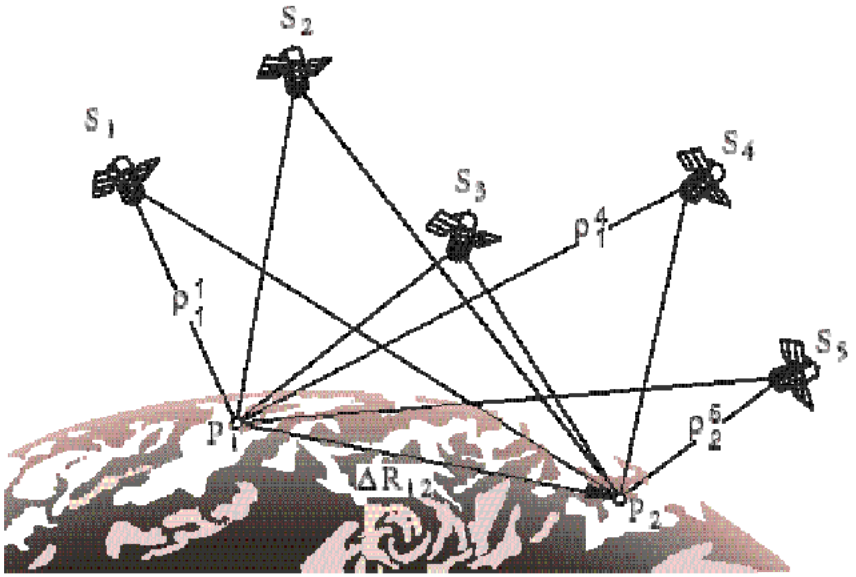
2 types of GPS positioning

Absolute pos.



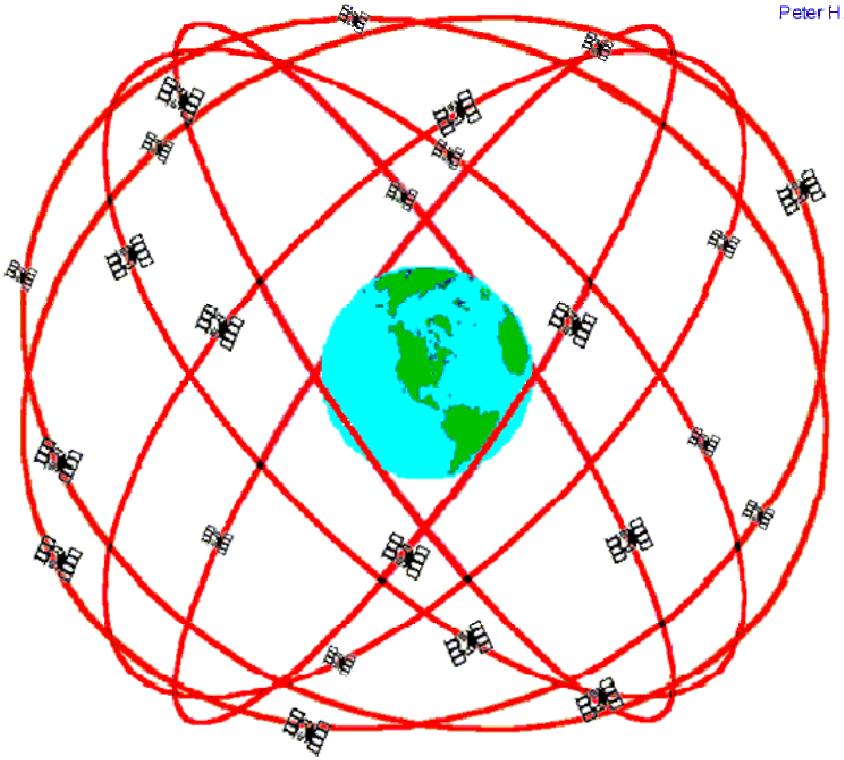
Metric accuracy

Relative pos.



Accuracy on the baseline length: few mm to few m.

Space segment



GPS Nominal Constellation
24 Satellites in 6 Orbital Planes
4 Satellites in each Plane
20,200 km Altitudes, 55 Degree Inclination

24 nominal satellites:

- **altitude: 20, 000 km**
- **velocity: 4 km/s**

- **Revolution period: less than 12h**

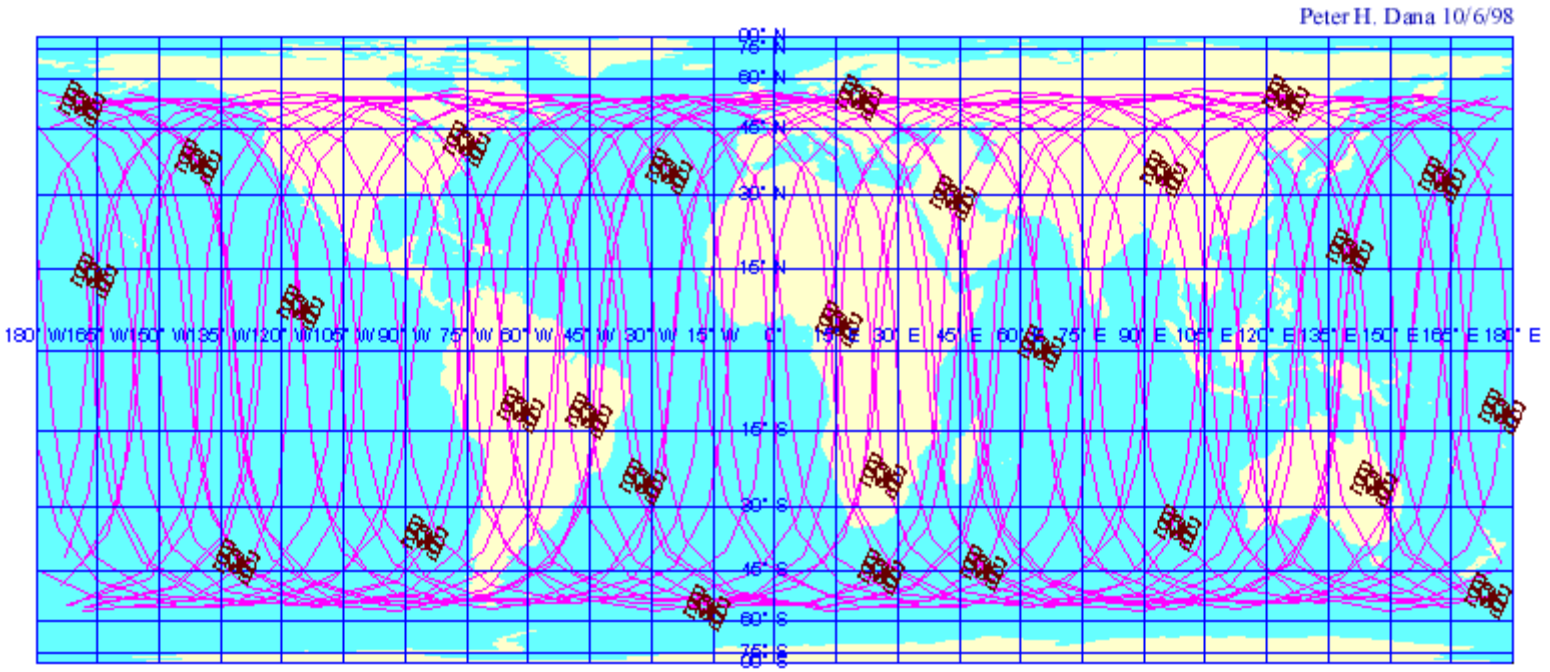
- **Nearly circular orbit**

Every satellite emits a signal on two frequencies in L-band.

L1 and L2

Every satellite is equipped with an atomic clock

Space segment

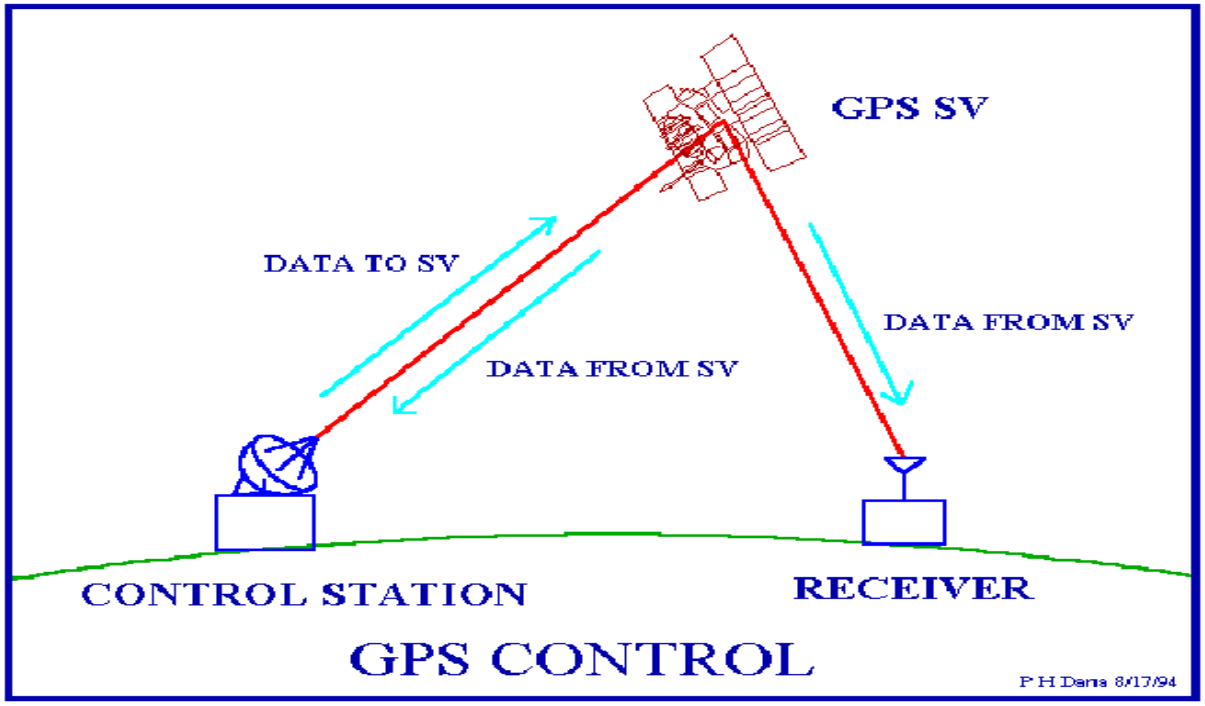


Global Positioning System Satellites and Orbits
for 27 Operational Satellites on September 29, 1998
Satellite Positions at 00:00:00 9/29/98 with 24 hours (2 orbits) of Ground Tracks to 00:00:00 9/30/98

Space segment

Block	Launch period	Success	Failure	In preparation	Planned	Currently in orbit and healthy (oct 2012)
I	1978 - 1985	10	1	0	0	0
II	1989 - 1990	9	0	0	0	0
IIA	1990 - 1997	19	0	0	0	9
IIR	1997 - 2004	12	1	0	0	12
IIR-M	2005 - 2009	8	0	0	0	7
IIF	2010 -	3	0	10	0	3
IIIA	2014 -	0	0	0	12	0
	Total	61	2	10	12	31

Control segment

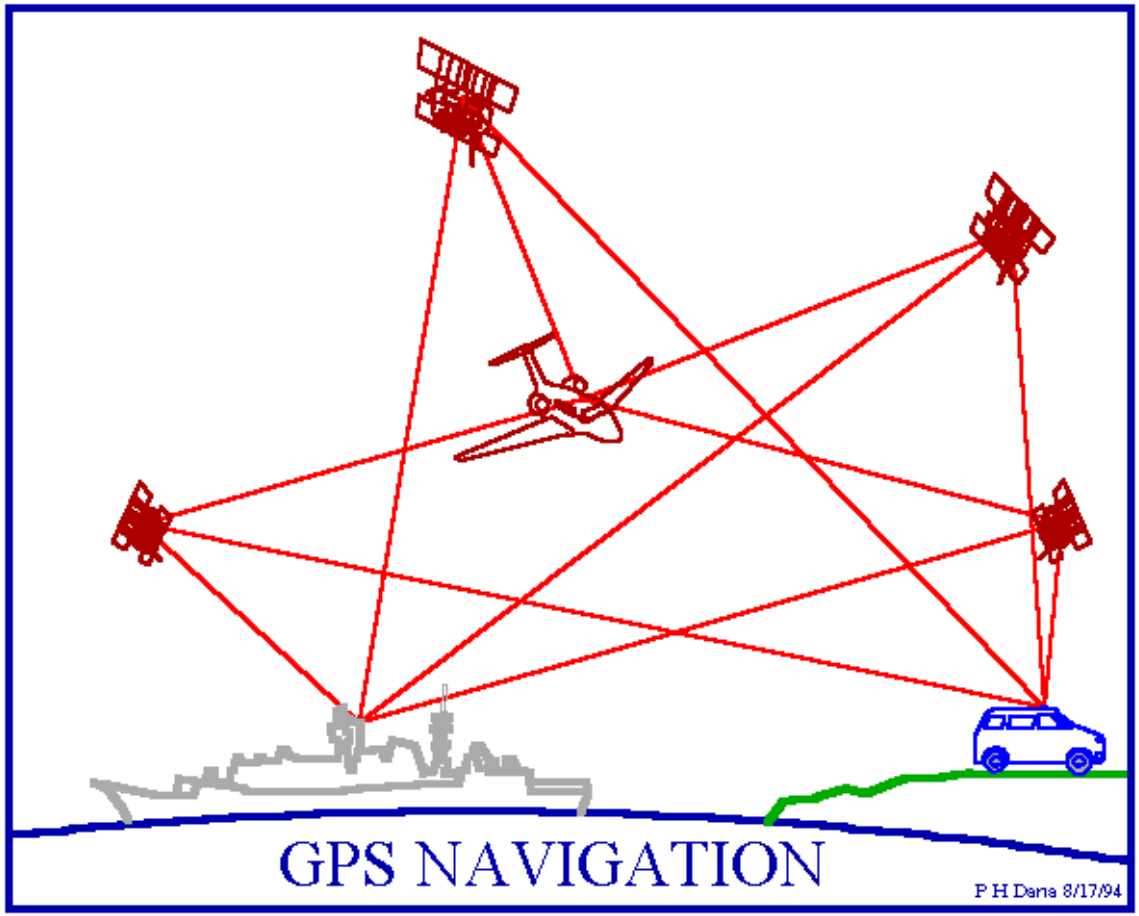


⇒ Control segment: compute the broadcast orbit

Control segment

Global Positioning System (GPS) Master Control and Monitor Station Network

User segment



Different receivers and antennas

Permanent GPS

GPS pillar (Strasbourg)

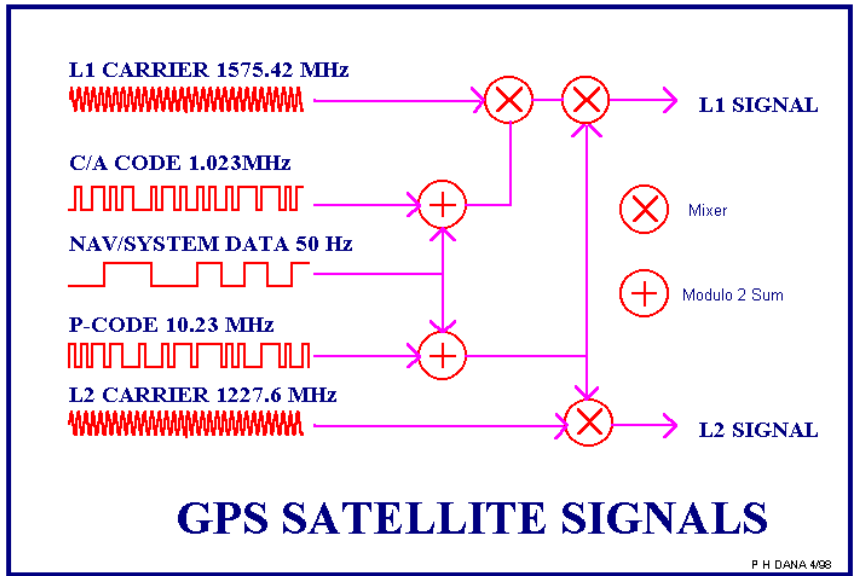
Antenna with a radome

Steel mast (Toulouse)

GPS on a tripod or on a rod

GPS signal structure

- Two carriers L1 and L2 are generated on board
  - f1 =1575.42 MHz (wavelength of 19 cm)
  - f2 =1227.60 MHz (24cm)



Two pseudo-random codes are modulated

=>C/A-Code Coarse Acquisition
(*acquisition grossière*) on L1
=>P-Code (Precise) on L1 and L2
Encrypted into Y-code for military purposes

GPS signals contain the navigation message :
satellite informations:
(numbers, health, …)
broadcast ephemeris (*éphémérides radio-diffusées*)

Denial and accuracy access of GPS signal

- GPS = military system → deny access for other users
- Different denial access for civilian use of full GPS system
  - SA (Selective access, *accès sélectif*)
    - SA on → position precision limited to 100 m in real time
    - SA off →turned off on May 2, 2000 **➔ position hz 2-10m, V 10-50m**
  - A/S (Anti-spoofing, *anti-leurrage*)
    - To protect the GPS from other signals closed to the GPS one.
  - P-Code is replaced by the unknown Y-code (military code)

Navigation file in RINEX format

```
                (OPPOSITE TO PREVIOUS SETTINGS)                COMMENT

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
```

TABLE A8

GPS NAVIGATION MESSAGE FILE - EXAMPLE

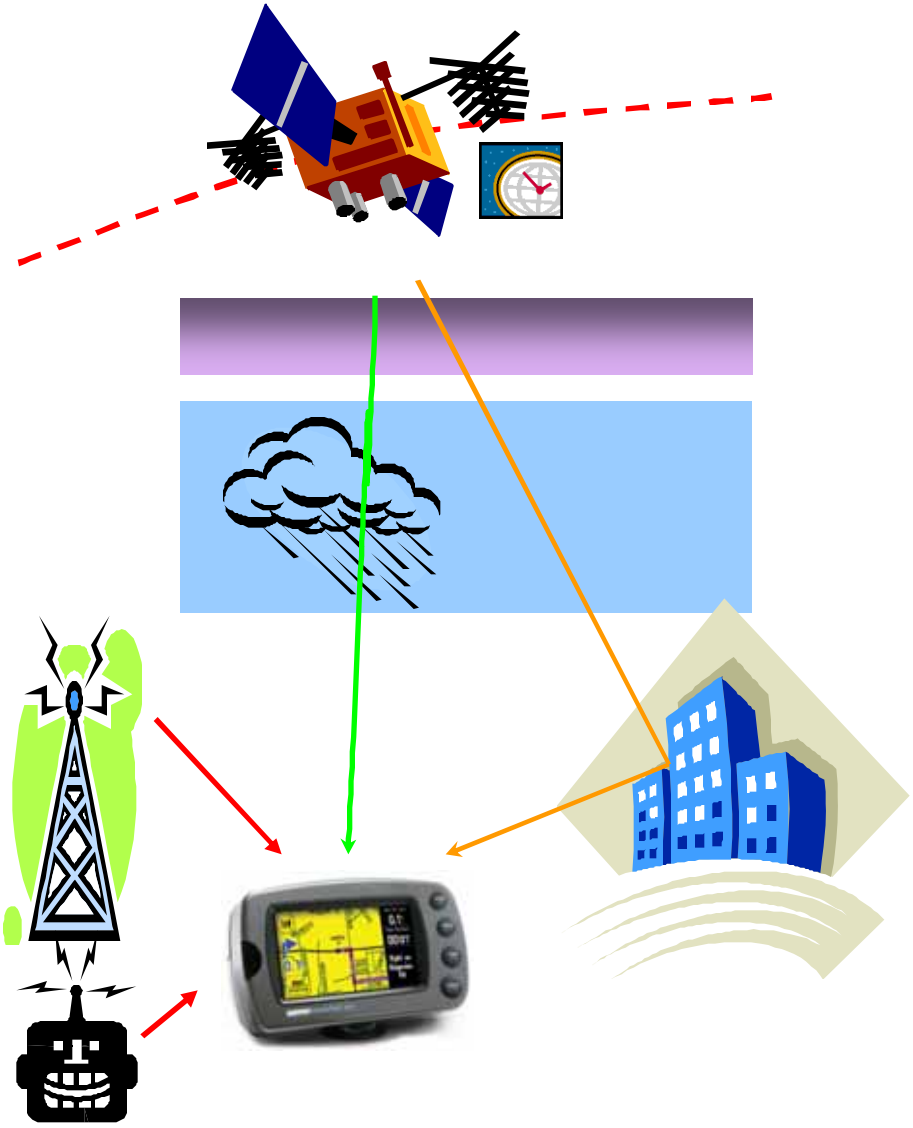
```
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|

     2.10           N: GPS NAV DATA                         RINEX VERSION / TYPE
XXRINEXN V2.10      AIUB                 3-SEP-99 15:22     PGM / RUN BY / DATE
EXAMPLE OF VERSION 2.10 FORMAT                              COMMENT
     .1676D-07   .2235D-07  -.1192D-06  -.1192D-06          ION ALPHA
     .1208D+06   .1310D+06  -.1310D+06  -.1966D+06          ION BETA
     .133179128170D-06  .107469588780D-12   552960     1025 DELTA-UTC: A0,A1,T,W
    13                                                      LEAP SECONDS
                                                            END OF HEADER
 6 99  9  2 17 51 44.0 -.839701388031D-03 -.165982783074D-10  .000000000000D+00
     .910000000000D+02  .934062500000D+02  .116040547840D-08  .162092304801D+00
     .484101474285D-05  .626740418375D-02  .652112066746D-05  .515365489006D+04
     .409904000000D+06 -.242143869400D-07  .329237003460D+00 -.596046447754D-07
     .111541663136D+01  .326593750000D+03  .206958726335D+01 -.638312302555D-08
     .307155651409D-09  .000000000000D+00  .102500000000D+04  .000000000000D+00
     .000000000000D+00  .000000000000D+00  .000000000000D+00  .910000000000D+02
     .406800000000D+06  .000000000000D+00
13 99  9  2 19  0  0.0  .490025617182D-03  .204636307899D-11  .000000000000D+00
     .133000000000D+03 -.963125000000D+02  .146970407622D-08  .292961152146D+01
    -.498816370964D-05  .200239347760D-02  .928156077862D-05  .515328476143D+04
     .414000000000D+06 -.279396772385D-07  .243031939942D+01 -.558793544769D-07
     .110192796930D+01  .271187500000D+03 -.232757915425D+01 -.619632953057D-08
    -.785747015231D-11  .000000000000D+00  .102500000000D+04  .000000000000D+00
     .000000000000D+00  .000000000000D+00  .000000000000D+00  .389000000000D+03
     .410400000000D+06  .000000000000D+00

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
```

TABLE A9

Error sources on the GPS measurements



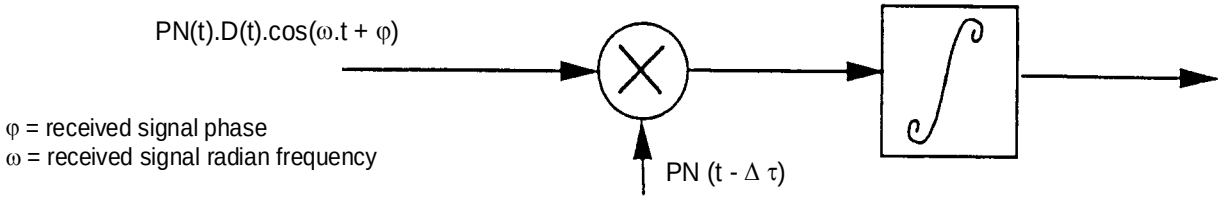
- Satellite
  - Orbits
  - Offset of the on-board clock
- Atmospheric errors
  - Ionosphere (70 → 1000km)
  - Troposphere (0 to 20km)
  - Multi-paths
  - Interferences
- Receiver:
  - Thermal noise

Types of measurements

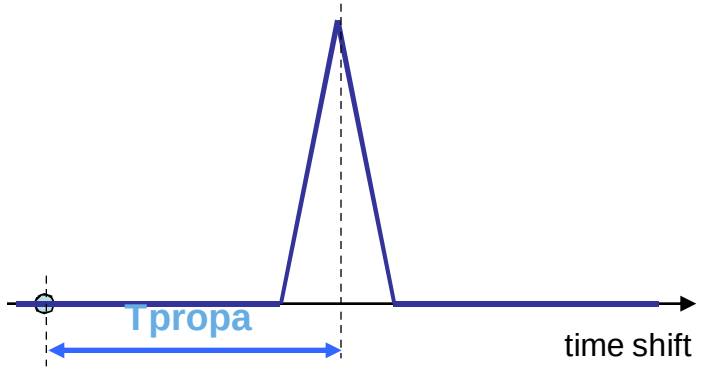
- Pseudo-range
  - Using the C/A or P-code
  - Used for navigation
  - pseudo-range = velocity of the wave x time travel
- Phase measurement
  - Highly precise (in theory: 3/1000 of cycle i.e. 1 to 2 mm on the distance receiver-satellite)
  - Non absolute measurement

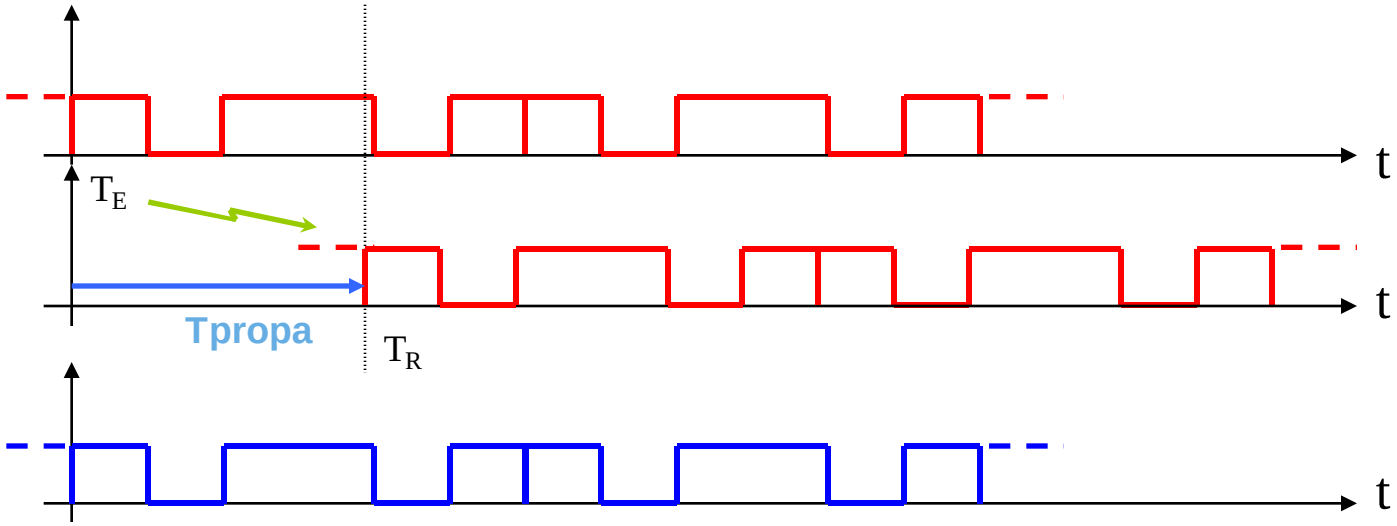
Range measurement with PRN code (Pseudo random noise)

- A replica of the received signal is generated by the receiver



- This replica is shifted in time to reach the maximum of correlation



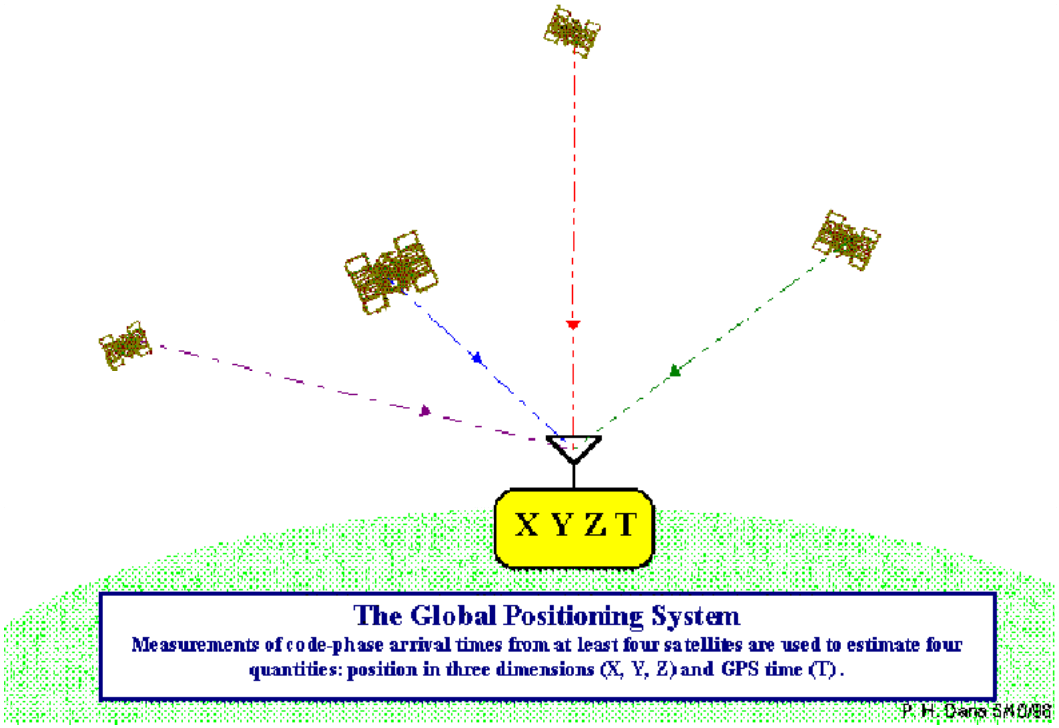


Signal emitted

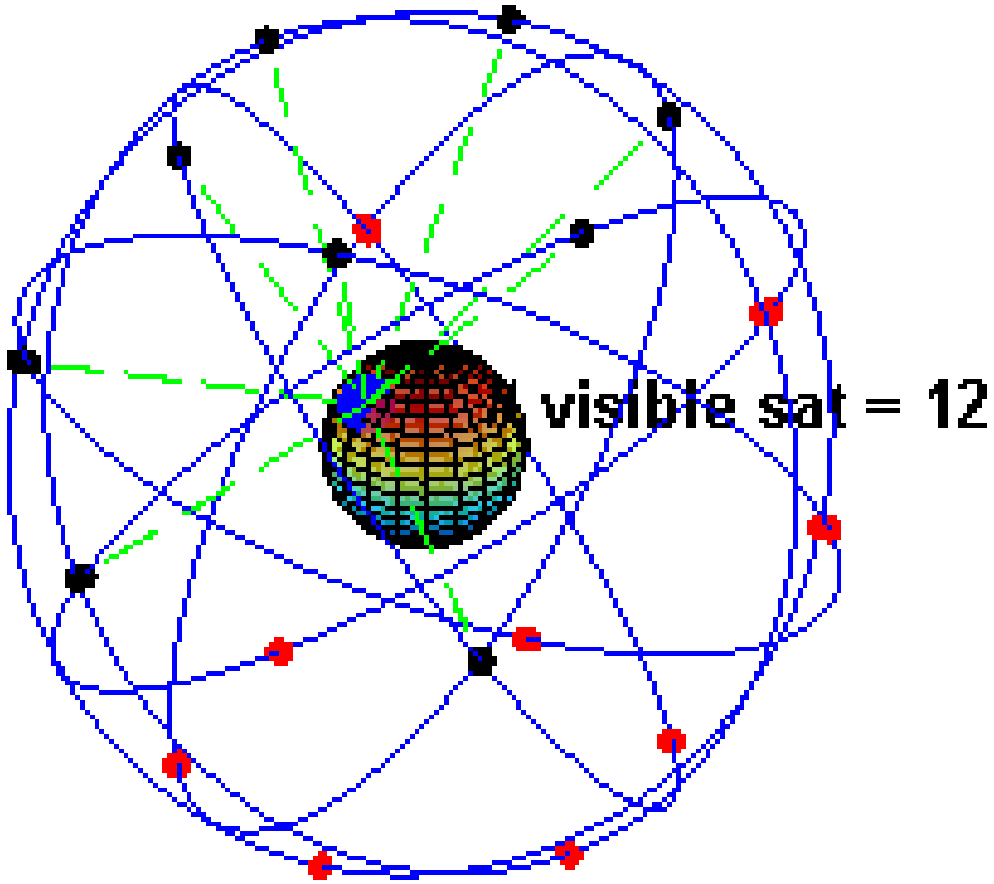
Signal received

Local replica

Abolute positioning using C/A-code



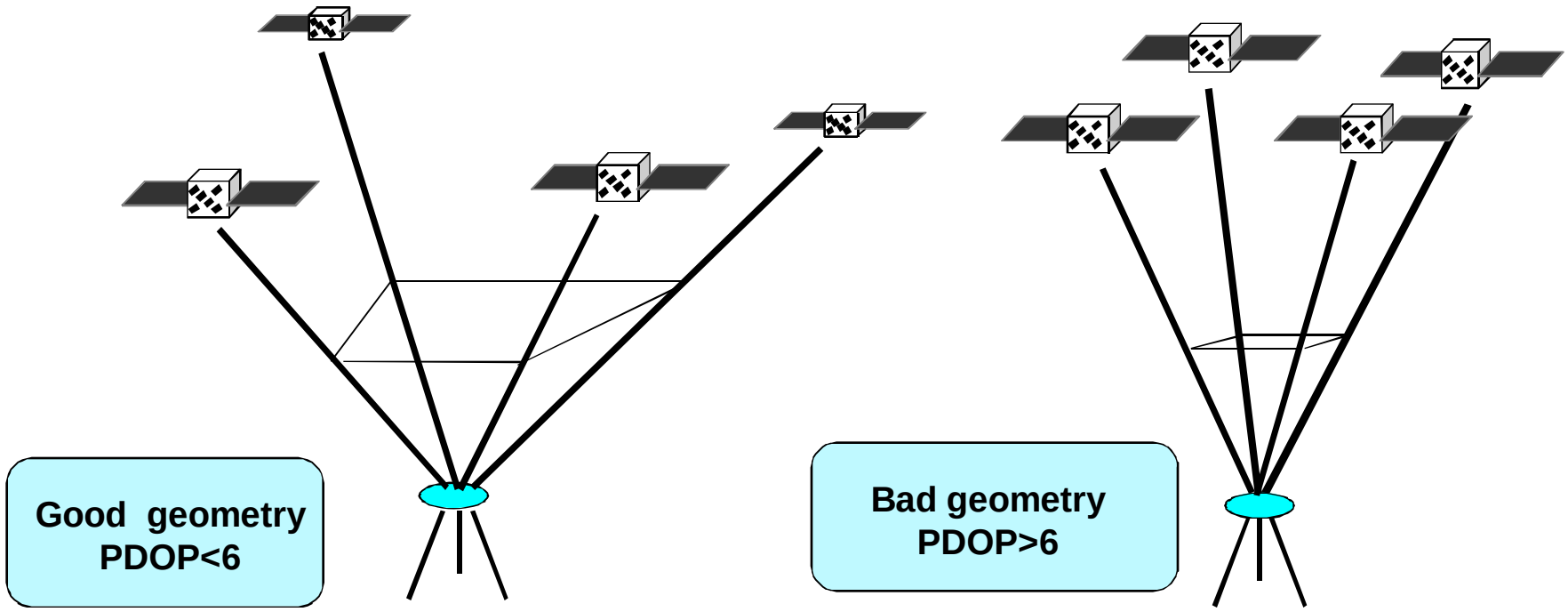
4 distances between satellites and receiver


visible sat = 12

PDOP (Position Dilution Of Precision)

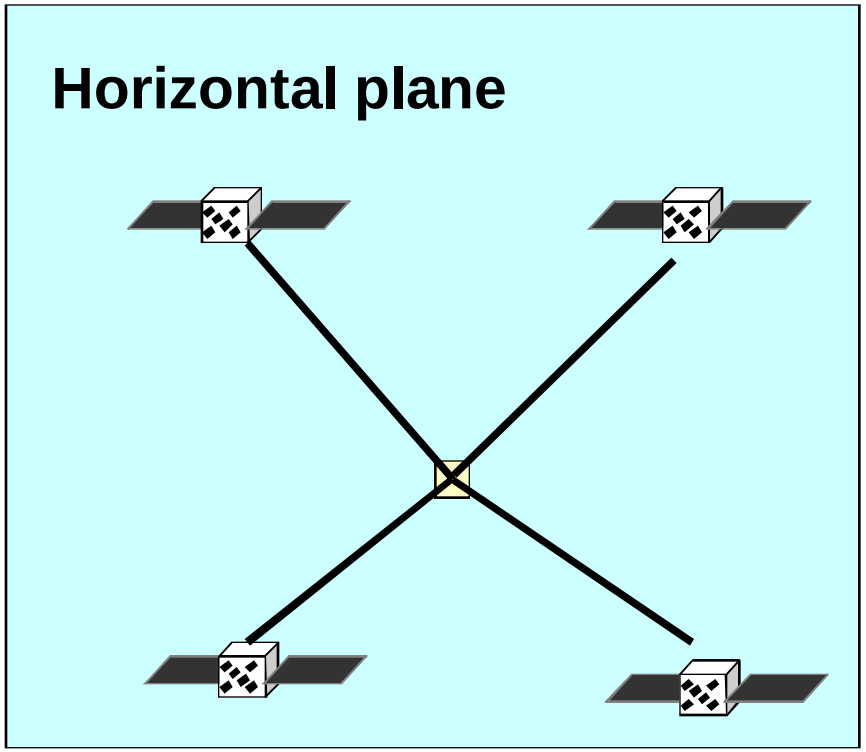
= facteur d'affaiblissement de précision
du résultat de positionnement instantané

- Purely geometric method of positioning using the range measurements.
- PDOP: is an indicator computed instantly by the receiver.

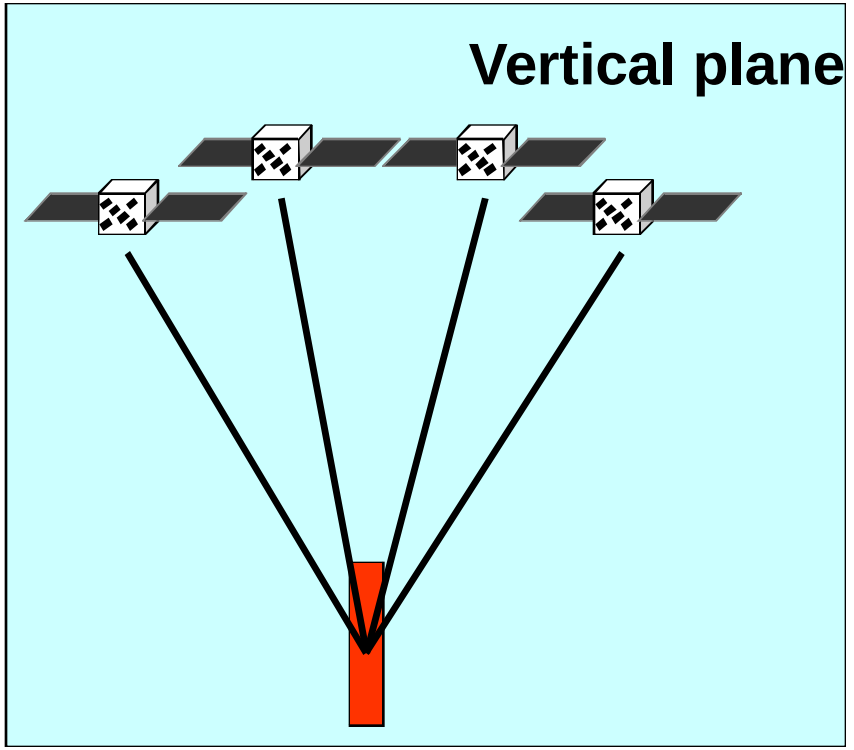


Impact of the geometry

- The geometry implies that the vertical component is 3 to 5 times less precise than the horizontal component.



Good constrain in Horizontal



Bad constrain on vertical

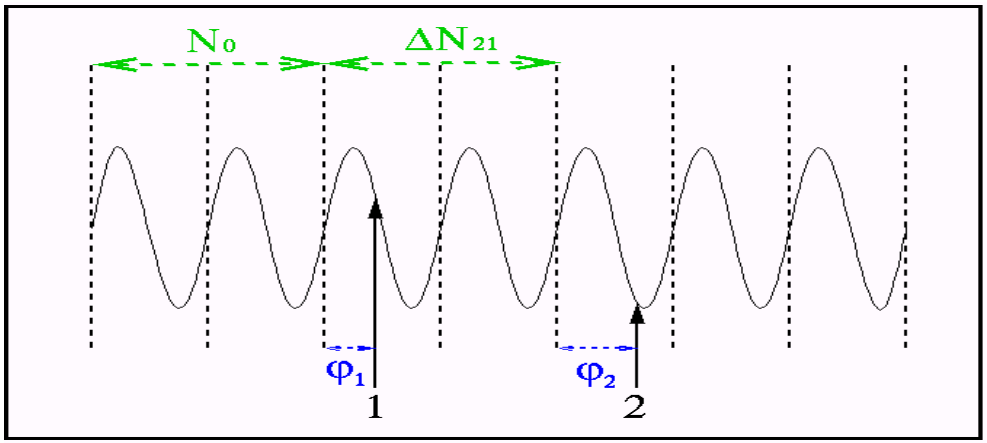
Different DOP parameters

- GDOP: Geometric (pos. 3D+ time)
- PDOP : position (3D)
- TDOP : time
- HDOP : horizontal (2D)
- VDOP : vertical (1D)
  - >> Instantly computed, indicator of the position precision.

DOP Value	Rating	Description
< 1	Ideal	
1-2	Excellent	
2-5	Good	
5-10	Moderate	
10-20	Fair	
➢20	Poor	

Phase measurement and ambiguity resolution (N0)

- Determination of the small phase
- Estimation a floating value for N0 (floating solution)
- Estimation an integer value for N0 (initialization process)

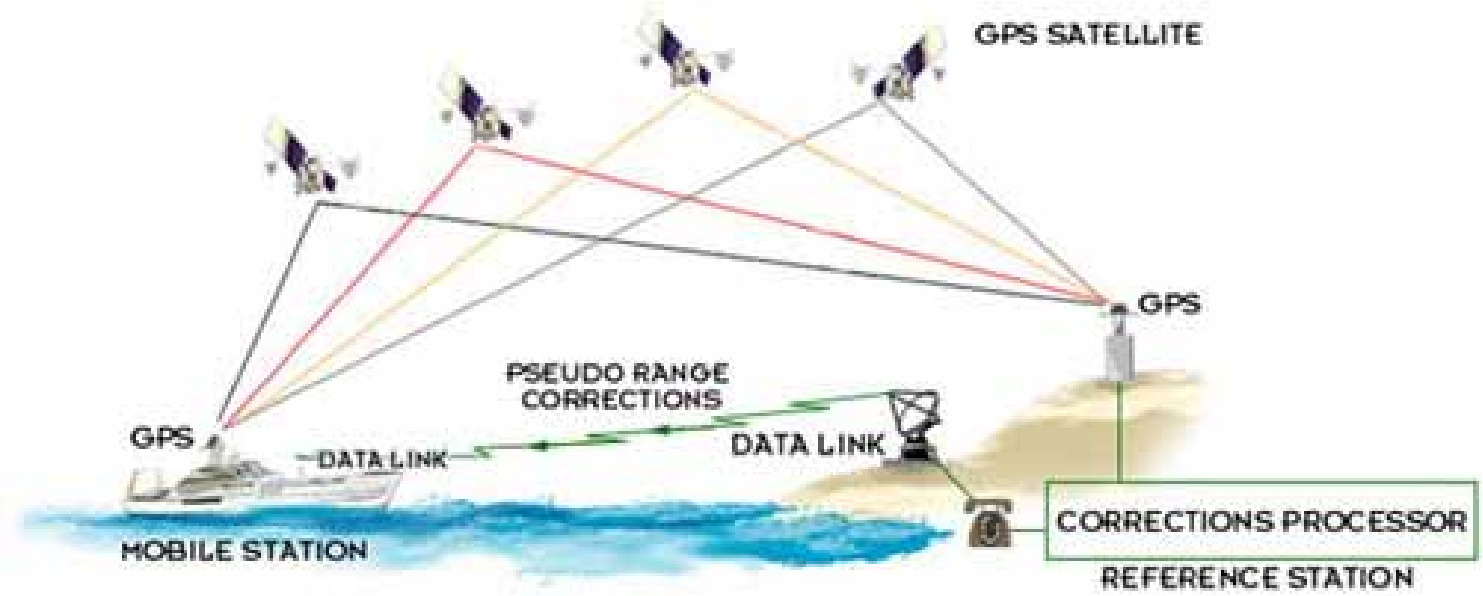


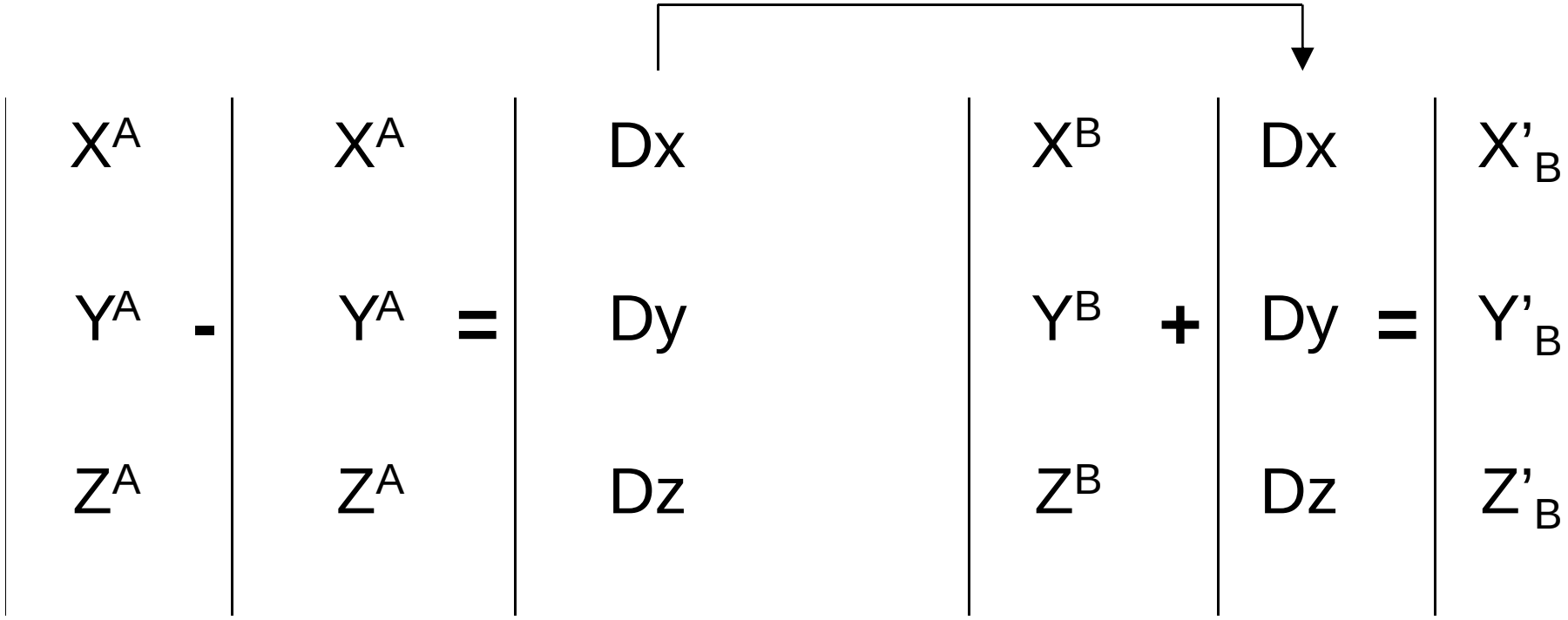
Emission time **Reception Time 1**

Differential positioning : DGPS

➔ Use a fixed receiver A at a known position

➔Transmit in real time differential corrections to receivers B.





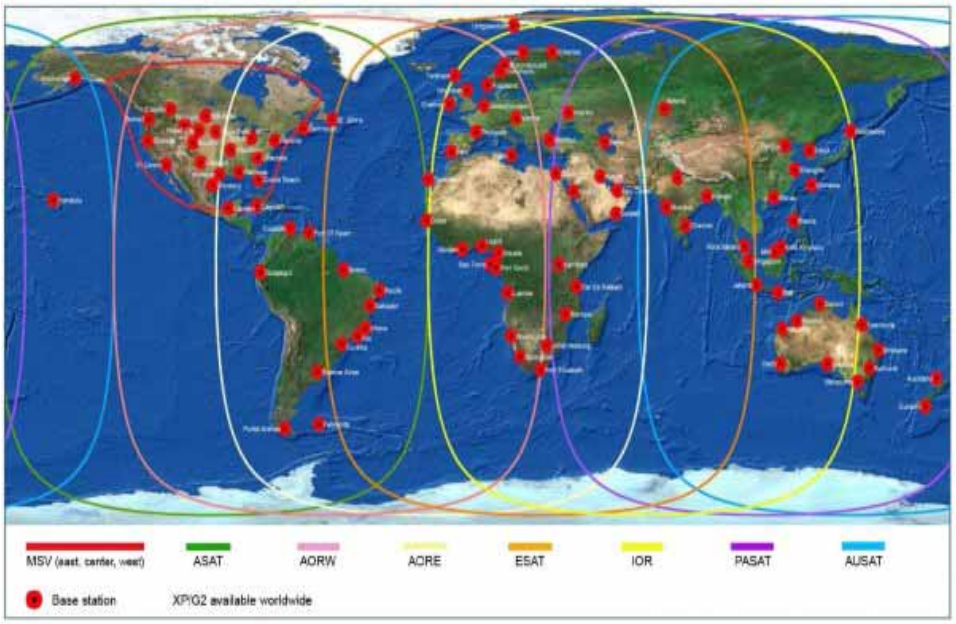
A : Reference Point

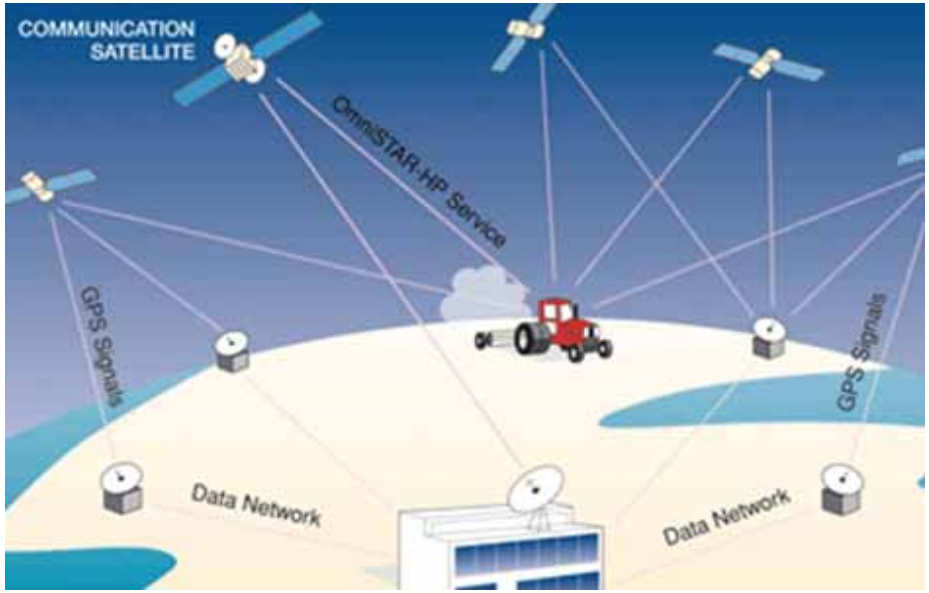
Position known

Unknown position

single-frequency receiver with usign C/A-code

DGPS by Omnistar system

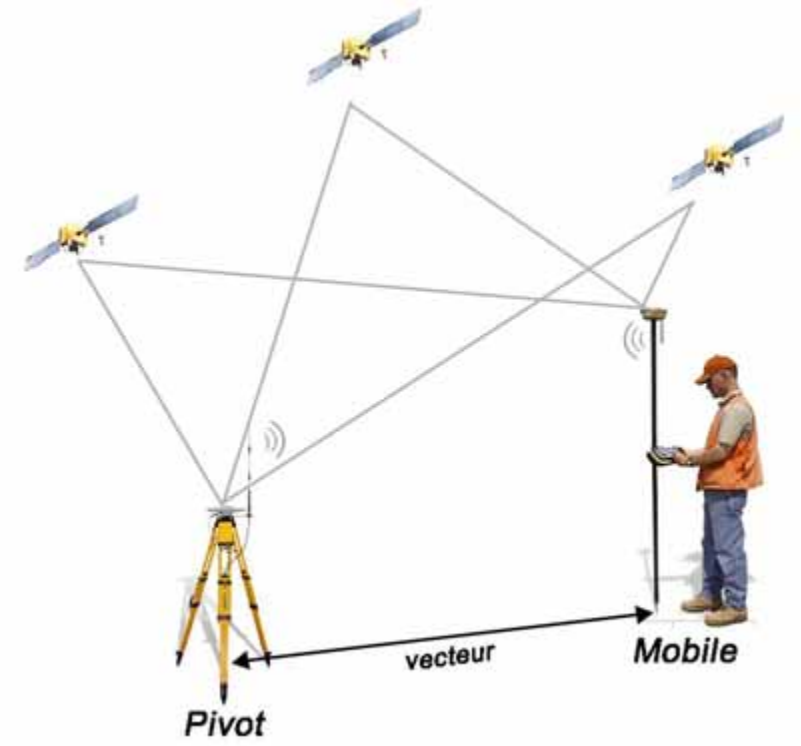




Corrections sent by 8 geostationnary satellites

(DGPS positioning at dm level : for agriculture etc)

Real Time Kinematic (RTK cm)

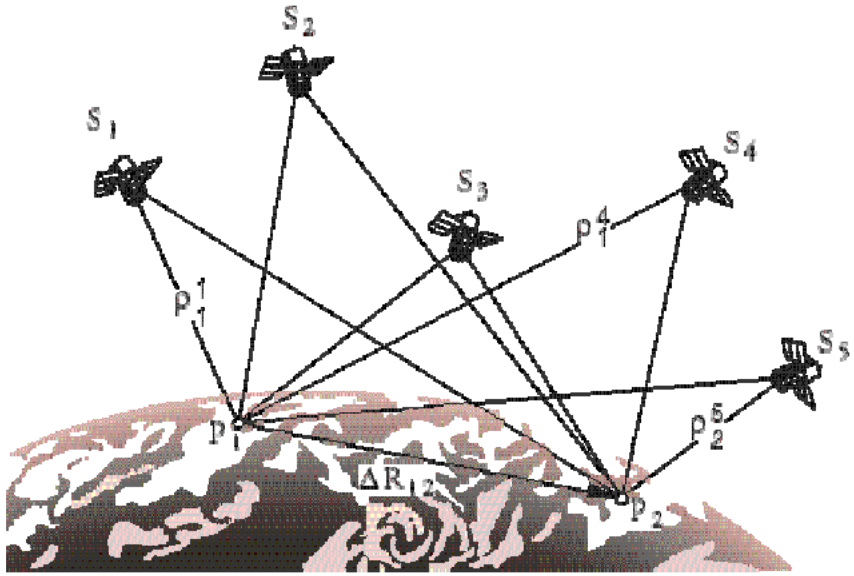


Base and **Rover/or Mobile**

Data sent by radio or phone

➔ precision Hz 1-2 cm, Vertical 3-5 cm

Relative GPS positioning



- 2 static GPS receivers
- Post-processing

➔ Accuracy on the baseline length: few mm to few cm.

Different modes of GPS positioning

- Absolute / relative positioning (DGPS, RTK, network)
- Real-time positioning (base + UHF radio or GSM or geostationnary satellites) / post-processing
- Static / kinematic positioning
- ➔ 8 possible « combinations »

GPS field measurements

- Relative positioning
- Post-processing
- Static positioning

- ➔ Equipment:
- Trimble 5700 receiver
- Controller
- GPS antenna