GPS/GNSS Antenna Characterization

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Volpe The National Transportation Systems Center

Advancing transportation innovation for the public good

U.S. Department of Transportation
Office of Research and Technology
John A. Volpe National Transportation Systems Center

Overview

- One component of the Department of Transportation's GPS Adjacent Band Compatibility Study is the characterization of GPS/GNSS receiver antennas

- Such characterization is needed to:
  - Compare radiated and conducted (wired) test results
  - Apply interference tolerance masks (ITMs) to use cases where adjacent band transmitters are seen by GPS/GNSS receiver antennas at any direction besides zenith (antenna boresight)

- This presentation summarizes characterization data obtained thus far:
  - Gain patterns for 14 external antennas
    - Right-hand/left-hand circular polarization (RHCP/LHCP), vertical (V), and horizontal (H) polarizations
    - 22 frequencies: 1475, 1490, 1495, 1505, 1520, 1530, 1535, 1540, 1545, 1550, 1555, 1575, 1595, 1615, 1620, 1625, 1630, 1635, 1640, 1645, 1660, and 1675 MHz
  - Approximate L1 RHCP relative gain patterns for 4 antennas integrated with receivers
  - Saturation measurements for the 14 external (all active) antennas
  - All antennas provided by the USG

Gain Pattern Measurement Approach

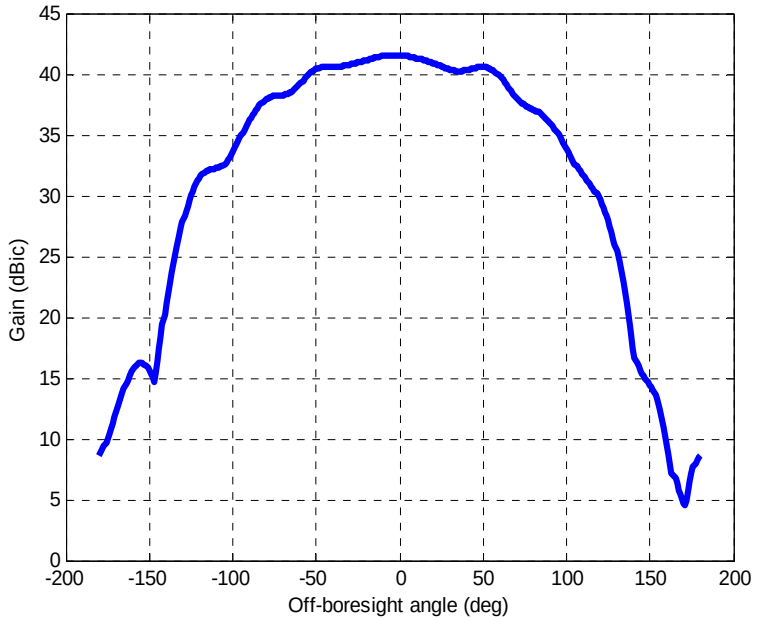
- External antennas
  - Measured in 30’ x 21’ x 15’ anechoic chamber at MITRE, Bedford, MA
  - Calibrated absolute patterns produced using Nearfield Systems Inc measurement system and software
  - Full azimuth/elevation patterns produced for RHCP, LHCP, V, and H polarizations at 22 frequencies
- Integrated antennas
  - Approximate relative RHCP gain patterns at L1 estimated using live-sky GPS C/A-code C/N_0 measurements

External Antenna Gain Measurements*

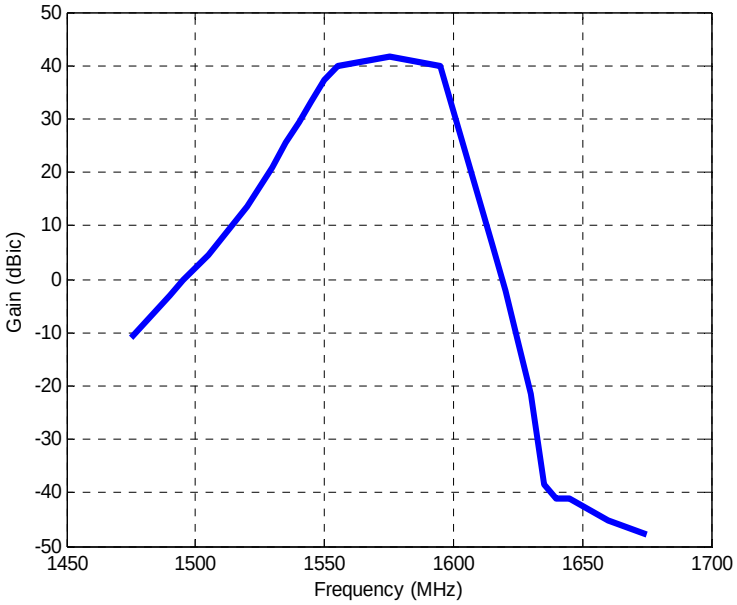
*Note:

1. Only RHCP results shown in this presentation as examples. LHCP, V, and H polarization gains were additionally measured.
2. When viewing gain vs frequency plots, please keep in mind that measurements were made on only the 22 frequencies listed earlier.
3. All external antennas measured were active, and measured gain is for the entire transducer (passive antenna element + active subassembly)

Antenna #1 (TIM)



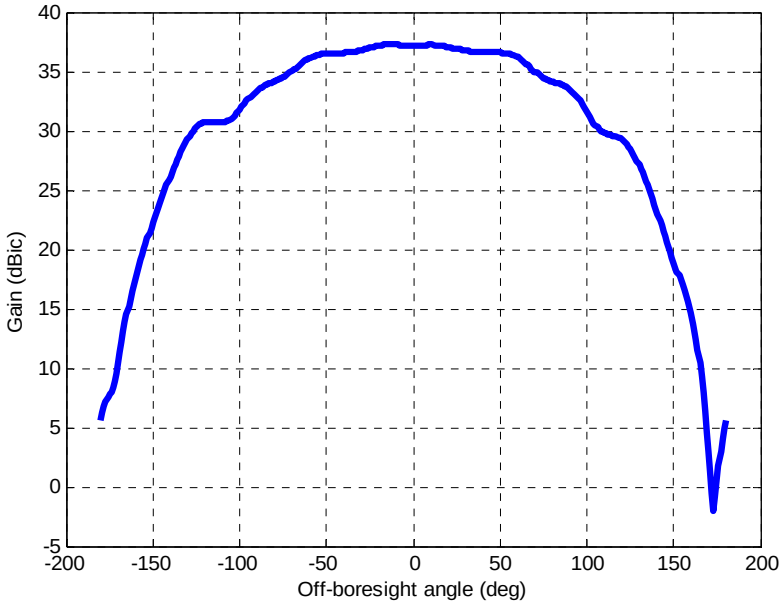
RHCP Gain at L1 vs Off-boresight Angle



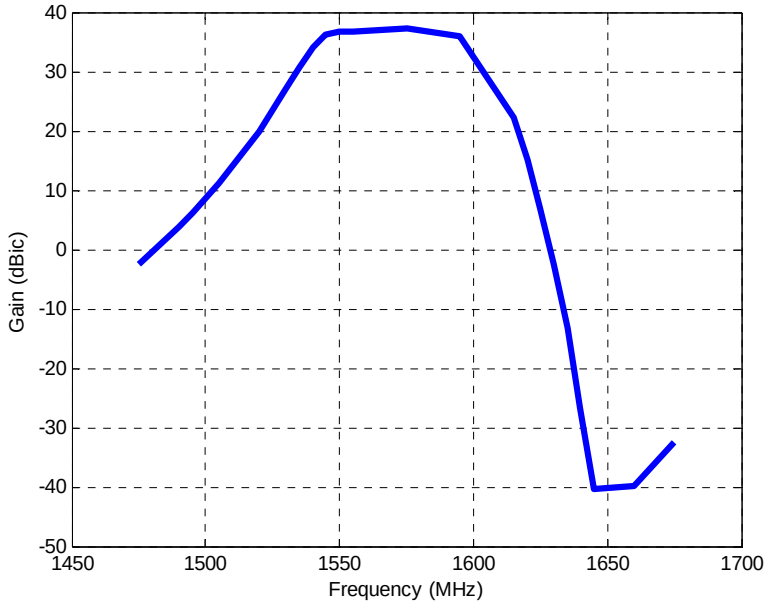
RHCP Gain at Boresight vs Frequency

Peak RHCP gain = 41.5 dBic
Directivity = 4.4 dBic
Difference in RHCP gain between 90 and 5 deg = 4.6 dB

Antenna #2 (HPR)



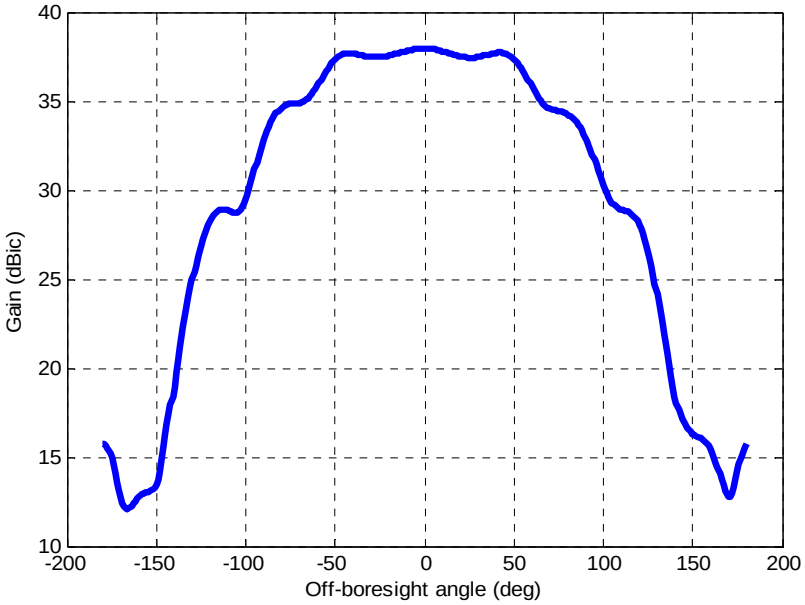
RHCP Gain at L1 vs Off-boresight Angle



RHCP Gain at Boresight vs Frequency

Peak RHCP gain = 37.2 dBic
Directivity = 3.2 dBic
Difference in RHCP gain between 90 and 5 deg = 3.3 dB

Antenna #3 (TIM)

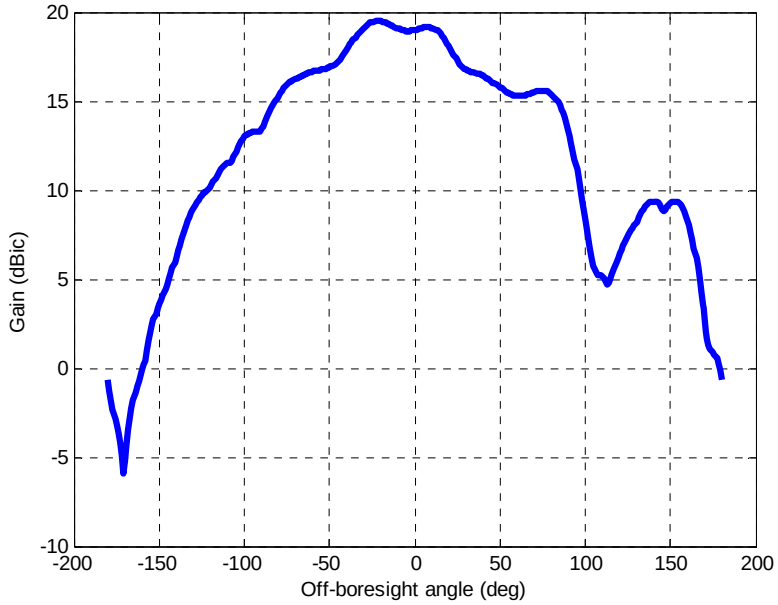


RHCP Gain at L1 vs Off-boresight Angle

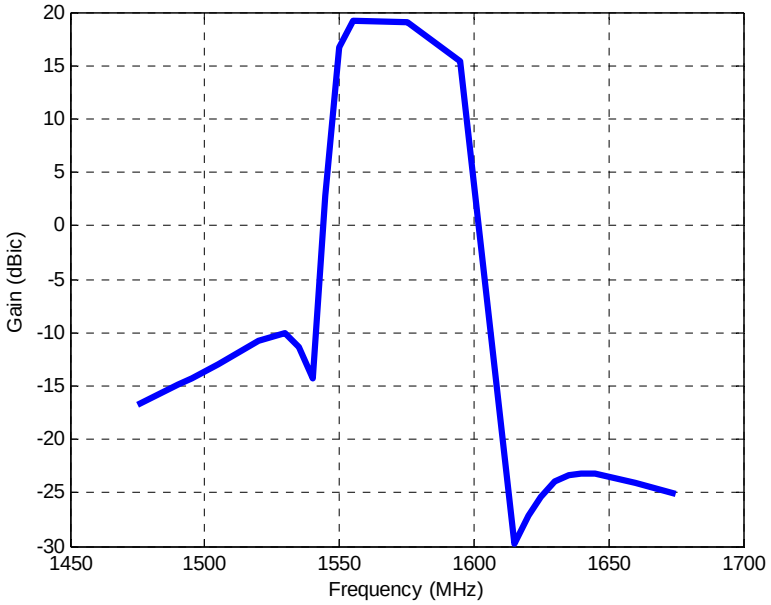
RHCP Gain at Boresight vs Frequency

Peak RHCP gain = 38.0 dBic
Directivity = 3.9 dBic
Difference in RHCP gain between 90 and 5 deg = 4.1 dB

Antenna #4 (GLN)



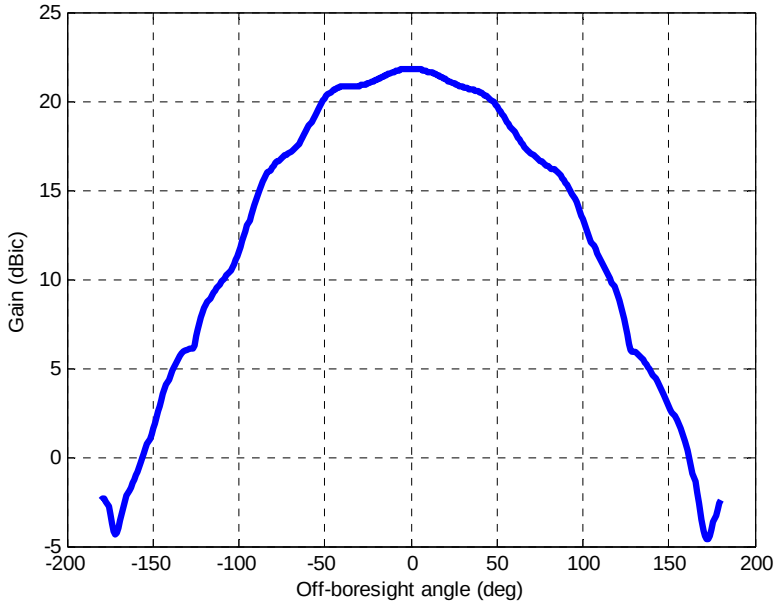
RHCP Gain at L1 vs Off-boresight Angle



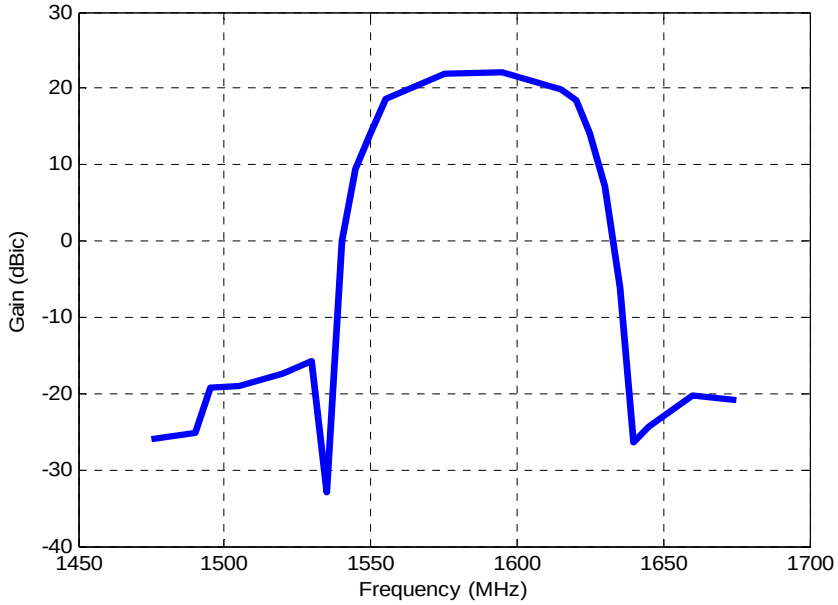
RHCP Gain at Boresight vs Frequency

Peak RHCP gain = 19.0 dBic
Directivity = 4.4 dBic
Difference in RHCP gain between 90 and 5 deg = 4.4 dB

Antenna #5 (GLN)



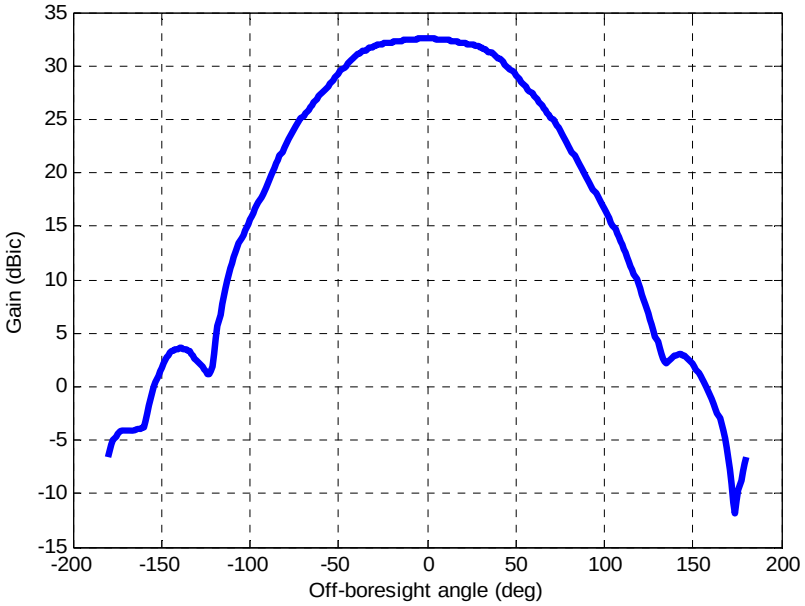
RHCP Gain at L1 vs Off-boresight Angle



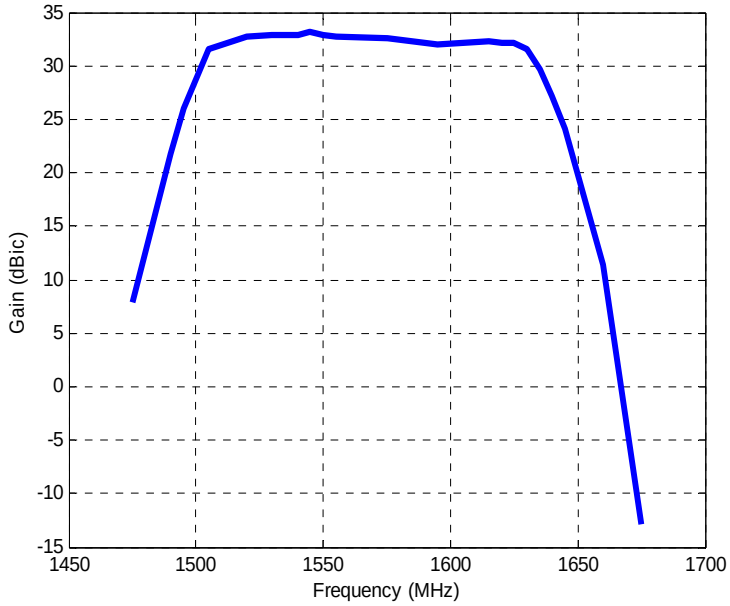
RHCP Gain at Boresight vs Frequency

Peak RHCP gain = 21.8 dBic
Directivity = 4.4 dBic
Difference in RHCP gain between 90 and 5 deg = 6.0 dB

Antenna #6 (HPR)



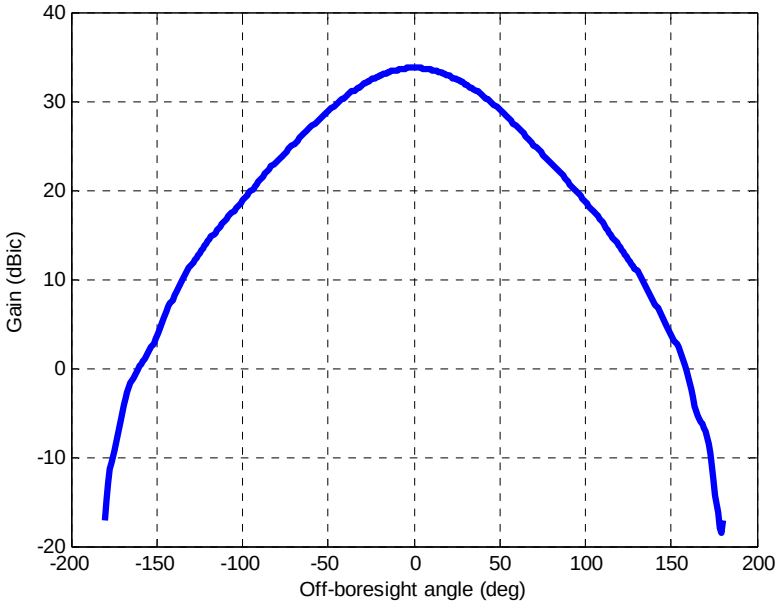
RHCP Gain at L1 vs Off-boresight Angle



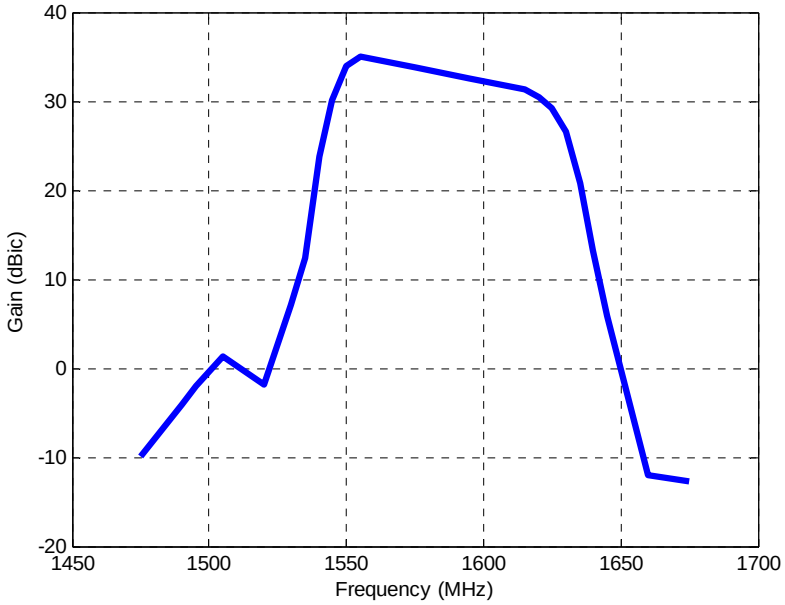
RHCP Gain at Boresight vs Frequency

Peak RHCP gain = 32.5 dBic
Directivity = 6.7 dBic
Difference in RHCP gain between 90 and 5 deg = 11.6 dB

Antenna #7 (HPR)



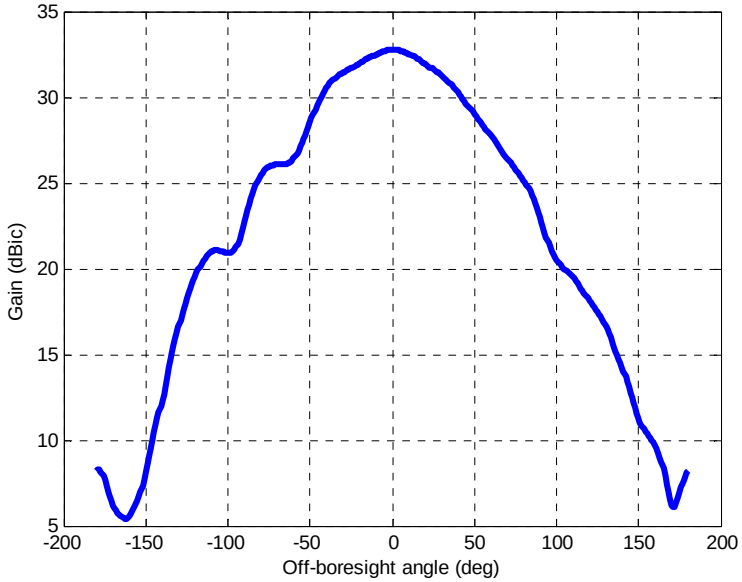
RHCP Gain at L1 vs Off-boresight Angle



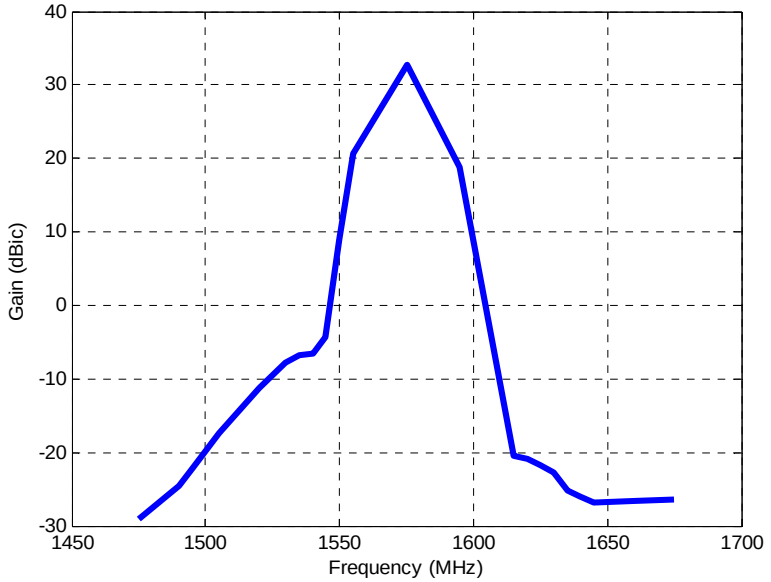
RHCP Gain at Boresight vs Frequency

Peak RHCP gain = 33.7 dBic
Directivity = 7.8 dBic
Difference in RHCP gain between 90 and 5 deg = 11.6 dB

Antenna #8 (TIM)



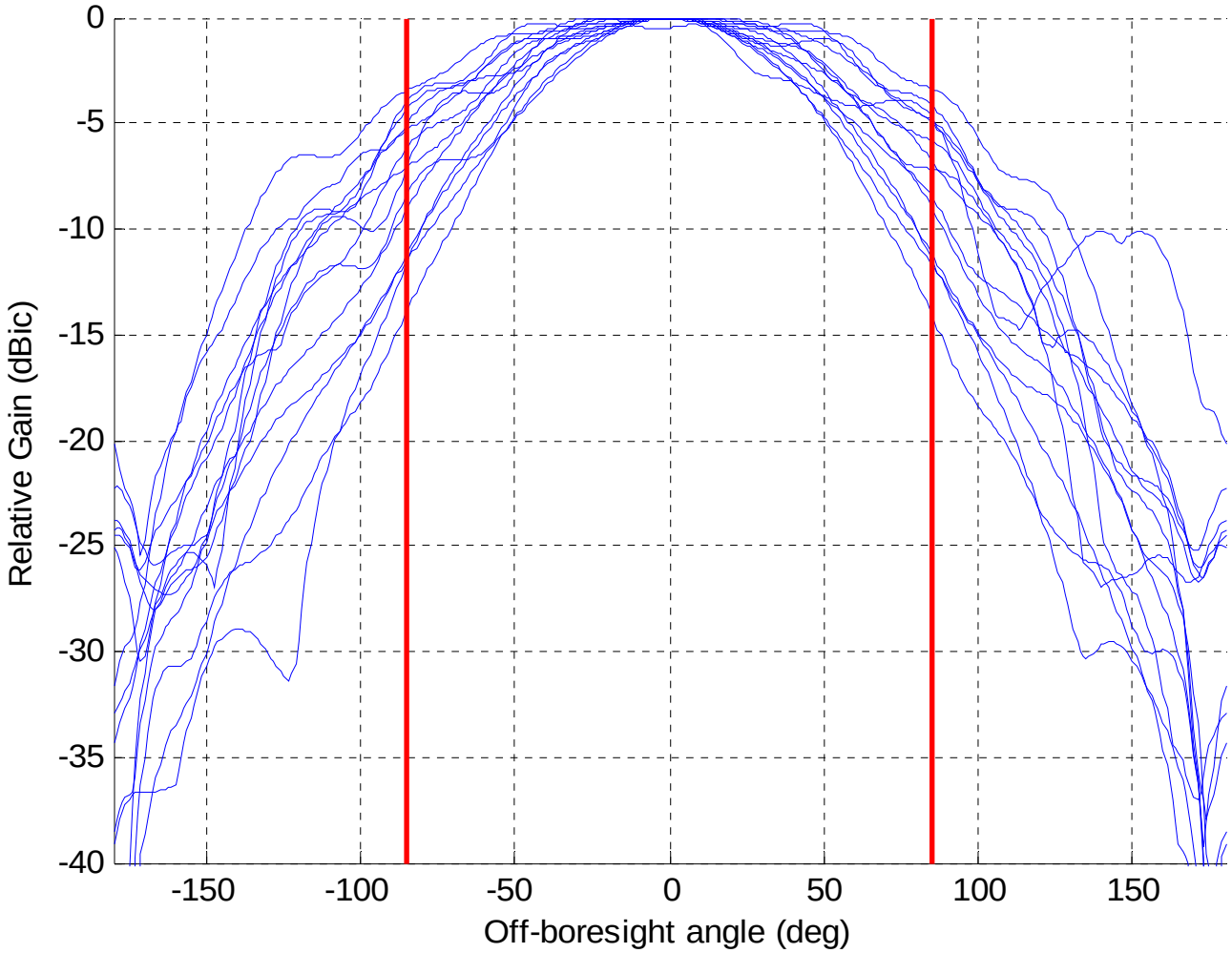
RHCP Gain at L1 vs Off-boresight Angle



RHCP Gain at Boresight vs Frequency

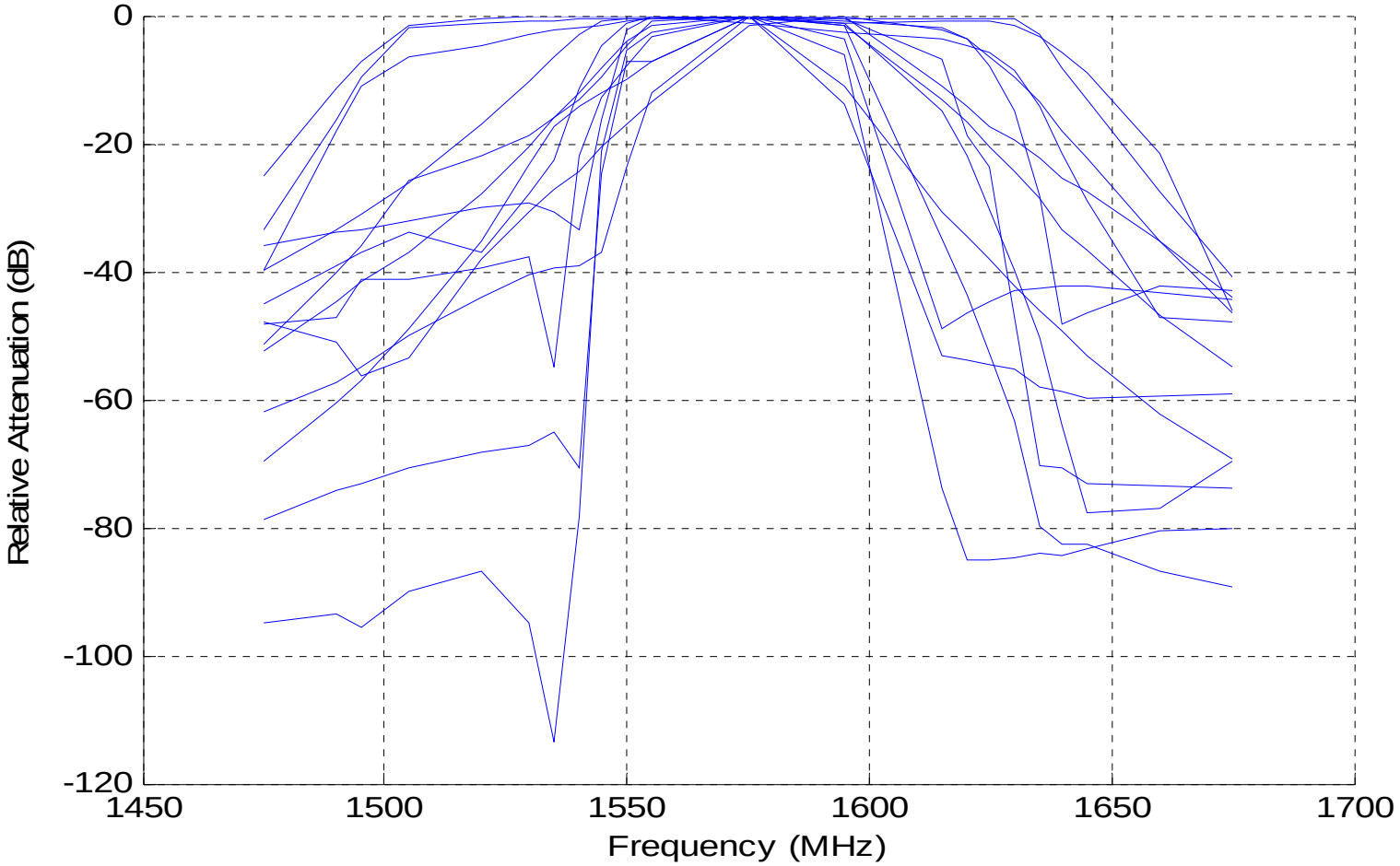
Peak RHCP gain = 32.8 dBic
Directivity = 5.0 dBic
Difference in RHCP gain between 90 and 5 deg = 8.4 dB

L1 RHCP Relative Gain Pattern Summary



Red lines correspond to 5 deg elevation angle on either side of antenna.

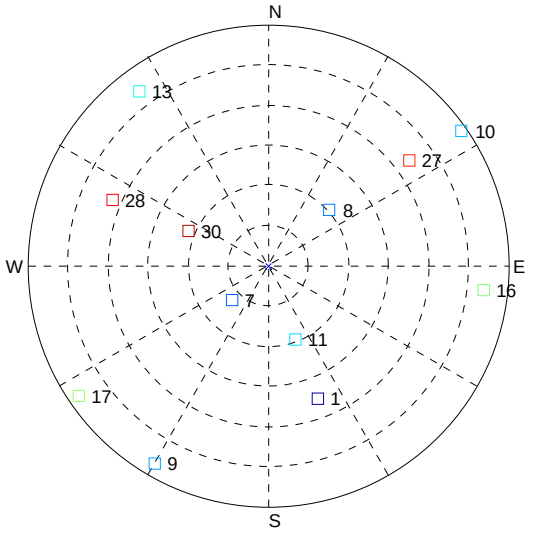
Boresight RHCP Frequency Selectivity Summary

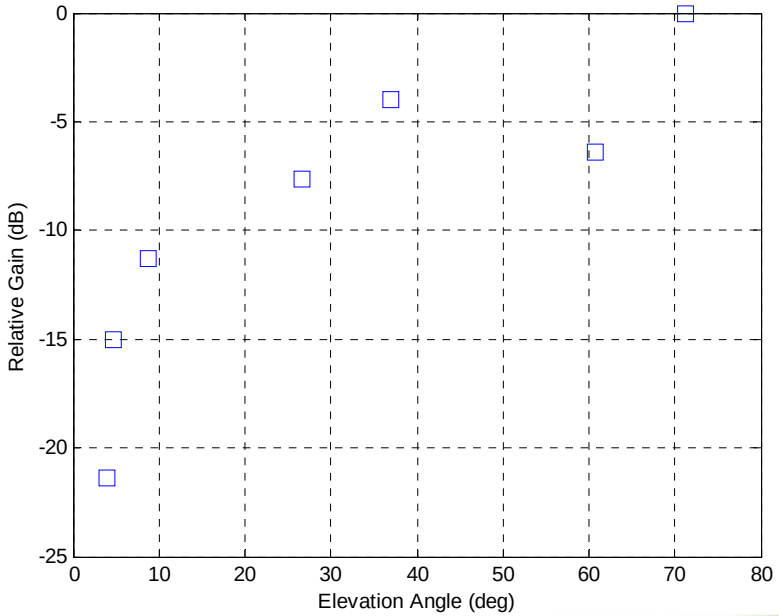


Integrated Antenna Gain Measurements

Antenna #9 (GLN)

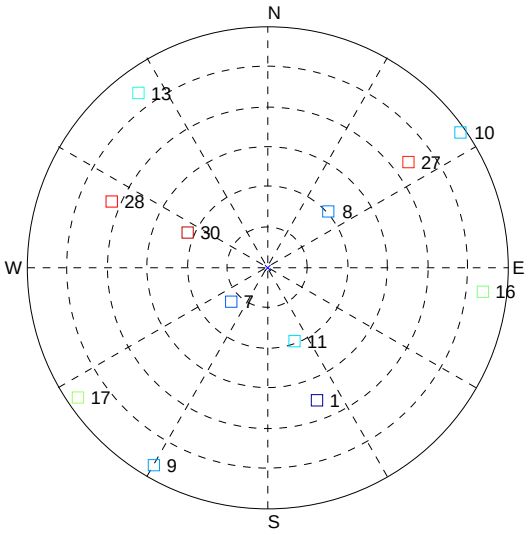
PRN	Elevation (deg)	C/N_0 (dB-Hz)
1	36.9	43.5
7	71.2	47.4
9	4.7	32.4
11	60.8	41.0
16	8.8	36.2
17	3.9	26.0
28	26.7	39.8

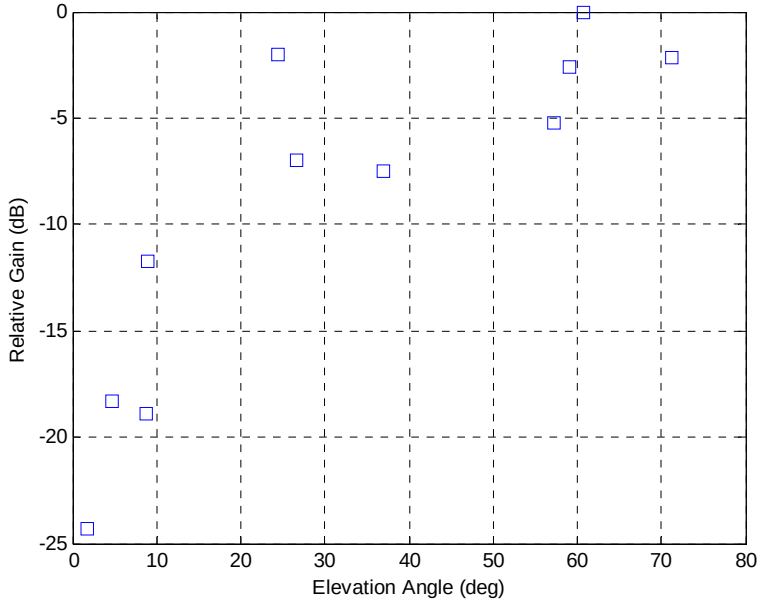




Antenna #10 (GLN)

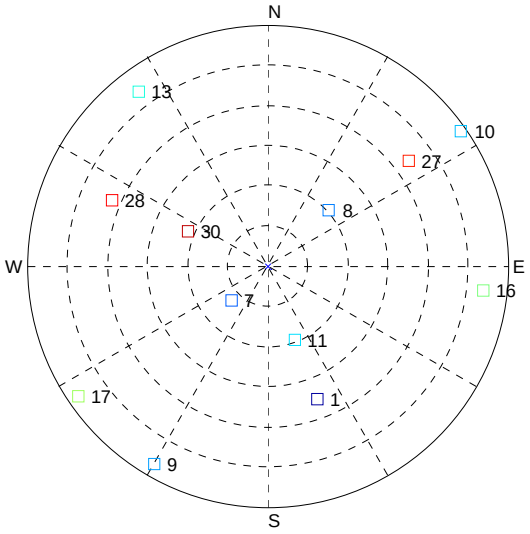
PRN	Elevation (deg)	C/N_0 (dB-Hz)
1	36.9	42.1
7	71.2	47.5
8	59.1	47.0
9	4.7	31.3
10	1.8	25.3
11	60.8	49.6
13	49.6	37.9
17	3.9	30.7
27	24.4	47.6
28	26.7	42.6
30	57.3	44.4

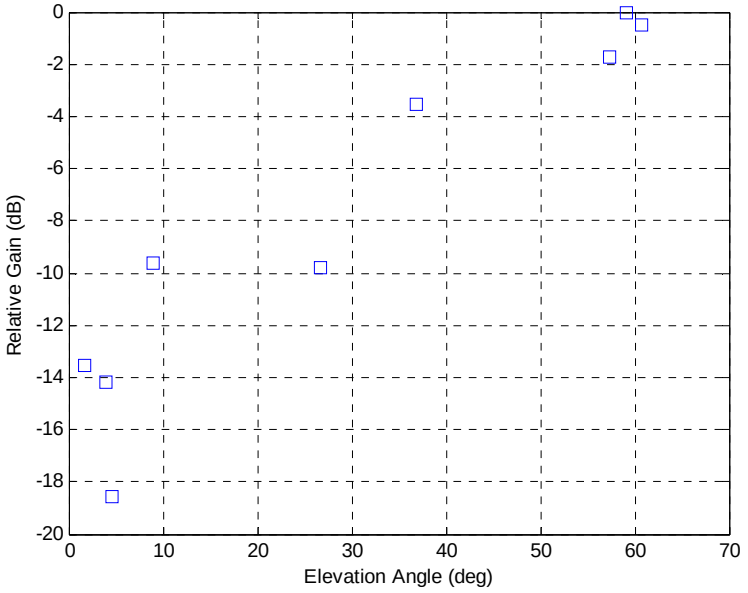




Antenna #11 (GLN)

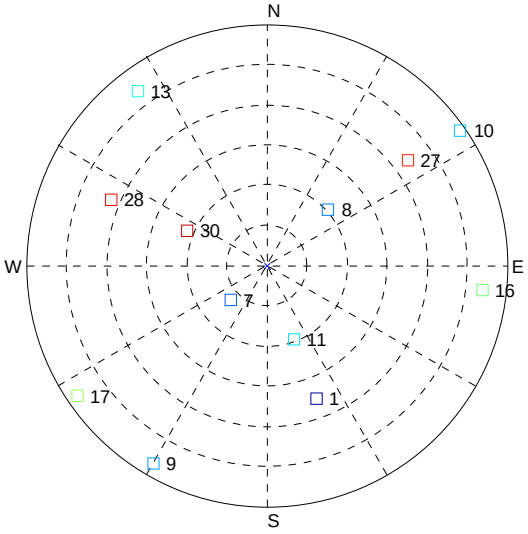
PRN	Elevation (deg)	C/N_0 (dB-Hz)
1	36.9	41.9
8	59.1	45.4
9	4.7	26.9
10	1.8	31.9
11	60.8	44.9
13	9.0	35.8
17	3.9	31.3
28	26.7	35.6
30	57.3	43.7

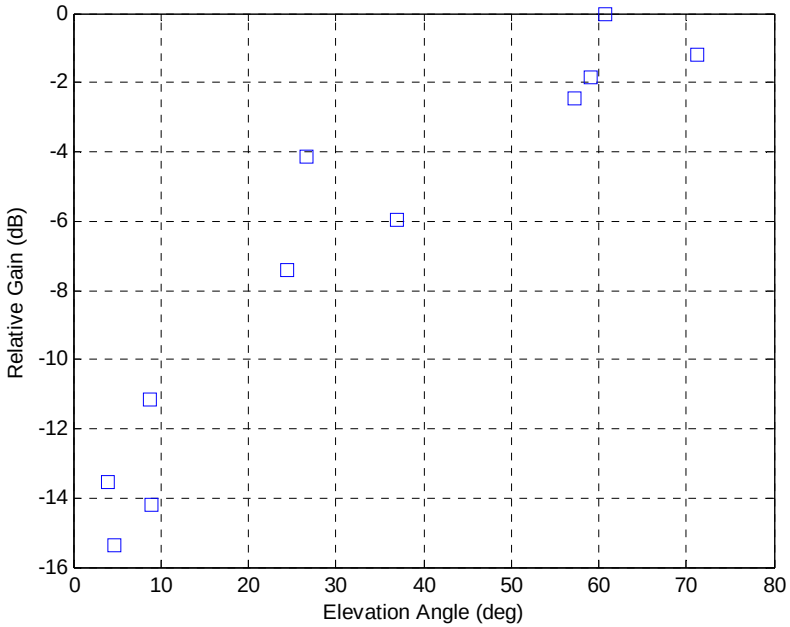




Antenna #12 (HPR)

PRN	Elevation (deg)	C/N_0 (dB-Hz)
1	36.9	47.2
7	71.2	52.0
8	59.1	51.3
9	4.7	37.8
11	60.8	53.2
13	9.0	39.0
16	8.8	42.0
17	3.9	39.6
27	24.4	45.8
28	26.7	49.0
30	57.3	50.7

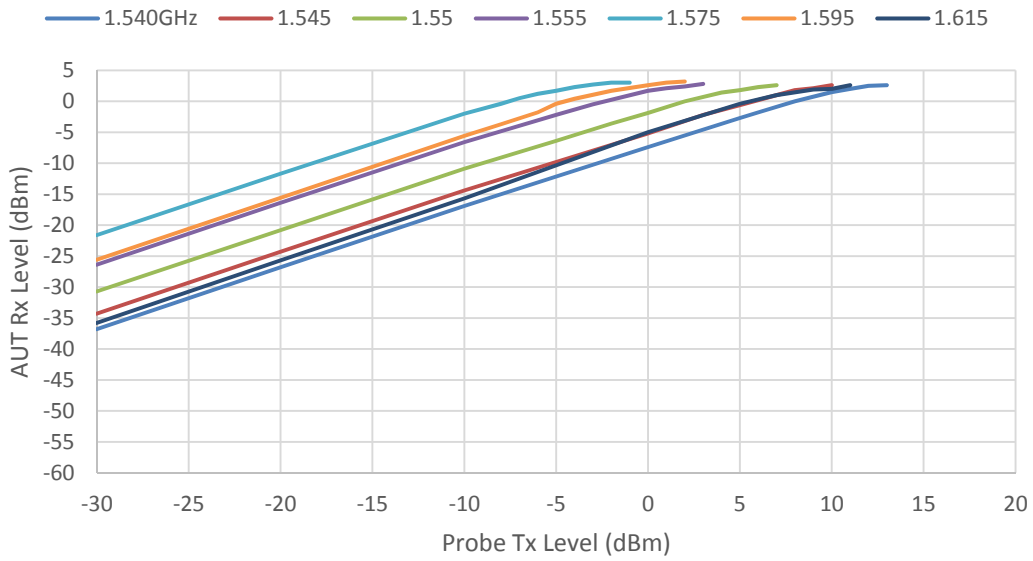




Saturation Measurements and Summary

Saturation Measurements

- For 14 external antennas, output vs input power measured for single tone at 22 frequencies (see example results below)
- Results are being processed to estimate small-signal 1-dB compression point vs frequency
- Processing will take into account 2:1 difference in compression between small-signal and large-signal gain*



*See, e.g., Domino et al., "Polynomial Model of Blocker Effects…", *Applied Microwave & Wireless*, June 2001.

Summary

- GPS/GNSS receiver antenna characterization is an important component of the Department of Transportation's GPS Adjacent Band Compatibility Study

- 18 antennas have thus far been characterized
  - RHCP, LHCP, V, and H gain at 22 frequencies for 14 external antennas measured in anechoic chamber
    - Single-tone saturation data for these antennas additionally collected
  - RHCP L1 relative gain for 4 integrated antennas estimated through live-sky C/N_0 measurements

- Next steps:
  - Processing of saturation data
  - Characterization of additional antennas