

Experimental Comparison of Outdoor Baseline Measurements by Different Methods

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Abstract. Outdoor baseline is the special length standard in the field of surveying and mapping, it can be used to verify the addition and multiplication constants of the total station and other photoelectric rangefinders. In order to ensure the authenticity, accuracy and reliability of verification results, conducting outdoor baseline traceability periodically is essential. At present, direct measurement by 24m invar tape or high precision electro-optical measurement is mainly used to achieve the traceability of outdoor baseline in China. Based on Shenyang baseline field, high precision rangefinder μ -base, 24m invar tape and high precision GNSS receivers are used for comparison experiments, and the experimental results are analyzed.

1 Introduction

At present, there are three calibration methods to measure the standard length of outdoor baseline, optical interferometry by Vaisala interference comparator, direct measurement by 24m invar tape and high precision electro-optical measurement.

Optical interferometry by Vaisala interference comparator is the most accurate method to calibrate baseline in the world. With the help of the Finnish geodetic research institute, based on the experience of building the Nummela baseline, there were built 432m, 576m and 378m baselines in Changyang, Liqun and Chengdu respectively. Due to urban construction, Wenchuan earthquake and other factors, those baselines accuracy was low, and now it has been abandoned.

The first geodetic survey team is the only national field large-length quantity transmission institution authorized by the state, and undertakes the periodic verification work of dozens of outdoor baselines. The measurement method by 24m invar tape is intuitive, and the error correction model is clear, but the measurement efficiency is low. In the field, the measurement will also be affected by temperature, tension, wind speed and other factors. If the baseline is long, the cumulative error generated by piecewise measurement will increase.

In terms of photoelectric ranging, μ -base, a new generation of high-precision range finder launched in 2012, is convenient to carry, simple to operate, and has good performance. After model correction of meteorological parameters, the instrument can achieve high accuracy, which can be used for outdoor baseline calibration.

In China, the method by 24m invar tape or high-precision photoelectric rangefinder is mainly used to calibrate outdoor baseline. A large number of

experimental facts have shown that the transmission of quantity value of outdoor baseline is still inconsistent with that in foreign countries. Through the unremitting efforts of researchers, the systematic error is gradually reduced. Compared with those two methods, the measurement baseline accuracy of high-precision GNSS receiver is lower, which is not in line with the relevant requirements of outdoor baseline long measurement transmission system in China.

Through the outdoor baseline consistency comparison experiment, this paper also conducted an in-depth study on the measurement of high-precision GNSS receiver, in order to continuously improve the length measurement value transfer system for beneficial exploration.

2 Comparing experiment

2.1 Measuring method by μ -base rangefinder

On the afternoon of July 31, 2019, in Shenyang outdoor baseline, the measurement was made by using μ -base rangefinder. Two sets of ventilation meteorological sensors were used to measure meteorological elements by "two-point method", and the meteorological elements were input into Pilot software for ranging correction in real time. In order to ensure the ranging accuracy, ADM signal strength should not be lower than 150. It is often considered that the effective ranging range of μ -base is 1.5~160m. Under favorable weather conditions such as cloudy days and no wind, the maximum measuring distance can exceed 200m. The setting of the observation scheme is shown in figure 1.

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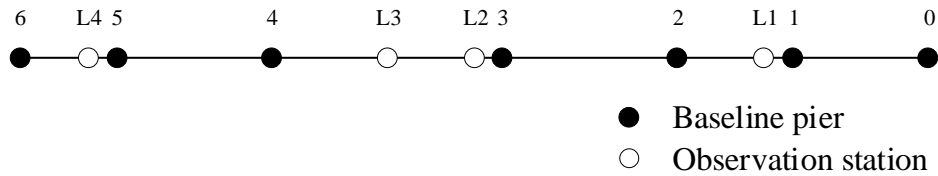


Fig. 1. Schematic diagram of μ -base rangefinder observation.



Fig. 2. Schematic diagram of field observation.



Fig. 3. A spherical prism is placed on the baseline pier and meteorological elements are measured by a ventilated weather sensor.

In the whole process from the beginning to the end of the measurement, the temperature change and wind speed were small, the illumination was not strong, μ -

base rangefinder reading had a good repeatability. The original measurement data is shown in table 1.

Table 1. Raw data results of measurement.

Measurement route	Slope distance of μ -base/m			Atmospheric pressure/ hPa	Temperature/°C	Humidity/%
L1-0	169083.983	169083.986	169083.985	997.8	30.8	70
L1-1	1073.270	1073.270	1073.270	997.8	30.8	70
L1-2	143027.575	143027.580	143027.585	997.8	30.8	70
L2-2	217060.710	217060.703	217060.698	997.7	30.7	72
L2-3	1059.268	1059.269	1059.265	997.7	30.7	72
L3-3	143281.852	143281.844	143281.842	997.8	30.3	74
L3-4	144751.863	144751.857	144751.854	997.8	30.3	74
L4-4	193170.159	193170.148	193170.191	997.8	30.2	73
L4-5	1112.710	1112.704	1112.700	997.8	30.2	73
L4-6	94895.974	94895.972	94895.976	997.8	30.2	73

On August 2, the first geodetic survey team used electronic level to measure the height difference of the

baseline piers. Horizontal distance results are obtained by using Pythagorean theorem, as shown in table 2.

Table 2. Calculation results of horizontal distance.

Measurement route	Height difference /m	Slope distance of μ -base /m	Slope distance of μ -base /m
0-1	-0.0655	168.01071	168.01070
1-2	0.0705	144.10085	144.10083
2-3	0.258	216.00144	216.00129

3-4	0.163	288.0337	288.03365
4-5	0.2185	192.05746	192.05734
5-6	0.1265	96.00868	96.00860

2.2 Static measurement by GNSS receivers

On August 1, static measurement experiment was carried out. Three Trimble NetR9 receivers were set up at baseline piers 3, 5 and 6 with a wide field of view, the antenna was uniformly oriented to the north, the sampling interval was 10s, the height cut-off Angle was 10°, and the measurement time was 24 hours. Before starting up the receivers, measure the antenna height, as shown in figure 4, and the field diagram of measurement is shown in figure 5.



Fig. 4. Measure the height of the instrument from three directions and find an average value.



Fig. 5. A Trimble NetR9 receiver was set up at baseline piers 3 for static measurement experiment.

We select Trimble DL mobile application to send raw data files to PC via bluetooth communication. GAMIT 10.5 software is used for baseline calculation, it runs on the LINUX operating system. Data preparation is required before calculation. Convert the original observation file of Trimble too file by Convert To RINEX program. And download the corresponding precise ephemeris SP3 file, navigation message file and table files that need to be updated.

The most critical of these is to configure four table files.

- Station approximate coordinate file. Based on the research of Liu Yangyang, station approximate coordinate file is generated by

using the results of single point positioning solution.

- Station information file. Enter the correct parameters manually, such as antenna height, antenna type, antenna high measurement mode, receiver software version number, etc.
- Station constraint table. We chose the short sittbl, the most important thing is to set 3d coordinate constraint, generally, it is set as the 2-3 times median error of coordinate accuracy. Considering the accuracy of single point positioning measurement, 3d coordinate constraints are all set to 9.999m.
- Data processing parameter setting table. Some parameters are set as follows, Choice of Experiment = RELAX, Type of Analysis = 1-ITER, Choice of Observable = LC_AUTCLN, Zenith Delay Estimation = Y, Interval zen = 1, Tides applied = 31, Elevation Cutoff = 15.

After the file preparation and configuration is completed, enter the commands in turn according to the GAMIT baseline calculation process. Table 3 shows the results of baseline calculation and horizontal distance.

Table 3. Font styles for a reference to a journal article.

Measurement route	Slope distance /m	Horizontal distance /m
5-6	96.0125	96.01242
3-5	480.0874	480.08725
3-6	576.0999	576.09968

In the output o file, standard root mean square NRMS is an evaluation index of baseline solution accuracy. The smaller the value of NRMS is, the higher the solution accuracy is. The value of NRMS in this experiment is 0.25, indicating that the solution result is reliable.

2.3 Direct measurement by 24m invar tape

From August 2 to 3, the first geodetic survey team measured the baseline by 24m invar tape. The measurement process is shown in figure 6 and 7.



Fig. 6. The members of the first geodetic survey team cooperate closely to measure the baseline.



Fig. 7. When measuring, the surveyor takes a reading of the moment. The 24m invar tape has mm marks on both ends less than 8cm.

They used a tape measure to divide the baseline into three sections of equal distance, and used four 24m invar tapes with different expansion coefficients to carry out sub-group measurement. In each section, two went to the measurement and two went back to the measurement.

The measurement results of each ruler were corrected by temperature correction, ruler length correction and tilt correction, and the measurement results of 4 rulers were averaged. The whole length of the baseline was the sum of the lengths of each segment.

The measurement results are shown in table 4.

Table 4. Measurement results of the 24m invar tape.

Measurement route	Horizontal distance/m
0-1	168.01104
1-2	144.10073
2-3	216.00097
3-4	288.03432
4-5	192.05703
5-6	96.00871

3 Conclusions

The comparison results are shown in table 5 and 6.

According to table 5, the system error between μ -base and 24m invar tape is submillimeter, but it can not be ignored for the accuracy of baseline calibration. According to the preliminary experimental results, the error compensation algorithm and calculation model should be further optimized. For the GNSS receiver measurement method, there are several tall trees on the side of point 5, which results in the accuracy of the two baselines involved in the calculation is damaged. In the next step, the comparison experiment between μ -base and GNSS receiver can be carried out in open areas to reduce the influence of multipath effect.

Table 5. Results of consistency comparison between μ -base and 24m invar tape.

Measurement route	μ -base/m	Invar tape/m	System error	
			mm	mm/km
0-1	168.01070	168.01104	-0.343	-2.0
1-2	144.10083	144.10073	0.103	0.7
2-3	216.00129	216.00097	0.316	1.5
3-4	288.03365	288.03432	-0.666	-2.3
4-5	192.05734	192.05703	0.306	1.6
5-6	96.00860	96.00871	-0.113	-1.2

Table 6. Comparison results of three measurement methods.

Measurement route	Invar tape/m	μ -base/m	GNSS/m	System error/ mm		
				1-2	1-3	2-3
3-5	480.09135	480.09099	480.08725	0.36	4.10	3.74
3-6	576.10006	576.09959	576.09968	0.47	0.38	-0.09
5-6	96.00871	96.00860	96.01242	0.11	-3.71	-3.82

Outdoor baseline precision ranging will play a crucial role in the verification of precision measuring instruments, it is beneficial to the progress of length measurement system in China and the development of basic areas, it can play an important role in national defense construction, major infrastructure construction, aerospace, equipment support, national economy and other fields.

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Acknowledgments

This research is funded by National key R&D Program of China (2017YFF0206000), authors thank Senior engineer Fan Gang and Teacher Jia Zhen for their help.

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