Validation of GPS III antenna patterns

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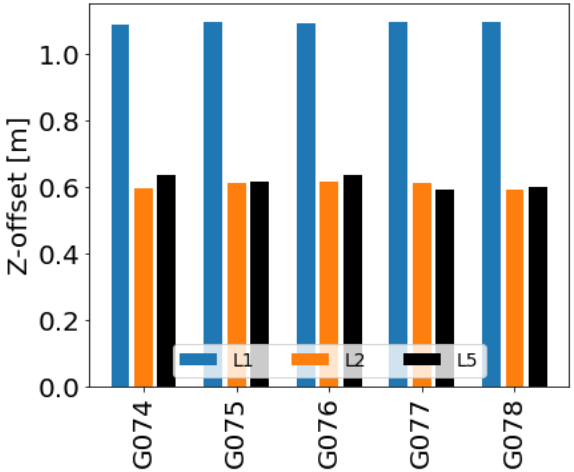
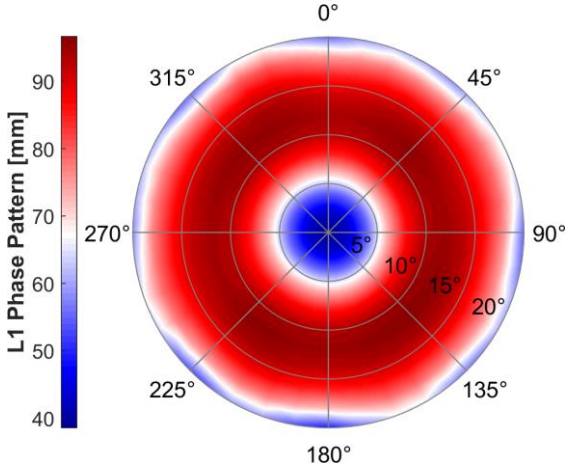
Introduction

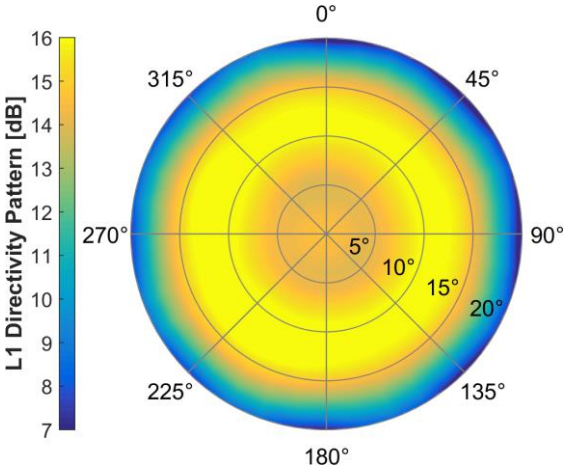
Publication of GPS III satellite metadata by manufacturer Lockheed Martin (LM)



Phase Center Offsets



Phase Patterns



Directivity Patterns

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Phase Center Offsets

PCO estimation with NAPEOS:

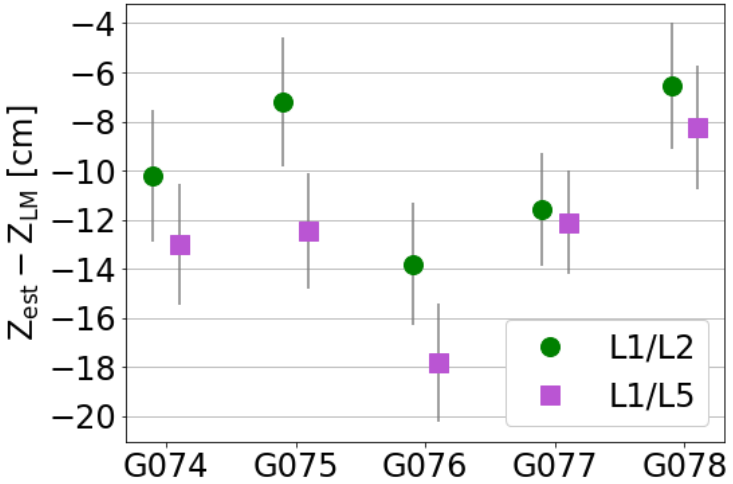
– 140 GPS and Galileo stations with multi-frequency receiver antenna calibrations

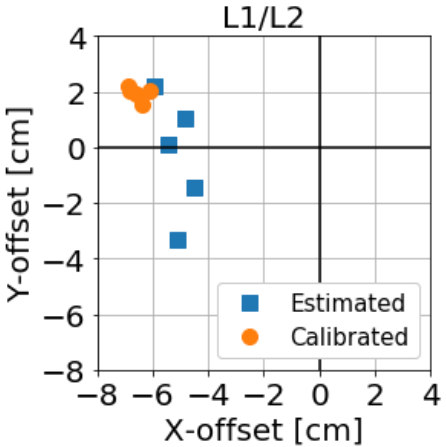
– Ionosphere-free linear combinations of L1/L2 and L1/L5

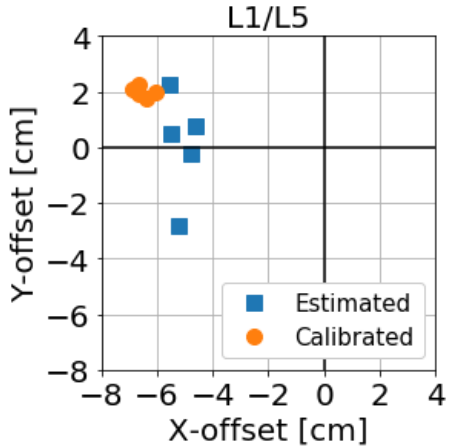
– IGS20 scale fixed

– 14 months of data

GPS III igs20.atx PCOs: LM values shifted by 8.9 cm







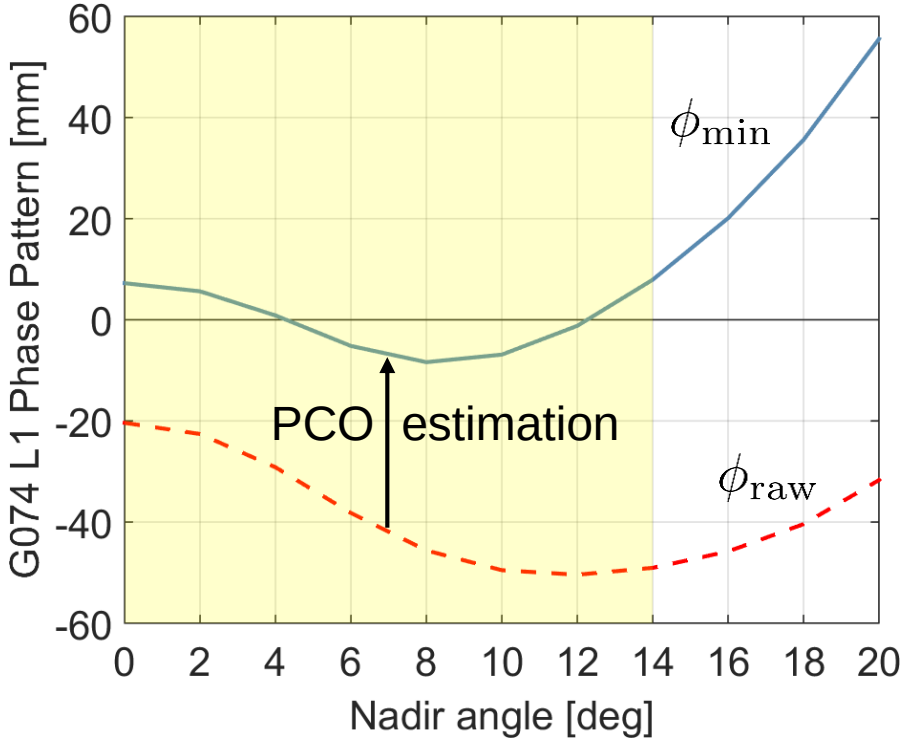
Manufacturer Phase Pattern

– Raw phase pattern ϕ_{raw} w.r.t. unknown calibration reference point for phase calibration

– Estimation of minimized phase pattern ϕ_{min} :

· grid values from 0 to 14°

· equal weighting



Estimated Phase Pattern

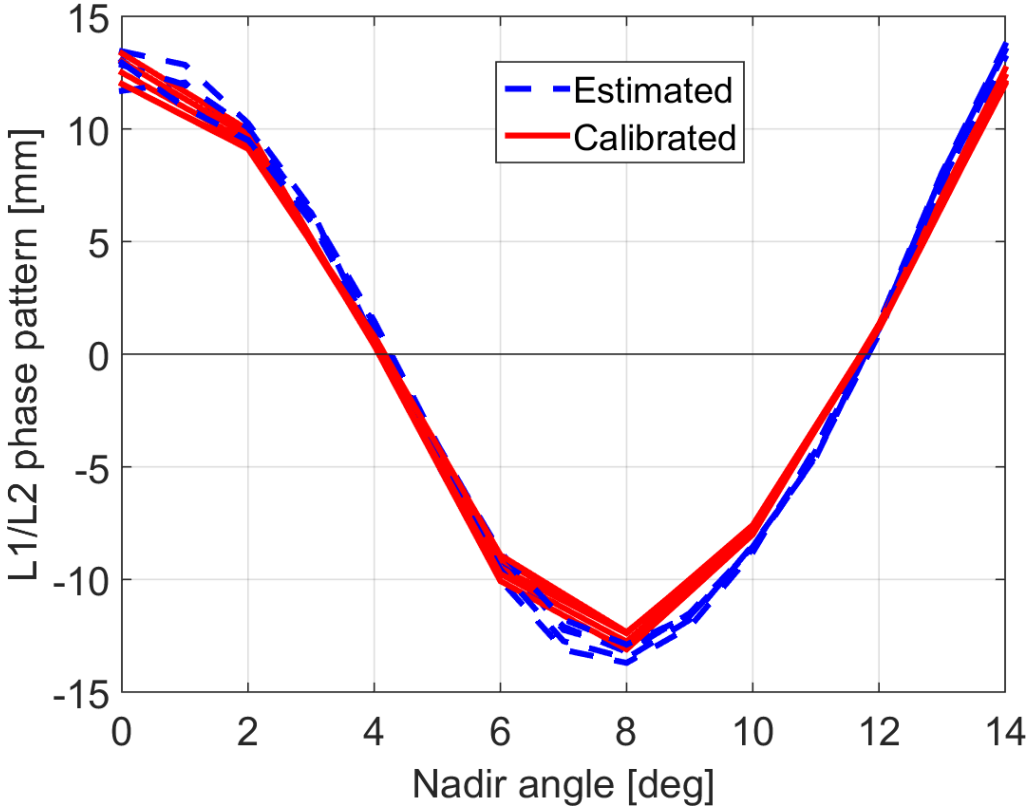
Phase pattern estimation with Bernese GNSS Software:

– L1/L2 ionosphere-free

– 14 months of data

– IGS20 scale fixed

– 1 deg nadir-dependent



EIRP Measurements

Measurement of equivalent isotropic radiated power with 30 m high-gain antenna

$$P_\mathrm{r} = P_\mathrm{s} + D_\mathrm{s} + G_\mathrm{cf} + G_\mathrm{r} - L_0 - L_\mathrm{a}$$

P_r	received power [dBW]
P_s	transmitted power [dBW]
D_s	transmit antenna directivity [dB]
G_cf	gain correction factor [dB]
G_r	receive antenna gain [dB]
L_0	free space loss [dB]
L_a	atmospheric loss [dB]

measured
modeled
unknown

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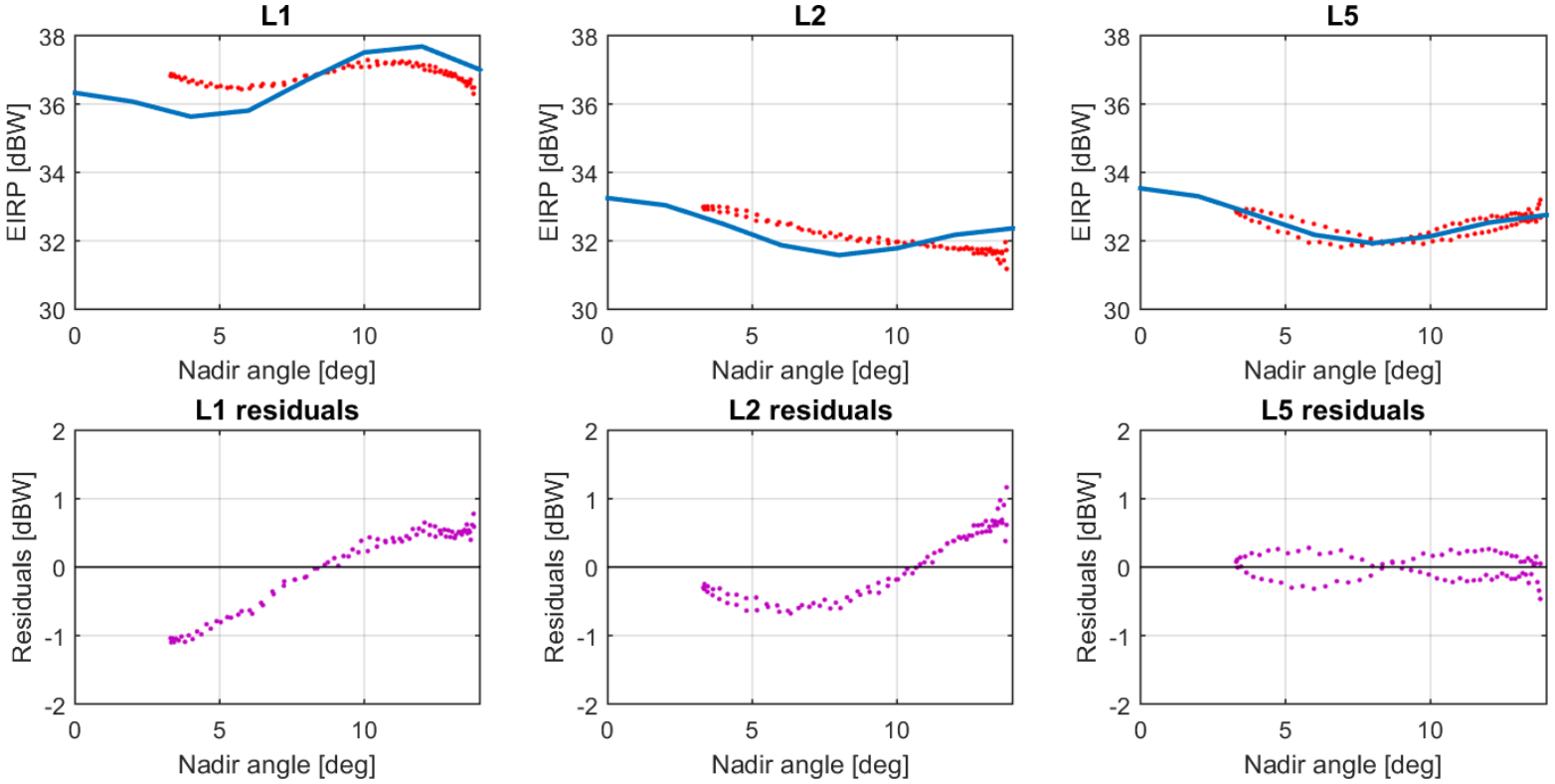
EIRP Measurements G075



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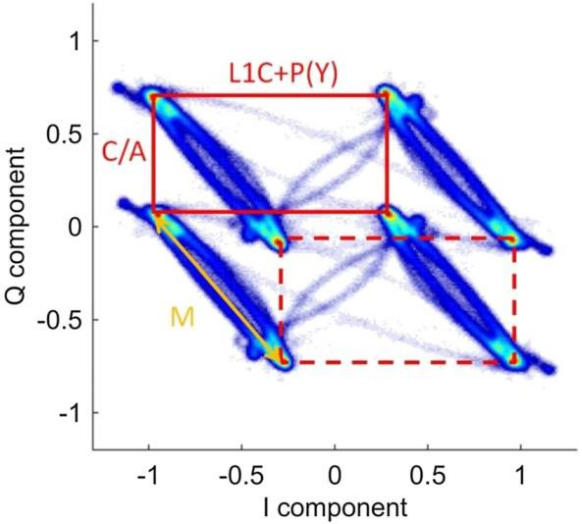
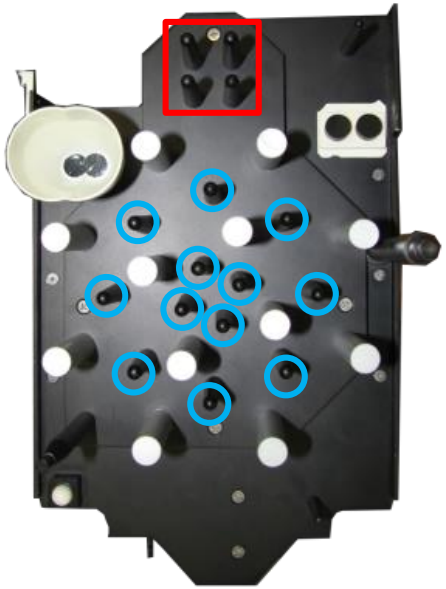
GPS III Transmit Antennas

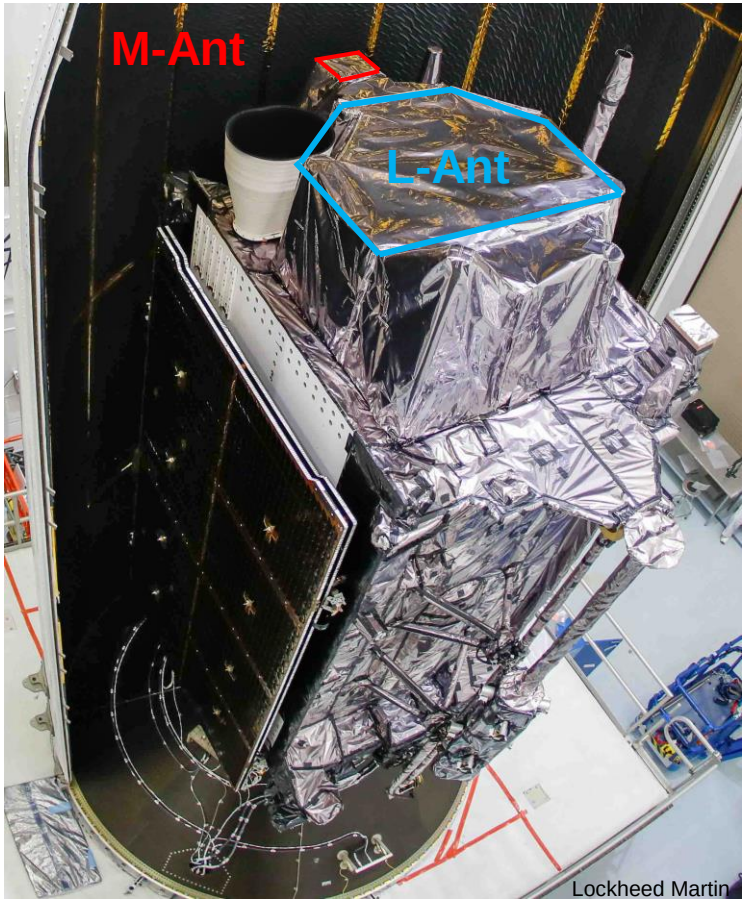
Main L-Band Navigation Antenna Array

M-Code Antenna Array





Thoelert S, Steigenberger P, Montenbruck O, Meurer M (2019) Signal analysis of the first GPS III satellite. GPS Solutions 23. https://doi.org/10.1007/s10291-019-0882-7



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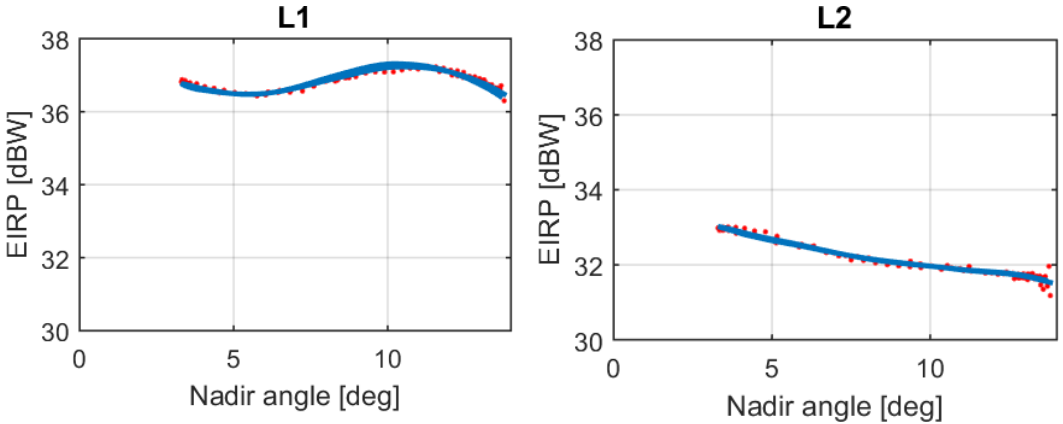
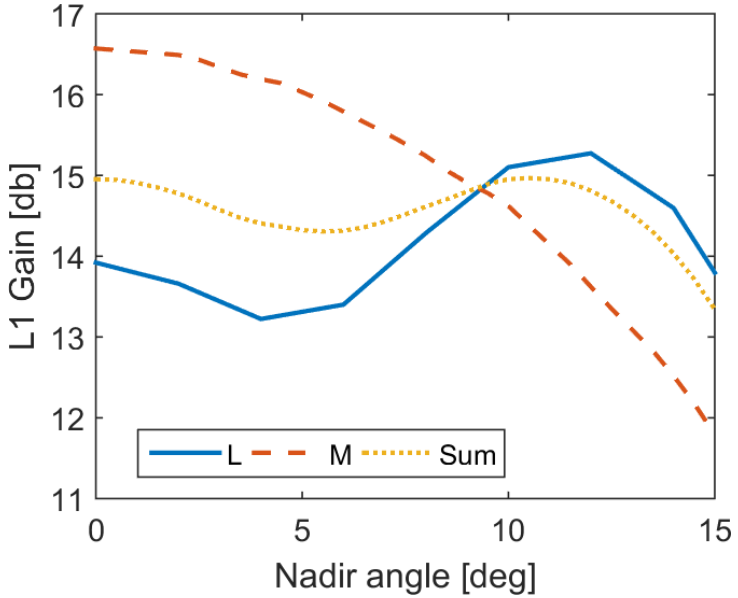
EIRP Residuals with Adjusted Gain Patterns

Assumptions:

– Gain pattern of M-Ant identical with inner ring of L-Ant of Brumbaugh et al. (1976)

– -1.0 dB gain correction factor for L-Ant





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Summary and Conclusions

Phase center offsets

- LM PCOs show systematic offset of 10 cm w.r.t. estimates with ITRF2020 scale
- cm-level consistency of L1/L2 and L1/L5

Phase pattern

- Minimization of raw pattern: 1 mm-level agreement of LM calibrations with estimates

Directivity pattern

- M-code antenna significantly impacts measured EIRP patterns

Recommendations

- Inclusion of minimized GPS III phase pattern in igs20.atx
- Update and publication of further GPS III metadata

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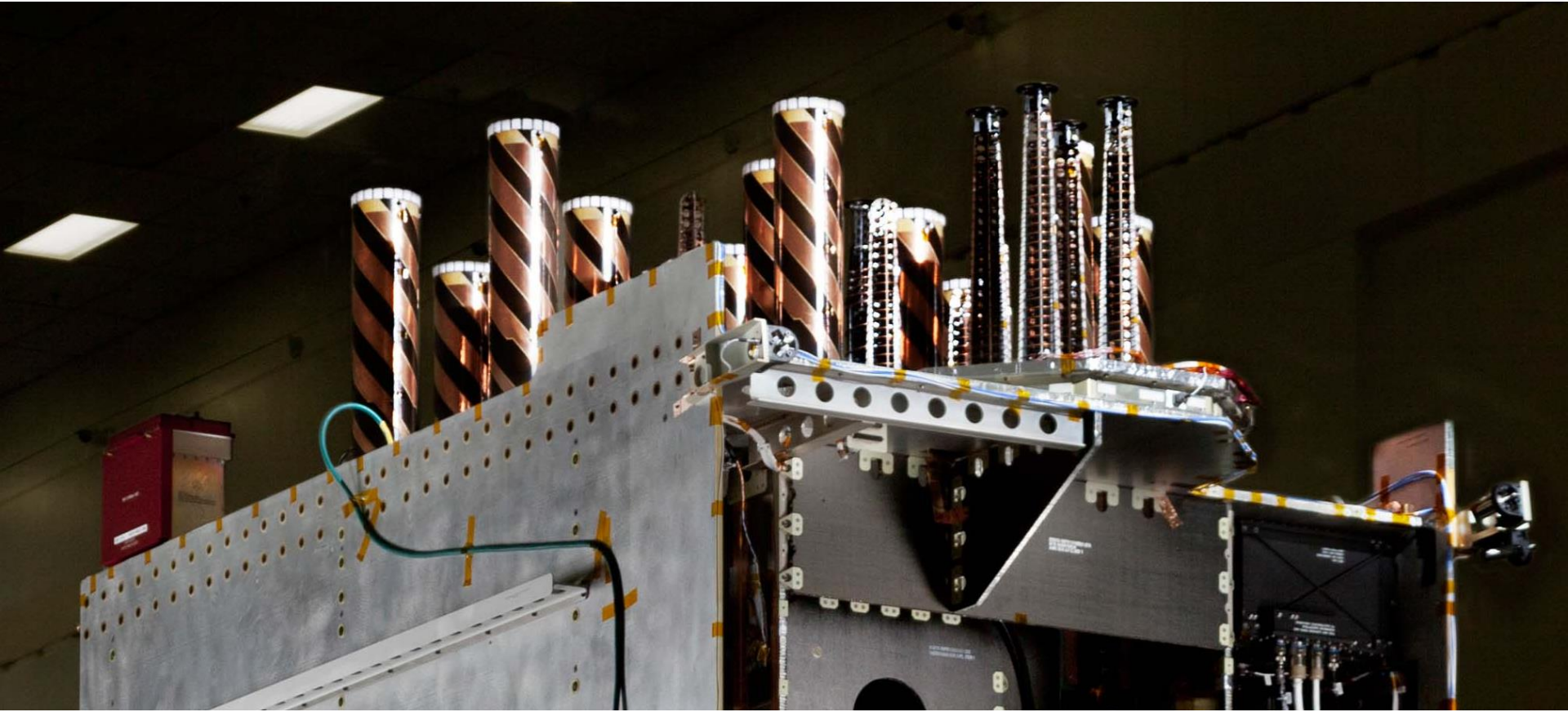

Lockheed Martin

Resources

- GPS Satellite Antenna Panel Patterns: https://www.navcen.uscg.gov/gps-technical-references
- Marquis W, Shaw M (2011) Design of the GPS III Space Vehicle, ION ITM 2011, pp. 3067–3075
- Thoelert S, Steigenberger P, Montenbruck O, Meurer M (2019) Signal analysis of the first GPS III satellite, GPS Solutions, 23(4), https://doi.org/10.1007/s10291-019-0882-7
- Marquis WA, Reigh DL (2015) The GPS Block IIR and IIR-M Broadcast L-band Antenna Panel: Its Pattern and Performance, Navigation, 62(4):329–347, https://doi.org/10.1002/navi.123
- Brumbaugh CT, Love AW, Randall GM, Waineo DK, Wong SH (1976) Shaped Beam Antenna for the Global Positioning Satellite System, 1976 Antennas and Propagation Society International Symposium, pp. 117–120, https://doi.org/10.1109/aps.1976.1147624

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