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BY682 High-Precision GNSS Board

OBSERVATION DATA

QUALITY ASSESSMENT

ABSTRACT:

This report summarizes the performances between BY682 high-precision GNSS positioning and heading board (hereinafter referred to as BY682) and two other competitor boards in typical application scenarios, with emphasis on long-term stability, observation data and post-processing accuracy. The test methodology and environments were selected to represent real-world cases and conditions where high-precision users regularly operate and the observation data is available for downloading.

The results show that all the boards perform well in the open-sky conditions and BY682 has outstanding advantages in the especially complex environment. BY682 can consistently provide highly accurate and available observation data in different testing environments. Further, the Galileo signal receiving performance of BY682 is obviously better than that of competitor.

TEST PRINCIPLE:

The two core modules of high-precision GNSS receiver are baseband signal processing module and high-precision positioning processing module. The baseband signal processing module outputs observation data to the positioning processing module, and the positioning processing module fixes high-precision positioning through RTK processing. It can be seen that the quality of observation data which is the basis of high-precision positioning, directly affects the positioning accuracy.

The observation data quality is closely related to the test environment. The tests reported here were conducted in the following scenarios:

- Open-sky
- Foliage canopy
- Urban canyon(Static & Dynamic vehicle)

QC tests were conducted on all the observation data using the following criteria:

(1) MP- pseudorange multipath. MP values are calculated with pseudorange and carrier phase weighted and reflect the multipath mitigation of the board. The smaller the MP values are, the stronger the multipath mitigation of the board is. MP1 < 0.5 and MP2 < 0.75 are preferred.

(2) DI- observation data integrity(DI) rate. DI is the number of valid observation data output by the board divided by the receivable number of observation data that is calculated by ephemeris. The larger the DI is, the more complete the observation data is.

(3) O/slps- observations per slip. O/slps is the number of valid observation data output by the board divided by the number of detected cycle slip (when the number of cycle slip is 0, the divisor is 1). The larger the value, the smaller number of cycle slip of the data. O/slps > 200 is preferred.

The above criteria can be obtained from QC test using TEQC toolkit. TEQC is an open and free toolkit developed by UNAVCO Facility for GPS monitoring station. The toolkit has superior advantages in fast and comprehensive assessment of observation data quality.

In addition, the observation data of open-sky are post-processed and evaluated. The post-processing is carried out by using the Inertial Explorer 8.70 software developed by Novatel, and the positioning accuracy is evaluated using RMS (RMS-root mean square; reflects the degree of deviation between the test value and the real value, i.e. accuracy).

TEST SET-UP AND METHODOLOGY

The test set-up is shown in **Figure 1**. To remove biases between test boards to isolate performance, the set-up ensure:

All the test boards used the same GNSS antenna;

All the test boards used the same cables;

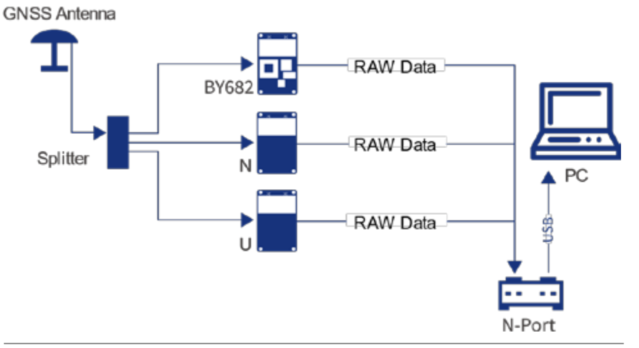
All the test boards were disconnected with the satellite signals whenever interruption occurred;

Power supply was within the range of each board, and was turned on and off at the same time;

All the test boards used the same carrier board;

All the test boards were connected to the PC via MOXA port to ensure the consistency of serial communication and data transmission.

Figure 1 Test set-up



TEST RESULTS

1.Open-Sky ---Long-term testing

As shown in **Figure 2**, the base station and the rover station antennas were placed on the rooftop of building with open and unobstructed view. The baseline was about 1.1 km, the receiver operated and output observation data continuously for 15 hours. After the test data was converted into RINEX file, the post-processing solution was carried out by using the Inertial Explorer 8.70. Results are shown in **Figure 3** and **Table 1**.

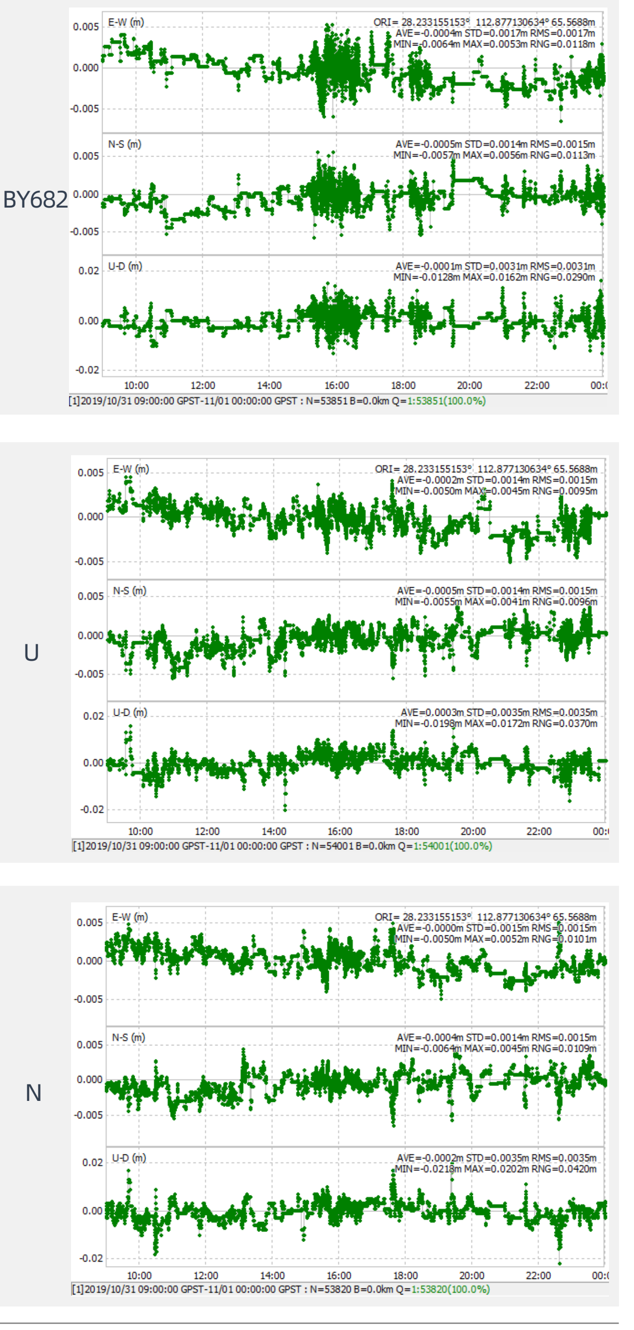
As shown in **Figure 3** and **Table 1**, all the test boards have approximate and high accuracy, with RMS less than 2 mm in horizontal direction and less than 4 mm in vertical direction. All the test boards showed position outliers at the same time, but the outlier from BY682 was the smallest in amplitude.

Figure 2 Antenna location

Table 1 Position accuracy——long-term

Board	Position accuracy RMS/mm		
	E	N	U
BY682	1.7	1.5	3.1
N	1.5	1.5	3.5
U	1.5	1.5	3.5

Figure 3 Position accuracy——long-term post-processing



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2. Open sky ——exchanging antennas

The testing environment is shown in **Figure 2**. There were two antennas in rover station with a distance of 2 m and each antenna was used on alternate half hour. After output by the receiver, the observation data was converted into RINEX file, the post-processed using Inertial Explorer 8.70. The results of the third test are shown in **Figure 4**, and the positioning accuracy of the whole test groups are shown in **Table 2**.

As shown in **Figure 4** and **Table 2**, all the test boards showed approximate and high accuracy. The RMS was less than 3 mm in horizontal direction except for the fourth test of antenna NO.2; the RMS was less than 10 mm in vertical direction except for the second and third tests of antenna NO.1. Mostly, stable and high-precision positions can be obtained, i.e., the exchange of antenna has no significant influence on the accuracy. However, the three boards showed positioning outliers in the same time and the same direction, which was caused by the distribution of satellites. All the test boards showed position outliers at the same time, but the outlier of BY682 had the smallest amplitude.

Figure 4 Position accuracy——exchange antennas post-processing

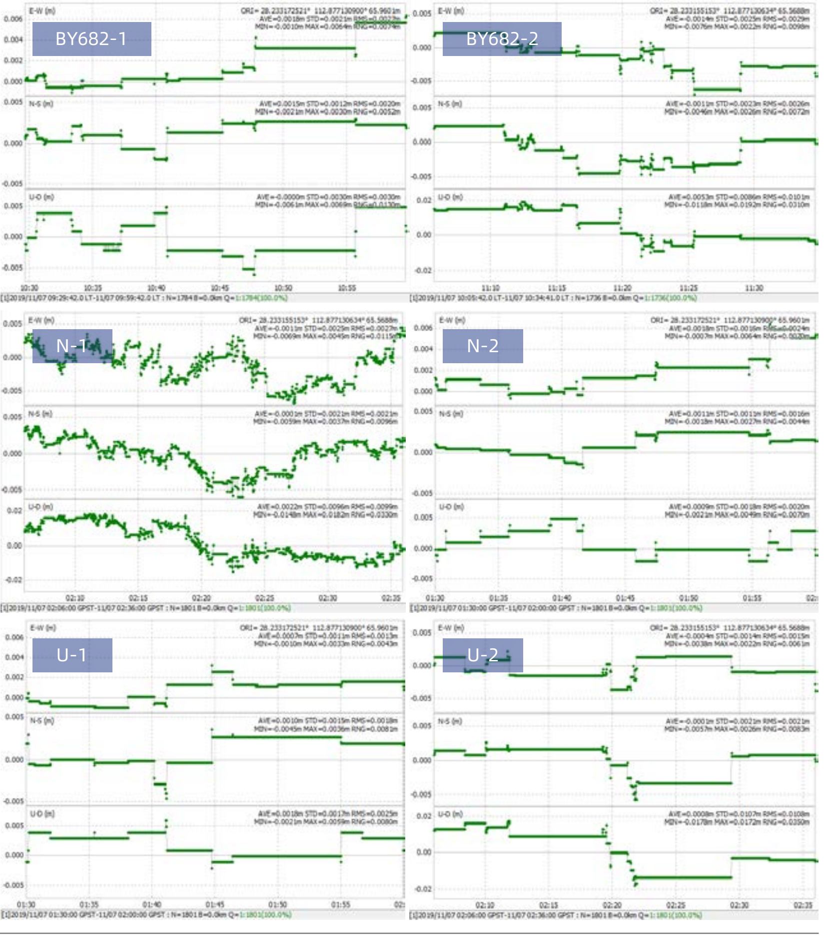


Table 2 Position accuracy —— exchanging antennas

Test group	Board	Accuracy of antenna1 RMS/mm			Accuracy of antenna2 RMS/mm		
		E	N	U	E	N	U
Group No.1	BY682	0.8	0.8	2.6	1.1	1.7	5.7
	N	0.7	0.6	2.9	1.0	1.4	4.5
	U	0.7	1.0	3.4	0.7	1.1	3.4
Group No.2	BY682	1.8	2.0	12.6	1.3	1.4	4.4
	N	2.2	2.7	10.8	1.5	2.1	3.0
	U	1.9	2.2	13.5	1.3	1.0	2.8
Group No.3	BY682	1.5	2.1	10.8	1.3	1.8	2.5
	N	2.7	2.1	9.9	2.4	1.6	2.0
	U	2.9	2.6	10.1	2.7	2.0	3.0
Group No.4	BY682	2.2	1.0	5.2	5.3	4.0	8.5
	N	2.5	2.3	4.7	7.5	2.6	8.7
	U	2.0	2.0	8.9	7.6	2.5	8.2
Group No.5	BY682	0.9	2.1	8.0	2.2	2.6	8.6
	N	2.2	2.1	7.7	1.7	3.5	7.9
	U	1.3	1.2	4.0	2.0	3.4	8.3

3. Open sky——static test

The selected test environment is shown in **Figure 2**. The boards operated and output observation data continuously for 7×24 hours. After the test data was converted into RINEX files, QC test was performed by TEQC. The results are shown in **Table 3**. **Table 4** shows an example from one-hour data.

Table 3 Results of 7×24h Observation data in Open Sky

Satellite system	Board	Criteria			
		MP1(m)	MP2(m)	DI(%)	O/Slps
BDS	BY682	0.09	0.10	65	6590
	N	0.11	0.12	76	1066
GPS	BY682	0.14	0.17	87	3622
	N	0.17	0.15	96	543
GLONASS	BY682	0.14	0.16	92	1890
	N	0.13	0.15	92	4547

* Failed to collect complete observation data of board U;

* Failed to collect complete GALILEO ephemeris data;

* QC-full detection was performed by using default parameters of TEQC toolkit; MP1 < 0.5 and MP2 < 0.75 are preferred. The smaller the MP values are, the stronger the multipath mitigation of the board is. The larger the DI value, the more integrity the observation data get. O/slps > 200 is preferred; and the larger the O/slps value, the smaller number of cycle slip of the data.

As shown in **Table 3**, the two boards showed stable and good performance of observation data quality for the whole time. The MP values of the two boards were both less than 0.2 m, suggesting that they had strong multipath mitigation in the open-sky condition. The integrity rate of GPS and GLONASS data were above 85%. Since these two boards only received L1 of BD3, and the number of BD3 satellites received by BY682 is higher than that of board N, the BDS data integrity rate of the two boards were lower. O/slps were more than 500.The integrity rate of GPS data of BY682, the cycle slip detection and repair of board N are still to be optimized.

As shown in **Table 4**, the two boards also showed stable and good performance of observation data quality in a short term(1h). MP values of both boards were less than 0.15 m; The data integrity rate of GPS and GLONASS data were above 99%, whereas the BDS data integrity rate of the two boards were relatively low. O/slps were above 500. The result that the GPS O/slps of board N are about 10 times of BY682 was because open-sky condition is the ideal environment for satellite signals, and board N detected 0 GPS cycle slip in the one-hour testing period but BY682 detected 10. To compare O/slps, a comprehensive analysis should be conducted in combination with the test environment and the number of cycle slip.

As shown in **Table 3** and **Table 4**, the results of long-term observation data quality (**Table 3**, 7*24 h) are relatively consistent with the short-term observation data (**Table 4**, 1 h). The subsequent tests were conducted on the short-term(1 h) observation data from different environments. BY682 and board N both showed good performance in multipath mitigation and data integrity rate. BY682's long-term GPS data integrity rate needs to be optimized. The cycle slip detection and repair of the two boards can be optimized.

Table 4 Results of 1h Observation data in Open Sky

Satellite system	Board	Criteria			
		MP1(m)	MP2(m)	RATIO(%)	O/Slps
BDS	BY682	0.10	0.11	79	10206
	N	0.07	0.08	79	638
GPS	BY682	0.12	0.14	99	2864
	N	0.06	0.07	100	28808
GLONASS	BY682	0.08	0.10	100	18005
	N	0.05	0.06	100	18005

* QC-full detection was performed by using default parameters of TEQC toolkit; MP1 < 0.5 and MP2 < 0.75 are preferred. The smaller the MP values are, the stronger the multipath mitigation of the board is. The larger the DI value, the more integrity the observation data get. O/slps > 200 is preferred; and the larger the O/slps value, the smaller number of cycle slip of the data.

4. Foliage canopy

The selected test environment is shown in **Figure 5**. The satellite signals blocked by dense branches and leaves. GNSS antenna was placed on the top of the test vehicle and other equipment was placed in the test vehicle. The receiver operated continuously for one hour. Results are shown in **Table 5**.

Compared with the open-sky (**Table 3 & 4**), the performance of test boards in the foliage canopy(**Table 5**) was obviously deteriorated. The results of the three boards were poor, only part of MP values of BY682 met the reference standard values, and the data integrity rate was low.

For BDS observation data, the MP value of BY682 was the smallest, the MP value of board N was slightly larger, and board U was about 2 times of BY682. The data integrity rate of the three boards were lower than 85%, and the number of cycle slip were large.

For GPS observation data, the MP value of BY682 was the smallest, and that of board N and board U were about 2 times of BY682. The data integrity rate of the three boards were lower than 90%, and the number of cycle slip were large.

For GLONASS observation data, the MP value of BY682 was the smallest, and that of board N and board U were about 2-4 times of BY682. The data integrity rate of the three boards were lower than 80%, and the number of cycle slip were large.

In GALILEO, the MP value of BY682 was small, and that of board U was about 3-4 times of BY682. The data integrity rate were less than 80%, and the number of cycle slip were large.

To sum up, under the foliage canopy, BY682 had good performance in multipath mitigation, while that of board N and board U were poor. The signal stable tracking, cycle slip detection and repair of the three boards were not ideal. The quality of observation data can be definite optimized in board design.

Figure 5 Typical foliage canopy environment

Table 5 Results of 1hour Observation data in Foliage Canopy

Satellite system	Board	Criteria			
		MP1(m)	MP2(m)	DI(%)	O/Slps
BDS	BY682	0.44	0.47	68	38
	N	0.78	0.64	64	31
	U	1.23	0.95	83	74
GPS	BY682	0.49	0.95	72	36
	N	1.13	1.51	87	27
	U	1.46	2.04	78	48
GLONASS	BY682	0.44	0.45	78	29
	N	0.90	0.87	68	78
	U	2.10	2.04	64	35
GALILEO	BY682	0.53	0.28	73	33
	N(not supported)	/	/	/	/
	U	1.78	1.16	-	50

* BY682 and board N receive L1 of BD3 satellite, so the data integrity rate was low.

* Failed to calculate DI in GALILEO of board U for few satellites tracked.

* QC-full detection was performed by using default parameters of TEQC toolkit; MP1 < 0.5 and MP2 < 0.75 are preferred. The smaller the MP values are, the stronger the multipath mitigation of the board is. The larger the DI value, the more integrity the observation data get. O/slps > 200 is preferred; and the larger the O/slps value, the smaller number of cycle slip of the data.

5. Urban canyon

The test environment is selected as shown in **Figure 6**, with tall buildings in vision and limitation in satellite signal availability. GNSS antenna was placed on the top of the test vehicle, and other equipment was placed in the test vehicle. The receiver operated continuously for one hour. Results are shown in **Table 6**.

Compared with the open sky (**Table 3 & 4**), the performance of test boards of the urban canyon (**Table 6**) were obviously worse, slightly worse than that of the foliage canopy (**Table 5**). The results of the observation data of the three boards were poor, only part of MP values of BY682 met the reference standard values, and the data integrity rate were low. The number of cycle slip were large.

For BDS observation data, the MP value of BY682 was less than 0.55 m, and that of board N and board U were about 2-4 times of BY682. The data integrity rate of the three boards were relatively low and the number of cycle slip were large.

For GPS observation data, MP value of BY682 was less than 0.7 m, and that of board N and board U were about 2-5 times of BY682. The data integrity rate of the three boards were lower than 60%, and the number of cycle slip of the board N was large, which is about 4 times that of the board U and 10 times that of BY682.

For GLONASS observation data, MP value of BY682 was less than 0.6 m, MP value of board N and board U were about 5-8 times of BY682; The data integrity rate of the three boards were lower than 80%, and the cycle slip of the board N was about 3 times that of the board U and BY682 board.

In GALILEO, the MP value of BY682 was small, and the MP value of board U was about 10 times of BY682.

To sum up, in the urban canyon, BY682 had better performance in multipath mitigation, while that of board N and board U were poorer. The cycle slip detection and repair of the three boards have a lot to optimize.

Figure 6 Typical urban canyon environment

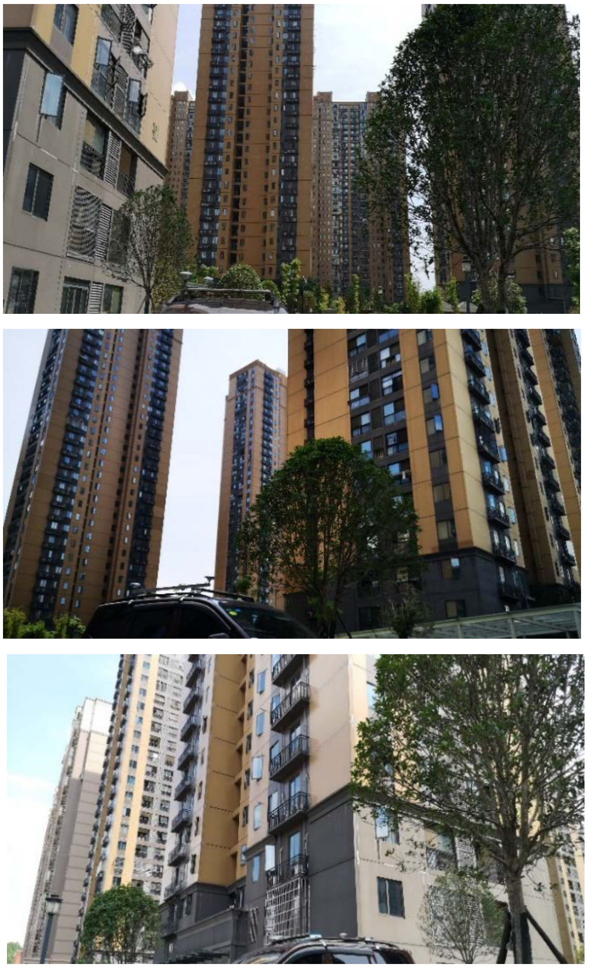


Table 6 Results of 1hour Observation data in urban canyon

Satellite system	Board	Criteria			
		MP1(m)	MP2(m)	DI(%)	O/Slps
BDS	BY682	0.44	0.54	47	39
	N	2.26	2.00	49	20
	U	2.03	1.48	84	92
GPS	BY682	0.58	0.70	41	121
	N	2.28	1.89	58	12
	U	3.06	3.84	50	56
GLONASS	BY682	0.58	0.49	-	70
	N	4.27	3.87	49	20
	U	3.25	3.15	65	64
GALILEO	BY682	0.74	0.20	-	234
	N((not supported))	/	/	/	/
	U	3.32	2.97	-	213

* BY682 and board N receive L1 of BD3 satellite, so the data integrity rate was low.

* Failed to calculate DI in GLONASS of BY682 for few satellites tracked. Failed to calculate DI in GALILEO of board and U BY682 for few satellites tracked.

* QC-full detection was performed by using default parameters of TEQC toolkit; MP1 < 0.5 and MP2 < 0.75 are preferred. The smaller the MP values are, the stronger the multipath mitigation of the board is. The larger the DI value, the more integrity the observation data get. O/slps > 200 is preferred; and the larger the O/slps value, the smaller number of cycle slip of the data.

6. Urban Environment (Dynamic vehicle)

The real world environment of the vehicle route is shown in **Figure 7**, which includes open-sky, foliage canopy, elevated road, urban canyon, low-rise buildings. The board repeated experienced the process of stabilizing tracking, unlocking, reacquisition and re-stabilizing tracking when receiving satellite signals . GNSS antenna was placed on the top of the test vehicle, and other equipment was placed in the test vehicle. The receiver operated continuously for 20 minutes while driving. The results are shown in **Table 7**.

Compared with the static test (**Table 3-6**), the performance in the dynamic vehicle (**Table 7**) were overall worse. For BY682, the MP values of each system were all less than 0.55 m; The MP value of different system of board N was unstable, ranging from 0.59 m to 1.29 m. MP value of board U was about 1 m, and the maximum value was 2.67 m.

The whole data integrity rate did not exceed 70%. The tracking capabilities of GLONASS signal of the three board all need to improve.

Affected by the complex urban road environment, the three boards detected a lot of cycle slip. In average, a cycle slip was detected in every 20 observation data samples.

To sum up, in urban environment, BY682 had better performance in multipath mitigation. Multipath mitigation of board N was worse, and board U was the worst. The ability to detect and repair cycle slip of the three boards all needs to improve, especially in urban environment.

Figure 7 Typical urban environment

Table 7 Results of Observation data in Urban Environment

Satellite system	Board	Criteria			
		MP1(m)	MP2(m)	DI(%)	O/Slps
BDS	BY682	0.25	0.31	56	19
	N	0.94	0.95	63	10
	U	1.18	1.15	68	18
GPS	BY682	0.20	0.28	56	18
	N	1.29	0.87	70	18
	U	1.61	1.51	64	23
GLONASS	BY682	0.48	0.53	50	12
	N	1.01	0.59	45	25
	U	2.16	2.67	50	11
GALILEO	BY682	0.27	0.12	-	17
	N(not supported)	/	/	/	/
	U	1.14	0.53	-	30

* BY682 and board N receive L1 of BD3 satellite, so the data integrity rate was low.

* Failed to calculate DI in GALILEO of board and U BY682 for few satellites tracked.

* QC-full detection was performed by using default parameters of TEQC toolkit; MP1 < 0.5 and MP2 < 0.75 are preferred. The smaller the MP values are, the stronger the multipath mitigation of the board is. The larger the DI value, the more integrity the observation data get. O/slps > 200 is preferred; and the larger the O/slps value, the smaller number of cycle slip of the data.

SUMMARY:

In order to compare the performance of different GNSS boards in typical application scenarios, we conducted tests in different degrees of occlusion environment. The post-processing solution was carried out by using the Inertial Explorer 8.70, and RMS was used to assess the post-processing position accuracy. The TEQC toolkit was used for QC testing. MP value, DI value and O/Slps were used as criteria of observation data, and the testing results were compared and analyzed in detail.

`The post-processing test` showed that the post-processing accuracy of BY682, board N and board U were equivalent, the RMS values in horizontal direction were both less than 2 mm, and the RMS values in vertical direction were less than 4 mm. Three boards showed position outliers at the same time, but the outlier of BY682 were the smallest in amplitude.

`Tests in open-sky` showed that BY682 and board N had stable multipath mitigation. The data integrity rate of the two boards were good.

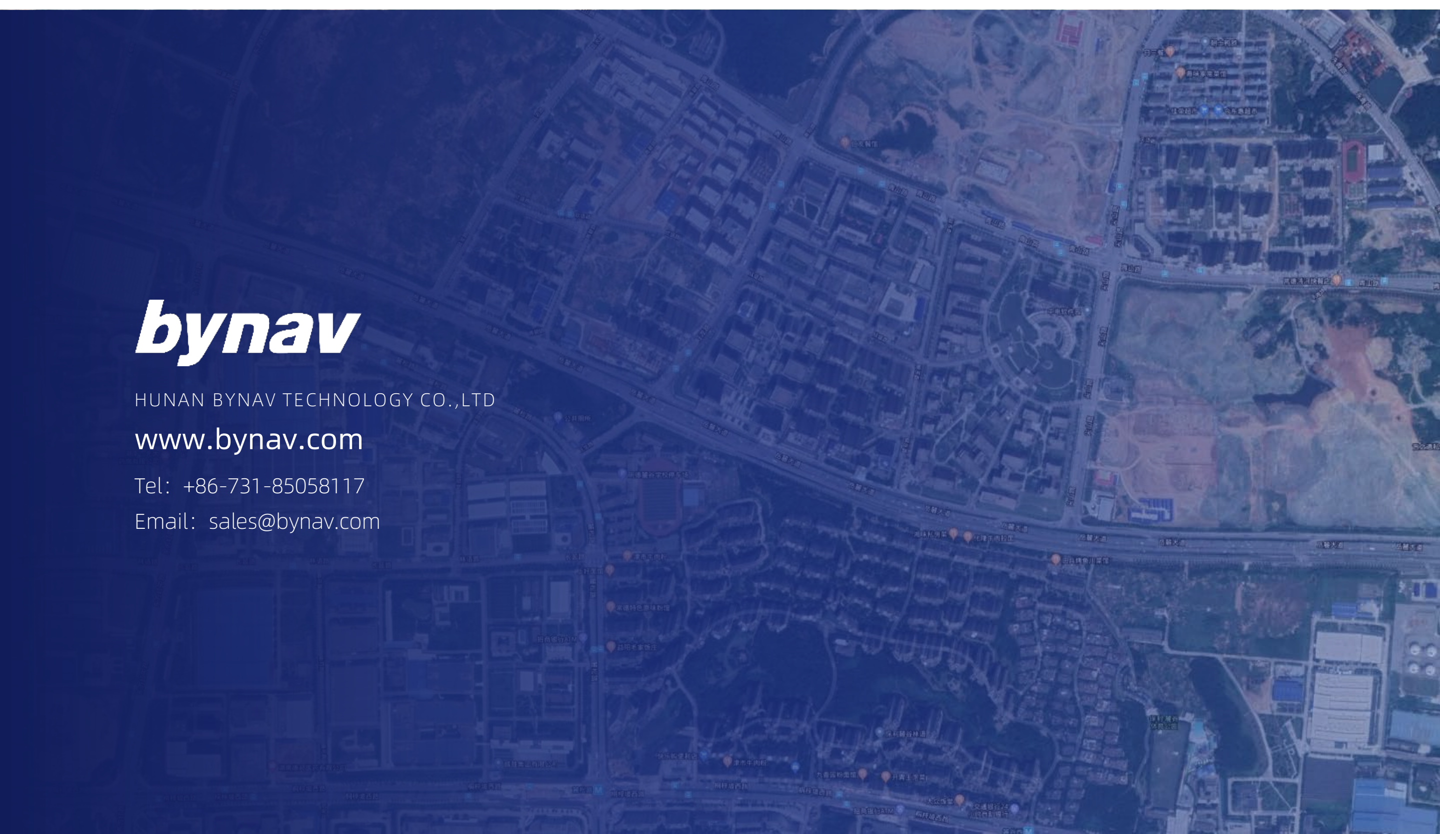
`In foliage canopy and urban canyon,` only BY682 showed consistently strong multipath mitigation, followed by board N, and board U showed the worst performance.

`In the dynamic urban environment,` BY682 had the best multipath mitigation, followed by board N, and board U was the worst. The cycle slip of the three boards were all high.

The test results showed that all competitors had equivalent performance in open-sky. Only BY682 had outstanding advantages in especially complex environment and consistently provided high-quality and available observation data. In addition, the quality of Galileo observation data of BY682 was obviously better than that of competitor (board N does not support Galileo for the time being).

Download the observation data of this test:

http://www.bynav.com/cn/resource/bywork/geek-observation/rawdata.html/



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