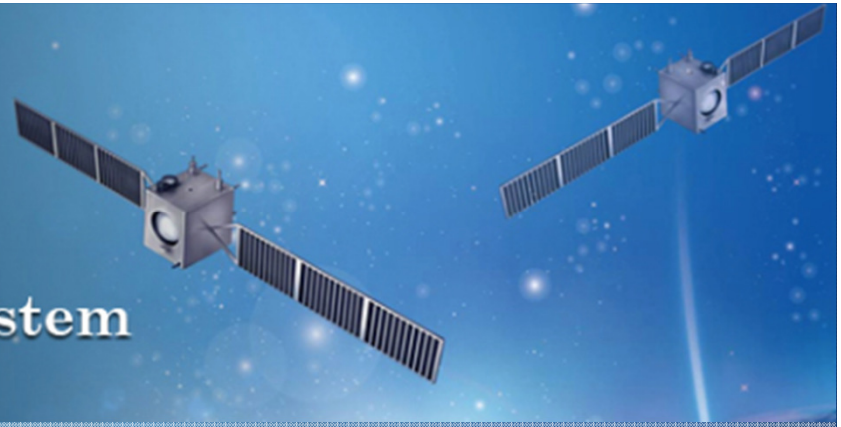

BeiDou
Navigation Satellite System

Space Service Volume Performance of BDS

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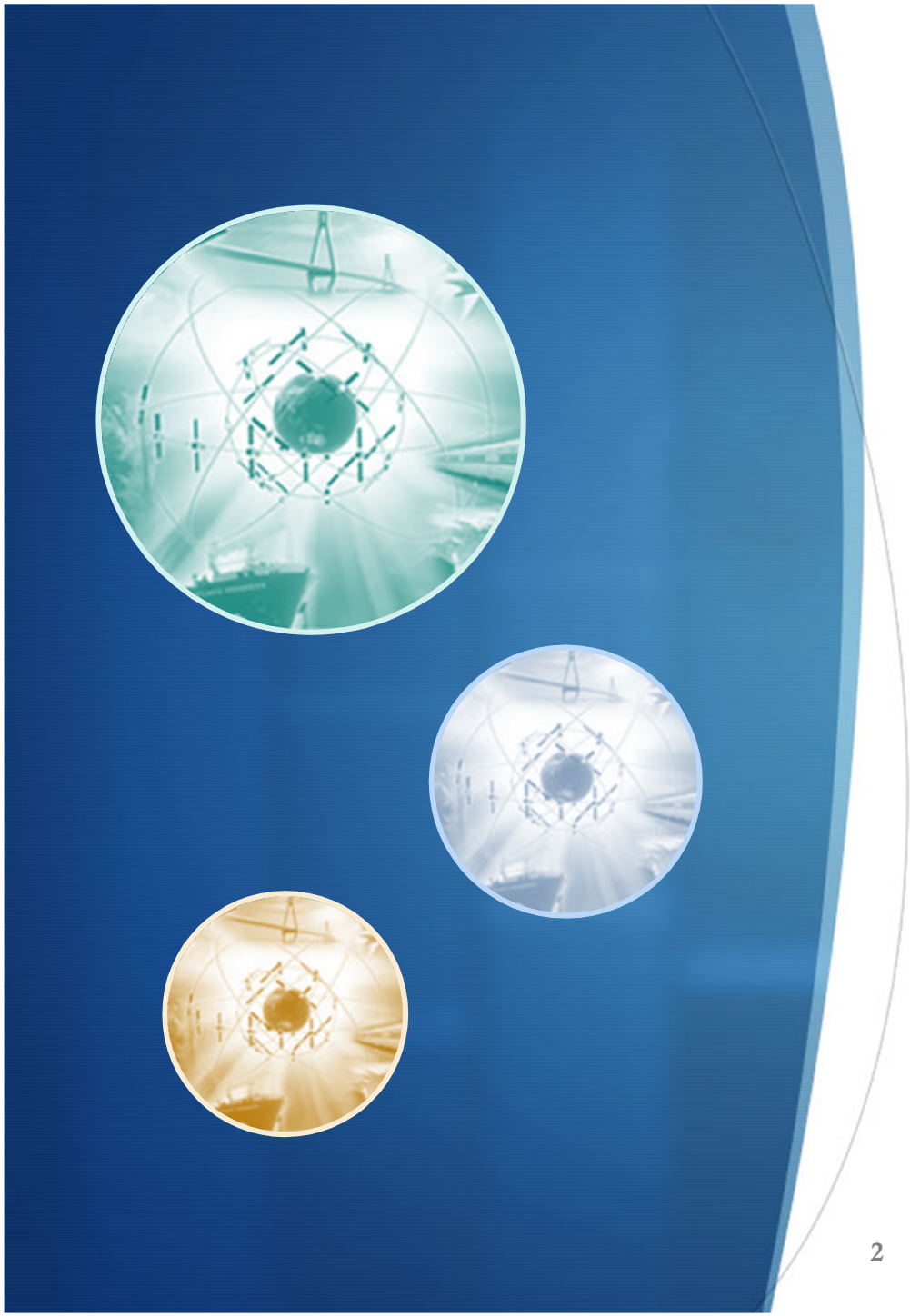
China Academy of Space Technology, China

Boulder, U.S.A Nov,2015

ICG International Committee on Global Navigation Satellite Systems



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2. Outline of BDS SSV Booklet
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Overview of BDS SSV

Previously,

- BDS SSV performance was first presented at ICG-8.
- SSV signal availability and PDOP satisfaction of BDS hybrid constellation was presented at ICG-9.

- BDS is willing to participate in the interoperable GNSS SSV for the benefit of space applications.
- As a WG-B recommendation of ICG-9, the idea of elaborating a booklet that characterize the contribution of each GNSS to an interoperable SSV for the benefit of the users was raised.
- This reports includes BDS booklet instruction, BDS construction and operation status update and SSV application experience.

Outline of BDS SSV Booklet

BeiDou Navigation Satellite System (BDS) Space Service Volume

Openness, Compatibility, Independency and Gradualness

SERVE THE WORLD
BENEFIT ALL MANKIND

SPACE SEGMENT

Regional Coverage Constellation

5 GEO + 5 IGSO + 4 MEO

- The equatorial projections of the GEO satellites are at 58.75°E, 80° E, 110.5°E, 140°E and 160°E .
- The crossing longitudes of 3 IGSO satellites locate at 118°E, and the other 2 satellites locate at 95°E.
- The 4 MEO satellites are in the 7th and 8th phases of the 1st orbital plane, and in the 3rd and 4th phases of the 2nd orbital plane. (Walker24/3/1)

Global Coverage Constellation

5 GEO + 3IGSO + 27MEO

- The equatorial projections of the GEO satellites are at 58.75°E, 80° E, 110.5°E, 140°E and 160°E .
- The crossing longitudes of 3 IGSO satellites locate at 118°E.
- 24 out of 27 MEO satellites shape up into Walker 24/3/1, and the remaining 3 ones are separately taken as spare satellites in each orbit plane .

Timetable of Deployment

- The 17th BDS Satellite launched 30 Mar 2015
- The 18th&19th BDS Satellites launched 25 Jul 2015
- The 20th BDS Satellite launched 30 Sep 2015

SERVICE PROVIDED

BDS can provide 2 types of service at the global level

OPEN SERVICE

Operational OS signals and Service

- BDS Signal in Space Interface Control Document —Open Service Signal(V2.0)
- BDS Open Service Performance Standard (V1.0)

Available on:
http://www.beidou.gov.cn

Modernized OS signals

OS Signal	Carrier Frequency (MHz)	
B1-C$_D$	1575.42	◆The performance of modernized OS signals is enhanced significantly from the operational OS signals.
B1-C$_P$		
B2-a$_D$	1,191.795	◆B1I signal will continue to provide service in the transitional status of BDS.
B2-a$_P$		
B2-b$_D$		
B2-b$_P$		

AUTHORIZED SERVICE

- Short-message Communication Service
- Wide-area Differential and Integrity Service
- RDSS

Outline of BDS SSV Booklet

POLICY AND PLANS

- Provide open services globally and free of user charge.
- Provide continuous, stable and reliable services.
- Improve performance continuously.
- Encourage compatibility and interoperability with other GNSS.
- Enhance application efficiency, broaden application domains, promote international applications.

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BDS SSV PERFORMANCE

Parameters	Original		Modernized	
Minimum Received Power	0 dBi RCP antenna	Reference off-Boresite Angel	0 dBi RCP antenna	Reference off-Boresite Angel
B1(MEO)	-183.1	22	-184.1	25
B1(GEO/IGSO)	-183.8	21	-185.8	19
B2(MEO)	-182.0	28	-182.7	28
B2(GEO/IGSO)	-182.4	29	-184.4	22

Signal Availability	BD1(24M)		BD1(24M/3I/5G)	
MEO SIV	≥1 Signal	≥4 Signals	≥1 Signal	≥4 Signals
B1	100%	≥99.8%	100%	100%
B2	100%	100%	100%	100%
HEO/GEO SIV	≥1 Signal	≥4 Signals	≥1 Signal	≥4 Signals
B1	≥98%	≥2.5%	≥99%	≥22%
B2	100%	≥17%	100%	≥49%

- SSV users could benefit from BDS hybrid constellation containing IGSO and GEO satellites.
- Signal availability of GEO/HEO SSV could be improved significantly by GNSS interoperation.

ANTENNA PARAMETERS

OS Signal	Beam width(°) Original			Beam width(°) Modernized		
	FH	-6dBi	0dBi	FH	-6dBi	0dBi
B1(M)	±21	±21	±20	±26	±25	±24
B1(I/G)	±22	±21	±20	±20	±19	±18
B2(M)	±30	±28	±26	±30	±28	±26
B2(I/G)	±30	±29	±28	±26	±22	±21

SSV APPLICATION IN CHINA

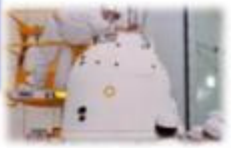
Lunar Exploration Spacecraft -CHANG'E 5-T1

Launch date: 2014-10-25

Re-entry date: 2014-11-1

GNSS SSV Application : The re-entry module equipped with a GNSS receiver for tracking.

In-Orbit Testing shows GNSS could provide good service during atmospheric re-entry around 60000km.



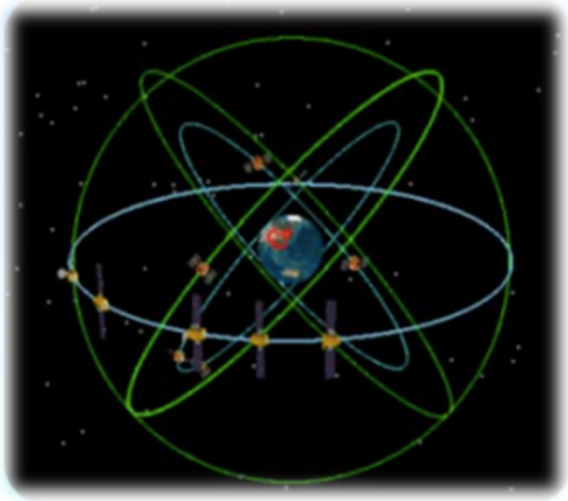
BDS Space Segment

BDS Constellation - Regional Coverage

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

  5 GEO + 5 IGSO + 4 MEO

  - The equatorial projections of the 5 GEO satellites are at 58.75° E, 80° E, 110.5° E, 140° E and 160° E.
  - The crossing longitudes of 3 IGSO satellites locate at 118° E, and the other 2 satellites locate at 95° E.
  - The 4 MEO satellites are in the 7th and 8th phases of the 1st orbital plane, and in the 3rd and 4th phases of the 2nd orbital plane. (Walker24/3/1)



- 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.

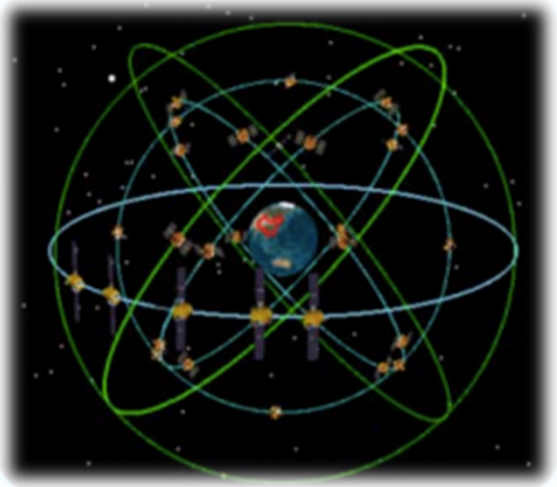
BDS Space Segment

BDS Constellation - Global Coverage

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

  5 GEO +3 IGSO +27MEO

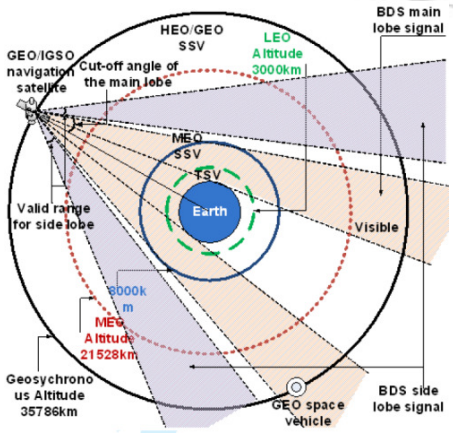
  - The equatorial projections of the 5 GEO satellites are at 58.75° E, 80° E, 110.5° E, 140° E and 160° E.
  - The crossing longitudes of 3 IGSO satellites locate at 118° E.
  - 24 out of 27 MEO satellites shape up into Walker 24/3/1, and the remaining 3 ones are separately taken as spare satellites in each orbit plane .



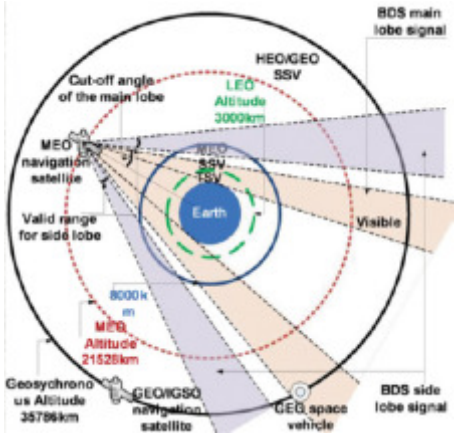
- The GEO and IGSO satellites are deployed for regional augmentation.

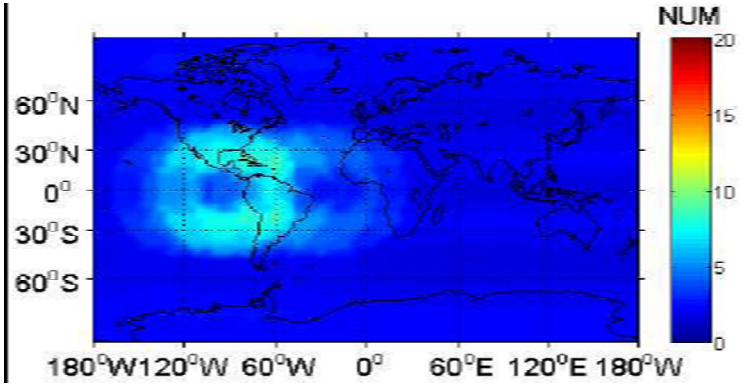
BDS Space Segment

BDS Constellation Parameters



- Earth Blocked Angle (EBA) of BDS MEO and GEO/IGSO satellites are 13.20° and 8.69° respectively.
- The maximum distance of geosynchronous altitude spacecraft receiver and BDS MEO and GEO/IGSO satellites are 68806km and 83346km respectively.





- The signal beams from BDS GEO and IGSO satellites overlap each other above 120° W to 60° W at the altitude of 36000km.
- SSV users may benefit from this steady visibility at this area.

BDS Space Segment

BDS Constellation Status

Num	Type	Date	Status	Num	Type	Date	Status
1	MEO	2007.4.14		11	GEO	2012.2.25	
2	GEO	2009.4.15		12	MEO	2012.4.30	
3	GEO	2010.1.17		13	MEO	2012.4.30	
4	GEO	2010.6.2		14	MEO	2012.9.19	
5	IGSO	2010.8.1		15	MEO	2012.9.19	
6	GEO	2010.11.1		16	GEO	2012.10.25	
7	IGSO	2010.12.18		**17**	**IGSO**	**2015.3.30**	
8	IGSO	2011.4.10		**18**	**MEO**	**2015.7.25**	
9	IGSO	2011.7.27		**19**	**MEO**	**2015.7.25**	
10	IGSO	2011.12.2		**20**	**IGSO**	**2015.9.30**	

Operational

In maintenance

Flight Test

Retired(de-orbit)

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BDS Space Segment

2015 – Starting Transition to Global Coverage

Num	Type	Date	Num	Type	Date
17	IGSO	2015.3.30	19	MEO	2015.7.25
18	MEO	2015.7.25	20	IGSO	2015.9.30

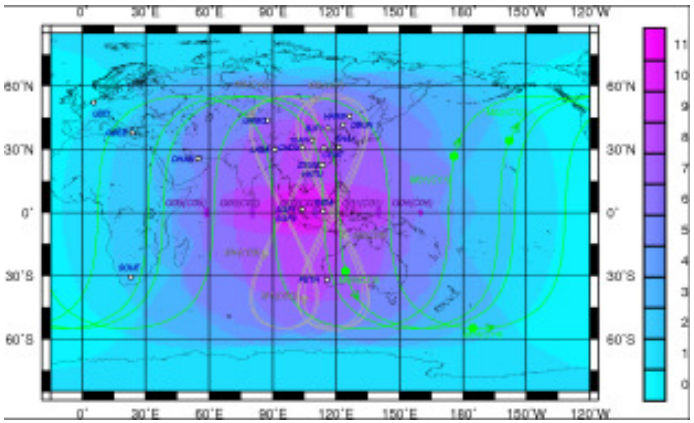
- 4 BDS Satellites were launched in 2015 from Xi Chang Satellite Launch Center.
  - Simultaneous deployment of 2 MEO Satellites by upper stage vehicle
  - New generation payload validation (Rb atomic clock and H maser, etc.)
  - Modernized navigation signals validation
  - Inter-satellite demonstration
  - Higher integrity platform and increased design lifetime
- In orbit test of new launched BDS satellites are being conducted and the results are satisfactory.

BDS Open Service (OS) Signals

Operational BDS Open Service (OS) Signals

OS Signal	Carrier Frequency (MHz)	Modulation	BW(MHz)	NAV message data rate
B1I	1561.098	QPSK	4.092	500(G)/50(M/I)bps
B2I	1207.14	QPSK	20.46	500(G)/50(M/I)bps

Currently BDS provides free and reliable positioning, velocity and timing services at Asian-Pacific region.



BDS-SIS-ICD-V2.0

BDS-OS-PS-V1.0

BDS Open Service (OS) Signals

Modernized BDS Open Service (OS) Signals

- The performance of modernized OS signals B1-C(1575.42MHz), B2-a & B2-b (1191.795MHz) are enhanced significantly from the operational OS signals.
  - Dual frequency operation
  - Improved time and poisoning accuracy, etc.
- B1I signal will continue to provide service in the transitional status of BDS.
- For SSV users in the near future the legacy B1I signal is suggested.
- Modernized signals could provide better interoperability with other GNSSs..

BDS Antenna Parameters

Operational Satellites Navigation Antenna Parameters

- Operational satellites navigation antenna parameter of BDS from pre-flight ground test.

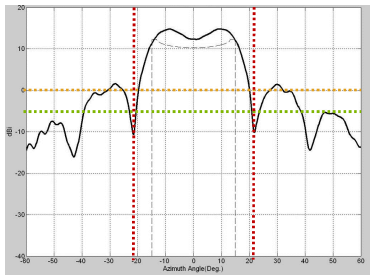
MEO

OS Signal	FN BW	-5dBi BW	0dBi BW
B1I	±21°	±21°	±20°
B2I	±30°	±28°	±26°

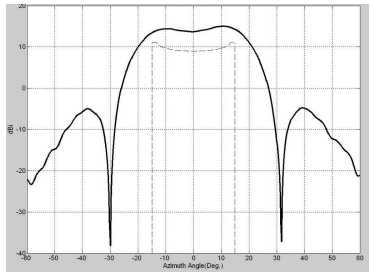
GEO/IGSO

OS Signal	FN BW	-5dBi BW	0dBi BW
B1I	±22°	±21°	±20°
B2I	±30°	±29°	±28°

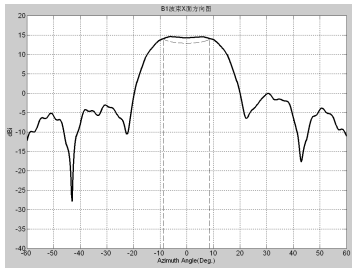
B1 (MEO)



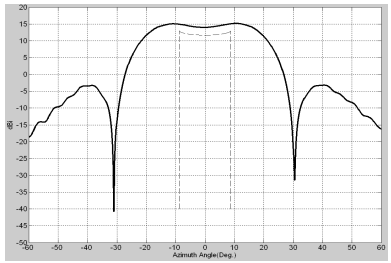
B2 (MEO)



B1 (GEO/IGSO)



B2 (GEO/IGSO)



BDS Antenna Parameters

Modernized Satellites Navigation Antenna Parameters

- Modernized satellites antenna parameters of BDS from simulation*.

MEO

OS Signal	FN BW	-5dBi BW	0dBi BW	EOE Angle
B1	±26°	±25°	±24°	±13.2°
B2	±30°	±28°	±26°	±13.2°
B3	±30°	±28°	±26°	±13.2°

GEO/IGSO

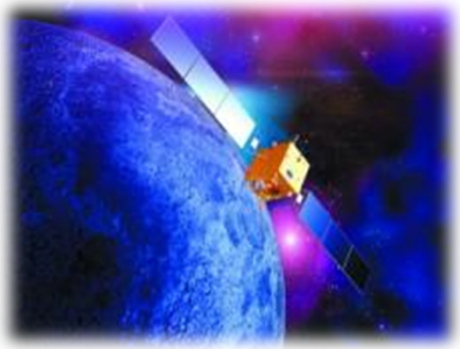
OS Signal	FN BW	-5dBi BW	0dBi BW	EOE Angle
B1	±20°	±19°	±18°	±8.7°
B2	±26°	±22°	±21°	±8.7°
B3	±26°	±22°	±21°	±8.7°

*The simulation results are similar to the pre-flight ground test of satellites in orbit flight test.

Recent GNSS SSV Application in China

Lunar Exploration Spacecraft - CHANG'E 5-T1

- **CHANG'E 5-T1**
- Launch date: 2014-10-25
- Re-entry date: 2014-11-1
- GNSS SSV Applications : The re-entry module equipped with a GNSS receiver for tracking.
- In-Orbit Testing shows GNSS could provide good service during atmospheric re-entry around 60000km.



BDS SSV Performance

Signal Availability and PDOP Satisfaction

- Minimum received power of SSV receiver.(Planed antenna)

Orbit Type	MEO		GEO/IGSO	
Signal Type	B1	B2	B1	B2
Carrier Frequency (MHz)	1575	1192	1575	1192
Input Power of Antenna (dBW)	20	19	20	19
Antenna Gain(dBi)	-5	-5	-5	-5
EIRP(dBW)	15	14	15	14
Signal Power Split Loss(dB)	6	6	6	6
Maximum Distance (km)	68806	68806	83346	83346
Maximum Free Space Loss(dB)	193.1	190.7	194.8	192.4
Minimum Received Power (dBi)	-184.1	-182.7	-185.8	-184.4

Parameters	Value	
Minimum Received Power	0 dBi RCP antenna	Reference off-Boresite Angel
B1(MEO)	-184.1	25
B1(GEO/IGSO)	-185.8	19
B2(MEO)	-182.7	28
B2(GEO/IGSO)	-184.4	22

BDS SSV Performance

Signal Availability and PDOP Satisfaction

Signal Availability	BDS(24M)		BDS(24M/3I/5G)		BDS(24M) + another GNSS		BDS(24M/3I/5G) + another GNSS	
MEO SSV	≥ 1	≥ 4	≥ 1	≥ 4	≥ 1	≥ 4	≥ 1	≥ 4
B1/L1	100%	≥99.8%	100%	100%	100%	100%	100%	100%
B2,B3/L2,L5	100%	100%	100%	100%	100%	100%	100%	100%
GEO/HEO SSV	≥ 1	≥ 4	≥ 1	≥ 4	≥ 1	≥ 4	≥ 1	≥ 4
B1/L1	≥93%	≥2.5%	≥96%	≥22%	≥98.5%	≥50%	≥99%	≥64%
B2,B3/L2,L5	100%	≥17%	100%	≥45%	100%	≥83%	100%	≥88.5%

- Signal availability are improved if GEO/IGSO are taken into consideration.
- Working with another interoperable GNSS the signal availability of GEO SSV will be increased by nearly two times.

Summary

- The outline of SSV booklet is discussed for users' better understanding of BDS and its space service volume availability.
- GNSS space users could benefit from BDS hybrid constellation containing IGSO and GEO satellites.
- The modernized BDS Open Service (OS) signals will make more contribution to SSV interoperation.
- New generation BDS satellites are under validation test in orbit. Better service will be delivered to territorial and space users in the near future.
- GNSS applications of SSV has been achieved in China and demand for SSV service will continue to increase.

Thank you for your attention !