BeiDou
Navigation Satellite System

Interoperable GNSS Space Service Volume Simulation Configuration

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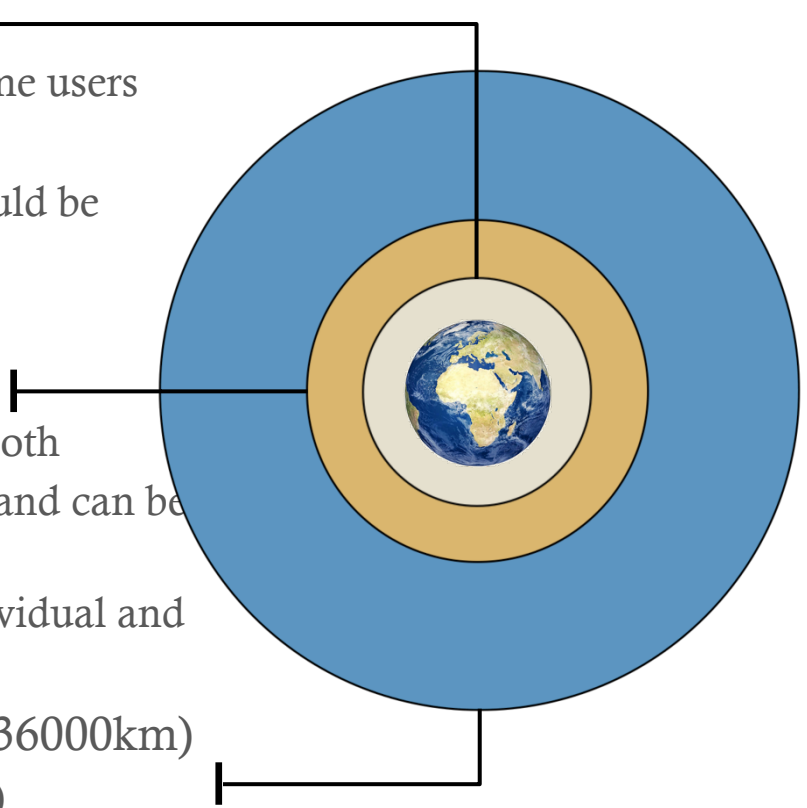
Interoperable GNSS SSV

Understanding of Interoperable GNSS SSV

- Extended Terrestrial Volume (~3000km)
  - Users with zenith antenna as land, air and maritime users
  - Similar PNT service to terrestrial users
  - Number of visible satellites, URE and DOP should be evaluated for individual constellation.
- Space Service Volume for Medium Altitude (3000~8000km)
  - User antenna direction tradeoff: zenith, nadir or both
  - PNT service is available with single constellation and can be improved by multi-constellation.
  - All above parameters should be evaluated for individual and multi-constellation
- Space Service Volume for High Altitude(8000~36000km)
  - User with nadir antenna (add zenith if necessary)
  - PNT service is limited with single constellation. Multi-constellation will improve the visibility.
  - Outage time and received power should also be evaluated.



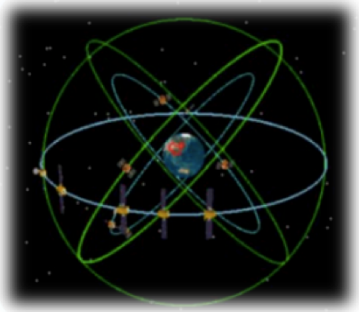
SSV Simulation

Phase 1 Configuration —— BDS Constellation

- The regional BDS space segment consists of 14 satellites in orbit

  5 GEO + 5 IGSO + 4 MEO

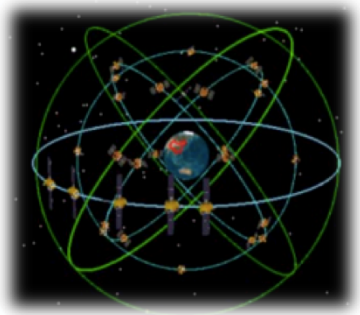
  - The 5GEO+5IGSO constellation can provide regional coverage, and the MEO satellites were deployed for flight test of global service, performance improvement and system redundancy.



- BDS will be in full operation in 2020 and consist of 35 satellites.

  5 GEO +3 IGSO +27MEO

  - The GEO and IGSO satellites are deployed for regional augmentation.
  - The 3 spare MEO satellites are not incorporated in the SSV simulation configuration.



SSV Simulation

Phase 1 Configuration ——BDS OS Signals

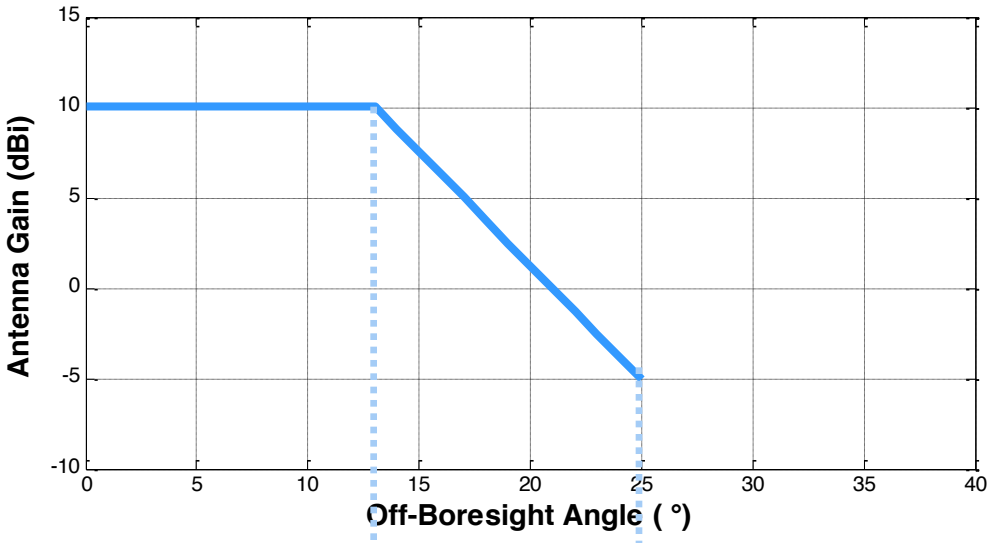
BDS-SIS-ICD-V2.0

BDS-OS-PS-V1.0

- The operational BDS OS signals are B1I（1561MHz) and B2I(1207MHz). They are providing free and reliable positioning, velocity and timing services at Asian-Pacific region.
- The performance of modernized OS signals B1-C(1575MHz), B2-a & B2-b (1191MHz) is enhanced significantly from the operational OS signals.
- Modernized signals can provide better interoperability with other GNSS signals.

SSV Simulation

Phase 2 Configuration —— GNSS Satellite Antenna Pattern



Edge of Earth Angle

Reference Off-Boresight Angle

GEO/IGSO

	FN BW	-5dBi BW	0dBi BW	EOE Angle
B1	±20°	**±19°**	±18°	**±8.7°**
B2	±26°	**±22°**	±21°	**±8.7°**

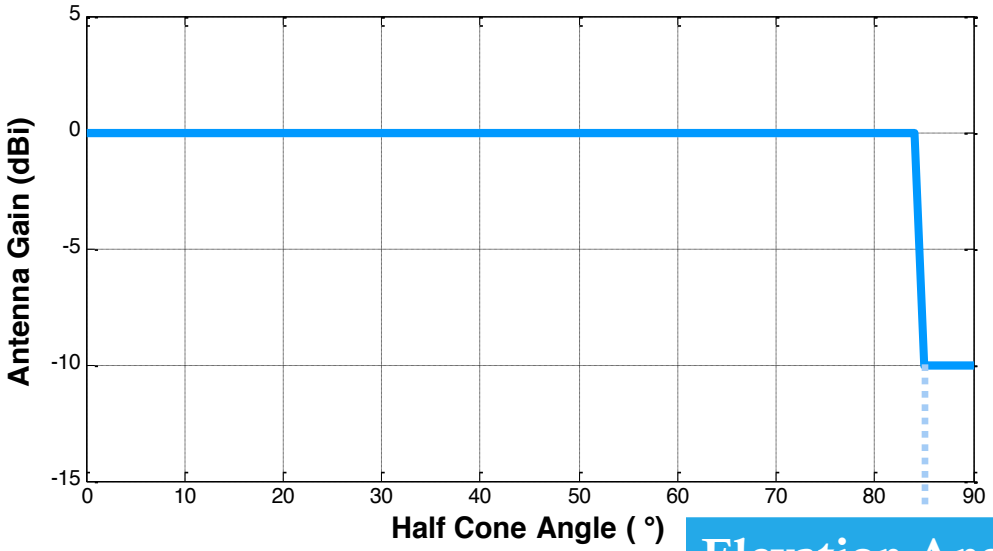
MEO

	FN BW	-5dBi BW	0dBi BW	EOE Angle
B1	±26°	**±25°**	±24°	**±13.2°**
B2	±30°	**±28°**	±26°	**±13.2°**

- Representative BDS Satellites antenna parameters provided on ICG-10.
- The parameters are characterization of modernized BDS test satellite, and do not represent a specification of BDS antenna performance.

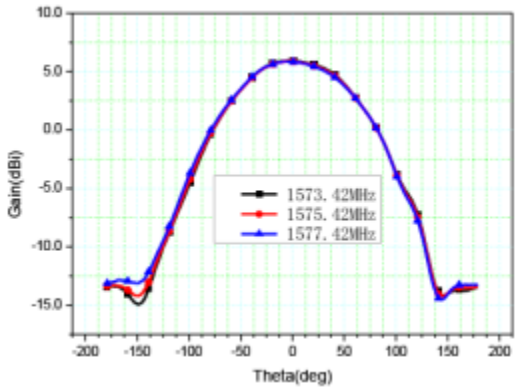
SSV Simulation

Phase 2 Configuration —— User Antenna Pattern

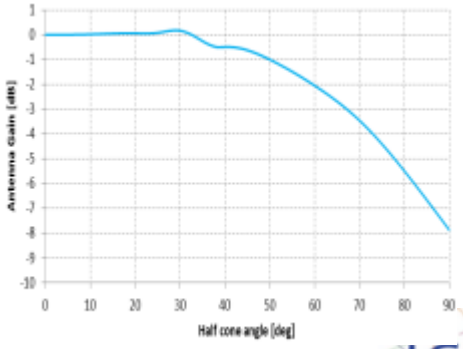


- Proposed user Antenna is nadir pointing with 0 dBi gain and cut-off at elevation angle 5°.
- SSV user antenna patterns design varies with its mission.
- The proposed pattern can minimize the influence of antenna differences.

Elevation Angle 5 °



Receiver Antenna pattern of CE-5T1 Mission *



Typical Receiver Patch Antenna Pattern provided by ESA

SSV Simulation

Phase 2 Configuration —— Link Budget

Orbit Type	MEO		GEO/IGSO	
Signal Type	B1	B2	B1	B2
Carrier Frequency (MHz)	1575	1191	1575	1191
Input Power of Antenna (dBW)	14	13	14	13
Antenna Gain(dBi)	**-5**	**-5**	**-5**	**-5**
EIRP(dBW)	**9**	**8**	**9**	**8**
Maximum Distance (km)	68806	68806	83346	83346
Maximum Free Space Loss(dB)	193.1	190.7	194.8	192.4
Minimum Received Power (dBW)	**-184.1**	**-182.7**	**-185.8**	**-184.4**

- User received power at GEO altitude between the EOE angle and the reference off-boresight angle shall always be higher than the received power level specified as minimum received power .
- The typical power threshold of receiver is around -175dBW.

SSV Simulation

Phase 2 Configuration —— Figure of Merits

Scenario 1: 8000km sphere grid, nadir/zenith/nadir and zenith pointing

- Number of visible satellites (minimum/95%/average over time spans, average grid if necessary)
- DOP(minimum/95%/average over time spans, average grid if necessary)
- Pseudo-range Accuracy
- Individual constellation and multi-constellation

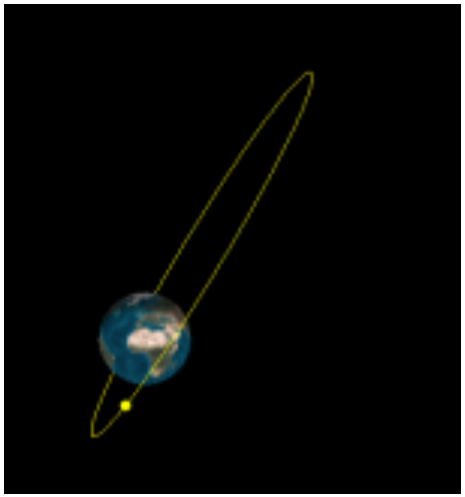
Scenario 2: 36000km sphere grid，nadir pointing

- Outage time (1 satellite visible，4 satellites visible)
- Number of visible satellites (minimum/95%/average in time spans, average grid if necessary)
- Individual constellation and multi-constellation

SSV Simulation

Phase 3 Configuration —— User Trajectory

- **Scenario 1**: Highly-inclined Elliptical Orbit Space Users



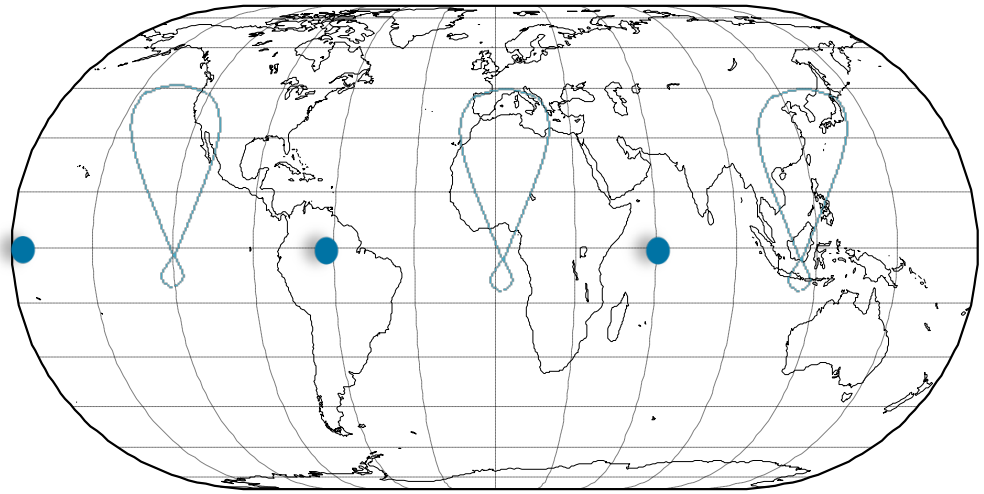
- HEO SVs
- Inclination:40~ 60°
- Semi-axis：28378.1 km
- Apogee: 36000km
- Perigee: 8000km

- This scenario covers all altitude of higher SSV where interoperable GNSS SSV shows the most interests.
- The specific parameter of the HEO should be discussed and agreed by all simulation participants.

SSV Simulation

Phase 3 Configuration —— User Trajectory

- **Scenario 2**: Geostationary or Inclined Geosynchronous Orbit Space Users



- 4~6 GEO/IGSO SVs
- IGSO Inclination: 40~60°
- Semi-major Axis: 42164km
- The crossing longitudes locate at interval of 60°or 90°.

- This scenario represents most SSV users at present, and to some extend it can show the distinctive meaning of GNSS SSV for GEO orbit resource problem.
- Considering simulation phase 1 and 2 have already covered the assessment of GEO equator and sphere(36000km), this scenario exists some duplicate work .

SSV Simulation

Phase 3 Configuration —— User Trajectory

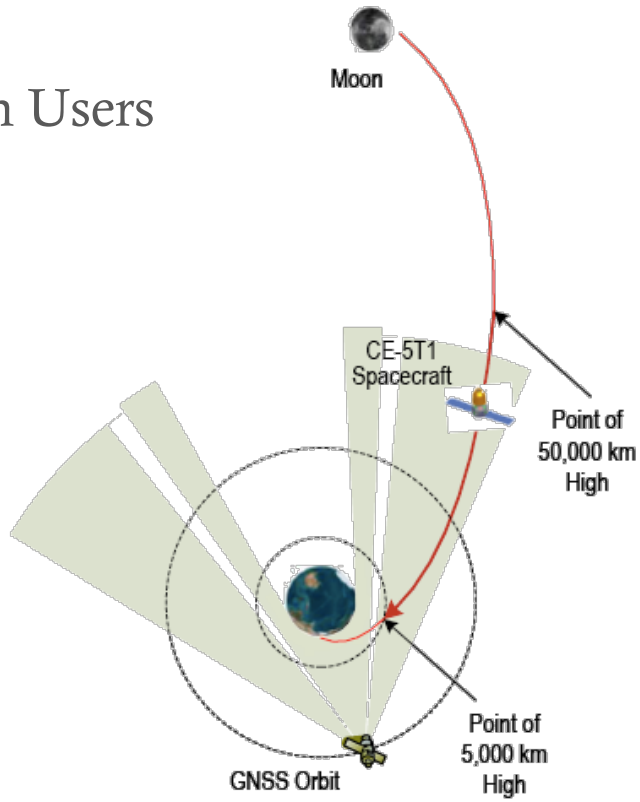
- **Scenario 3**: Upper Stage Space Users

  - Upper stage are widely used in MEO and HEO spacecraft deployment.
  - Autonomous navigation and low cost are significant for upper stage, so upper stage users will greatly increased along with the development of a interoperable GNSS SSV.
  - The upper stage mission includes multiple orbit transfer and the attitude of SV is varied, so upper stage trajectory need to be discussed to cover typical missions.

SSV Simulation

Phase 3 Configuration —— User Trajectory

- **Scenario 4**: Lunar and other Deep Space Mission Users
  - For earth-moon transfer orbit and re-entry of deep space exploration missions trajectory determination by GNSS can overcome long ground-based observation.
  - Depending on the specific orbit, the receiver may need to track signals not only from main-lobe but also side-lobe which is not included in SSV simulation at present.
  - The phase of deep space mission and specific trajectory need to be discussed to cover typical missions.



Flight arc of CE-5T1 GNSS experiment*

*IAC-15-B2.3.13

Conclusions

- Considering the difference of GNSS satellites antenna design, to adopt a simplified antenna pattern with 2 parameters will benefit the joint simulation.
- SSV receiver (including antenna, sensitivity, etc.) design varies with its mission, thus user antenna with conservative gain and omni-direction pattern is suggest so that simulation result can be universally applied.
- Trajectory selection for simulation phase 3 should consider representativeness of SSV as well as GNSS space service demand, and should be agreed on by all simulation participants.
- BDS is willing to participate in the interoperable GNSS SSV for the benefit of space applications.

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Thank you for your attention !

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