Views on Multilateral Compatibility Coordination

China Satellite Navigation Office

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Background of ICG

- **Purpose of ICG**
  - To promote cooperation related to civil satellite-based PNT and value-added services.
  - To increase GNSS use to support sustainable development, particularly in the developing countries.

Background of ICG

- **Property of ICG**
  - Established on a voluntary basis as an informal body
  - respecting the roles and functions of GNSS service providers and intergovernmental bodies such as ITU
  - All ICG or its working groups recommendations will be decided on the basis of consensus of its members , do not create legal obligations, and will be acted upon at the discretion of each member

Focus of ICG

- Focus on Open Civil signals: Open and free of direct user charge
- Realization of Open Civil signal Interoperability
  - ✓Common carrier frequency and spectrum: beneficial
  - ✓Frequency diversity
- Compatibility aiming to interoperability: limited to open civil signals

Compatibility Scope on ICG platform

- The ability of multiple civil satellite navigation systems to be used separately or together:
  - without causing harmful interference with use of each individual service or signal
  - Open civil signals to be spectral separated with all other services or signals
  - Compatibility among CS/PRS/AS/Military signals to be discussed through bilateral coordination in the framework of ITU or other suitable channels

Realization of Compatibility

- Compatibility aiming at interoperability of civil signals:
  - same or similar link budgets;
  - common maximum and minimum received power level: assuring common max/min carrier-noise ratio;
  - comparable noise contribution: the more signals put into one frequency band, the more noise floor increased, limit noise floor level is beneficial.

Multilateral Compatibility Coordination

- Requirement analysis
- Related rules
- Some concerns

Multilateral Compatibility Coordination

- Requirement analysis
  - may be convenient when there's a need to achieve consensus for concerned systems on the same issue:
    - L1C/B1C/E1OS/…
    - L5/B2a/E5a/…
  - contributing to GNSS rules and standardization
    - ICG output may be proposed as new questions and studies for ITU, ICAO and IMO consideritions through approriate mechanisms
    - GNSS international rules and standards would benefit the promotion of mass-market and specialized applications

Multilateral Compatibility Coordination

- Related rules
  - Basic principles: rational, equitable, efficient and economical use of RF spectrum
  - At present, relevant ITU regulations and recommendations such as ITU-R Res.610 and Rec. ITU-R M.1831 are effective and widely adopted ways for GNSS bilateral compatibility coordination which can cover the whole range of PNT signals and services as bilaterally wished
  - others

Multilateral Compatibility Coordination

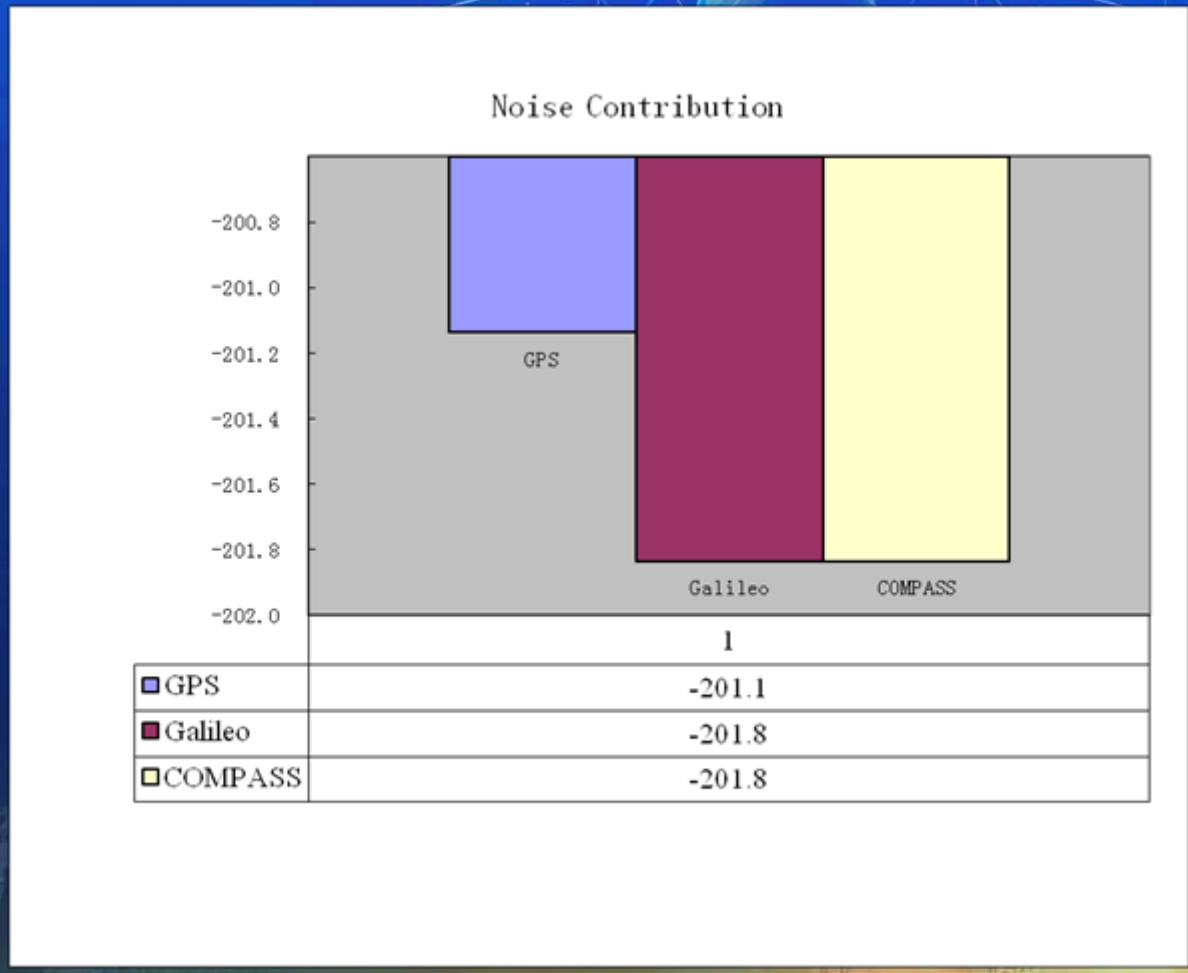
- Some concerns
  - Bilateral compatibility coordination between GNSSs is in process or completed. Prior to successful bilateral coordination, multilateral compatibility coordination will probably increase the complexity of the issue.
  - Adding limit such as satellite number or signal number in one band may influence the design, development and modernization of GNSSs.

Example 1: Noise Contribution of L1C/B1C/E1OS

	GPS L1C	GPS L1CA	GPS L1P	WAAS L1CA	Galileo E1OS	EGNOS E1 CA	COMPASS MEO B1C	COMPASS GEO B1C
Maximum Received Power (dBW)	-152	-153	-150	-152.5	-152	-155	-152	-153
Minimum Received Power (dBW)	-157	-158.5	-161.5	-158.5	-157	-161	-157	-157.7
SSC(dB/Hz)	-65.4	-68.1	-68.1	-68.1	-65.4	-68.1	-65.4	-65.4
Gagg (dB)	13.1	13.1	13.1	6.7	11.5	6.4	11.5	11.2
Noise Contribution (dBW/Hz)	-204.3	-208	-205	-213.9	-205.9	-216.7	-205.9	-207.2
Thermal noise (dBW/Hz)	-204							
GPS noise contribution (dBW/Hz)	-201.1	-200.6		-203.6	NA			
Galileo noise contribution (dBW/Hz)	NA				-201.8	-203.8	NA	
COMPASS noise contribution (dBW/Hz)	NA						-201.8	-202.3
Total noise excluding regional system (dBW/Hz)	-197.5							

Example 1: Noise Contribution of L1C/B1C/E1OS

- GPS, Galileo and BeiDou have comparable noise contribution level;
- The maximum difference is only 0.7dB.



Example 1: Noise Contribution of L1C/B1C/E1OS

C/N0 (dB/Hz)	GPS L1C	Galileo E1OS	COMPASS MEO B1C
Maximum	45.5	45.5	45.5
Minimum	40.5	40.5	40.5

- If all the signals adopt same minimum/maximum received power, the minimum/maximum C/N0 for all signals are common.
- This will be beneficial and equal for all the GNSSs as well as users.

Example 2: DOPs Improvement percentage with Compass

Global Area	GDOP	HDOP	VDOP
GPS	48.1%	45.8%	47.9%
GPS+GLONASS	33.9%	31.8%	33.9%
GPS + GLONASS + Galileo	23.6%	24.6%	24.6%

Europe Area	GDOP	HDOP	VDOP
GPS	49.7%	48.9%	48.7%
GPS+GLONASS	34.0%	33.3%	33.8%
GPS + GLONASS + Galileo	23.8%	24.2%	23.4%

Example 3: Calculation for Visible Satellites

- BeiDou notably improves the visibility of satellites in high elevation angles.

	30° (90%>)		40° (90%>)	
scheme	min	mean	min	mean
GPS	3	3.6	1	2.1
GPS+BeiDou	7	9.4	3	5.9
GPS+GLONASS	4	6.4	2	3.8
GPS+GLONASS+BeiDou	8	12.2	5	7.9
GPS+ GLONASS+GALILEO	8	10.8	5	6.8
GPS+ GLONASS+GALILEO+BeiDou	12	16.6	7	10.1

Conclusions

- Multi-GNSSs is good for users.
- GNSS compatibility is a critical and technical issue for all system providers with a common goal for better user applications;
- ICG is seeking its role, ways forward and relationship with other coordination platforms to promote civil PNT services;
- Multiple compatibility coordination is beneficial to find solutions of issues of common interest.

Future works

- Some technical issues to discuss in order to achieve multiple compatibility:
  - Establishing receiver models which can be accepted by all GNSSs and determining the relevant parameters.
  - Determining the minimum receiver C/N_0 and reasonable protective threshold.
  - determining the reference assumptions for computations, etc.

Thanks for your attention!

beidouint@beidou.gov.cn

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