GPS Adjacent Band Compatibility Assessment Test Results

International Committee on GNSS-11 WG-S

November 2016

Approach to DOT GPS Adjacent Band Compatibility Assessment

- Certified aviation portion of effort led by FAA
- The assessment for other civil applications (including non certified aviation) led by DOT/OST-R Volpe Center
- DOT Extended Pos/Nav Working Group (civil departments and agencies)

  - GPS Directorate, Aerospace, MITRE, Zeta Associates, and Stansell Consulting

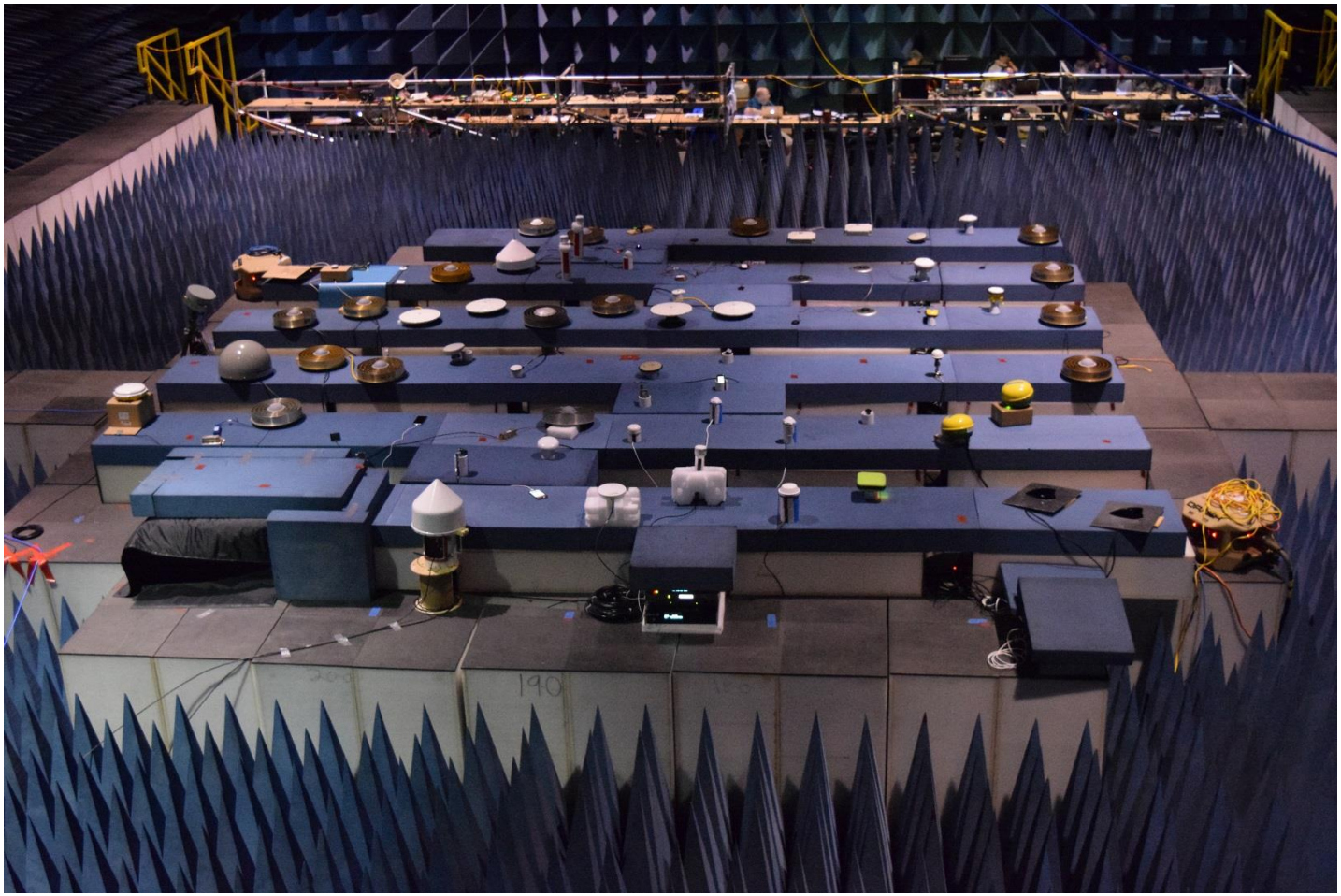
- Conduct public outreach to ensure the plan, on going work, and assumptions are vetted and an opportunity to gain feedback

  - Held five public workshops
  - Federal Register Notice for comments/input on draft test plan
  - One-on-one discussions with industry
  - Open and transparent approach as possible

Radiated Testing Overview

- GPS receiver testing was carried out April 25-29, 2016 at the Army Research Laboratory's (ARL) Electromagnetic Vulnerability Assessment Facility (EMVAF), White Sands Missile Range (WSMR), NM
  - EMVAF – 100’ x 70’ x 40’ Anechoic Chamber
- Participation included DOT’s federal partners/agencies (USCG, NASA, NOAA, USGS, and FAA) and GPS manufacturers
  - Air Force/GPS Directorate conducted testing week of April 18th
- 80 receivers were tested representing six categories of GPS/GNSS receivers: General Aviation (non certified), General Location/Navigation, High Precision & Networks, Timing, Space Based, and Cellular
- Tests performed in the anechoic chamber:
  - Linearity (receivers CNR estimators are operating in the linear region)
  - 1 MHz Bandpass Noise (Type 1)
  - 10 MHz Long Term Evolution (LTE) (Type 2)
  - Intermodulation (effects of 3rd order intermodulation)

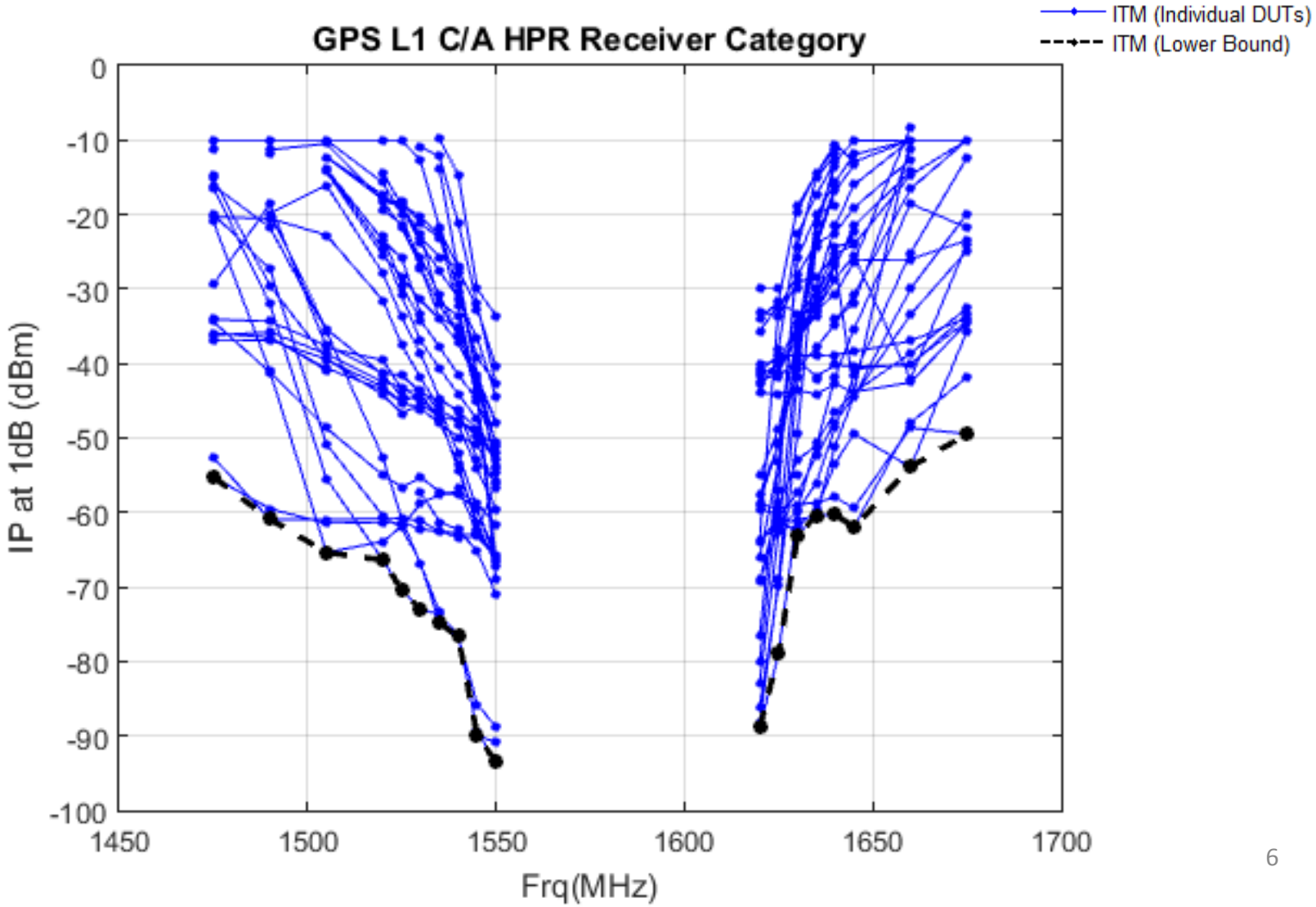
Chamber Setup



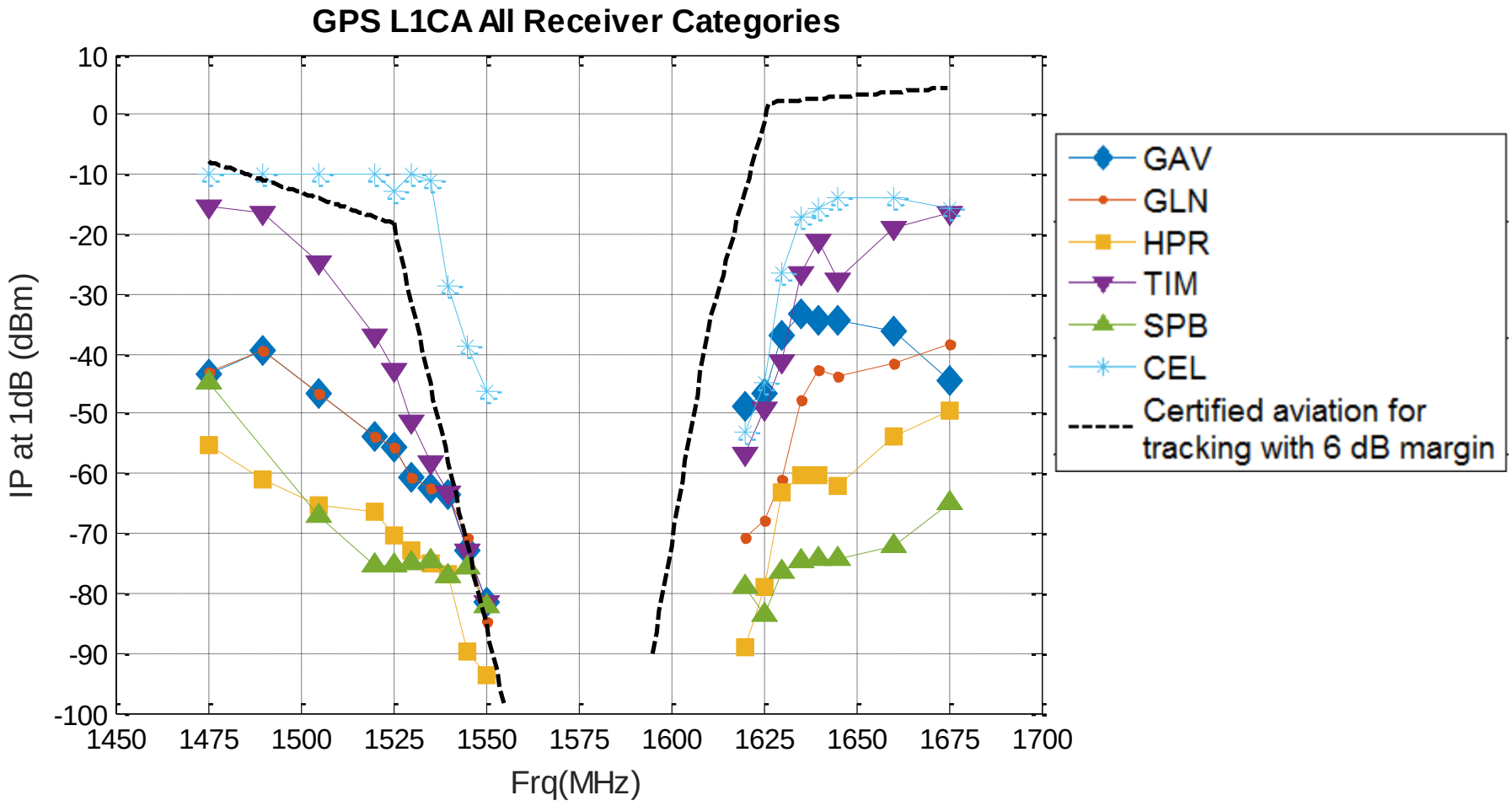
GNSS Signals Used in Testing

Signal
GPS L1 C/A-code
GPS L1 P-code
GPS L1C
GPS L1 M-code
GPS L2 P-code
SBAS L1
GLONASS L1 C
GLONASS L1 P
BeiDou B1I
Galileo E1 B/C

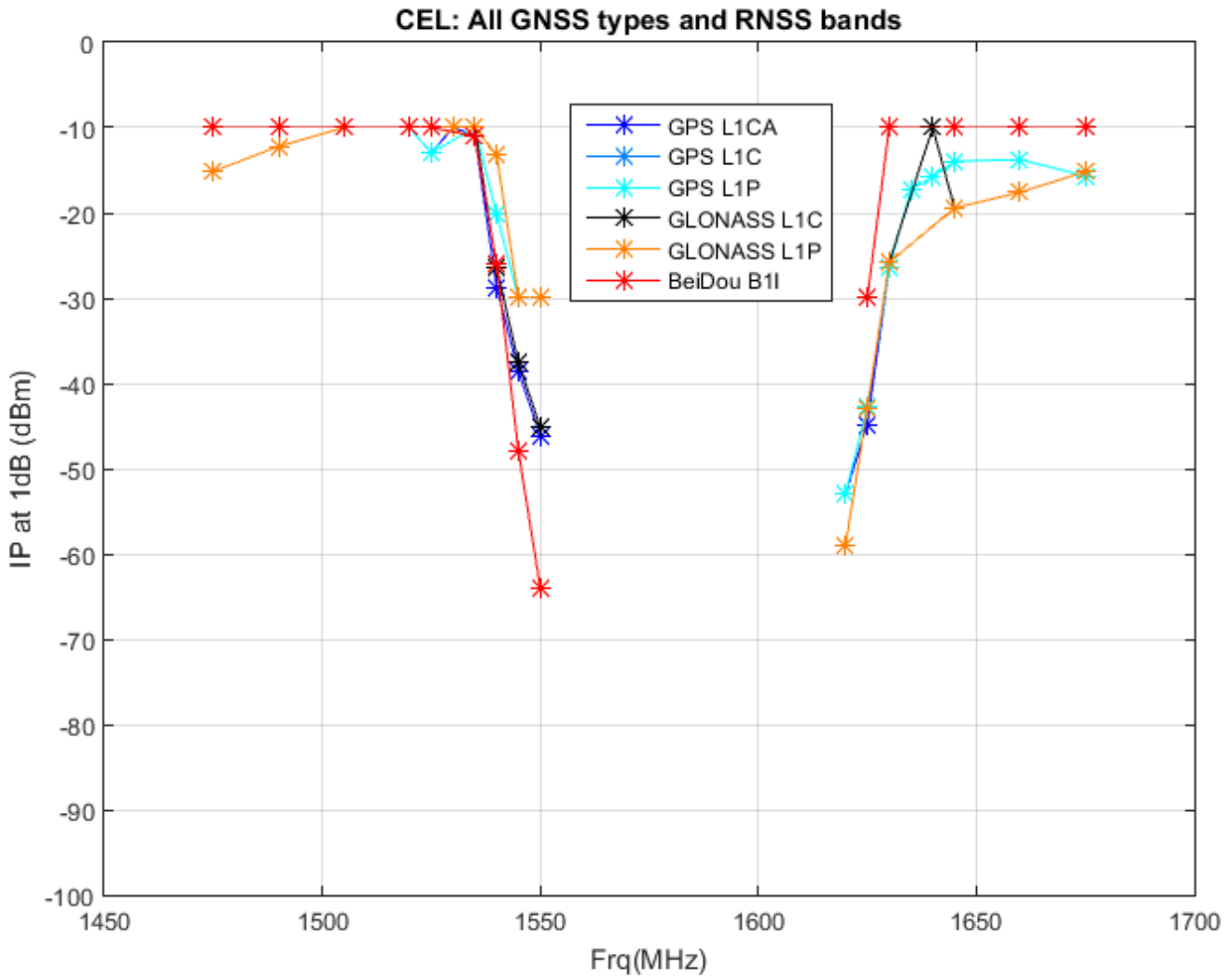
GPS L1 C/A
High Precision (35 DUTs)



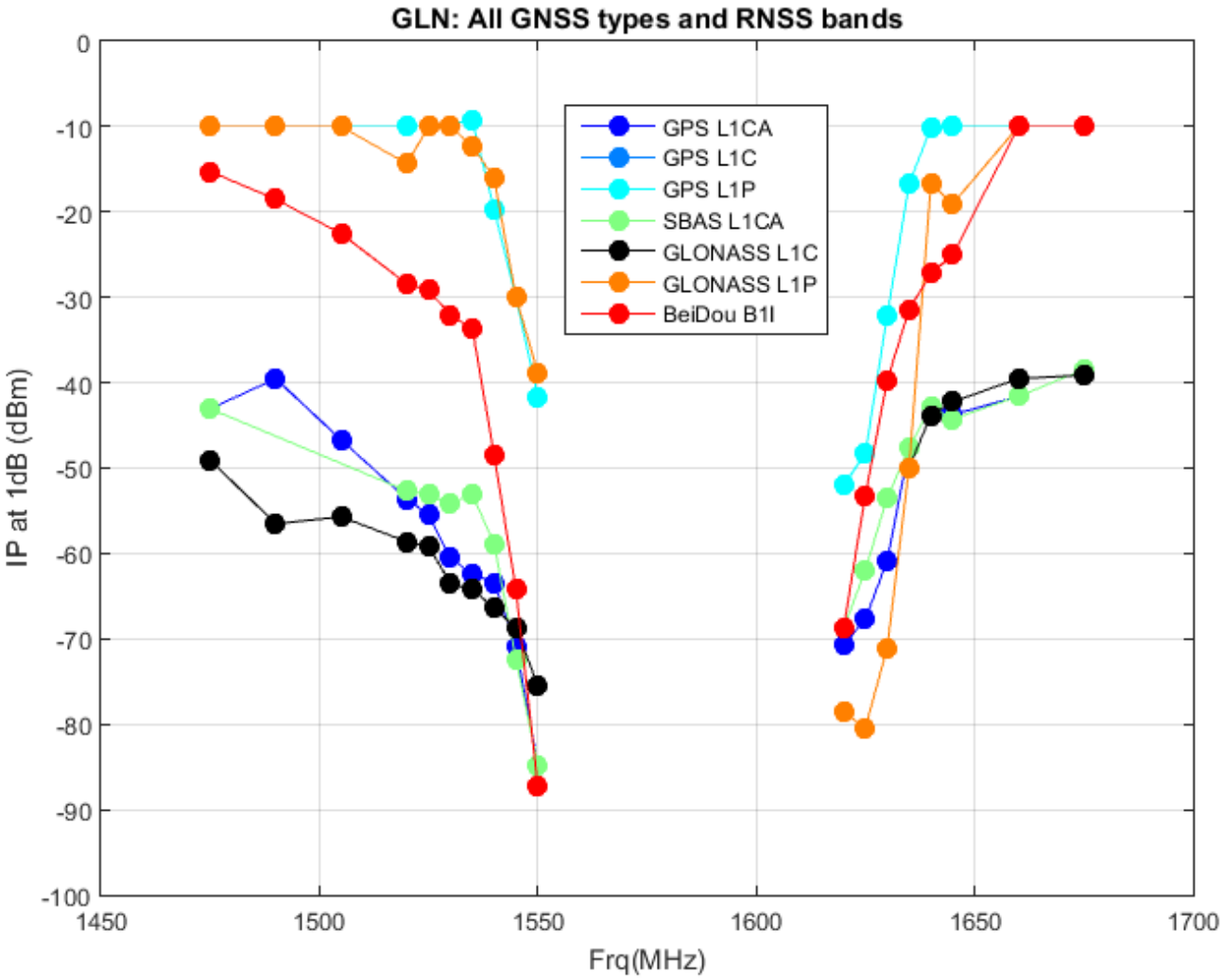
L1 C/A Bounding Masks Compared With Certified Aviation Mask



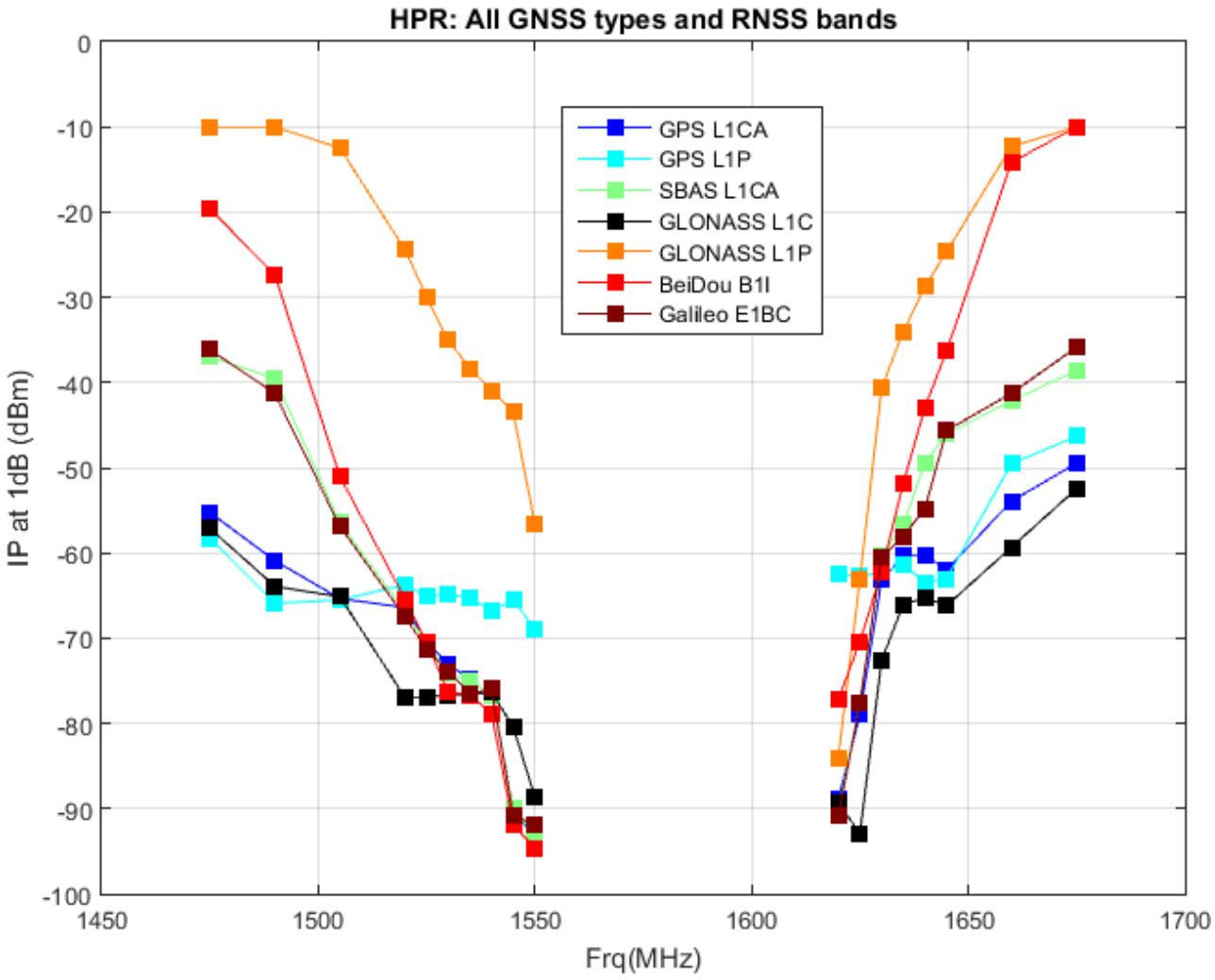
Cellular: Summary of Bounding Masks



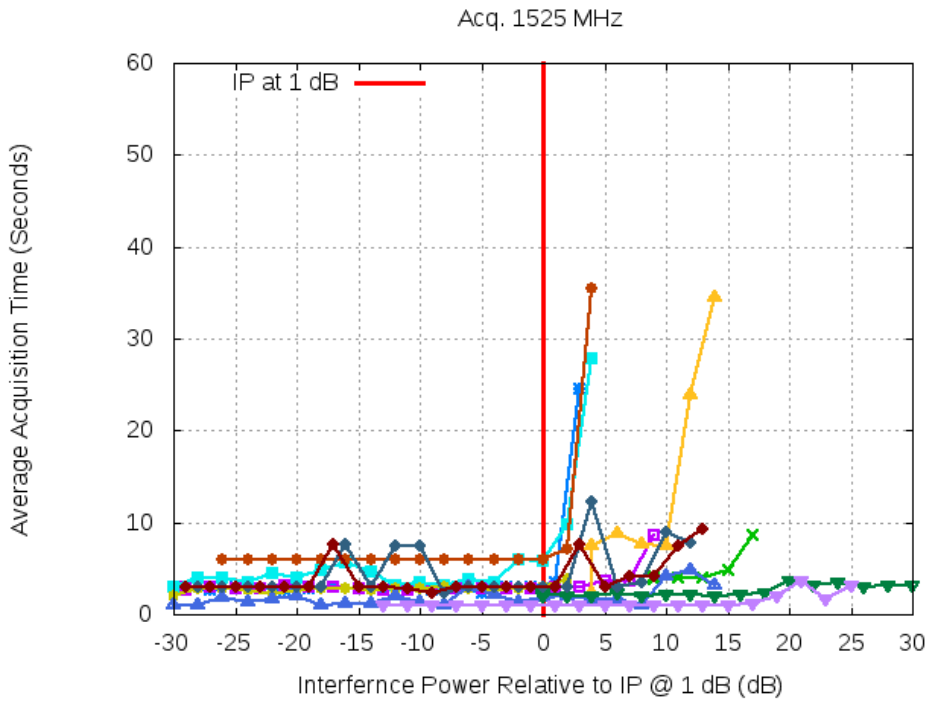
General Location/Navigation Summary of Bounding Masks



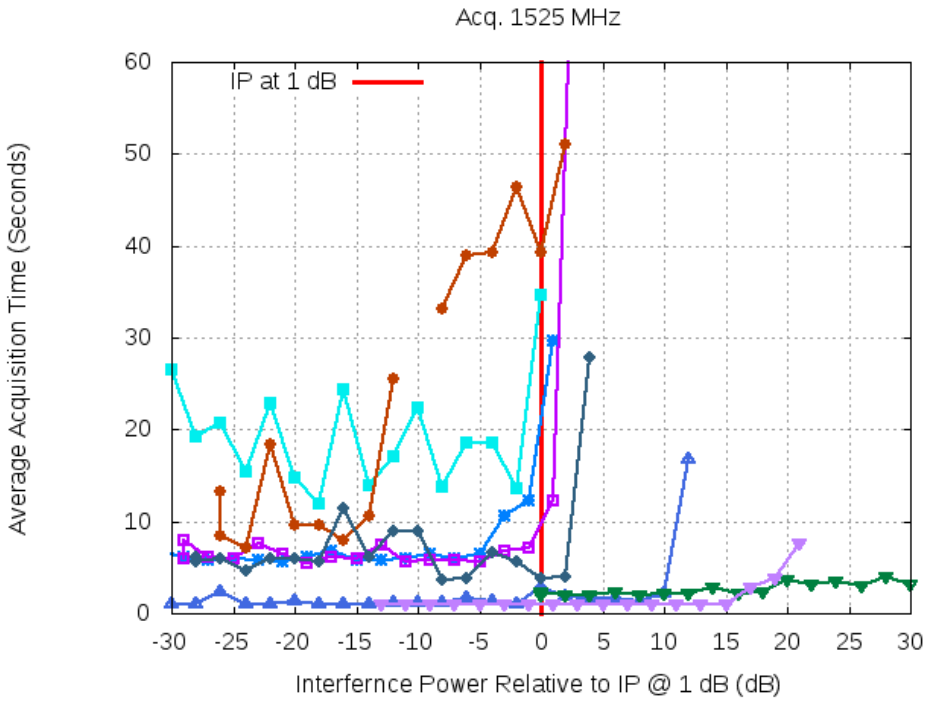
High Precision
Summary of Bounding Masks



Acquisition Performance -1525 MHz



ICD Min. Power



Low Elevation

Summary of Results

- ITMs have been produced as a function of interference center frequency for all emulated GNSS signals
- Results show good consistency between repeated tests
- Certified aviation receiver mask does not bound the masks of the 6 civil receiver categories
- Satellite acquisition time observed to degrade at interference level similar to IP @ 1 dB
  - In some instances receivers failed to acquire satellite emulating low elevation conditions at this interference level
- Suggests exceeding the 1 dB interference level can adversely affect receiver performance by slowing satellite acquisition times
  - Effectively raises elevation angle that satellites are acquired at and reduces satellite availability

Next Steps

- Use Case Development
  - Developing representative use cases for receivers
  - Defining parameters for transmit application for uplink and down link
- Defining and finalize propagation models to be used
- Additional Antenna Characterization
- Refining the inverse modeling frame work to determine tolerable EIRP levels

(www.gps.gov/spectrum/ABC)

Questions?

BACKUP SLIDES

Test Participants

- United States Coast Guard (USCG)
- National Aeronautics and Space Administration (NASA)
- National Oceanic and Atmospheric Administration (NOAA)
- United States Geological Survey (USGS)
- Federal Aviation Administration (FAA)
- United States Department of Transportation (USDOT)
- General Motors (GM)
- u-blox
- NovAtel
- Trimble
- John Deere
- UNAVCO

Receiver Test List (1/2)

No.	Receiver
1	Trimble SPS461
2	Furuno GP-33
3	TriG
4	TriG V2
5	Septentrio PolaRx4TR Pro
6	Ashtech Z-12
7	Javad Delta-3
8	Ashtech uZ-CGRS
9	Javad EGGDT-160
10	Novatel OEM628V-G1S-B0G-TTN-H
11	Javad Delta II
12	Septentrio PolaRx4Pro
13	Trimble NETR5
14	Trimble NETR5
15	Trimble NETR9
16	Leica GRX1200GGPRO
17	Trimble 5700
18	Leica GRX1200GGPRO
19	Trimble NETRS
20	Trimble NETRS

No.	Receiver
21	Trimble NETRS
22	Topcon Net-G3A Sigma
23	Garmin GPSMap 295
24	Garmin - GPSMap 696
25	Garmin - Area 560
26	Garmin - GLOGPS (GPS & GLONASS)
27	Dual Electronics - SkyPro XGPS 150
28	EVA-7M EVK-7EVA-0
29	MAX-7C EVK-7C-0
30	MAX-7Q EVK-7N-0
31	EVA-M8M EVK-M8EVA-0
32	LEA-M8F EVK-M8F-0
33	MAX-M8Q EVK-M8N-0
34	LEA-M8S EVK-M8N-0
35	uBlox EVU-6P-0-001
36	SiRF III
37	Trimble NETR5
38	Symmetricom Xli
39	Symmetricom-GPS
40	Trimble SMT360 GPS receiver

Receivers included in the wired/conducted test

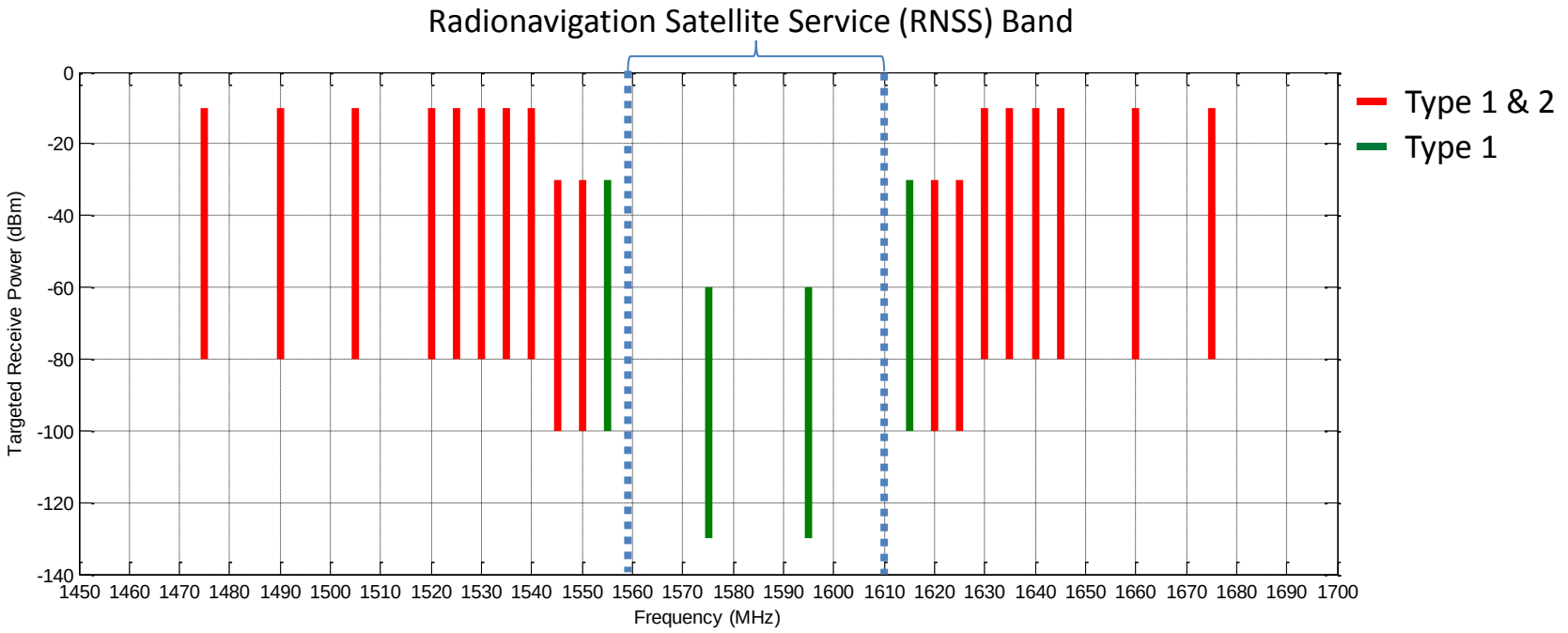
Receiver Test List (2/2)

No.	Receiver
41	Dynon 250
42	Dynon 2020
43	Garmin EDGE 1000
44	Garmin GPSMAP 64
45	Garmin ETREX 20x
46	Garmin FORERUNNER 230
47	Garmin GPSMAP 741
48	Symmetricom Xli
49	JAVAD Triumph-1
50	Hemisphere R330
51	NAVCOM SF3050
52	Symmetricom SyncServer S350
53	Arbiter Systems 1088B
54	Arbiter Systems 1094B
55	Schweitzer Eng. Labs SEL-2401
56	Android S5
57	Android S6
58	Android S7
59	Supercruise "VCP"
60	Supercruise "VCP"

No.	Receiver
61	EVK-M8N
62	EVK-M8T
63	MAX-M8Q
64	EVK-7P
65	EVK-6n
66	NovAtel 628 Card w/ Flex pack
67	Trimble Ag-382
68	Trimble Geo 7X
69	Trimble Bison III
70	Trimble R8
71	Trimble SPS985
72	Trimble SPS855
73	Trimble Acutime 360
74	Trimble Ag-382
75	SF3000
76	SF3000
77	Septentrio PolaRx5TR Pro
78	Septentrio PolaRx5TR Pro
79	Trimble NetRS
80	Trimble NETR9

Receivers included in the wired/conducted test

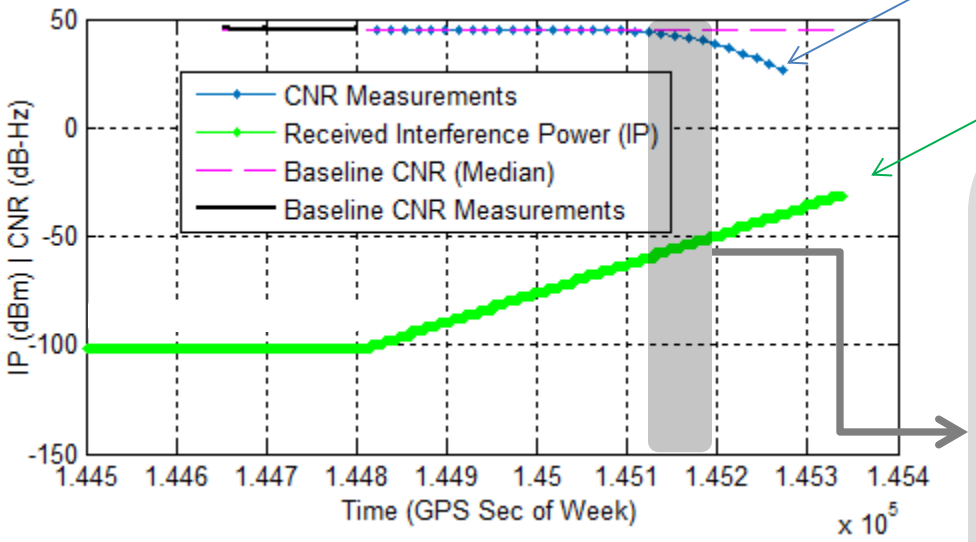
Interference Test Signal Frequencies and Power Profiles



Data Processed to Produce a 1 dB Interference Tolerance Mask (ITM)

- Example for determining ITM for 1 frequency (1545 MHz) for PRN 31 for one of the Devices Under Test (DUT)

CNR vs. Time



IP vs. Time