

Performance Analysis and Test Evaluations For the BeiDou Open Services

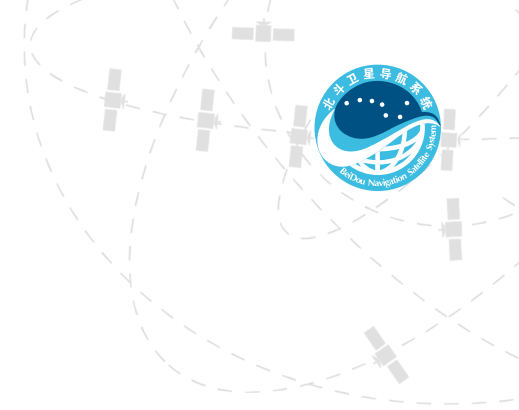
13th Meeting of the International Committee on
Global Navigation Satellite Systems

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Beijing Satellite Navigation Center

Xi'an, China Nov. 2018





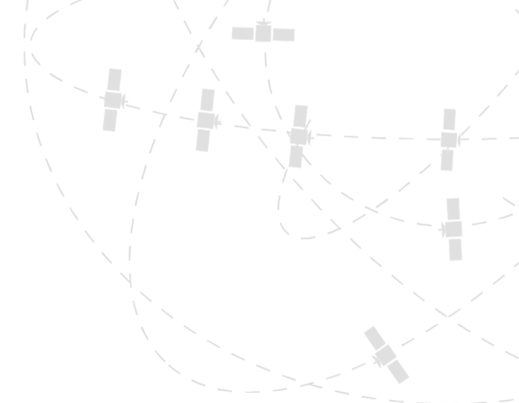
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01

Backgrounds

- For the sake of monitoring the integrity, availability, continuity and feasibility of the BeiDou Navigation System(BDS), the Applications and Verifying System(AVS) has been set up to monitor the services and performances of BDS.
- The AVS mainly consists of THREE parts: Verifying Terminals, Datum Analysis and Evaluation Platform, and the Transmission Networks.
- The Verifying Terminals are deployed around and outside China, which receive and process the GNSS signals, to obtain the raw datum.
- The Platform collects all raw datum from the Verifying Terminals, including the information of power levels of the signals, locations, timing, pseudorange and navigation messages, etc., to conduct the analysis and evaluate the performances of BDS.
- The AVS is placed in Beijing Satellite Navigation Center(BSNC).
- This presentation illustrates the monitoring outcomes of the performances and services for the BeiDou open signals, carried out by AVS.



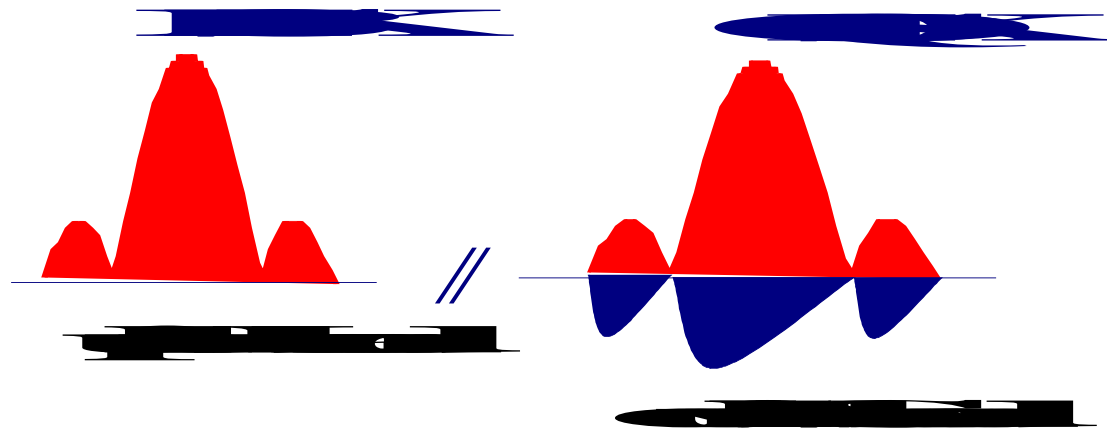
02

A Brief Introduction to the Services and Signals of BDS

● BDS-1

- The BDS-1 only provided the RDSS in the Asia and Pacific Area.
- The civil service and authorized service were available for BDS-1.
- There existed TWO signals for the user terminals: the downlink signal and the uplink signal, within S-band and L-band respectively.
- The downlink and uplink signals employed the modulation schemes of OQPSK and BPSK respectively.
- BDS-1 was decommissioned.

The spectrums of the signals of BDS-1(RDSS)

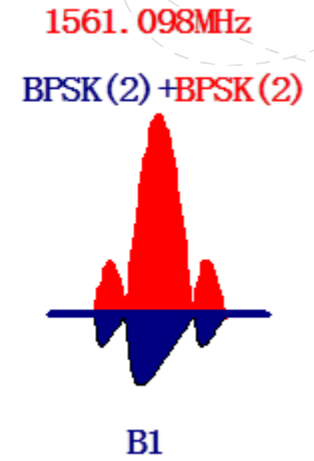
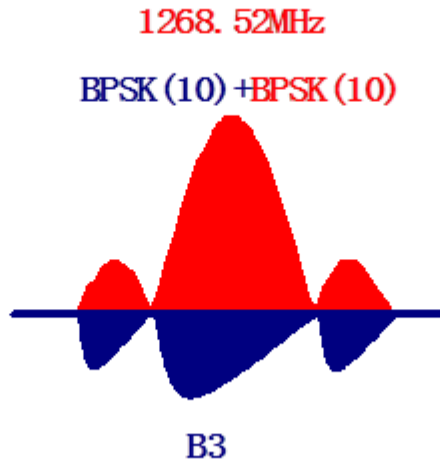
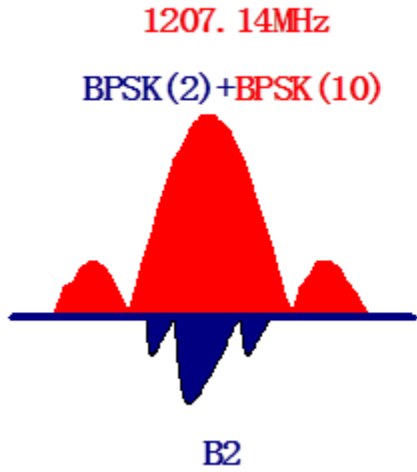


● BDS-2

- BDS-2 is providing the Asia and Pacific Area with both RNSS and RDSS.
- The signal structures of RDSS in BDS-2 are compatible completely with the ones in BDS-1, also including the civil and authorized services.
- There are THREE open signals for RNSS of BDS-2, all within L-band.

Signal	Carrier Frequency (MHz)	Modulation	Service
B1	1561.098	BPSK-R(2)	Open
		BPSK-R(2)	Authorized
B2	1207.14	BPSK-R(2)	Open
		BPSK-R(10)	Authorized
B3	1268.52	BPSK-R(10)	Open
		BPSK-R(10)	Authorized

The spectrums of the signals of BDS-2(RNSS)



●BDS-3

- BDS-3 is about to provide multiple services: **RNSS(Global)**; **RDSS(Regional)**; **SBAS(Regional)**; **Precise positioning(Regional)** and **SAR(Global)**.
- The signals of BDS-3 are as the following table.

Service		Signal	Satellite
RNSS	Open	B1I, B3I, B1C, B2a, B2b	3GEO+3IGSO +24MEO
	Authorized	B1A, B3Q, B3A	
SBAS	Open	B1C, B2a	3GEO
	Authorized	B1A	
Local short message communication	Authorized	L, S	3GEO
Global short message communication		L (up), B2b (down)	14MEO
Precise position		B2b	3GEO
SAR		uplink: 406MHz downlink: 1544.21MHz	6MEO

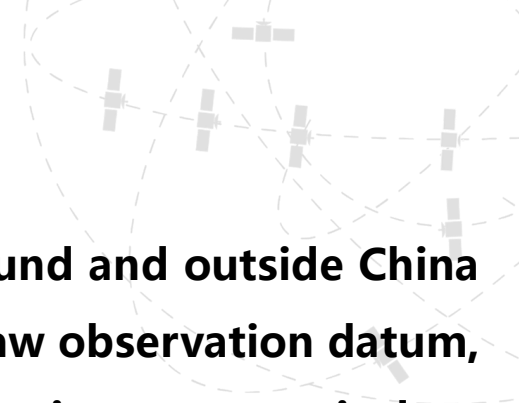
Parameters of open signals of BDS-3

Signal	Carrier (MHz)	Chip rate (MHz)	modulation	Service
B1I	1561.098	2.046	QPSK	Open
B1C	1575.42	1.023	BOC	Open
B3I	1268.52	10.23	QPSK	Open
B2a	1176.45	10.23	QPSK	Open
B2b	1207.14	10.23	QPSK	Open

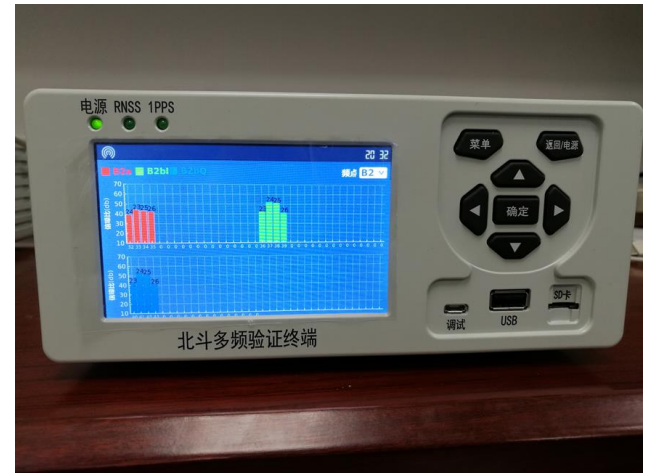
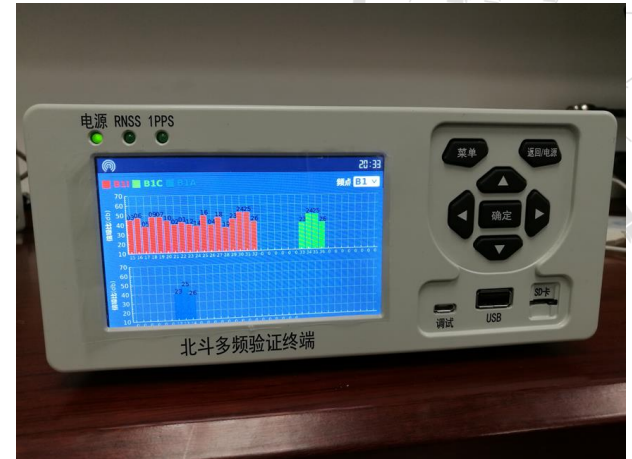
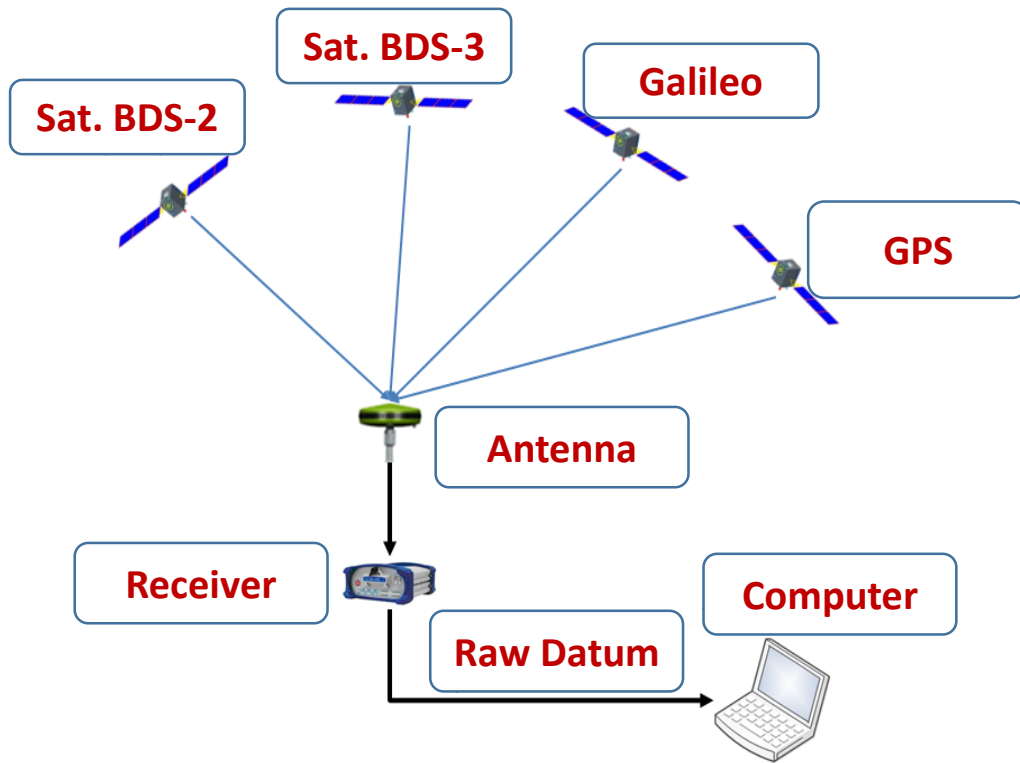


03

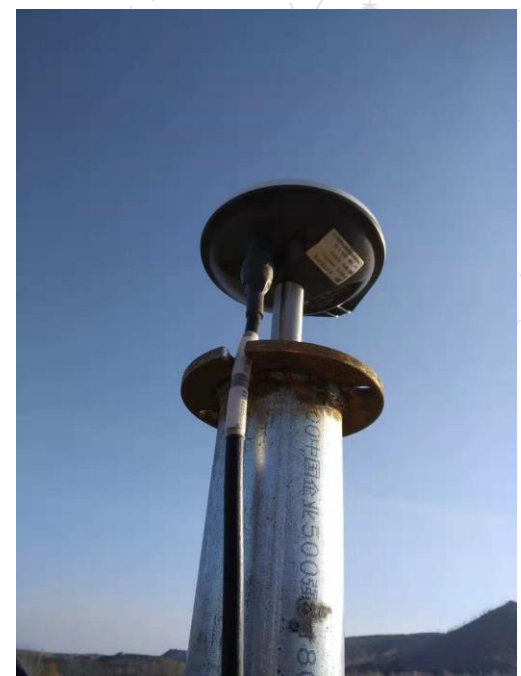
Performances and Evaluations of the Open Services for BDS

- 
- **The Verifying Terminals are deployed in different places around and outside China to receive and process the GNSS signals, and to collect the raw observation datum, including power levels of the signals, positioning, pseudoranging, user equivalent range error(UERE), timing, navigation messages, etc.**
 - **All the datum are sent to the Analysis and Evaluation Platform in BSNC via the Transmission Networks. The Platform conducts the analysis and evaluates the performances of the navigation signals.**

Acquisitions of the observation datum

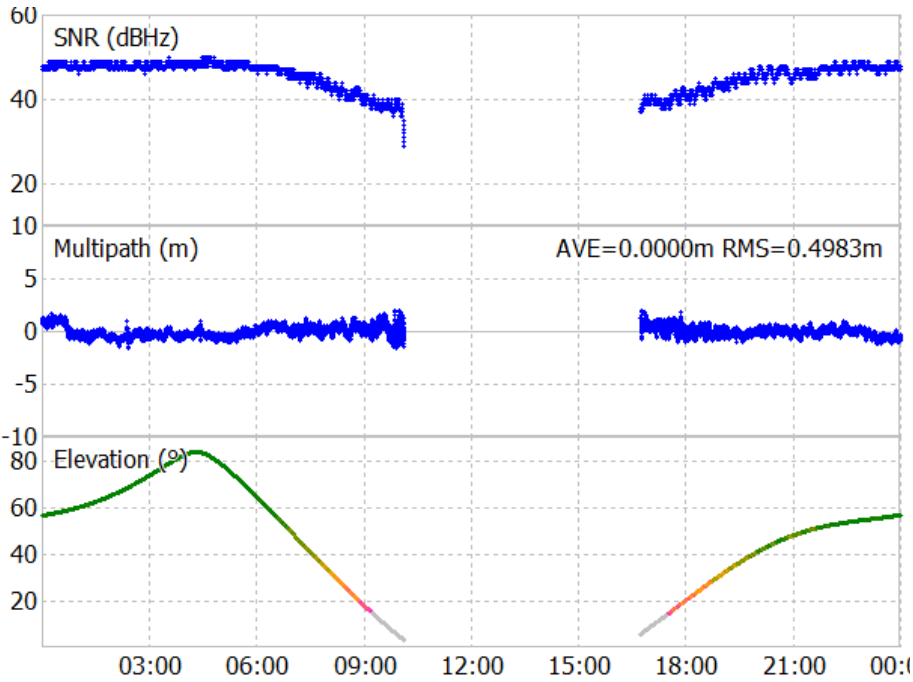


Verifying Terminals

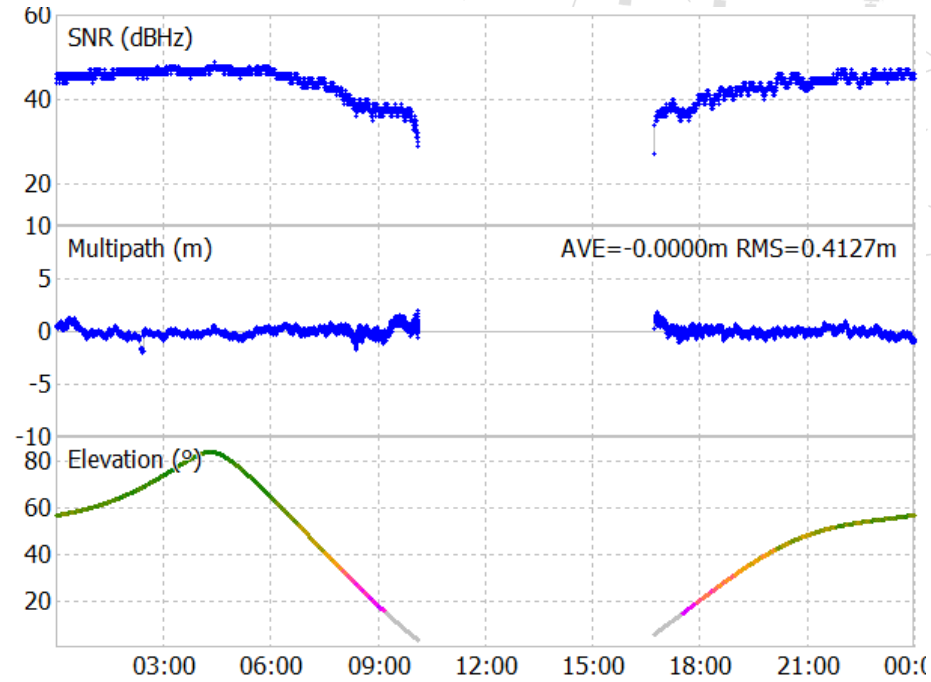


**Acquisitions of
the observation
datum**

The signal power level from **BDS-2 Satellite**



B1I, C12, BDS-2 Satellites



B3I, C12, BDS-2 Satellites

The power level on the ground > -160 dBW, stable.

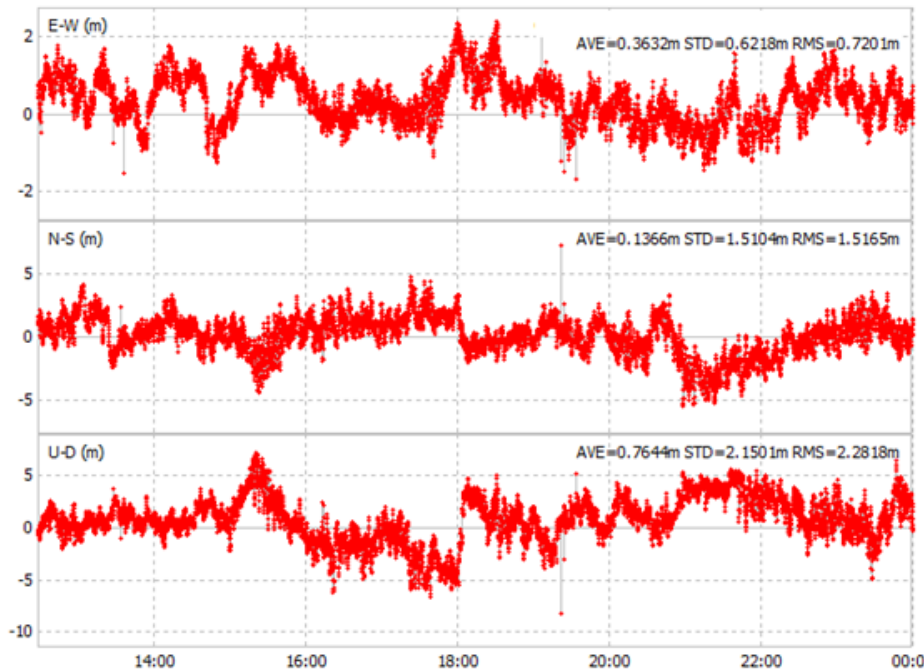
The effects of the multipath are small.

Not depend on the elevation angles.

Time: 00:00 30 Oct.2018 ---- 00:00 31 Oct.2018

Demonstrated by Verifying Terminals, AVS.

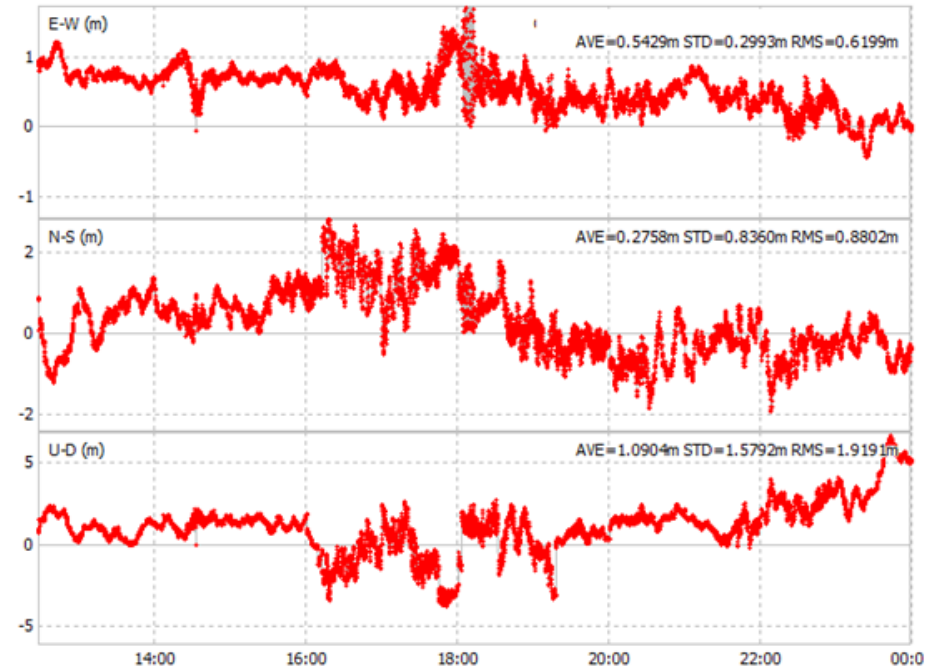
The positioning accuracy of **BDS-2 Satellites** with single frequency



B1I, All C1 to C14, BDS-2 Satellites

Horizontal < 1.7m

Vertical: < 2.3m



B3I, All C1 to C14, BDS-2 Satellites

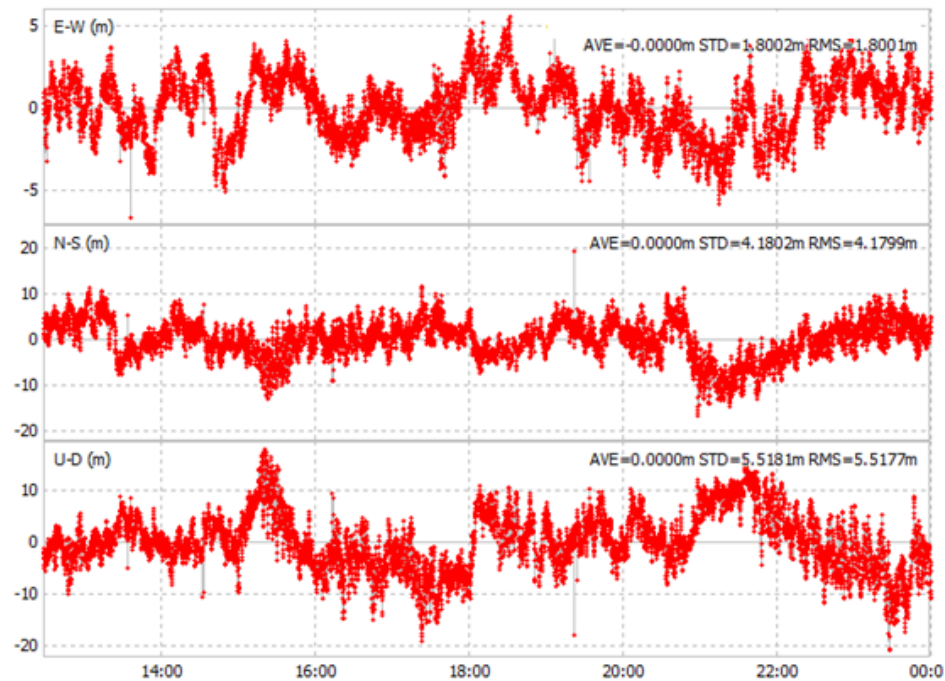
Horizontal < 1.1m

Vertical: < 2.0m

Time: 12:00 15 Oct.2018 ---- 0:00 16 Oct.2018

Demonstrated by Verifying Terminals, AVS.

The positioning accuracy of **BDS-2 Satellites** with dual frequency



Dual B1I & B3I, All C1 to C14, BDS-2 Satellites

Horizontal < 4.6m

Vertical: < 5.6m

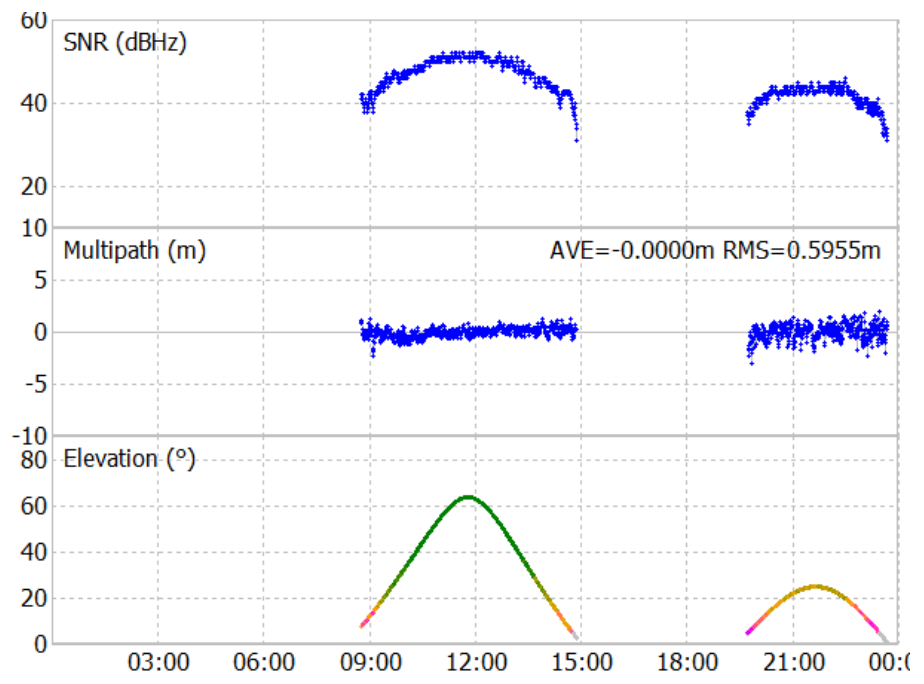
Time: 12:00 15 Oct.2018 ---- 0:00 16 Oct.2018

Demonstrated by Verifying Terminals, AVS.

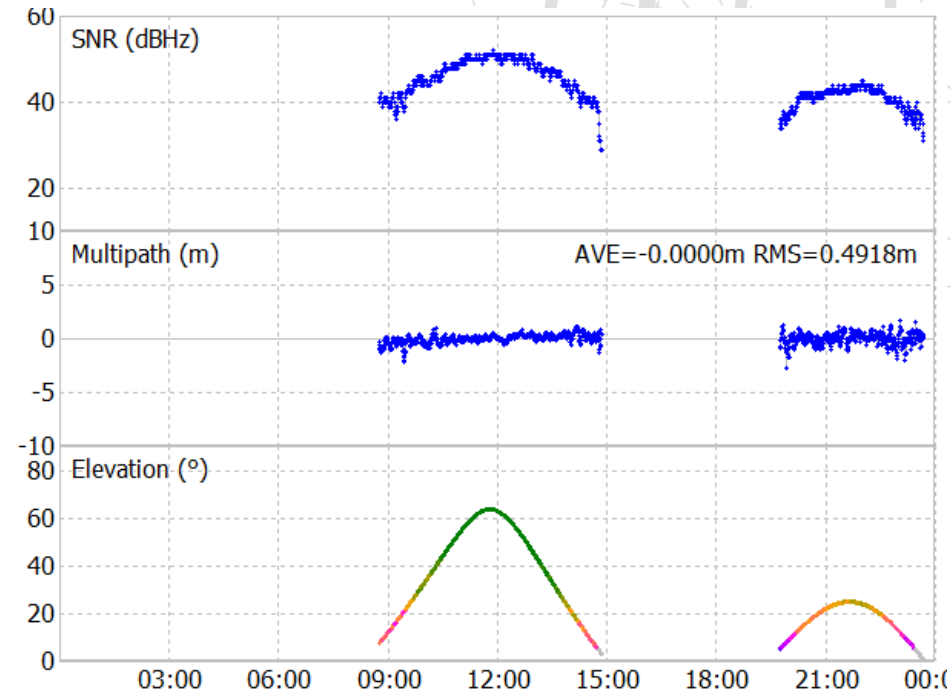
- Until now, 16 MEO satellites and 1 GEO satellite of BDS-3 have been launched into their orbits. Most of the BDS-3 satellites are on the tests, and the navigation messages and parameters are being adjusted.
- Here mainly presents the power level, UERE and positioning with the initial and simple constellation of BDS-3, carried out by AVS.
- The Verifying Terminals have been the capabilities to determine the locations via the signals of BDS-3 satellites. The following table illustrates the test results with a Verifying Terminal for the GNSS simulator in the laboratory.

Positioning	Accuracy(m) (Around China)		Accuracy(m) (Other Area)		Velocity (m/s)
	Horizontal	vertical	Horizontal	vertical	
B1C	1.18	2.40	2.13	5.69	0.08
B2a	2.10	4.52	2.10	4.54	0.09
B1C & B2a	0.45	0.68	0.65	2.81	0.08

The signal power level from **BDS-3 Satellite**



B1I, C20, BDS-3 Satellites



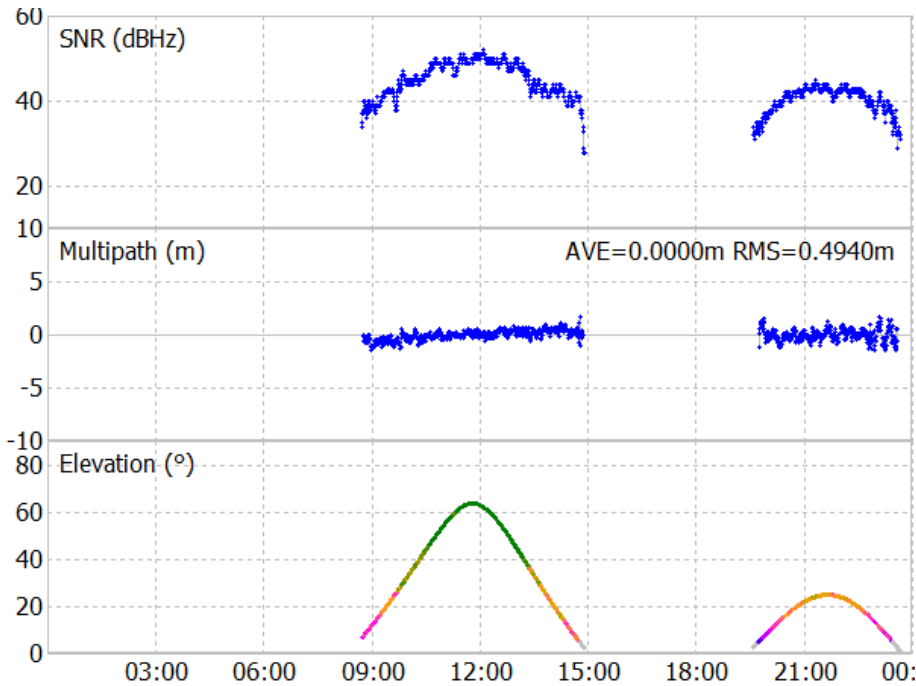
B3I, C20, BDS-3 Satellites

- The power level on the ground $> -160\text{dBW}$, stable.
- The effects of the multipath are small.
- Not depend on the elevation angles.

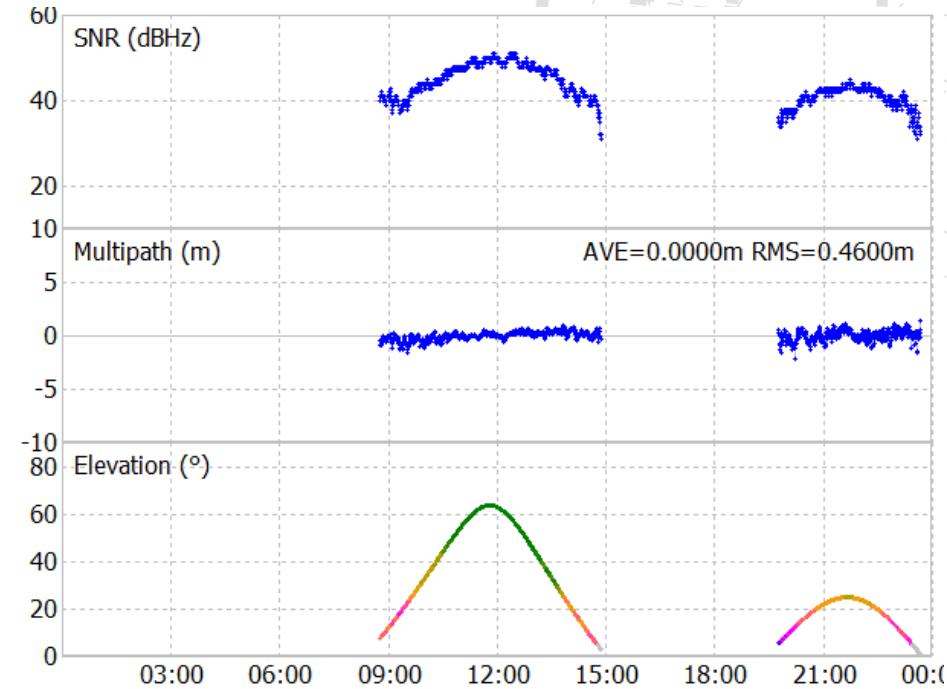
Time: 00:00 30 Oct.2018 ---- 00:00 31 Oct.2018

Demonstrated by Verifying Terminals, AVS.

The signal power level from **BDS-3 Satellite**



B1C, C20, BDS-3 Satellites



B2a, C20, BDS-3 Satellites

The power level on the ground > -160 dBW, stable.

The effects of the multipath are small.

Not depend on the elevation angles.

Time: 00:00 30 Oct.2018 ---- 00:00 31 Oct.2018

Demonstrated by Verifying Terminals, AVS.

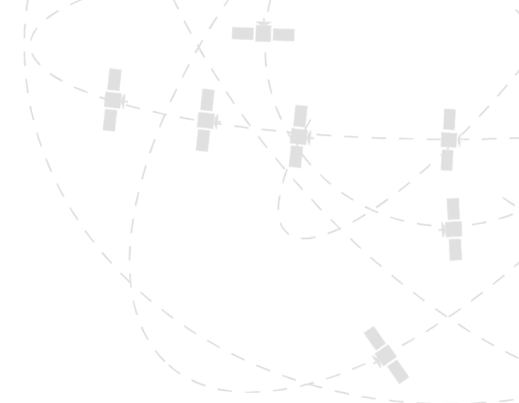
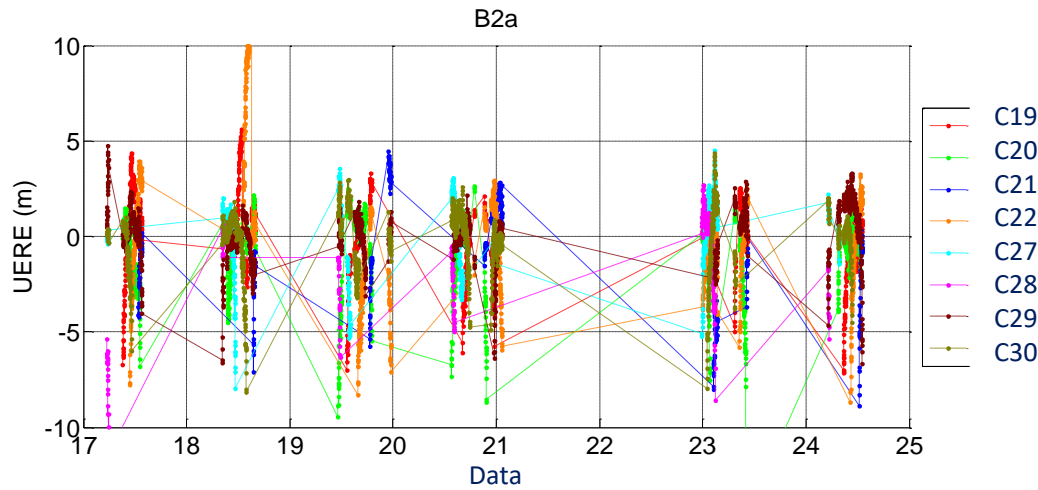
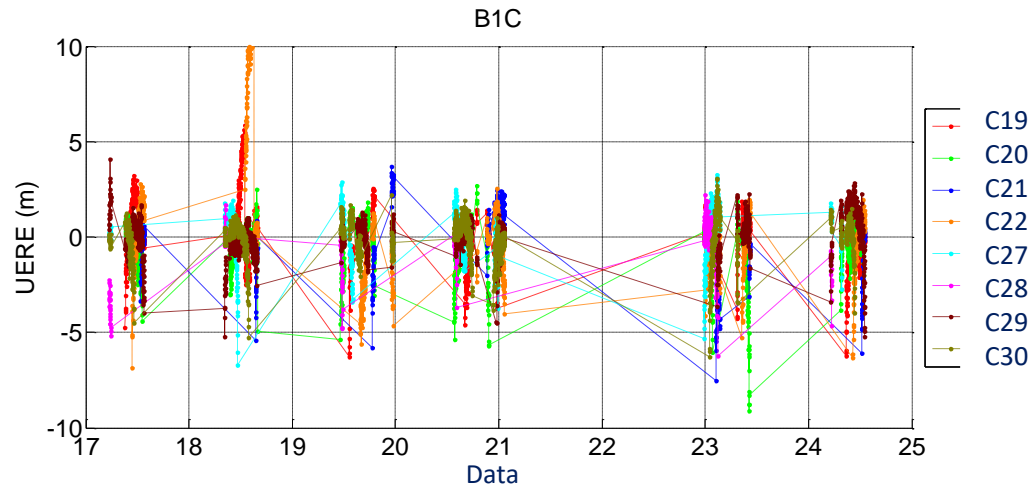
The UERE of the signals of **BDS-3 Satellites**

SV	B1C	B2a	B2b
	RMS(m)		
C19	1.62	2.00	1.88
C20	1.34	2.25	2.17
C21	2.07	2.89	2.87
C22	3.37	3.56	3.80
C27	1.40	1.99	1.90
C28	1.60	3.01	2.61
C29	1.01	1.32	1.08
C30	1.10	1.67	1.60
Average	1.69	2.34	2.24

Source: Initial system test & evaluation report, released Aug. 2018.

Demonstrated by Verifying Terminals, AVS.

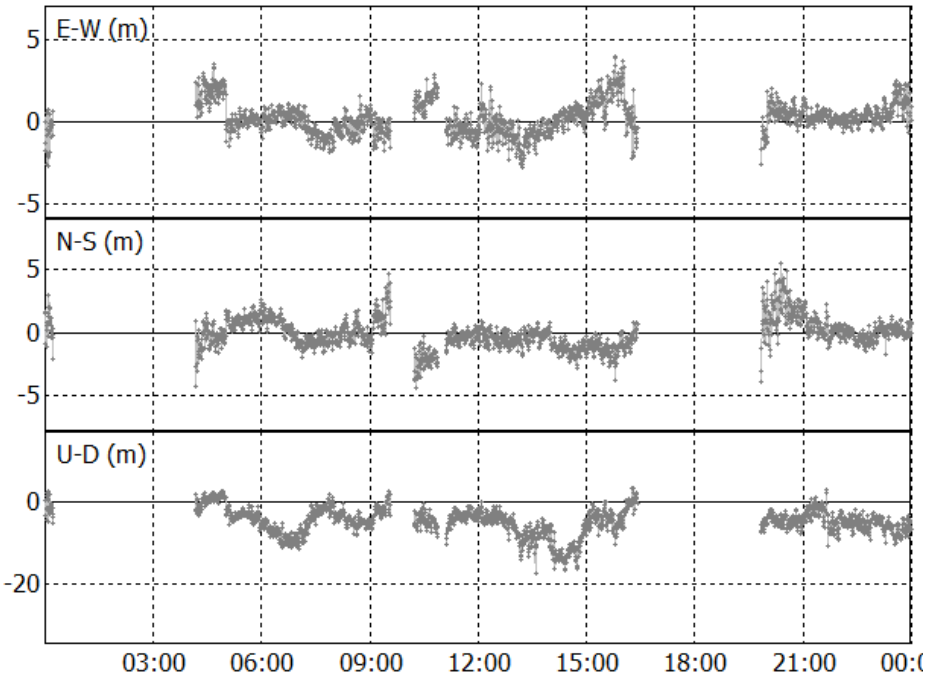
The UERE of the signals of **BDS-3 Satellites**



Source:
Initial system test & evaluation
report, released Aug. 2018.

**Demonstrated by Verifying Terminals,
AVS.**

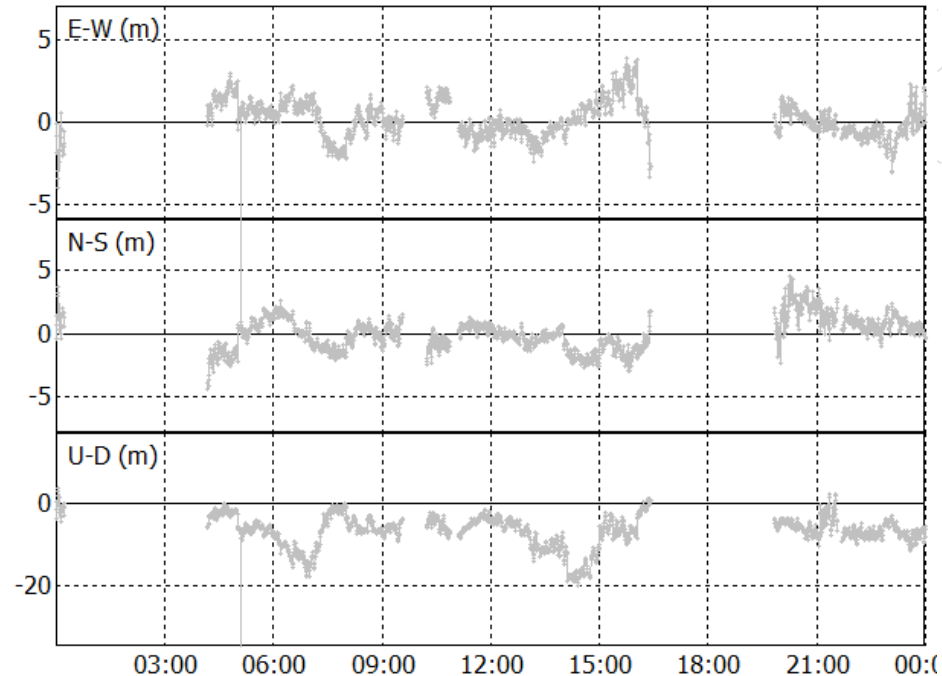
The positioning accuracy of **BDS-3 Satellites** with single frequency



B1I, BDS-3 Satellites

Horizontal <math>< 1.6\text{m}</math>

Vertical: <math>< 5.9\text{m}</math>



B3I, BDS-3 Satellites

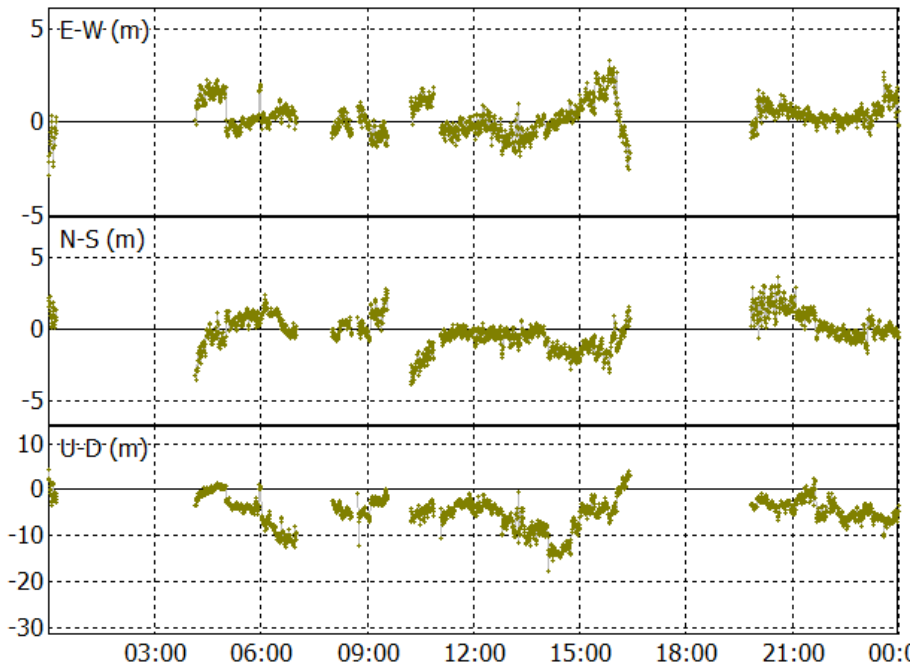
Horizontal <math>< 3.2\text{m}</math>

Vertical: <math>< 8.0\text{m}</math>

Time: 00:00 30 Oct.2018 ---- 00:00 31 Oct.2018

Demonstrated by Verifying Terminals, AVS.

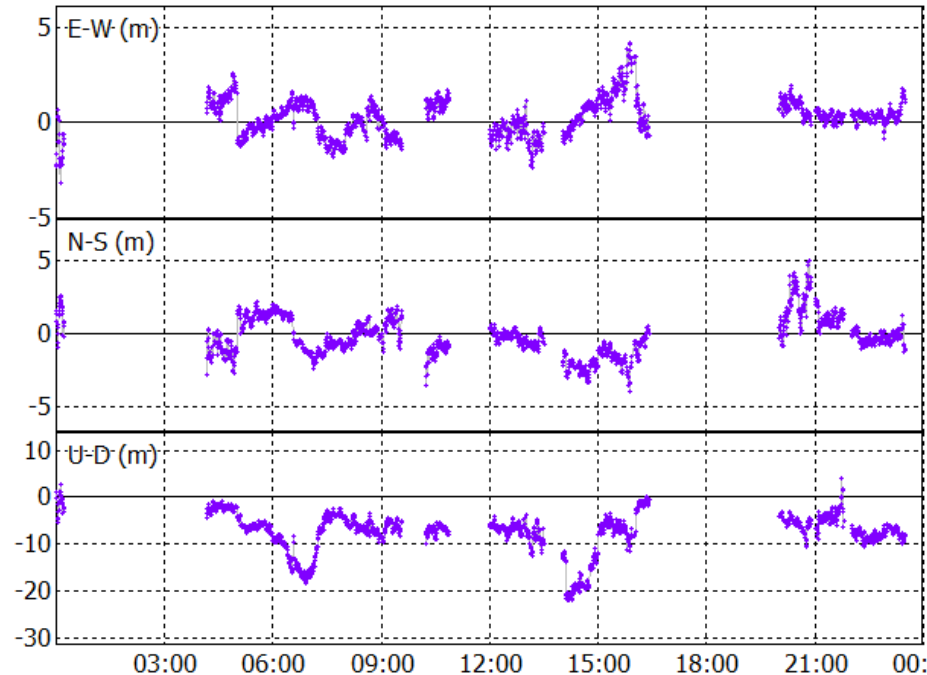
The positioning accuracy of **BDS-3 Satellites** with single frequency



B1C, BDS-3 Satellites

Horizontal < 1.5m

Vertical < 6.0m



B2a, BDS-3 Satellites

Horizontal < 1.7m

Vertical < 8.5m

Time: 00:00 30 Oct.2018 ---- 00:00 31 Oct.2018

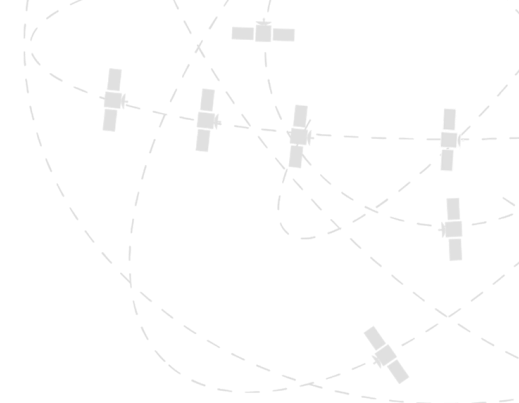
Demonstrated by Verifying Terminals, AVS.

The positioning accuracy of **BDS-3 Satellites** with single frequency

Signal	Horizontal(m)	Vertical(m)
	95%	
B1I	3.07	10.15
B3I	3.14	11.88
B1C	3.77	11.41
B2a	5.88	12.98
B2b	3.64	12.78

Time: 00:00 30 Oct.2018 ---- 00:00 31 Oct.2018

Demonstrated by Verifying Terminals, AVS.



04

Conclusions

1. The test outcomes, conducted by the Applications and Verifying System(AVS), show that the power levels on the ground from BDS-3 MEO satellites are stable, more than -160dBW, and the average UERE can be less than 2.5m, the multipath effects are smaller than the ones of BDS-2. The observation datum are independent from the angles.
2. The AVS carried out the positioning tests with all open signals B1I、 B3I、 B1C、 B2a and B2b **only from BDS-3 satellites** in the single frequency mode to determine the locations in the initial and simple constellation, showing that the of positioning accuracy is about 5m for horizontal, and 12m for vertical. The positioning accuracy is ideal in the half-constellation at present.
3. As the full constellation of BDS-3 is fulfilled by 2020, the highly accurate performances and services will be provided on the Globe, especially in the area of Asia and Pacific.

THANK YOU!

13th Meeting of the International Committee on
Global Navigation Satellite Systems

