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# 3G+C antenna in the Galileo Monitoring network

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International Federation of Surveyors
Fédération Internationale des Géomètres
Internationale Vereiningung der Vermessungsingenieure

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## Overview

- Status of Galileo
- Ground Segment
- Galileo Monitoring Stations
- Selection of GNSS Antennas
- Measurements
- Conclusion

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## Status of Galileo

First plan: full operable system in 2008
The public private partnership between EU and the Industry doesn't work
Giove A starts in 2007 and Giove B in 2008
Giove B with a hydrogen passive maser clock



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## In orbit validation (IOV)

Two satellites launched in 2011 and two satellites 2012
Main contractors EADS Astirum and OHB
first Galileo Position 12.03.2013
The two Ground control center in Oberpfaffenhofen, Germany and in Fucino, Italy works

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## Next steps for Galileo

OHB has the order to build 22 Galileo Satellites and EADS Astrium 4 more Satellites

Next launches:

- July – Galileo-FOC (2 sats) – Soyuz-STB/Fregat-MT (VS06) (or late Summer)
- late August-September – Galileo-FOC (2 sats) – Soyuz-STB/Fregat-MT (VS08)

Full operable in 2015 is the plan



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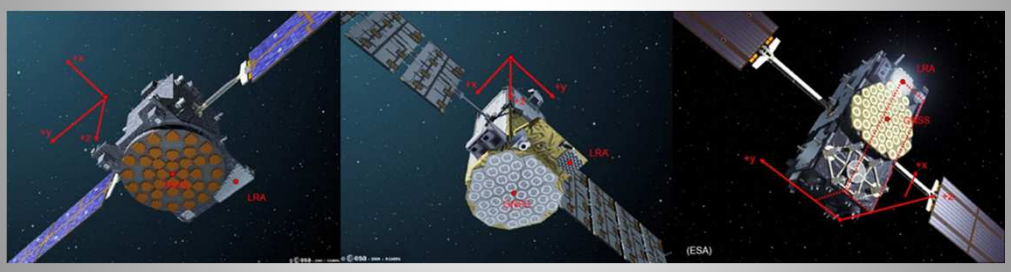
| Parameter | GIOVE-A | GIOVE-B | IOV | OHC |
|---|---|---|---|---|
| Launch mass | 602 kg | 530 kg | 700 kg | 733 kg |
| Dry mass | 550 kg | 502 kg | 640 kg | 680 kg |
| Body size | 1.3 m x 1.8 m x 1.65 m | 0.95 m x 0.95 m x 2.4 m | 2.74 m x 1.58 m x 1.59 m | 2.5 m x 1.2 m x 1.1 m |
| Solar array size | 2 x 2 x 1.74 m x 0.98 m | 2 x 4 x 1.5 m x 0.8 m | 2 x 2 x ~3 m x ~1 m | 2 x 2 x 2.5 m x 1.1 m |
| Span width | ~10 m | ~10 m | 14.5 m | 14.8 m |
| Cross section | 9 $m^2$ | 12 $m^2$ | n/a | n/a |
| SRP acceleration | 99 $nm/s^2$ | 151 $nm/s^2$ | 113 $nm/s^2$ | n/a |

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## Ground Segment

| | GPS | Galileo |
|---|---|---|
| Sensor Station | 6 | 40 (GSS) |
| Uplink Station | 3 | 9 (ULS) |
| TTC Stations | - | 5 (TTC) |
| Control Center | 1 | 2 (GCC) |

Sensor Stations: orbit determination and time synchronization
Uplink Stations: send navigation and integrity signals
TTC* Stations: 13 m antenna dish for telematics and remote control

*TTC - Telemetry, Tracking and Command



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## Galileo Monitoring Stations

The ESA plan to build up Galileo Monitoring Stations
Two reference stations and three rovers for every country in the EU
For these Job they need special receivers and very good commercial GNSS antennas
The receivers come from IFEN, Germany

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## Selection of GNSS Antennas


Trimble Zephyr Geodetic II  Leica AR10  navXperience 3G+C



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## Compare the technical data

| | Zephyr Geod. II | AR10 | 3G+C |
|---|---|---|---|
| **Tracking all signals** | **Yes** | **Yes** | **Yes** |
| **Minimum phase v.** | **Yes** | **Yes** | **Yes** |
| **Polarization** | **RHCP** | **RHCP** | **RHCP** |
| **Power** | **3.5 to 20 V** | **3.3 to 12 V** | **3.3 to 20 V** |
| **Antenna gain** | **50 dB** | **29 dB** | **29 dB the 3G+C**<br>**42 dB the 3G+C marine**<br>**48 dB the 3G+C reference** |
| **Axial Ratio (Zenit)** | **2 dB** | **1.4 dB** | **3 dB** |
| **Vibration rating** | **MIL-STD 810f** | **ISO9022-3** | **MIL-STD 810f** |
| **Weight** | **1.36 kg** | **1.12 kg** | **0.38 kg** |

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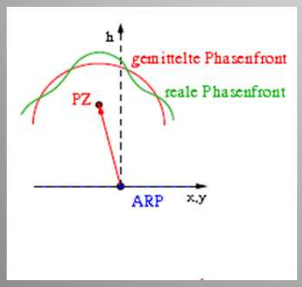
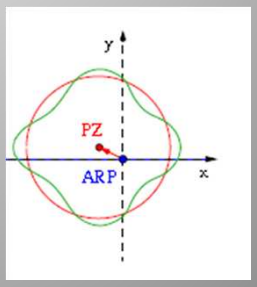
## Phase Center Variations (PCV)

**The Phase Center from a antenna change in dependence of the azimuth and the elevation angle**



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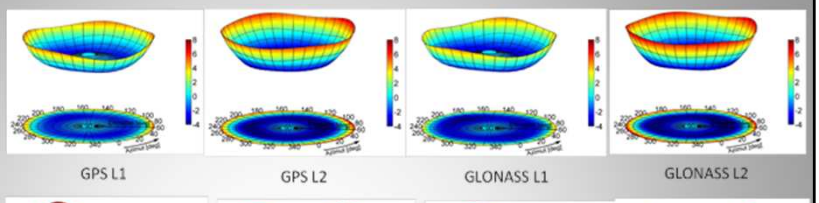
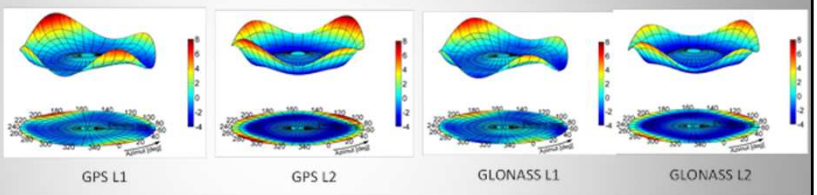
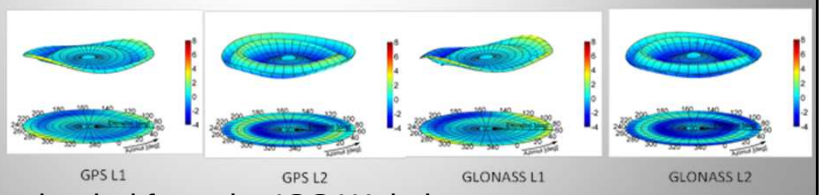
Zephyr Geo. II




AR 10




3G+C




Measured by Geo++, downloaded from the IGS Website

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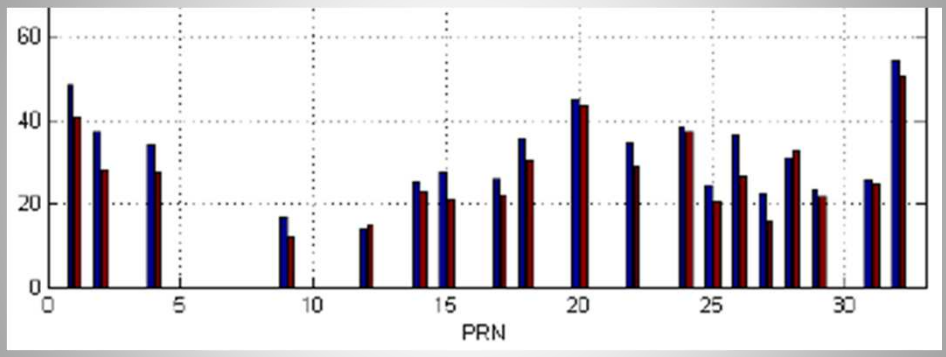
## Compare the signal to noise ratio (s/n)




Red – Trimble axial ratio 2 db, gain 50 db
Blue – navXperience axial ratio 3 db, gain 29 db



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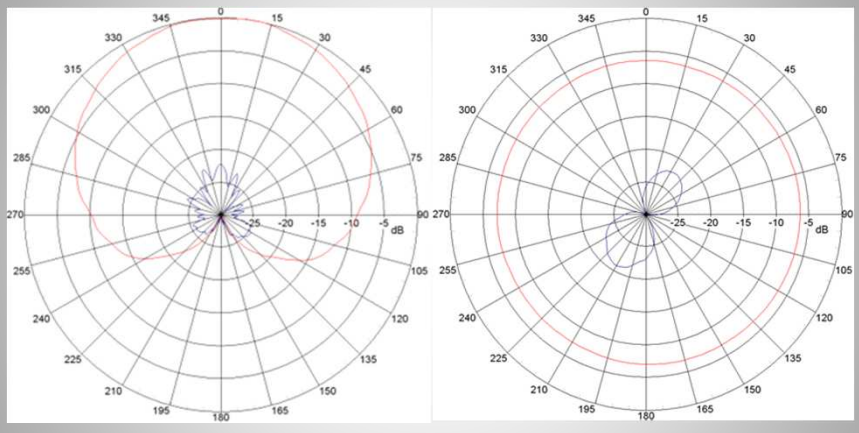
## Antenna Pattern from the 3G+C




Vertical slice horizontal slice

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## Group Delay Phase Variations

In theoretical you have no group delay (time shift) when the frequency of the signal doesn't change.
In practice you have a time shift when the same signal come from different directions.
The Group Delay is in depend of the azimuth and elevation angle.



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## Group Delay Phase Variations

We promised the ESA that our 3G+C GNSS antenna have maximum group delay close to 1 ns.
The light speed is 300.000 km/s.
The distance of the signal (light speed) in 1 ns is 0.3 m (300 mm)
In April the Geo++ Company get the order to make the measurement for the Group Delay Variations

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## Results of Group Delay measurements

90° 85° 80° 75° 70° 65° 60° 55° 50°

G02 START OF FREQUENCY

+8.68 +0.55 +129.95 NORTH / EAST / UP

| NOAZI | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | +0.00 | -0.88 | -3.33 | -6.88 | -10.99 | -15.35 | -19.86 | -24.53 | -29.08 |
| 0.0 | +0.00 | -5.55 | -11.86 | -17.04 | -20.03 | -21.05 | -21.34 | -22.32 | -24.58 |
| 5.0 | +0.00 | -5.50 | -11.93 | -17.40 | -20.71 | -21.92 | -22.25 | -23.30 | -25.91 |
| 10.0 | +0.00 | -5.41 | -11.89 | -17.61 | -21.25 | -22.71 | -23.18 | -24.38 | -27.39 |
| 15.0 | +0.00 | -5.27 | -11.74 | -17.65 | -21.61 | -23.40 | -24.12 | -25.54 | -28.92 |
| 20.0 | +0.00 | -5.08 | -11.48 | -17.53 | -21.81 | -23.99 | -25.06 | -26.77 | -30.43 |
| 25.0 | +0.00 | -4.85 | -11.10 | -17.22 | -21.83 | -24.49 | -26.01 | -28.03 | -31.86 |
| 30.0 | +0.00 | -4.58 | -10.61 | -16.75 | -21.67 | -24.86 | -26.94 | -29.31 | -33.17 |
| 35.0 | +0.00 | -4.26 | -10.02 | -16.10 | -21.31 | -25.08 | -27.80 | -30.56 | -34.36 |
| 40.0 | +0.00 | -3.92 | -9.34 | -15.30 | -20.76 | -25.13 | -28.54 | -31.72 | -35.39 |
| 45.0 | +0.00 | -3.54 | -8.58 | -14.35 | -20.02 | -24.96 | -29.08 | -32.72 | -36.25 |
| 50.0 | +0.00 | -3.14 | -7.75 | -13.28 | -19.07 | -24.54 | -29.36 | -33.48 | -36.92 |
| 55.0 | +0.00 | -2.72 | -6.87 | -12.10 | -17.94 | -23.85 | -29.31 | -33.92 | -37.34 |
| 60.0 | +0.00 | -2.29 | -5.96 | -10.84 | -16.64 | -22.87 | -28.88 | -33.96 | -37.49 |

The unit is mm



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Results of Group Delay measurements

45° 40° 35° 30° 25° 20° 15° 10° 5° 0°

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| -33.82 | -37.80 | -37.21 | -28.89 | -12.25 | +9.50 | +29.56 | +39.32 | +31.24 | +1.62 |
| -35.72 | -40.21 | -40.03 | -31.67 | -14.23 | +9.05 | +30.71 | +40.90 | +30.59 | -5.06 |
| -37.27 | -41.96 | -42.08 | -34.00 | -16.53 | +7.32 | +30.14 | +41.78 | +32.59 | -2.91 |
| -38.40 | -42.93 | -43.17 | -35.60 | -18.83 | +4.65 | +28.12 | +42.05 | +37.10 | +7.61 |
| -39.13 | -43.14 | -43.27 | -36.32 | -20.79 | +1.53 | +25.13 | +41.90 | +43.60 | +24.93 |
| -39.50 | -42.69 | -42.46 | -36.12 | -22.16 | -1.58 | +21.69 | +41.50 | +51.32 | +46.60 |
| -39.60 | -41.77 | -40.97 | -35.10 | -22.78 | -4.22 | +18.35 | +41.01 | +59.29 | +69.64 |
| -39.50 | -40.60 | -39.08 | -33.50 | -22.66 | -6.10 | +15.53 | +40.52 | +66.49 | +90.95 |
| -39.30 | -39.41 | -37.11 | -31.60 | -21.91 | -7.09 | +13.52 | +40.07 | +71.97 | +107.78 |
| -39.03 | -38.38 | -35.38 | -29.74 | -20.75 | -7.22 | +12.41 | +39.58 | +75.03 | +118.05 |
| -38.71 | -37.62 | -34.12 | -28.23 | -19.49 | -6.67 | +12.13 | +38.97 | +75.23 | +120.66 |
| -38.32 | -37.17 | -33.45 | -27.29 | -18.40 | -5.74 | +12.43 | +38.08 | +72.52 | +113.53 |
| -37.79 | -36.97 | -33.36 | -27.03 | -17.73 | -4.77 | +13.01 | +36.78 | +67.19 | +103.61 |
| -37.05 | -36.89 | -33.75 | -27.41 | -17.62 | -4.05 | +13.51 | +35.01 | +59.81 | +86.66 |
| -36.03 | -36.75 | -34.38 | -28.30 | -18.08 | -3.81 | +13.67 | +32.74 | +51.22 | +66.95 |
| -34.69 | -36.38 | -35.00 | -29.44 | -19.03 | -4.15 | +13.31 | +30.08 | +42.32 | +46.91 |
| -33.00 | -35.61 | -35.33 | -30.56 | -20.28 | -5.03 | +12.38 | +27.20 | +34.02 | +28.78 |
| -31.01 | -34.35 | -35.16 | -31.38 | -21.58 | -6.31 | +10.99 | +24.38 | +27.10 | +14.31 |
| -28.80 | -32.59 | -34.38 | -31.70 | -22.70 | -7.76 | +9.36 | +21.89 | +22.11 | +4.56 |
| -26.51 | -30.44 | -32.99 | -31.43 | -23.45 | -9.13 | +7.76 | +20.02 | +19.33 | -0.20 |

The unit is mm

120 mm was the max. ≈ **0.4 ns**

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## Conclusion

A disappointment was the leica AR10 4 wings antenna
The Trimble and the navXperience shows good results in PCV
The 3G+C from navXperience is an excellent antenna with close to perfect PCV and 0.4 ns is a very good result in Group Delay Variations



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Thank you very much for your attention

More information

www.navXperience.com

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