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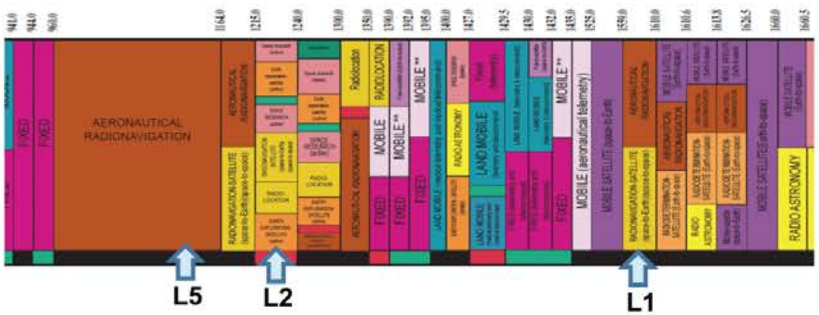
Tuesday, January 22, 2013

Noon – 1:30 pm PDT
1 pm – 2:30 pm MDT
2 pm – 3:30 pm CDT
3 pm – 4:30 pm EDT

GNSS PERFORMANCE STANDARDS & CERTIFICATION

BEYOND SPECTRUM PROTECTION



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WELCOME TO:

GNSS Performance Standards & Certification:

Beyond Spectrum Protection

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Overlook Systems Technologies, Inc.
VP, Strategy & Programs

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Ron Borsato
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Principal Architect

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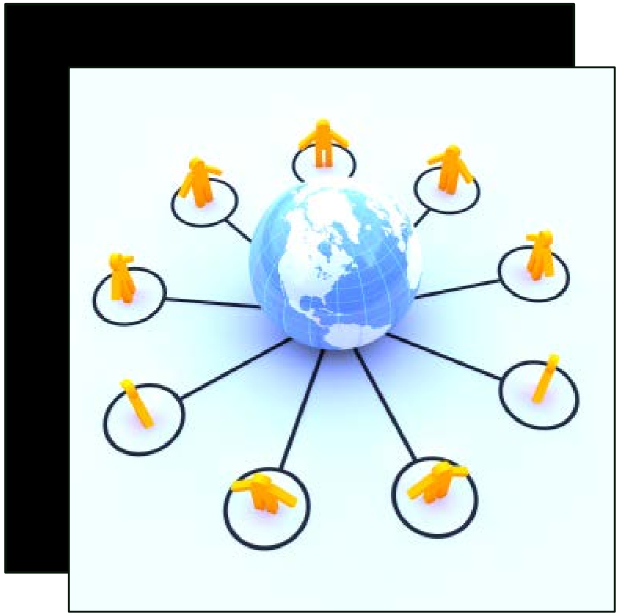
Moderator: Demoz Gebre-Egziabher, Aerospace Engineer and Mechanics Faculty at University of Minnesota

Co-Moderator: Lori Dearman, Sr. Webinar Producer

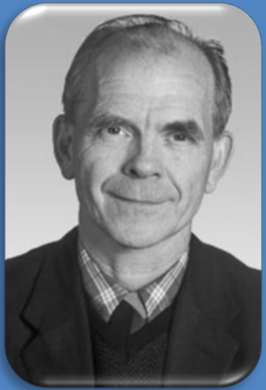
Who's In the Audience?

A diverse audience of over 375 professionals registered from 43 countries, 28 states and provinces representing the following roles:

- **22%** GNSS End User
- **22%** GNSS Equipment Manufacturer
- **20%** Government/Policy Maker
- **19%** Product / Application Designer
- **17%** System Integrator



Welcome from *Inside GNSS*



Glen Gibbons

Editor and Publisher
Inside GNSS

A word from the sponsor

Steve Hickling

Lead Product Manager
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GNSS & Space Weather:
Sources, Characteristics and Mitigation of Effects

Demoz Gebre-Egziabher

Aerospace Engineer and Mechanics Faculty, University of Minnesota

Poll #1

My understanding is that GNSS receiver standards and certification are primarily aimed at ensuring that:

1. *GNSS receivers work as intended when used*
2. *Wireless devices don't interfere with GNSS*
3. *All of the above*

Featured Presenters – Panel Intro

Jules McNeff
Overlook Systems Technologies, Inc.
VP, Strategy & Programs

Chris Hegarty
MITRE Corporation
Director, Communication, Navigation & Surveillance Engineering

Ron Borsato
Spirent Communications
Principal Architect

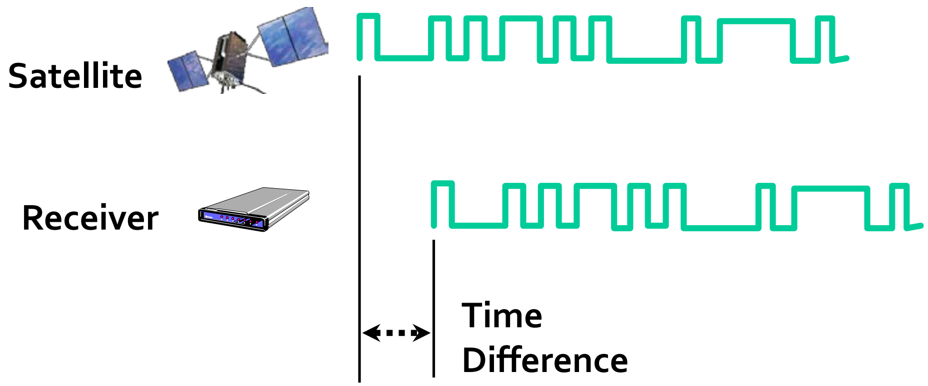
GPS Receiver Operation

Spectrum Access & Performance Certification

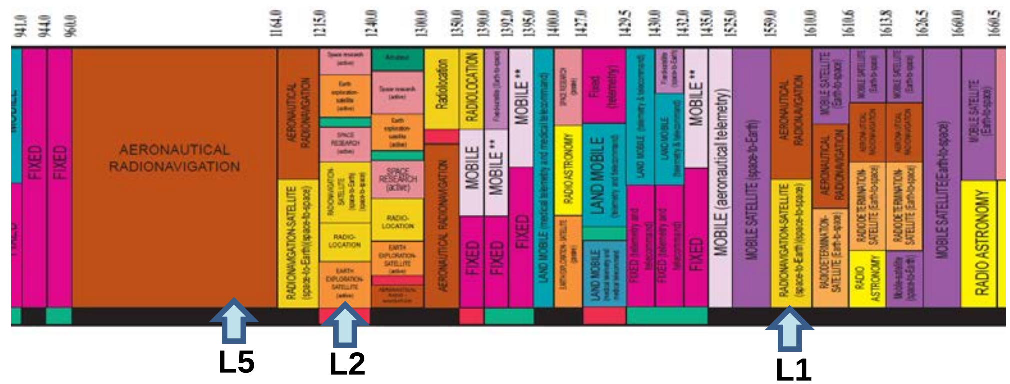
Jules McNeff
Overlook Systems Technologies, Inc.

Spectrum Realities & Obligations (1/2)

- **Spectrum Regulators (FCC & NTIA)**
  - Acknowledge GPS (GNSS) signal strength limitations
    - ~ -150 to -160 dB (below noise floor at ~ -145 dB)
  - Acknowledge unique GPS (GNSS) signal processing requirements
    - Navigation message bit transitions vital to precision
    - Digital communications focuses on bit detection, not on timing
    - Digital navigation focuses on bit transitions (bit sequence already known)



Spectrum Realities & Obligations (2/2)

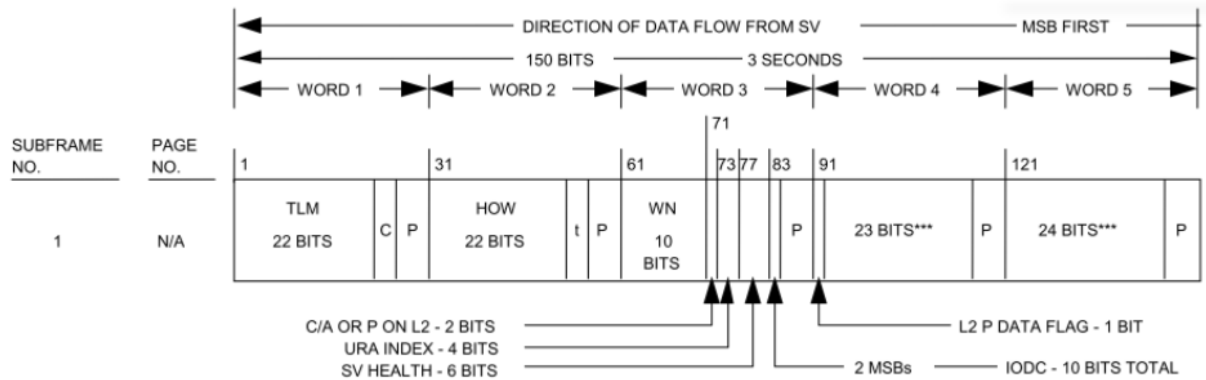


- **Spectrum Users (GPS Receivers)**
  - Live within RNSS bandwidth allocations
    - L1 GPS ~ 1560 to1590 MHz (L1 RNSS = 1559 to 1610 MHz)
  - Anticipate pressures for spectrum access in adjacent bands
    - Decreasing assurance of "quiet neighborhood"
    - Plan to use additional GPS signals for multi-frequency benefits
  - Accept that GPS cannot be made "bulletproof" to interference
    - GPS performance include consideration of augmentations & complements (Integrated PNT solutions) in the future

GPS Specifications & Standards

- **GPS Interface Specifications (IS) – available at GPS.gov**
  - IS-GPS-200E (Receiver interface requirements for L1 & L2)
    - C/A-code, P(Y)-Code, L2C-Code
  - IS-GPS-705A (Receiver interface requirements for L5)
  - IS-GPS-800A (Receiver interface requirements for L1C)

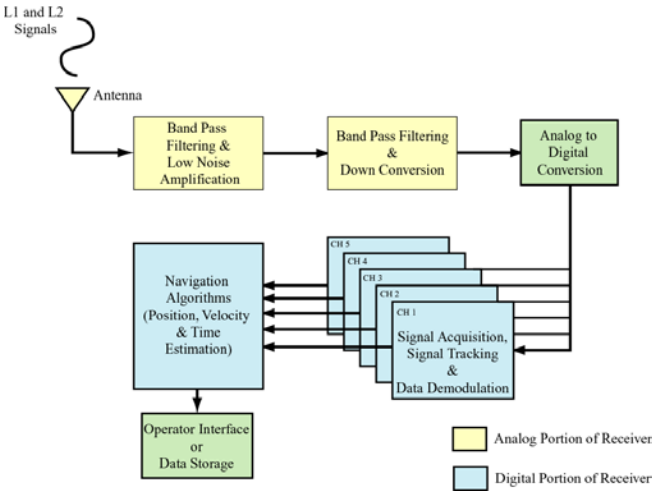
Excerpt: IS-GPS-200E



- **GPS Receiver Performance Standards/Criteria**
  - By application (i.e., aviation, maritime, timing/synchronization, etc.)
  - Defined by regulators and applications standards bodies

GPS Receiver Performance Elements

- **Signal reception**
  - Antenna, RF front end parameters (includes filtering)
- **Signal demodulation/down-conversion**
  - Code/carrier tracking, data detection (phase changes) & data demodulation – read navigation message
- **Signal processing**
  - Calculate navigation solution (Position, Velocity, Time)
- **Applications**
  - Qualitative requirements affect quantitative receiver design decisions



Remarks on "GNSS Performance Standards and Certification" from an Aviation Perspective

Christopher J. Hegarty
MITRE Corporation
Director, Communication, Navigation & Surveillance Engineering

GNSS Aviation Standards - Overview

- International
  - GNSS Standards and Recommended Practices (SARPs) first adopted by the International Civil Aviation Organization (ICAO) in 2001
  - Subsequently amended 11 times
- Domestic
  - FAA responsible for civil avionics certification per CFR Title 14
  - Technical Standard Orders (TSOs) - one popular certification path
- Current standards are for L1-only avionics

Source: www.icao.int.

Source: www.faa.gov.

FAA GNSS Technical Standard Orders

Equipment	TSO	Invoked RTCA Document	Date First Published	Status
Stand-alone GPS	TSO-C129	DO-208	1992	Cancelled
Stand-alone GPS	TSO-C196	DO-316	2009	Active
Antennas	TSO-C144	DO-228	1998	Active
Antennas	TSO-C190	DO-301	2007	Active
GPS/Satellite-based Augmentation System (SBAS)	TSO-C145	DO-229	1998	Active
GPS/SBAS	TSO-C146	DO-229	1998	Active
GPS/Ground-based Augmentation System (GBAS)	TSO-C161	DO-253	2003	Active

RTCA Minimum Operational Performance Standards (MOPS)

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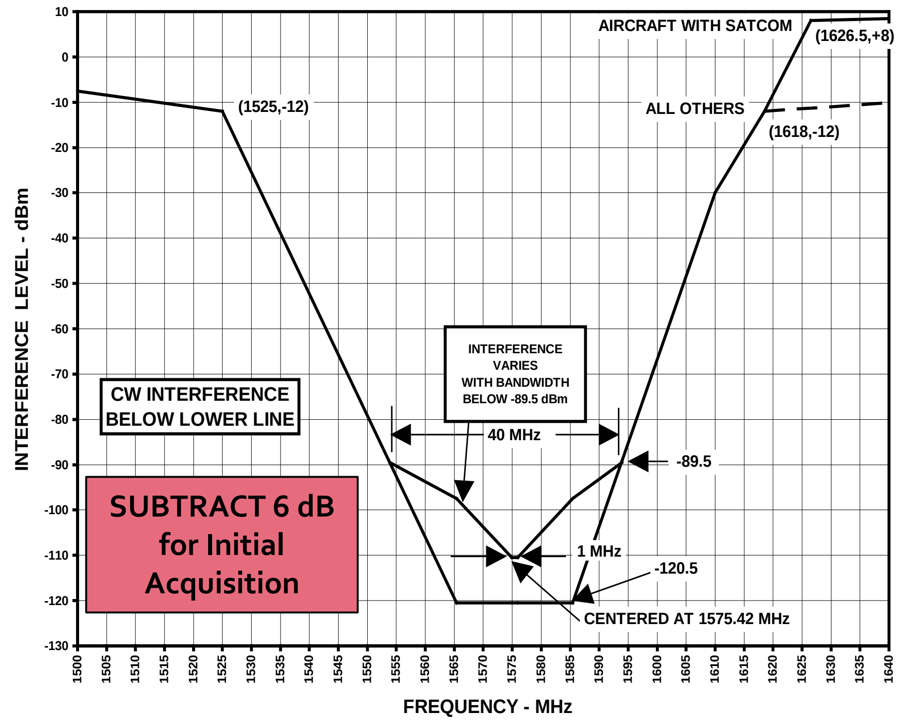
- Each typically hundreds of pages
- ~100's of requirements
  - Minimum functionality and performance
  - Environmental conditions
- Test procedures



Interference Requirements Span 1315 – 2000 MHz

GNSS Receiver Standards and Certification for Wireless Devices

GNSS Performance Standards & Certification:
Beyond Spectrum Protection

Ronald Borsato – Principle Architect
Spirent Communications

Who's Who In GNSS Conformance Testing for Wireless?

- **Standards Development Organizations:**
  - **3GPP**: 3rd Generation Partnership Project
    - WCDMA, GSM and LTE Conformance Tests
  - **3GPP2:** 3rd Generation Partnership Project 2
    - CDMA Conformance Tests
- **Certification Bodies**
  - **GCF**: Global Certification Forum
  - **PTCRB**: PCS Type Certification and Review Board
  - **CCF**: CDMA Certification Forum
  - **CTIA**: The Wireless Association
    - Test Plan for Wireless Device Over-the-Air Performance

A-GNSS Performance Standards

WCDMA
3GPP TS 34.171 – A-GPS RF minimum performance
3GPP TS 34.172 – A-GNSS RF minimum performance (GPS+GLONASS)
GSM
3GPP TS 51.010 - 70.11 – A-GPS Minimum Performance
3GPP TS 51.010 - 70.16 – A-GNSS Minimum Performance
LTE/WCDMA
3GPP TS 37.571-1 – LTE/WCDMA A-GNSS Minimum Performance
CDMA
3GPP2 C.S0036-0 v2.0 – A-GPS RF Minimum Performance
3GPP2 C.S0036-A – A-GNSS RF Minimum Performance
A-GPS OTA Test: CTIA Test Plan for Wireless Device Over-the-Air Performance

A-GNSS Minimum Performance Testing

- A-GPS, A-GPS+A-GLONASS and A-GLONASS Operation
- UE-based and UE-Assisted Positioning Modes
- A-GNSS Receiver Performance Tests
  - Nominal Accuracy
  - Sensitivity
  - Multipath
  - Dynamic Range
  - Moving scenario
- A-GNSS Aspects Only
  - No Additional Interferers other than Supporting Wireless Radio Bearer

A-GPS Over-the-Air Testing

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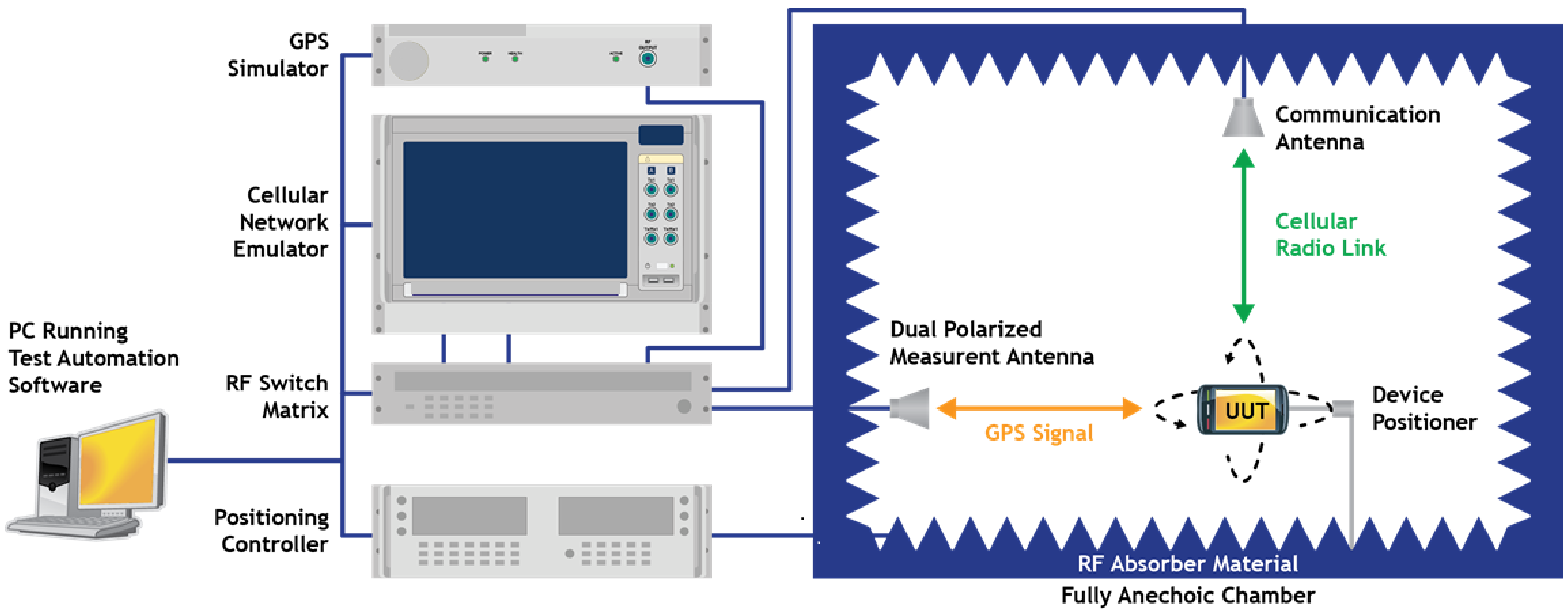
Typical Anechoic Chamber A-GPS OTA Test System



A-GPS Over-the-Air Testing

- CTIA A-GPS OTA test procedure:
  - Antenna pattern
    - Use UE SV C/N_0 measurements from GPS Accuracy test
    - Two Polarizations in 30° Increments in Theta (Θ) and Phi (ϕ)
  - Linearization
    - Correct UE SV C/N_0 measurements with a Known Signal Source
  - Radiated sensitivity (EIS_{ref})
    - Perform GPS Sensitivity Search at Pattern Peak (Θ = 0° to 90°)
    - Use same GPS Sensitivity test case (satellite scenario, performance metrics, etc.) as Industry Standard
    - Provides Traceability for OTA Test to Conducted Test

$$EIS(\theta, \phi, Polarization) = EIS_{ref} / P(\theta, \phi, Polarization)$$

A-GPS Over-the-Air Testing

- CTIA A-GPS OTA test procedure (cont):
  - Calculation of Spatially Averaged Quantities
    - Total Isotropic Sensitivity (TIS)
    - Upper Hemisphere Isotropic Sensitivity (UHIS)
    - Partial Isotropic GPS Sensitivity (PIGS) calculation

$$TIS \cong \frac{2NM}{\pi \sum_{i=1}^{N-1} \sum_{j=0}^{M-1} \left[\frac{1}{EIS_{\theta}(\theta_i, \phi_j)} + \frac{1}{EIS_{\phi}(\theta_i, \phi_j)} \right] \sin(\theta_i)}$$

  - Intermediate channel degradation
    - Evaluate Impact on GPS Performance at Wireless Device Radio Operating Frequencies
    - Compare Performance vs. Reference Frequencies Used for Full OTA Measurement

Ask the Experts – Part 1

Jules McNeff
Overlook Systems Technologies, Inc.
VP, Strategy & Programs

Chris Hegarty
MITRE Corporation
Director, Communication, Navigation & Surveillance Engineering

Ron Borsato
Spirent Communications
Principal Architect

Poll #2

Standards and certification are important so that I don't have to worry about performance details. (Select one)

1) *Agree*
2) *Disagree*

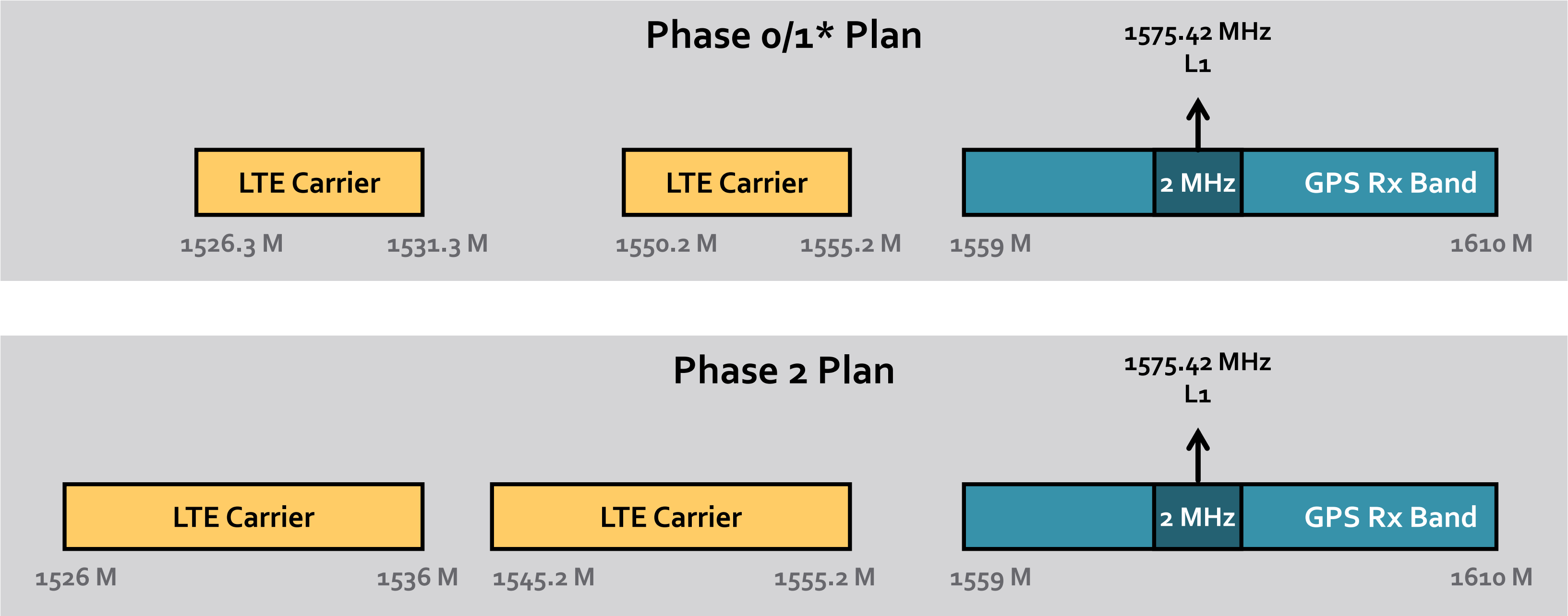
Part II

GNSS Performance Standards & Certification: Beyond Spectrum Protection

Ronald Borsato – Principle Architect
Spirent Communications

Lessons Learned and Specific Use Cases - Lightsquared

- Original Lightsquared Spectrum Deployment Plans



* Only upper 5-MHz LTE carrier is used in Phase-0. both 5-MHz carriers are used in Phase-1.

Lightsquared Downlink LTE L-Band and GPS Band

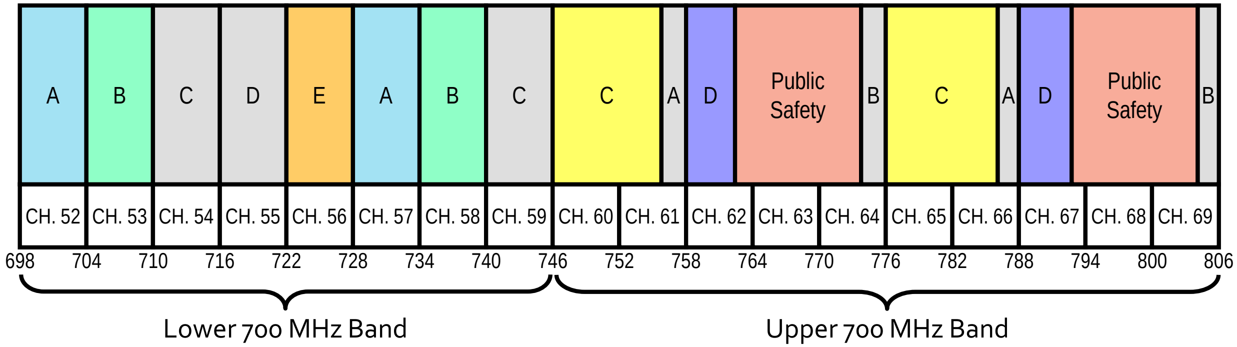
Source: Lightsquared, 3GPP R4-110470, January 2011

Lessons Learned and Specific Use Cases - Lightsquared

- Cellular TWG Developed Test Plan to Evaluate GPS Performance Impact of LTE Downlink Signals
  - Receiver Blocking and Intermodulation Test Scenarios
  - Utilized Realistic Interferers using Signal Generators
    - Frequency Allocations
      - Phase 1, Phase 2, and Lower 10 MHz Only
    - Modulation Coding Schemes (LTE DL – OFDM)
    - Interferer Signal Levels Varied to Determine Failure Point
- Test Cases Based on Existing Industry A-GPS Performance Standards
  - Impact Traceable to Defined Performance Criteria
- Cellular TWG Concluded that Lower 10 MHz did not Cause Harmful Interference to Cellular A-GPS Operations

Lessons Learned and Specific Use Cases – LTE Band 13

- LTE Band 13 Transmit Band 2nd Harmonic
  - UE Transmit Configuration (Upper C Block)
    - Carrier Frequency = 781 MHz
    - RF Channel BW = 10MHz (Actual: 50 RB * 180 kHz = 9 MHz)
  - Resource Allocation at Bandedge
    - Last Allocated Resource Extends to 786.5 MHz
  - 2nd Harmonic Falls at 1573 MHz
    - Any Out of Band Emissions Would Spill Over to GPS
  - Highlights the Need to Evaluate GPS Receive Performance with Specific Transmit Configurations



Possible Future GNSS Performance Standards

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- Interference Testing
  - Receiver Blocking and Intermodulation Tests
  - Utilize Realistic Interferers
    - Frequency Allocations
    - Modulation Coding Schemes
    - Interference Signal Levels
- Expanding OTA Testing to Include Additional Interference Sources
  - Multi-Radio Operation within Devices
- Applying A-GNSS Performance Testing Concepts in Other GNSS Market Segments
- Any Additions would Require Necessary Work Items in the Representative Standards and Certification Bodies

Part II

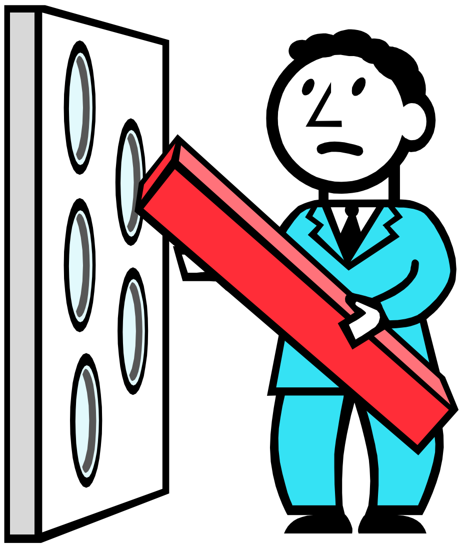
Christopher J. Hegarty
MITRE Corporation
Director, Communication, Navigation & Surveillance Engineer**ing**

Receiver Standards for Spectrum Efficiency – An Abbreviated History

- March 2003 – FCC Notice of Inquiry
- February 2012 – LightSquared Request (to FCC) for Initiation of Proceedings
- July 2012 – PCAST report
- November 2012 – House "Role of Receivers in a Spectrum Scarce World" hearing
- Feb 2013 – GAO report due per H.R. 3630

Observations

- **Receiver standards are onerous**
  - Not recommended for all
- **Existence of standards is *not* sufficient to avoid compatibility issues**
  - E.g., consider the aviation community's experience with LightSquared
- **Not a reasonable expectation that all GNSS receivers can conform to one interference mask**
  - Greatly-varied capabilities
  - Greatly-varied size, weight, power, and cost



RF Filter Size Comparison

SAW
(1.4 × 1.2 × 0.5 mm^3)

BAW
(3.3 × 1.6 × 0.8 mm^3)

3-pole ceramic
(20 × 14 × 7 mm^3)

U.S. Quarter
(24 mm × 1.8 mm)

6-pole cavity
(178 × 66 × 31 mm^3)

Part II

Spectrum Access & Performance Certification

Jules McNeff
Overlook Systems
Technologies, Inc.

Notional Receiver Certification Categories

- **Technical Certification**
  - Receiver engineering design IAW relevant GPS Interface Specification(s)
  - Operation within GPS assigned spectrum
  - Calculation of navigation solution
- **Performance Certification**
  - Receiver data processing IAW application performance requirements
  - Resiliency in the presence of interference
- **Security Certification (if applicable)**
  - Receiver processing of security information in navigation message
  - Protection of security features from unauthorized access

Issues Affecting Certification (1/2)

- **Certification scope**
  - Technical parameters for GPS receivers defined in IS
  - Performance parameters defined by application category
  - Consensus on common certification criteria?
    - Integrated System v Component level
    - Single frequency v multi-frequency

Issues Affecting Certification (2/2)

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- **Process models**
  - Government conducted/government oversight
    - Safety certification for aviation receivers
      - Approvals for design/manufacture (IAW FAA Orders)
    - DoD GPS receiver certification (military receivers only)
      - Planning stages at present
      - Process may be applicable to civil problem (separate funding)
  - Industry conducted
    - Independent laboratory (U/L model)
    - Individual self-certification (maritime compliance w/ IMO standards)
    - Industry associations set application standards

Future Considerations (1/2)

- **Role of Government (Federal Rulemaking Agencies, FCC & NTIA)**
  - Establish consistent, stable policies on PNT services
  - Conduct rulemaking in the open, solicit industry input
  - Establish performance parameters for critical infrastructure & safety applications
  - Take advantage of multiple civil signals for interference mitigation
  - Take account of unique GPS/GNSS reception & processing requirements

Future Considerations (2/2)

- **Role of Industry (GPS/GNSS receiver manufacturers)**
  - Develop consensus on receiver parameters
    - Application based framework
    - Operation within RNSS spectrum allocations
    - Take advantage of multiple frequencies
    - GPS Industry Council facilitation?
  - Be proactive rather than reactive with government regulators
    - Constantly work to ensure government regulators are taking account of the special nature of GPS signals (from slide 1) in their rulemaking actions

Poll #3

Testing to a standard would reduce test time development and save development costs.

1) *Agree*
2) *Disagree*

Next Steps

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For more information:

- **Visit www.insidegnss.com/webinars for:**
  - PDF of Presentation
  - List of resources provided

Ask the Experts – Part 2

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