Signal, orbit, and clock analysis of GPS III SV01

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Introduction

- New generation of GPS Block III satellites
  - Improved accuracy
  - Civil L1C signal
  - CNAV-2 navigation message
  - 15-year life time
- First launch on 23 December 2018
- Start of signal transmission on 9 January 2019
  - PRN G04
  - Still set unhealthy due to on-orbit testing

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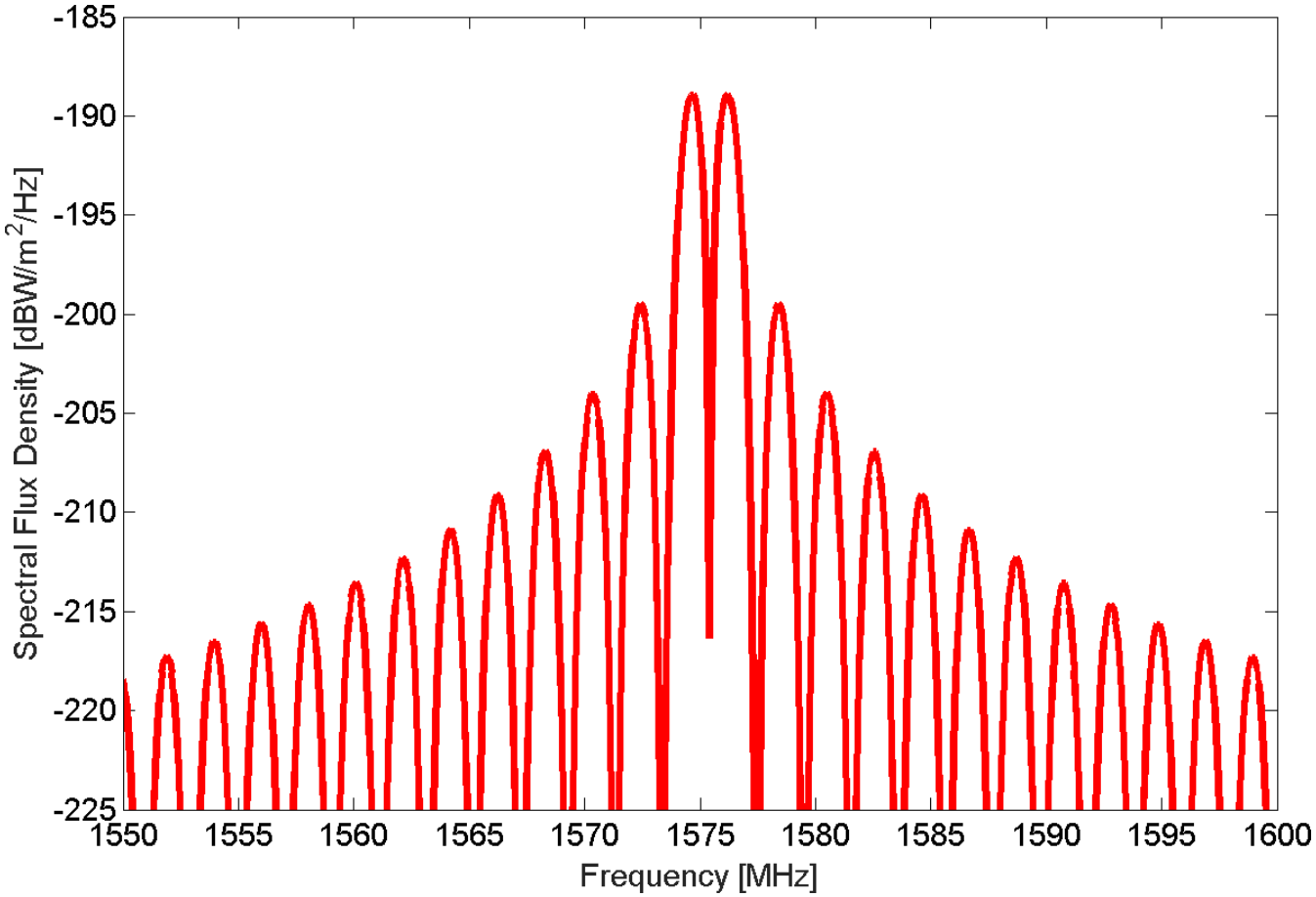
The L1C Signal

- Data and pilot component: power ratio 1:3
- PRN code length: 10,230 chips (10 x C/A)
- Binary Offset Carrier **BOC(1,1)**
- BOC(*n,m*)
  - ***n***: fundamental frequency of the subcarrier in multiples of 1.023 MHz
  - ***m***: chipping rate in multiples of 1.023 megachips per second
- Time-multiplexed BOC (TMBOC) for pilot
  - **BOC(1,1)**



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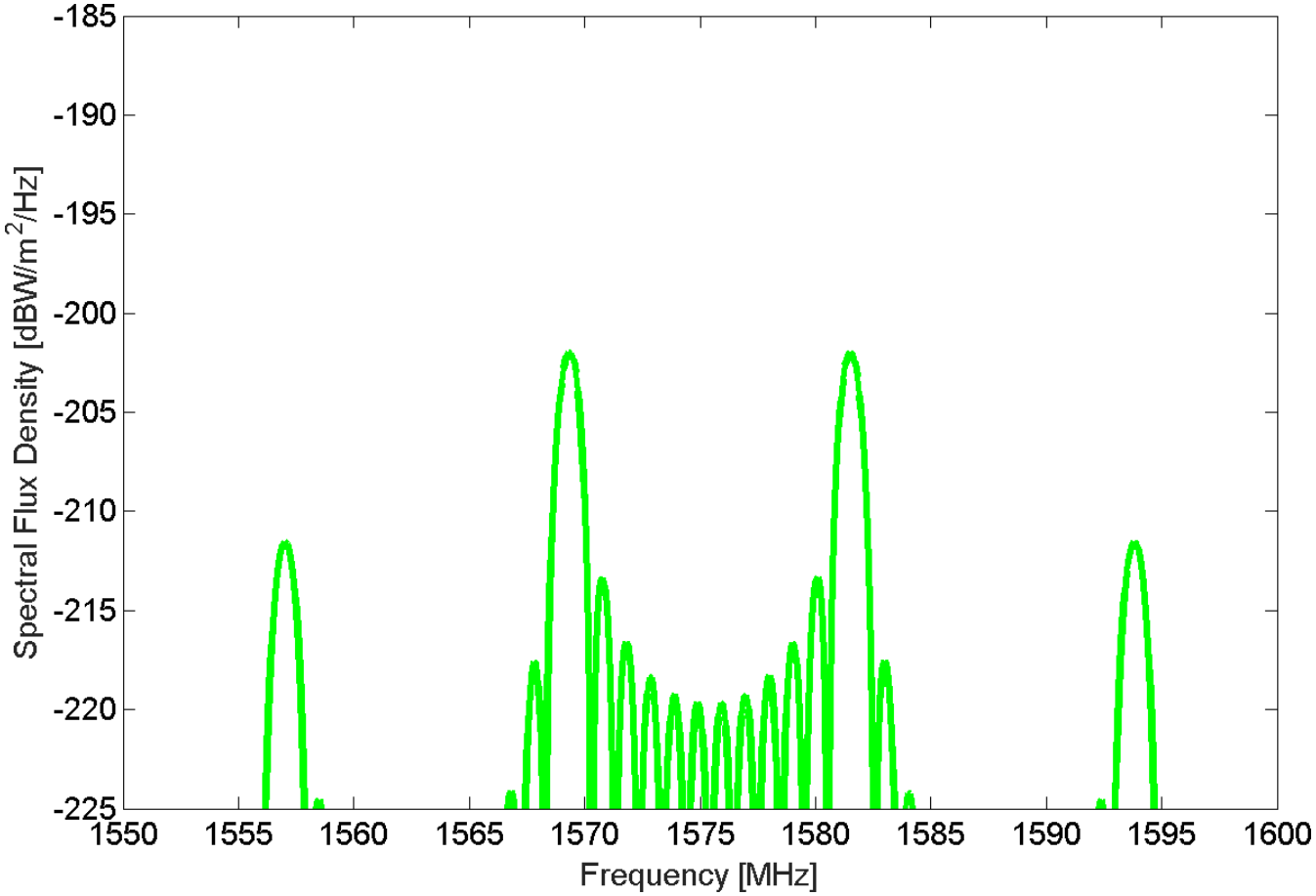
  - **BOC(1,1)**
  - **BOC(6,1)** improved multipath mitigation



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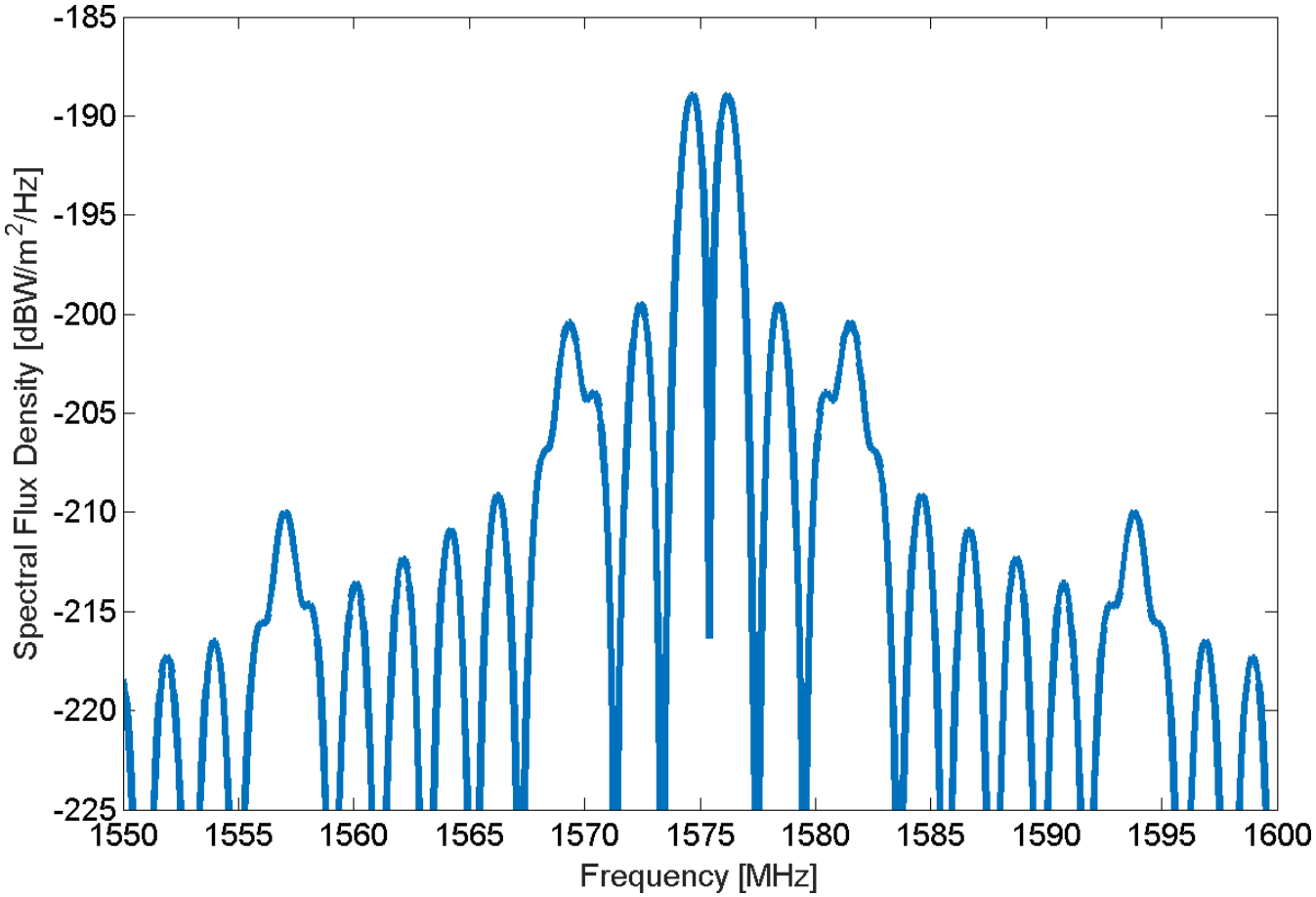
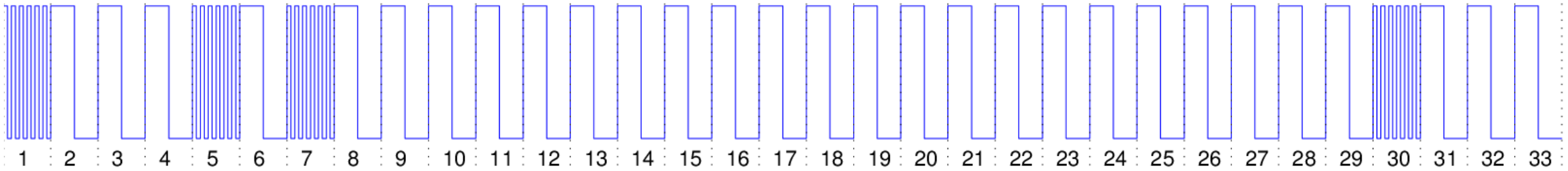
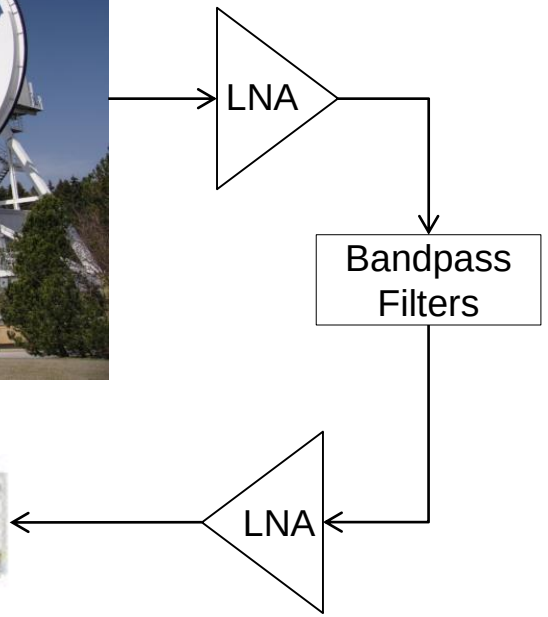


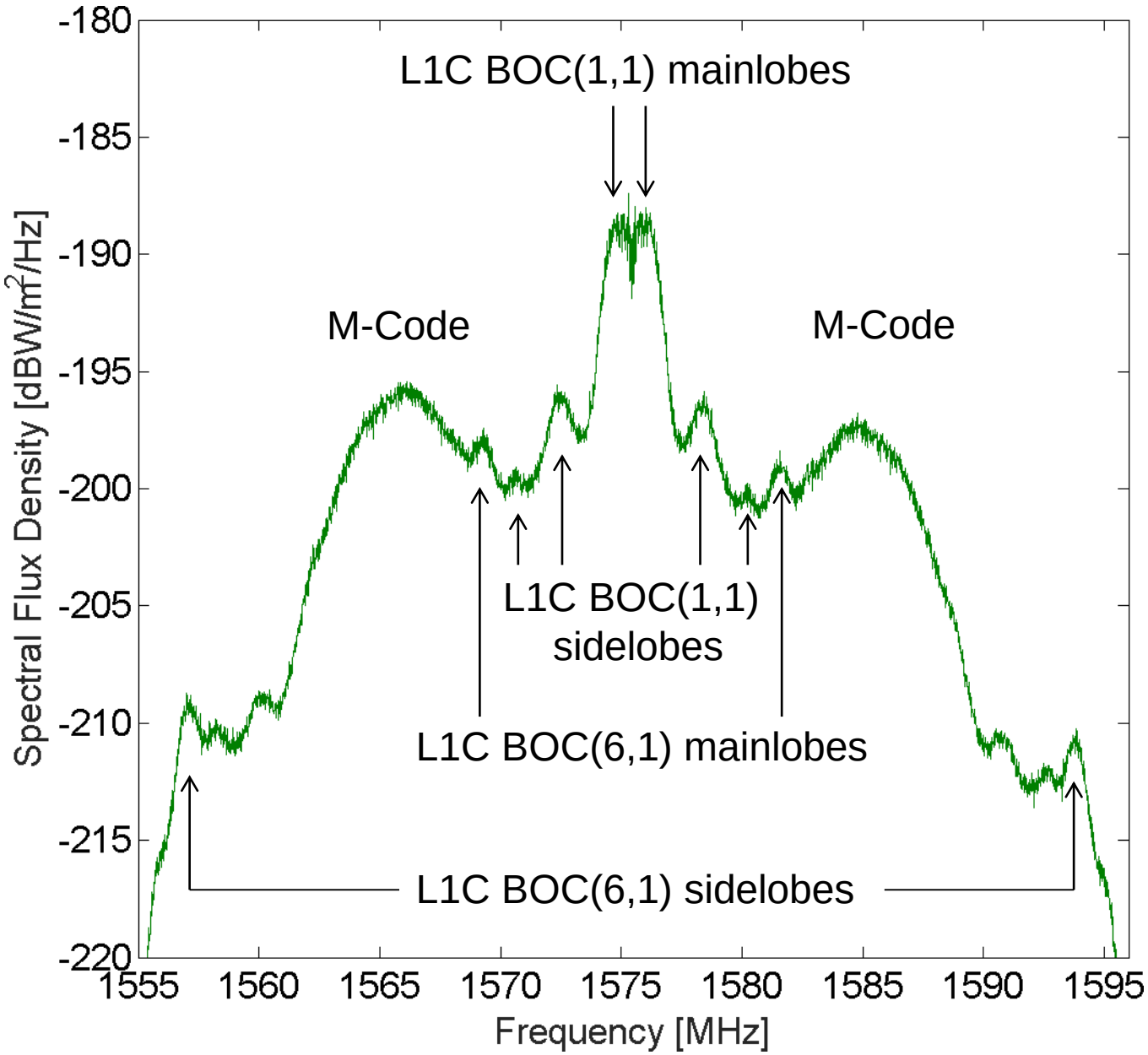


Measured L1 Spectrum

- 30 m high-gain antenna at Weilheim, Germany

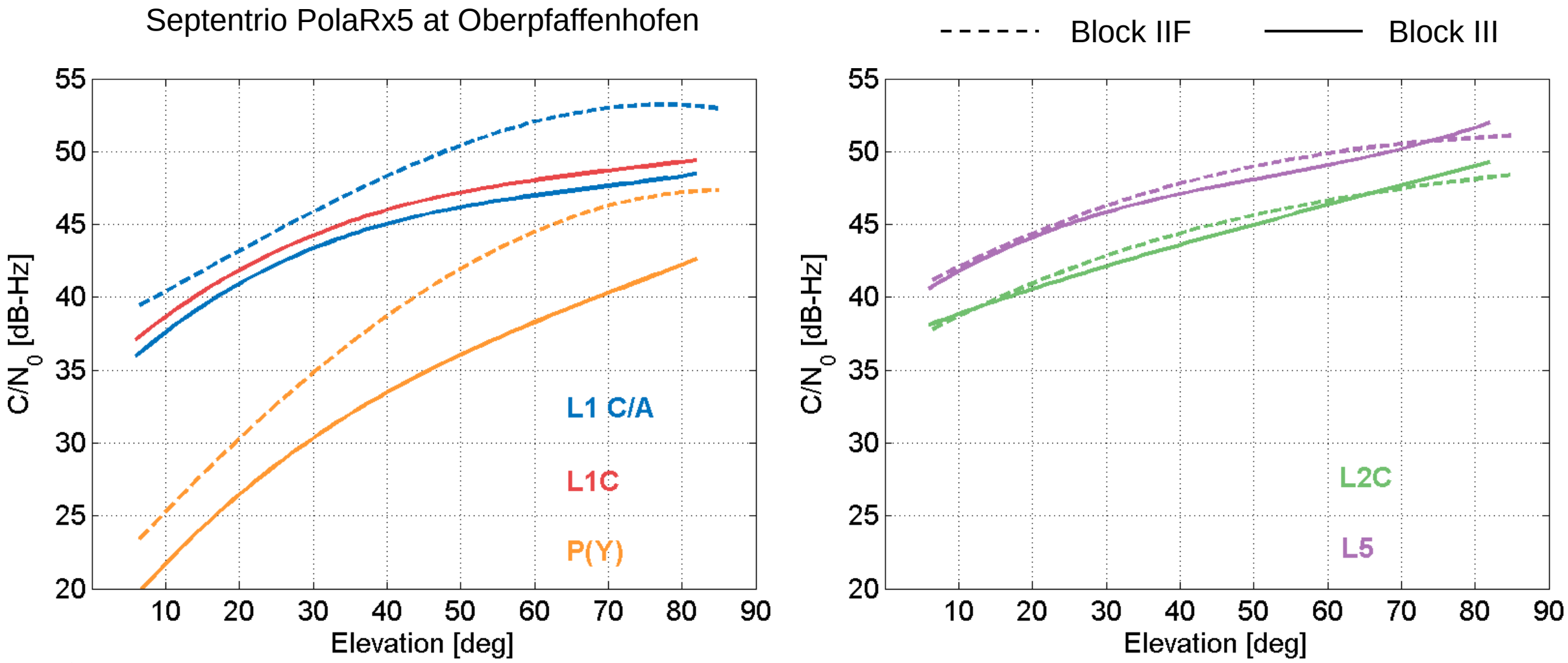
Vector Signal Analyzer



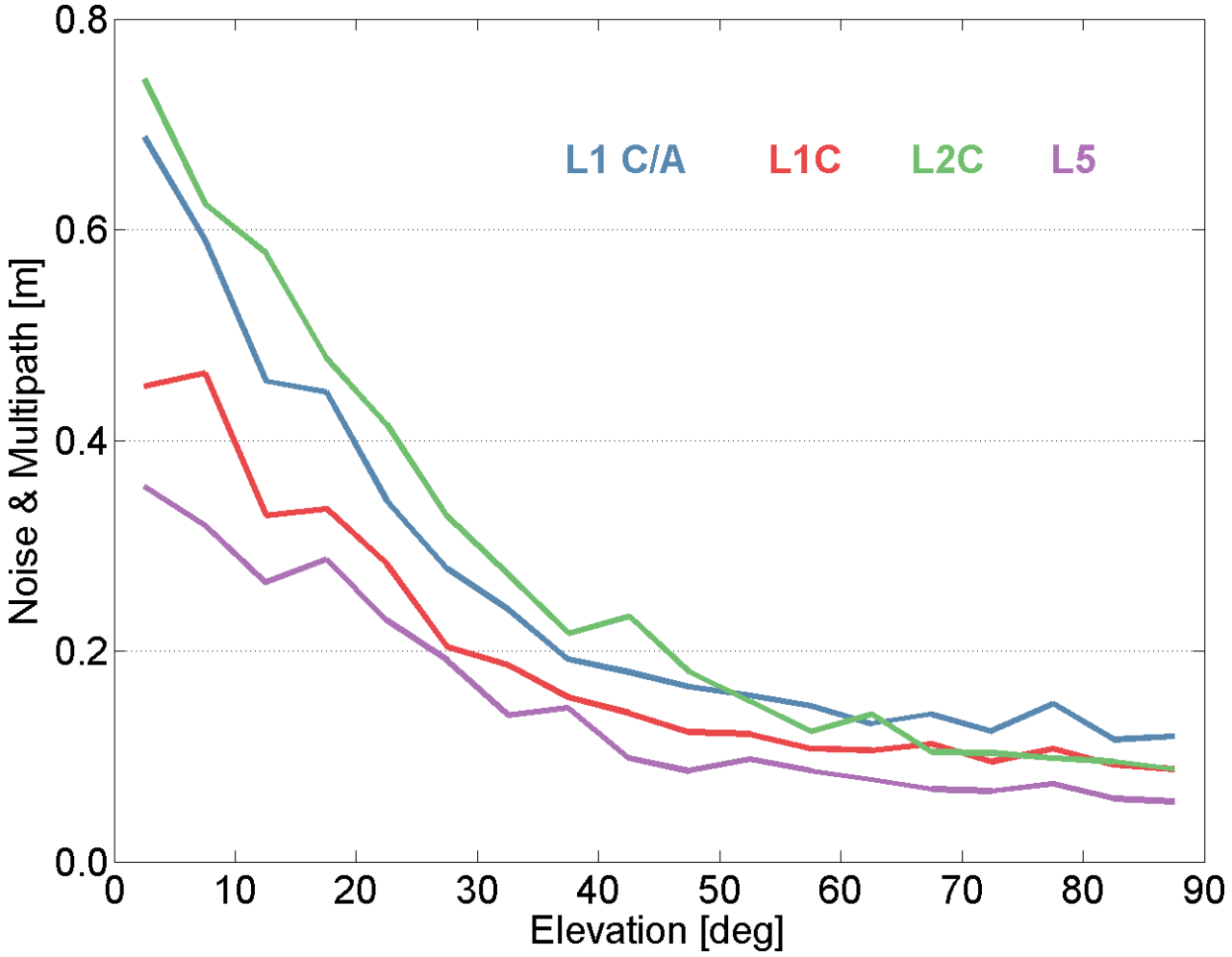


Receiver Tracking: Carrier-to-Noise Density Ratio

Septentrio PolaRx5 at Oberpfaffenhofen



Receiver Tracking: Code Noise and Multipath



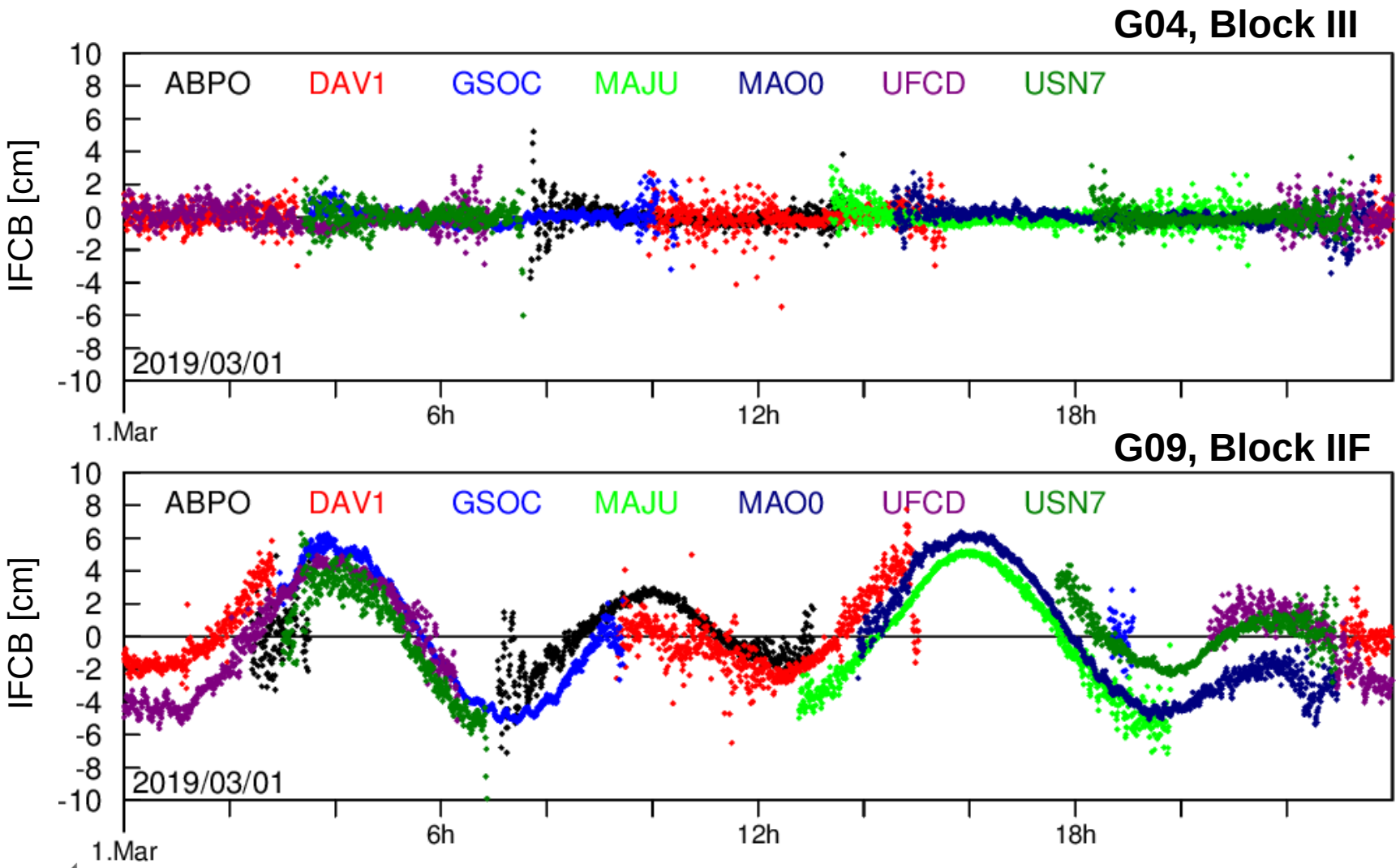
- Multipath combination

$$\mathrm{MP}(p_i, \varphi_i, \varphi_j) = p_i - \varphi_i - 2\frac{f_j^2}{f_i^2 - f_j^2}(\varphi_i - \varphi_j)$$

p_i	pseudorange observations
φ_i, φ_j	carrier phase observations
i, j	frequency index: $i, j = 1, 2, 5$

- RMS in 5 deg elevation bins
- Javad TRE_3 receiver at Potsdam, Germany (POTS00DEU)

Triple-Frequency Carrier Phase Linear Combination



- Ionosphere- and geometry-free linear combination of L1 C/A, L2 P(Y) and L5 I/Q phase observations
- Station-specific bias removed
- Difference of L1/L2 and L1/L5 clocks: Inter-frequency clock bias (IFCB)
- Orbit-periodic IFCB variations for Block IIF up to 20 cm

Montenbruck O., Hugentobler U., Dach R., Steigenberger P., Hauschild, A. (2012). Apparent clock variations of the Block IIF-1 (SVN62) GPS satellite. GPS Solutions 16(3), 303–313. DOI 1007/s10291-011-0232-x

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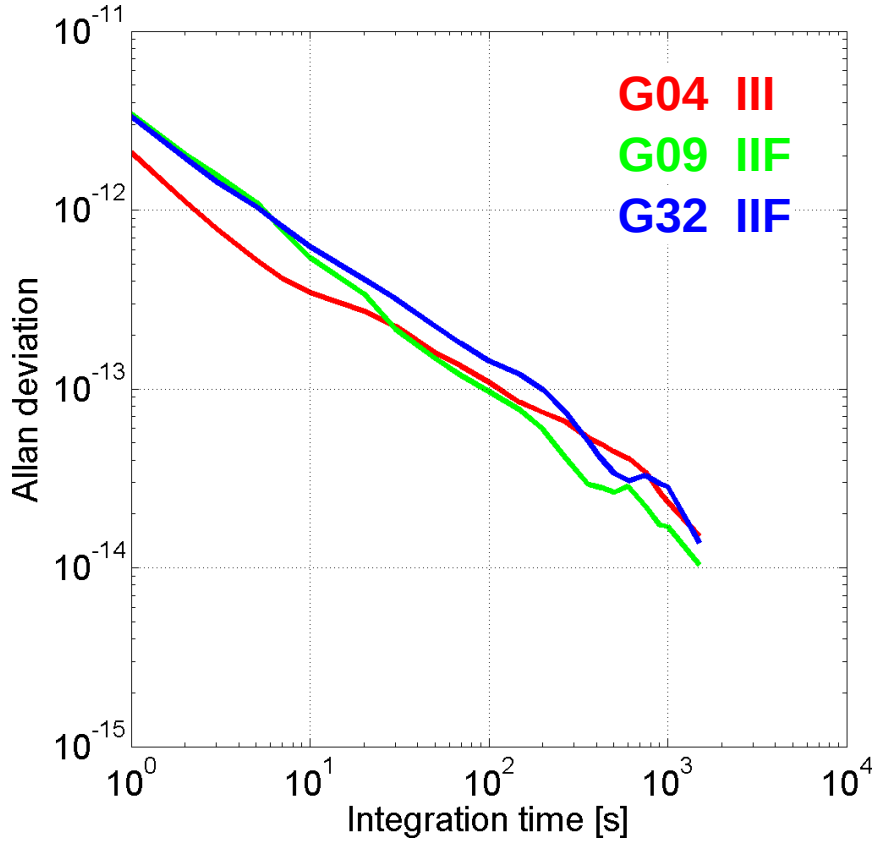
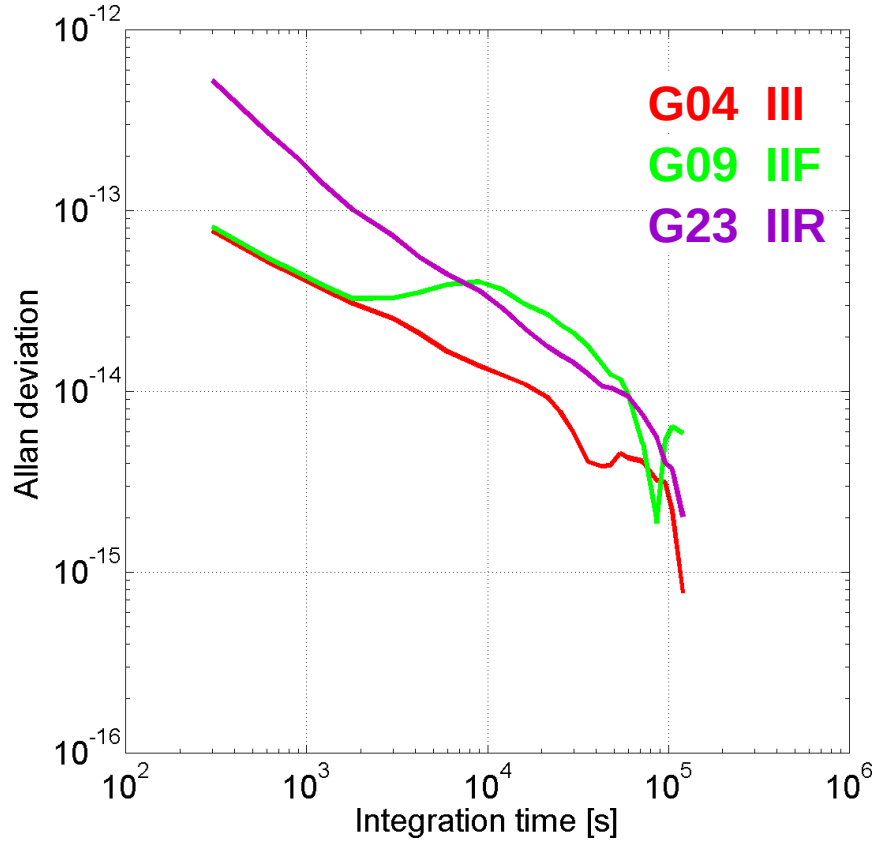
Satellite Clock Performance

One-way Carrier Phase Analysis
Tidbinbilla, Australia

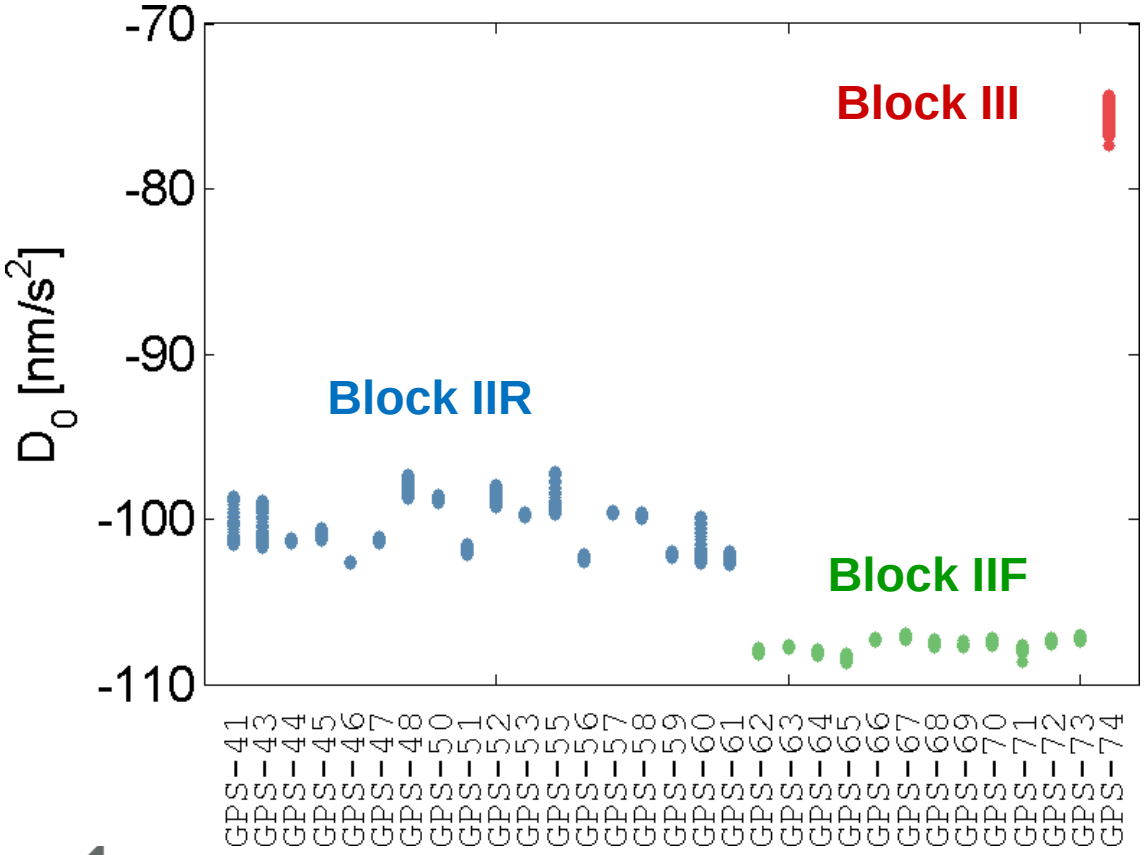


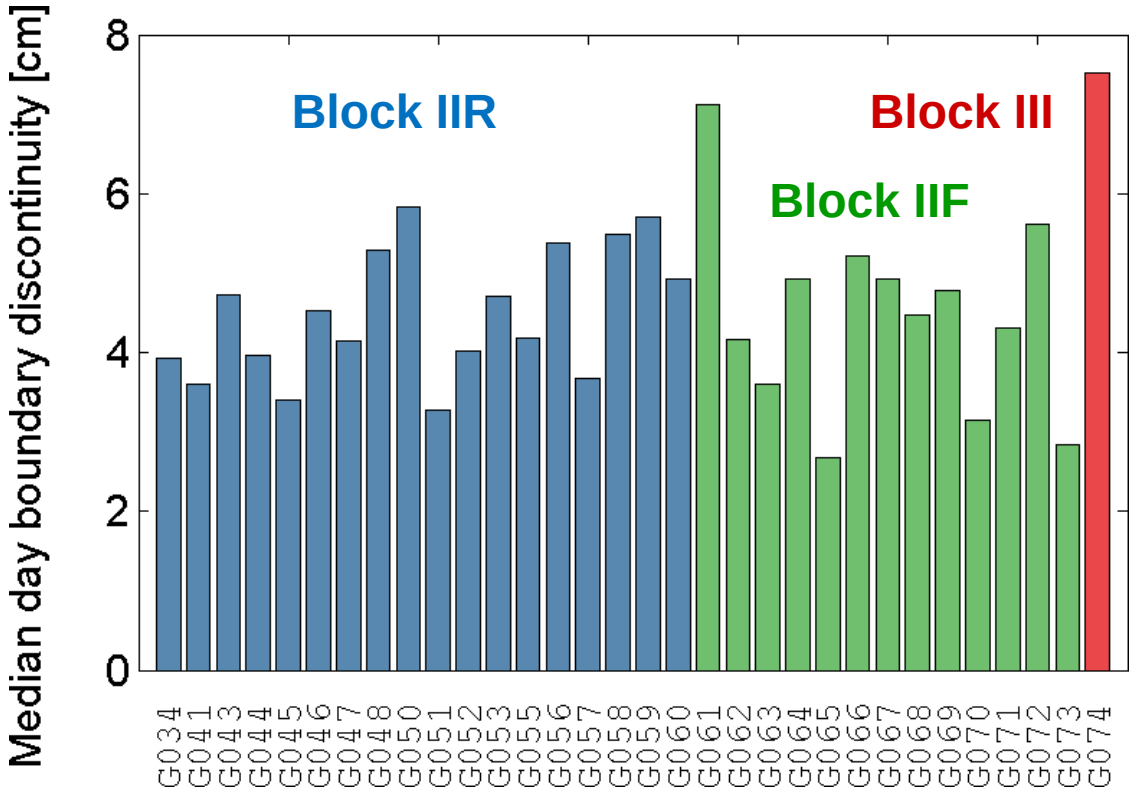
Global GNSS Solution
3-day orbit arc, 5 min clock estimation



Orbit Quality

ECOM-2, estimated direct solar radiation pressure





- 40 % less observations of GPS III compared to other GPS satellites
- Lower ambiguity fixing rate

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Satellite Antenna Offsets

- Public release of manufacturer calibrations
- Adopted for igs14.atx
- Phase center variations from ESA/CODE

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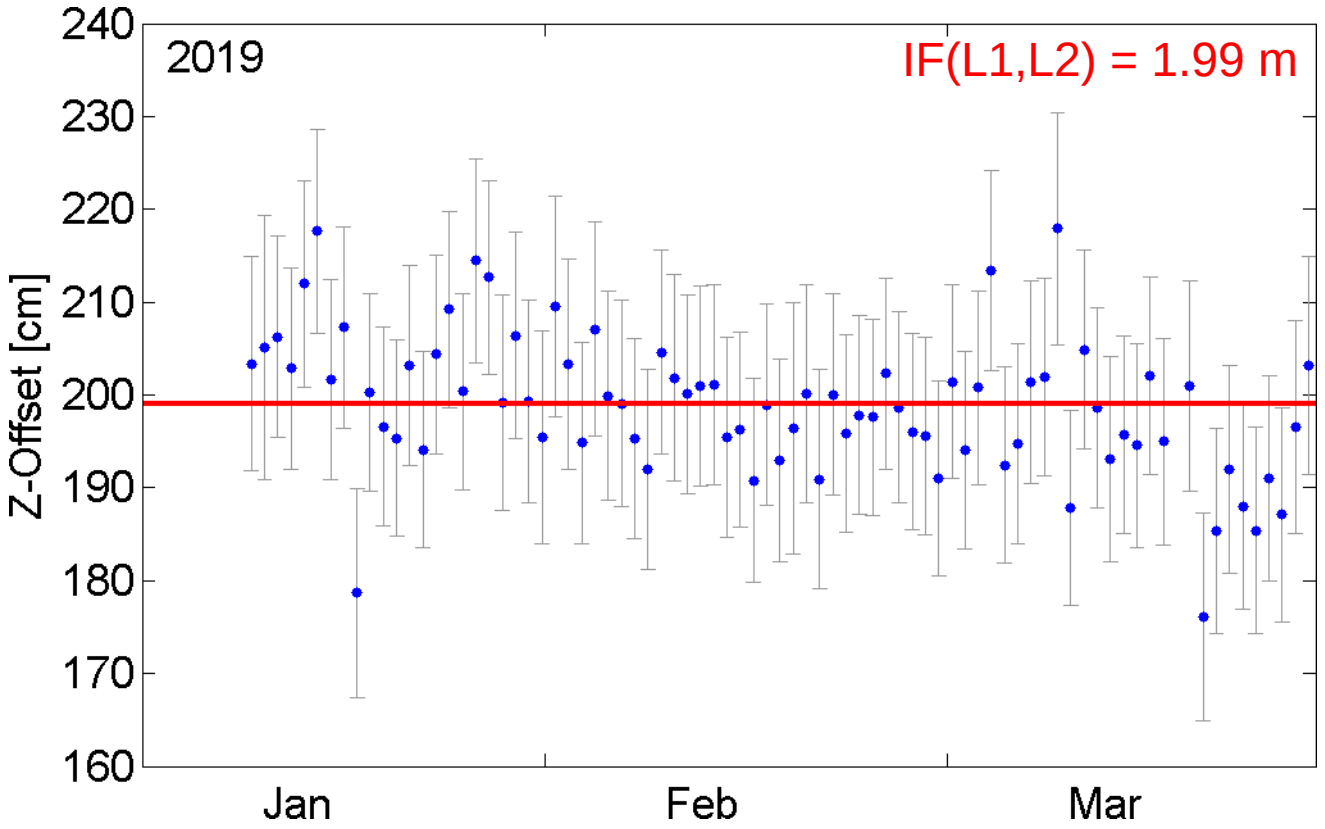
To Whom it May Concern –

The following information has been determined to be unclassified, non-proprietary to Lockheed Martin, and publicly releasable:

1) The following table presents the GPS III SV01 (SVN74) antenna phase center offsets of the L1, L2 and L5 signals for the Earth Coverage (EC) antenna deck. These values are measured with respect to the Space Vehicle center of mass.

	X (inches)	Y (inches)	Z (inches)
L1 freq	0.149	-0.712	48.521
L2 freq	0.122	-0.638	29.152
L5 freq	0.125	-0.641	30.657

Ionosphere-free L1/L2 z-offset estimates



Summary and Outlook

- GPS III SV01 tracked by many IGS stations, **very few stations** providing **L1C** (Javad from GFZ, BKG)
- **Improved noise and multipath characteristics** of L1C compared to L1 C/A
- **No** inter-frequency clock **bias variations** present
- Slightly improved clock performance compared to Block IIF
- Currently slightly worse orbit quality
- **Satellite metadata**:
  - Antenna phase center offsets and inter-signal corrections published
  - Transmit antenna gain pattern needed for transmit power estimation
  - Dimensions, optical properties and mass needed for advanced solar pressure modeling

- Second GPS III launch planned for 25 July 2019
- Another 8 GPS III satellites in production
- GPS III Follow On (GPS IIIF, SV11 – SV32)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