US WG-A Presentation on Compatibility and Interoperability at the 3rd meeting of the ICG

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Definitions of Compatibility

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- **1st ICG Providers Forum: Compatibility** refers to the ability of space-based positioning, navigation, and timing services to be used separately or together without interfering with each individual service or signal.
  - Radiofrequency compatibility should involve thorough consideration of detailed technical factors, including effects on receiver noise floor and cross-correlation between interfering and desired signals. The International Telecommunications Union (ITU) provides the framework for discussions on radiofrequency compatibility.
  - Compatibility should also involve spectral separation between each system's authorized service signals and other systems' signals.
- **US Policy:** "Compatible" refers to the ability of U.S. and foreign space-based positioning, navigation, and timing services to be used separately or together without interfering with use of each individual service or signal, and without adversely affecting navigation warfare

Compatible = Do No Harm

Spectral Separation of GPS Civil and M-code Signals in L1

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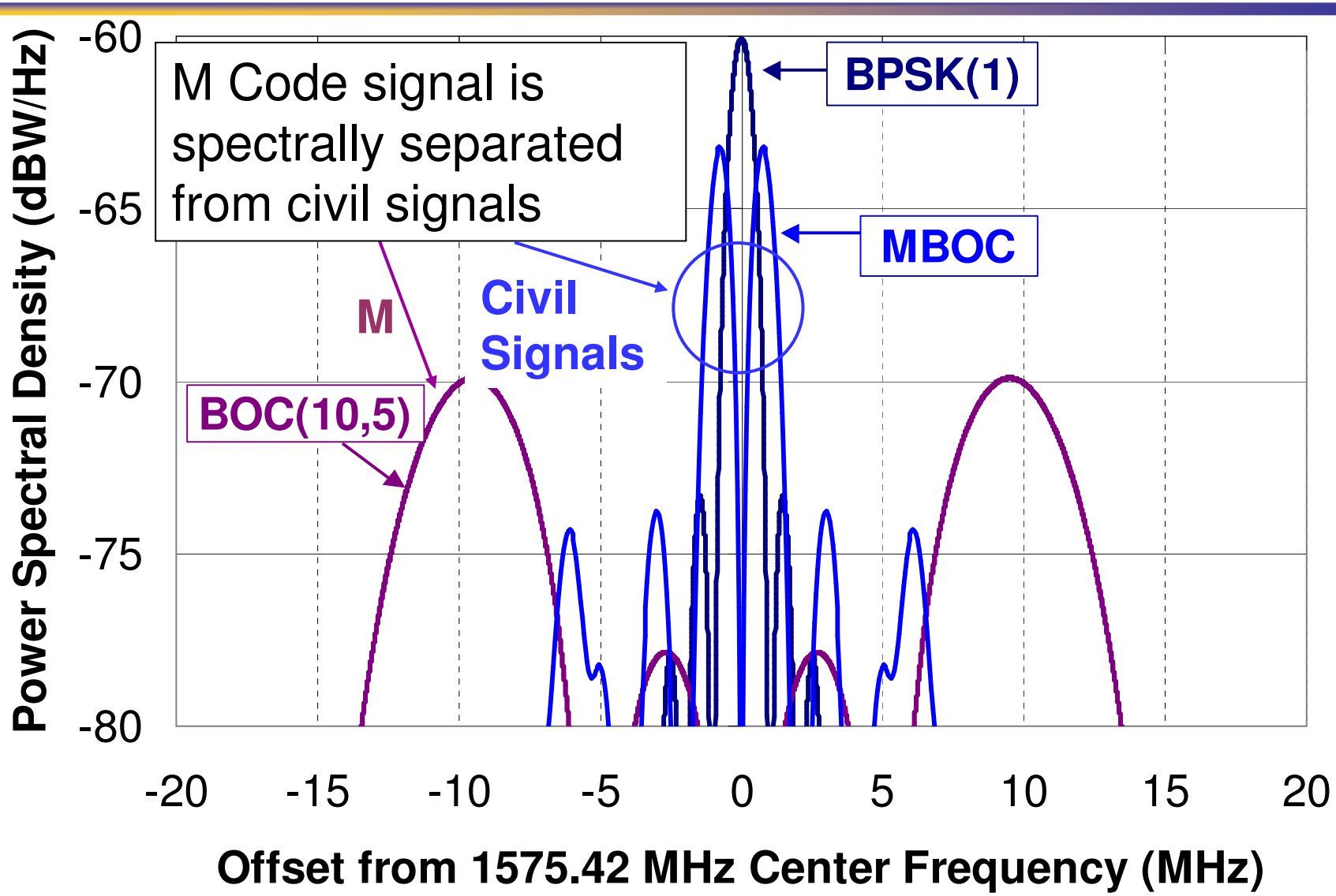

Benefits of Compatibility

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- U.S. suggests that compatibility, including spectral separation, is beneficial to both GPS and other systems
- Compatibility protects full utility of each system
  - For example, spectral separation from M code not only protects utility of M code, but also protects other systems signals
  - Avoids interference to other systems from higher power M code and large GPS constellation
- Compatible signals simplify international acceptance of other systems in ITU and other forums

Definitions of Interoperability

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- **1st ICG Providers Forum: Interoperability** refers to the ability of open global and regional satellite navigation and timing services to be used together to provide better capabilities at the user level than would be achieved by relying solely on one service or signal.
  - Ideal interoperability allows navigation with signals from at least four different systems with no additional receiver cost or complexity.
  - Common center frequencies are essential to interoperability, and commonality of other signal characteristics is desirable.
  - Multiple constellations broadcasting interoperable open signals will result in improved observed geometry, increasing end user accuracy everywhere and improving service availability in environments where satellite visibility is often obscured.
  - Geodetic reference frames and system time standards should also be considered.
- **US Policy:** "Interoperable" refers to the ability of U.S. and foreign space-based positioning, navigation, and timing services to be used separately or together to provide better capabilities at the user level than would be achieved by relying solely on one service or signal

Interoperable = Better Together Than Separate

Dimensions of Interoperability

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Characteristic	*Interoperability Benefit*
■Common time and reference frames, or broadcast offsets	■Navigation solutions can use measurements from different systems without solving for offsets
■Common carrier frequencies	■Common antenna and receiver front end—lower power and cost; common carrier tracking for higher accuracy
■Similar spreading modulation spectra	■Common-mode dispersive errors removed in navigation solution for higher accuracy
■Common Min/Max power	■Improves signal to noise environment for multi-system receivers
■Common spreading code lengths and common code family	■Lower crosscorrelation sidelobes for better weak-signal reception; common receiver processing for acquisition and tracking
■Common data message structure and encoding	■Common receiver processing for data message decoding and processing

Found by comparing signal specifications

Benefits of Civil Signal Interoperability

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- Civil signal interoperability benefits users and receiver manufacturers
  - Lower cost and better performance for receivers that use GPS and other systems signals together
  - More users benefit from both systems' signals
  - More rapid and extensive adoption of highly interoperable signals
- Civil signal interoperability benefits the provider
  - Highly interoperable signals simplify international acceptance of systems in ITU and other forums

U.S. Priorities

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1. Compatibility: Newly introduced signals should be compatible with GPS signals…and vice-versa
   - Radio frequency compatibility: signals do not unacceptably interfere with use of other signals
   - Spectral separation between M code and other signals

2. Interoperability: Encourage newly introduced civil signals to also be highly interoperable with GPS civil signals
   - Primary focus on common civil L1 and L5 signals
   - Common power levels is a dimension to consider adding as a necessary “principle of interoperability”

Current Prospective RNSS Spectra

Color code: Blue—open signals, Red—restricted or encrypted signals

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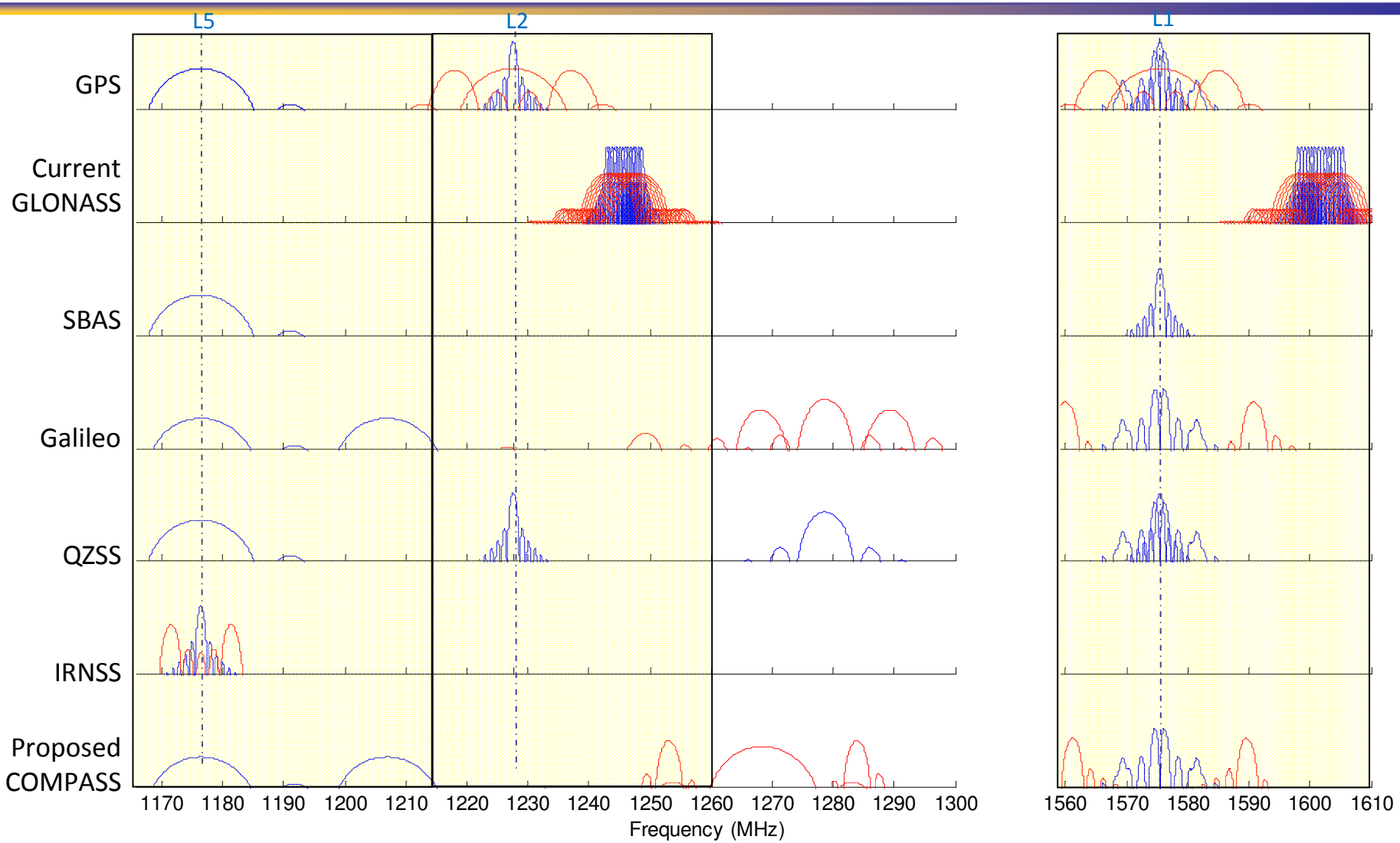

Beyond Compatibility and Interoperability: Service Assurance

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- Service Assurance: user confidence or provider commitment that a system will provide a specified level of service
  - Each new system should add value and not just contribute to the noise floor
  - Compatibility and interoperability are only the first steps to establishing a new service
- Like interoperability, service assurance is multidimensional:
  - In the case of the L1 and L5 multi-platform signals, service assurance should include the “open and free” provisions
  - Includes minimum performance levels for metrics like accuracy, availability, and integrity
  - Must address management and maintenance of the system
  - Some dimensions are more important than others
- Just like interoperability, different receiver manufacturers and different user classes will accept different levels service assurance

Priorities by User Class

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User Class	Acceptable Degree of Interoperability	Acceptable Degree of Service Assurance	Comments
Professional	Low	Low	Higher cost receivers can accommodate lower degrees of interoperability, and use infrastructure to verify quality of service
Safety of Life	Moderate	High	Higher cost receivers can accommodate moderate degrees of interoperability, but need high confidence in quality of service
Mass Market	High	Moderate	Low cost receivers need high degree of interoperability, but may accept modest degree of service assurance

GPS SPS Performance

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	GPS Performance Standard Metric	SPS Signal Specification August 1998 (user performance)	SPS Performance Standard October 2001 (signal in space)	SPS Performance Standard September 2008 * (signal in space)	CY 2007 Performance**
1	**Global Accuracy** All-in-View Horizontal 95% All-in-View Vertical 95%	≤ 100 meters ≤ 156 meters	≤ 13 meters ≤ 22 meters	≤ 9 meters ≤ 15 meters	2.32 meters 4.45 meters
2	**Worst Site Accuracy** All-in-View Horizontal 95% All-in-View Vertical 95%	≤ 100 meters ≤ 156 meters	≤ 36 meters ≤ 77 meters	≤ 17 meters ≤ 37 meters	3.63 meters 4.95 meters
3	**User Range Error (URE)**	NONE	≤ 6 meters RMS (Constellation RMS URE)	≤ 7.8 meters 95%, (Worst Satellite URE) *equivalent to 4 m RMS*	2.29 meters RMS (Worst Satellite URE)
4	**Geometry (PDOP ≤ 6)**	≥ 95.87% global ≥ 83.92% worst site	≥ 98% global ≥ 88% worst site	≥ 98% global ≥ 88% worst site	99.988% global 98.958% worst site
5	**Constellation Availability**	NONE	≥ 95% Probability of 24 Healthy Satellites ≥ 98% Probability of 21 Healthy Satellites (assumes 24 primary slots)	≥ 95% Probability of 24 Healthy Satellites ≥ 98% Probability of 21 Healthy Satellites ≥ 99.999% Probability of 20 Healthy Satellites (assumes 24 primary slots)	100% Probability of 24 Healthy Satellites 100% Probability of 22 Healthy Satellites in 24 primary slots (FY2008) ***

* Green color indicates improvement in U.S. Government commitment to GPS civil service

** As measured and reported at web site (http://www.nstb.tc.faa.gov/)

*** As measured and reported at web site (http://www.gps.afspc.af.mil/gpsoc/)

Service Assurance Cont.

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- The GPS SPS Performance Standard could be a basis for establishing many of the parameters associated with service assurance
- GPS standards could also be used as a starting point for establishing performance levels desired or provided from other systems
  - Accuracy, availability, integrity, etc
  - Issuance of international NOTAMs prior to any scheduled maintenance, and after the onset of any unscheduled outages
- Some dimensions of service assurance are qualitative—no widely adopted definitions or hard thresholds exist for them
  - Backwards compatibility
  - Mature maintenance practices
  - Commitment to maintain a complete constellation of satellites; and
- Individual providers will have to assess the need, desirability, and commitment for each parameter

Proposed new ICG principle: Every GNSS provider should establish documented performance commitments to address user expectations

Summary

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- Compatibility is essential
- Civil interoperability benefits civil users and providers
  - Proposed “common power levels” as an essential additional component for interoperable signals
- U.S. encourages compatibility and interoperability, between GPS and other systems
- Service assurance levels should be established in provider generated performance standards
  - Proposed “documented performance commitments” as a new ICG principle