Satellite geometry in single-GNSS and multi-GNSS scenarios

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GPS/GLONASS/Galileo constellations

- Ground tracks and their repetition rates
- Observing satellites by a typical global tracking network
- Sky plots and their repetition rates
- Number of observable satellites
- PDOP and its spectra
**GPS constellation**

**Orbital elements for GPS satellites**

- Semi-major axis: \( a \approx 26,560 \text{ km} \)
- Eccentricity: \( e \approx 0 \) (circular orbit)
- Inclination: \( i \approx 55^\circ \)

**Orbital planes**

- Number of planes: 6 plane at \( \Omega_n = \Omega_0 + n \cdot 60^\circ \)
- Satellites per plane: 4 irregularly distributed
  \[ = 24 \text{ nominal constellation (currently 32 active)} \]

**Repetition rates**

- Revolution period: 11 h 58min
- Repetition of the constellation: 1 sidereal day
- Repetition of the geometry: 23 h 56min 1 sidereal day

Repetition of the constellation means that the same satellite has to be over the same position of the Earth.
GPS constellation

GPS constellation (19–May–2012)

- BLOCK IIA
- BLOCK IIF
- BLOCK IIR–A
- BLOCK IIR–B
- BLOCK IIR–M

Ascending Node in deg.

Argument of Latitude in deg.
Ground track for G06 for 1 day (30-Mar-2012)
GPS constellation

Ground track for G06 for 10 days (30-Mar-2012 to 08-Apr-2012)
Ground track for all GPS satellites for 10 days (30-Mar-2012 to 08-Apr-2012)
GLONASS constellation

Orbital elements for GLONASS satellites
Semi-major axis: \( a \approx 25,510 \) km
Eccentricity: \( e \approx 0 \) (circular orbit)
Inclination: \( i \approx 65^\circ \)

Orbital planes
Number of planes: 3 plane at \( \Omega_n = \Omega_0 + n\cdot120^\circ \)
Satellites per plane: 8 regularly distributed
= 24 nominal constellation (currently 24 active)

Repetition rates
Revolution period: 11 h 16min
Repetition of the constellation: 8 sidereal day
Repetition of the geometry: 1/3 sidereal day with the next plane
1 sidereal day with the same plane
GLONASS constellation

GLONASS constellation (19–May–2012)
GLONASS constellation

Ground track for R04 for 1 day (30-Mar-2012)
GLONASS constellation

Ground track for R04 for 10 days (30-Mar-2012 to 08-Apr-2012)
GLONASS constellation

Ground track for R04 for 2 days (30-Mar-2012 to 31-Mar-2012)
GLONASS constellation

Ground track for R04 and R05 for 2 days (30-Mar-2012 to 31-Mar-2012)
GLONASS constellation

Ground track for R01 to R08 for 10 days (30-Mar-2012 to 08-Apr-2012)
Ground track for all GLONASS satellites for 10 days (30-Mar-2012 to 08-Apr-2012)
Galileo constellation

Orbital elements for Galileo satellites
Semi-major axis: \( a \approx 30,000 \text{ km} \)
Eccentricity: \( e \approx 0 \) (circular orbit)
Inclination: \( i \approx 56^\circ \)

Orbital planes
Number of planes: 3 plane at \( \Omega_n = \Omega_0 + n \cdot 120^\circ \)
Satellites per plane: 9 regularly distributed
= 27 nominal constellation

Repetition rates
Revolution period: 13 h 45min
Repetition of the constellation: 10 sidereal day
Repetition of the geometry: 10 sidereal day with the same plane
Galileo constellation

Ascending Node in deg. vs. Argument of Latitude in deg.

Fictive Galileo constellation

- GALILEO
Galileo constellation

Ground track for E04 for 1 day (fictive constellation)
Galileo constellation

Ground track for E04 for 2 days (fictive constellation)
Galileo constellation

Ground track for E04 for 10 days (fictive constellation)
Galileo constellation

Ground track for E04 and E05 for 2 days (fictive constellation)
Galileo constellation

Ground track for E01 to E09 for 2 days (fictive constellation)
Galileo constellation

Ground track for E01 to E09 for 10 days (fictive constellation)
Galileo constellation

Ground track for all Galileo satellites for 10 days (fictive constellation)
Global tracking network

250 IGS stations (assuming that all stations observe all available satellites)
Number of observations per satellite

1 day (30-Mar-2012)
Number of observations per satellite

3 days (30-Mar to 01-Apr-2012)
Number of observations per satellite

1 day (30-Mar-2012)
Number of observations per satellite

8 days (30-Mar to 06-Apr-2012)
Number of observations per satellite

10 days (30-Mar to 08-Apr-2012)

GPS Satellites

GLONASS Satellites

GALILEO Satellites
Satellite visibility: GPS

Sky plots for G06 for 1 day (30-Mar-2012)

Zimmerwald (Switzerland)
mid-latitude

Algonquin (Canada)
mid-latitude

Amundson-Scott (South pole)
pole

Malindi (Kenya)
equator
Satellite visibility: GPS

Sky plots for G06 for 10 days (30-Mar-2012 to 08-Apr-2012)

Zimmerwald (Switzerland) mid-latitude

Algonquin (Canada) mid-latitude

Amundson-Scott (South pole) pole

Malindi (Kenya) equator
Satellite visibility: GPS

Zimmerwald
(Switzerland)
mid-latitude

Algonquin
(Canada)
mid-latitude

Amundson-Scott
(South pole)
pole

Malindi
(Kenya)
equator

Sky plots for all GPS satellites for 10 days (30-Mar-2012 to 08-Apr-2012)
Satellite visibility: GLONASS

Zimmerwald
(Switzerland)
mid-latitude

Algonquin
(Canada)
mid-latitude

Amundson-Scott
(South pole)
pole

Malindi
(Kenya)
equator

Sky plots for R04 for 1 day (30-Mar-2012)
Satellite visibility: GLONASS

Zimmerwald (Switzerland) mid-latitude

Amundson-Scott (South pole) pole

Algonquin (Canada) mid-latitude

Malindi (Kenya) equator

Sky plots for R04 for 10 days (30-Mar-2012 to 08-Apr-2012)
Satellite visibility: GLONASS

Sky plots for all GLONASS satellites for 10 days (30-Mar-2012 to 08-Apr-2012)

Zimmerwald (Switzerland) mid-latitude

Algonquin (Canada) mid-latitude

Amundson-Scott (South pole) pole

Malindi (Kenya) equator
Satellite visibility: Galileo

Zimmerwald (Switzerland) mid-latitude

Algonquin (Canada) mid-latitude

Amundson-Scott (South pole) pole

Malindi (Kenya) equator

Sky plots for E06 for 1 day (fictive constellation)
Satellite visibility: Galileo

- Zimmerwald (Switzerland) mid-latitude
- Algonquin (Canada) mid-latitude
- Amundson-Scott (South pole) pole
- Malindi (Kenya) equator

Sky plots for E06 for 10 days (fictive constellation)
Satellite visibility: Galileo

Zimmerwald (Switzerland) mid-latitude

Algonquin (Canada) mid-latitude

Amundson-Scott (South pole) pole

Malindi (Kenya) equator

Sky plots for all Galileo satellites for 10 days (fictive constellation)
Sky plot for all GPS satellites for 1 day (30-Mar-2012)

Zimmerwald, Switzerland
mid-latitude

Elevation
Percent of Observations

Histogram for elevation and azimuth
Histogram for elevation and azimuth

Sky plot for all GPS satellites for 1 day (30-Mar-2012)
Histogram for elevation and azimuth

Zimmerwald, Switzerland
mid-latitude

Sky plot for all GLONASS satellites for 1 day (30-Mar-2012)
Histogram for elevation and azimuth

Zimmerwald, Switzerland
mid-latITUDE

Sky plot for all GLONASS satellites for 1 day (30-Mar-2012)
Histogram for elevation and azimuth

Sky plot for all GPS satellites for 1 day (30-Mar-2012)

Malindi, Kenya
equator
Histogram for elevation and azimuth

Sky plot for all GPS satellites for 1 day (30-Mar-2012)

Malindi, Kenya
equator
Histogram for elevation and azimuth

Amundson-Scott, South pole

Sky plot for all GPS satellites for 1 day (30-Mar-2012)
Histogram for elevation and azimuth

Amundson-Scott, South pole pole

Sky plot for all GLONASS satellites for 1 day (30-Mar-2012)
Histogram for elevation and azimuth

Amundson-Scott, South pole

Sky plot for all GPS satellites for 1 day (30-Mar-2012)
Histogram for elevation and azimuth

Amundson-Scott, South pole

Sky plot for all GLONASS satellites for 1 day (30-Mar-2012)
Number of satellites in view for Zimmerwald

Based on 10 days in May 2012
Number of satellites in view for Zimmerwald

Based on 10 days in May 2012
Number of satellites in view for Zimmerwald

Based on 10 days in May 2012
Number of satellites in view for Zimmerwald

Based on 10 days in May 2012
Number of satellites in view for Zimmerwald

Based on 10 days in May 2012
PDOP: Position Dilution of Precision

- PDOP values indicate how good a station position can be determined with the current satellite geometry.

- It is computed from the reciprocal of the normalized volume of the body formed by all tracked satellites and the receiver position.

- The PDOP can be extracted from the trace of the cofactor matrix:

  \[ C_{YY} = \begin{bmatrix} q_{XX} & q_{XY} & q_{XZ} \\ q_{YX} & q_{YY} & q_{YZ} \\ q_{ZX} & q_{ZY} & q_{ZZ} \end{bmatrix} \]

  \[ \text{PDOP} = \sqrt{q_{XX} + q_{YY} + q_{ZZ}} \]

- The smaller the PDOP value is, the better a position can be derived.
PDOP for Zimmerwald

Computed based on 10 days in May 2012
**PDOP for Zimmerwald**

Computed based on 10 days in May 2012
PDOP for Zimmerwald

Computed based on 10 days in May 2012
PDOP for Zimmerwald

Computed based on 10 days (fictive constellation)
PDOP for Zimmerwald

Computed based on 10 days in May 2012
Spectral analysis of the PDOP for Zimmerwald

Computed based on 60 days in April/May 2012
Spectral analysis of the PDOP for Zimmerwald

Computed based on 60 days in April/May 2012
Spectral analysis of the PDOP for Zimmerwald

Computed based on 60 days in April/May 2012
Spectral analysis of the PDOP for Zimmerwald

Computed based on 60 days in April/May 2012
Spectral analysis of the PDOP for Zimmerwald

Computed based on 60 days (fictive constellation)
Spectral analysis of the PDOP for Zimmerwald

Computed based on 60 days in April/May 2012
Spectral analysis of the PDOP for Zimmerwald

Computed based on 60 days in April/May 2012