

Modern state of metrological support of "digital level - barcode staff" measurement systems

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Abstract. In this work, several methods for studying measuring systems “digital level - barcode staff” are analyzed. The methods of different countries for checking means and technological schemes for monitoring the main metrological parameters of barcode strips are compared. Based on the material studied, it was revealed that metrological support for the “digital level - barcode staff” system is carried out in specialized laboratories, which is not available to every user. As a result, the study revealed that not one of the methods considered the influence of vertical refraction. Based on the research of this article, it is proposed to improve the control technique taking into account the influence of vertical refraction.

1 Introduction

In this work, metrological support and research of measuring systems “digital level - barcode staff” are analyzed. With the advent of digital levels in Uzbekistan, leveling led to a change in the technological scheme of production of all classes. In this regard, methods for checking means and technological schemes for monitoring the main metrological parameters of barcode strips and comparators of foreign countries were investigated and compared [1-14].

In the works listed below, all research is carried out separately with a digital level and a barcode staff. In this case, to study the “digital level - barcode staff” system, a specialized laboratory is required, which is not available to every user.

The studies carried out on the developed compact field comparators prove the sufficient accuracy and reliability of measuring the excess of the “digital level - barcode staff” measuring systems.

The obtained research results open up new directions in geodetic metrology in the context of complete automation of technological processes for verification and research of modern geodetic instruments.

Determining the metrological characteristics of barcode strips is also considered

The high-precision digital leveling system uses barcoded Invar rods and a linear CCD camera. The slats are made of aluminum alloy; therefore, the scale of the barcode depends on the temperature.

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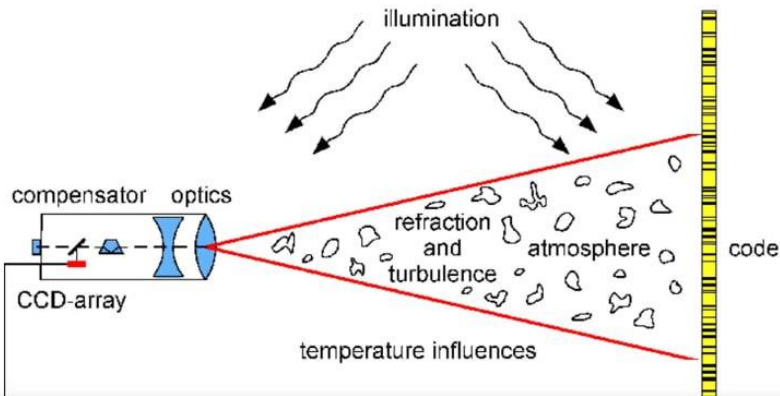


Fig. 1. The influence of the external environment at the time of measurement from barcode strips.

The scale and constant are determined by the calibration of the rod. When performing digital leveling, it is expected that the scale of the entire system, in fact the scale specified by the tool, will be equal to the scale of the rod. However, over time, the scale of the tool, as well as the rod, may change. To check the behavior of the entire system, that is, the bar and the tool together, we must use a “system calibration” procedure in which height readings are taken from different sectors of the barcode bar and compared with their true values obtained by the laser. Interferometer [3].

2 Methods

Theoretical research of methods and existing measuring devices, laboratories for a complete analysis and efficiency of verification of the “digital level - barcode staff” system.

It will ensure the required accuracy and reliability of leveling results performed by the measuring system “digital level - barcode staff”; it is necessary to carry out its periodic metrological certification. In relation to the “digital level - barcode staff” system, which uses a digital level and a barcode staff, it is extremely difficult to carry out a separate study in full only for the level and only for the barcode staff. This is due to the fact that the barcode rod, firstly, does not have a metric scale with evenly applied strokes (every 5 or 10 mm) and therefore the Geneva ruler or standard optical-mechanical comparators cannot be used for research.

In field conditions, any research is labor-intensive and difficult; in laboratory and factory testing conditions, the results are largely influenced by the external environment and have low accuracy. To verify technical characteristics, it is necessary to carry out studies of levels and slats together, but this is impossible under long-term field conditions.

In world practice, many analyzes, methods, means and technological schemes for monitoring the basic metrological parameters of barcode strips have been carried out. At the geodetic laboratory of the Bundeswehr University in Munich (Universität der Bundeswehr München), a horizontal comparator is used to verify barcode strips. Using the microscope of this comparator, which has only one photodetector, the position of the transition lines from the light field of the code to the dark and vice versa, from dark to light, is determined, i.e., the positions of the edges of the code strokes are determined. The rack moves in two directions - forward and backward. The average position of the edge of the stroke is calculated[10],[14].

An interference comparator for checking racks allows you to perform measurements with a standard deviation $\sigma_m \leq 1 \mu\text{m}$. The time spent on checking a 3 m long rack in forward and reverse motion does not exceed 20 minutes.

In Fig. 2. A diagram of a horizontal comparator is given for joint calibration of barcode strips with a digital level [14]. The code bar, located horizontally on the guides, can be moved using an electric drive at arbitrarily specified intervals. The rack movement intervals are measured using an interferometer. The digital level to be verified is installed on a U-shaped stand in such a way as not to block the path of rays in the measuring channel of the interferometric system[14].

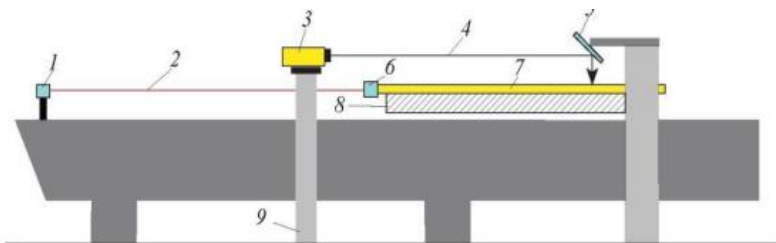


Fig. 2. Installation for verification of the measuring system “digital level - barcode staff”: 1 - interferometer; 2 — laser beam; 3 — digital level NA 2000/3000; 4 — sighting beam; 5 - mirror; 6 - reflector; 7 — leveling rod; 8 — guides; 9 - U-shaped stand[14].



Fig. 3. Horizontal comparator for calibration (Universitat der Bundeswehr Munchen)[14].

The disadvantages of this device are: the inability to determine the measurement error of the measuring system being verified “digital level - code staff” in its working vertical position of the staff [2],[14].

There is a wide range of foreign-made digital level models on the Russian market; tens of thousands of such devices have already been purchased by Russian consumers. Currently, in the field of geodesy and cartography in Russia there are no regulatory documents that would allow high-precision levels to be carried out using the “digital level - barcode staff” system. The problem is that when working at the station, there are no controls of geometric conditions known to geodesists from optical leveling that allow them to identify the occurrence of gross errors, and the influence of temperature deviations on the accuracy of field measurements is not known.

When using digital levels, the measurement uncertainty depends on the uncertainties of the barcode staff, which must be taken into account when processing measurement results[4],[13].

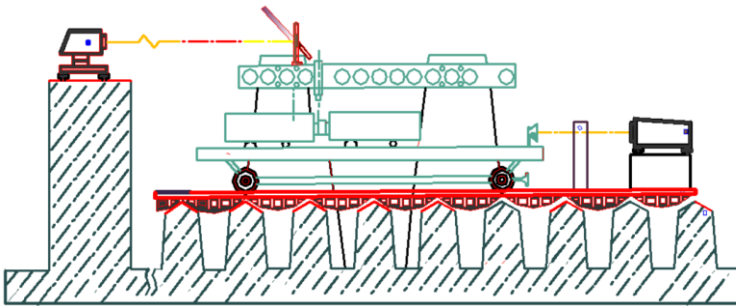


Fig. 4. Existing stand for studying the error of a digital level (FGBU VPO "MIIGAiK")[14].

Golygin Nikolay Khristoforovich, head of the metrology laboratory, professor of the department of "Design of optical devices", Ph.D., FSBI VPO "MIIGAiK", in 2008 received a patent "STAND FOR CHECKING AND CALIBRATING DIGITAL LEVELINGS AND BARCODE RACKS"

N.H. Golygin developed an additional method for checking and calibrating digital levels and barcode strips and patented a new stand. The stand additionally includes a block of end standard length measures, consisting of three end standard length measures of equal size, and a standard barcode rod, which is rigidly connected through the block of end measures to the rod being verified with heels facing each other.

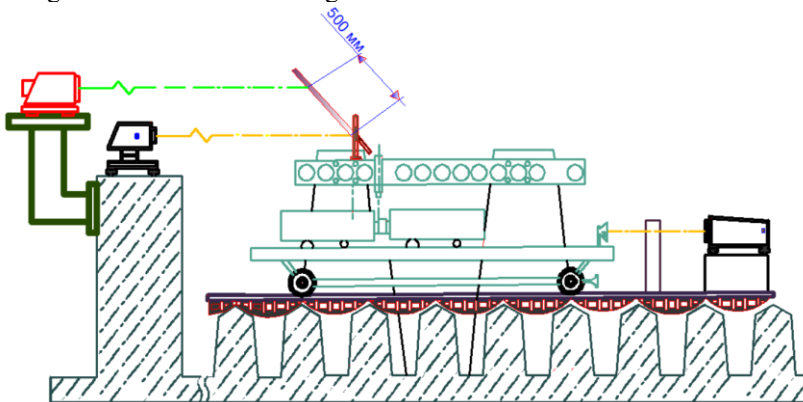


Fig. 5. Developed by N.H. Golygin stand for verification and calibration of digital levels and barcode strips[13].

The stand additionally includes a block of end standard length measures, consisting of three end standard length measures of equal size, and a standard barcode strip, which is rigidly connected through the block of end measures to the rod being verified with heels facing each other. The technical result is an increase in measurement accuracy and the ability to determine the heel and the difference in the heels of barcode strips[5],[13].

At the Finnish Geodetic Institute (FGI), automated rod calibration has been carried out since 1996 using the FGI vertical laser rod comparator, and system calibration since 2002. The FGI system calibration comparator uses elements of the existing FGI rod comparator. Some calibration results for Zeiss DiNi12 systems are presented. 1 Importance of system calibration System calibration (Rüger and Brunner, 2000) is used to determine the scale of

digital leveling systems, study their measurement performance, and estimate the standard uncertainty of digital leveling [8].

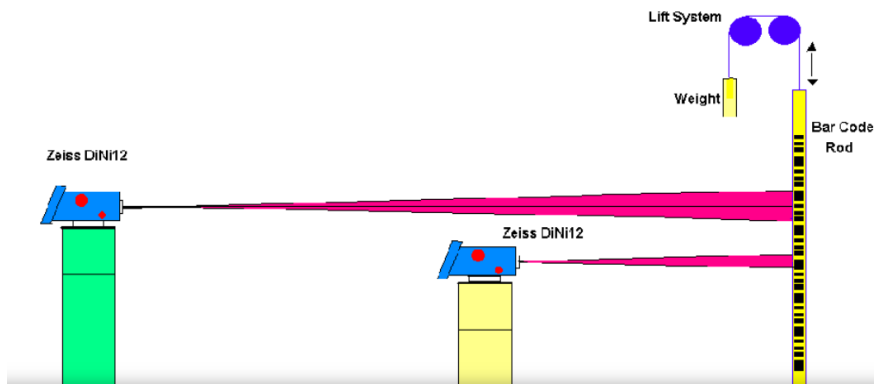


Fig. 6. System calibration comparator specifically designed for the Zeiss DiNi12 digital level system with two viewing posts.[8].

The system calibration procedure consists of forward (A) measurements from the bottom to the top end of the rod and backward (B) measurements from the top to the bottom end of the rod. When moving the rod, the step length is 25 mm and the sighting range is 7.5 m.

The FGI System Calibration Comparator is an effective tool

- determine the scale of the digital leveling system, which is the final output to correct leveling data;
- monitor changes in the scale, which may indicate changes in the rod;
- study the behavior of a digital leveling system, for example, at different ambient temperatures[2],[8].

Researchers at Moscow State University for Land Management Kulikovskiy D.R. and Phung Trung Thanh described research on the leveling kit “Dini-03 Level and Barcode Staff”. Three studies of the instrument leveling kit were carried out:

- 1) the influence of horizontal rotation of the barcode bar;
- 2) the influence of the vertical angle of inclination of the barcode bar;
- 3) the range of the covered part of the barcode staff in the field of the telescope of the device.

One of the main characteristics of the level is the mean square error per 1 km of double stroke (the characteristic is indicated in the technical data sheet of the device). It is worth noting that in engineering and technical leveling one of the most important indicators is the mean square error at the station. Thus, by the magnitude of the error at the station, one can assess the suitability of the level to perform work with the required accuracy. The listed studies are aimed at studying the influence of the non-standard position of the barcode staff on the mean square error at the station, as well as the conditions for making measurements when using the leveling kit “Dini-03 Level and Barcode Staff”[5],[10].

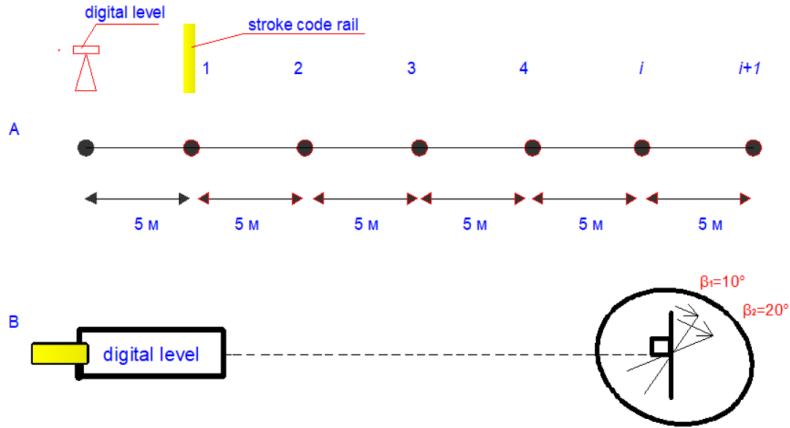


Fig. 7. a) base-line; b) layout diagram of the level and barcode staff [14].

This study proposes to explore the range of staff use when taking readings. Determine which range of the staff is unacceptable for taking a reading. The user manual recommends a visible length of 30 cm. This study will help us with further research on deformation code marks, namely, choosing the appropriate length of this mark. The studies were carried out on a flat surface. The rod was installed on metal dowels with a spherical head, driven into the concrete floor at various distances from the level[1],[11].

3 Results and discussion

The purpose of the study is to assess the current state of metrological support for measuring systems “digital level - barcode staff”. To achieve this goal, an experimental study was carried out.

According to the research analyses carried out in any comparator, the layout of which is horizontal or vertical, the data obtained is excellent, which satisfies all the requirements of the standards. Therefore, it is impossible to assess the accuracy of measurements from differences in double measurements. The results obtained during research at the laboratory of the Central Aerogeodetic Enterprise (Tashkent) were systematised (Table 1) and mathematically processed using the formula:

$$m_h = \sqrt{\frac{[d_i^2]}{2n}}$$

The measurement results are divided into methods, in each of which UPC measurements of the excess are obtained.

Table 1. Class II levelling journal inspection report

s trail stroke			m ove back			di, mm	Di2, mm	
Section	S,m	h,m	Δh,m	Section	S,m			h,m
1-2	49.118	1.4710	0.0046	2-1	49.118	1.4667	0.0038	0.8
	49.138	1.4664			49.138	1.4705		
2-3	49.142	1.4667	0.0015	3-2	49.142	1.4669	0.0024	-0.9
	49.102	1.4652			49.102	1.4645		
3-4	49.102	1.4649	0.0042	4-3	49.102	1.4645	0.0028	1.4
								2.0

	49.130	1.4608			49.130	1.4613				
4-5	49.135	1.4607	0.0027	5-4	49.135	1.4610	0.0041	-1.4	2.0	
	49.161	1.4580			49.161	1.4569				
5-6	49.170	1.4585	0.0004	6-5	49.170	1.4571	-0.0006	1.0	1.0	
	49.137	1.4581			49.137	1.4577				
6-7	49.134	1.4578	0.0002	7-6	49.134	1.4572	-0.0004	0.6	0.4	
	49.125	1.4576			49.125	1.4576				
7-8	49.130	1.4578	-0.0021	8-7	49.130	1.4582	-0.0007	-1.4	2.0	
	49.110	1.4599			49.110	1.4589				
8-9	49.115	1.4591	0.0081	9-8	49.115	1.4591	0.0088	-0.7	0.5	
	49.149	1.4510			49.149	1.4503				
9-10	49.139	1.4511	0.0086	10-9	49.139	1.4501	0.0072	1.4	2.0	
	49.118	1.4425			49.118	1.4429				
10-1	49.120	1.4428	-0.0278	1-10	49.120	1.4423	-0.0283	0.5	0.2	
	49.120	1.4706			49.116	1.4706				
S=1002.596		D h = 0.0004		S=1002.592		D h=-0.0009		1.30	11.4	

Table 2. TRIMBLE digital level DINI and optical level NA -1

Triposds order number No	The difference between the calculations obtained from the Dal'nomer thread		Calculation from the bisector (1/2 dm.)							
			From the main scale				From the additional scale			
			from Reykjavik		from the drum		from Reykjavik		from the drum	
			back	front	back	front	back	front	back	front
1	2	3	4	5	6	7	8	9	10	11
Stamp #9563 to rapper #2109 leveling way 18.04. 2024 Executor; Khudaikulov Sh. Journal No. 22, 24, 1124, 1021										
1	140	140	19,8	19,1	58	58	79,0	88,4	102	8
2	825	835	28,5	28,0	40	95	87,7	87,3	88	47
3	620	620	23,6	51,9	27	28	82,8	111,1	86	77
4	620	620	10,6	46,2	66	8	69,9	105,4	16	57
5	820	825	29,7	29,2	24	40	88,9	88,4	75	93
6	830	830	30,2	23,6	20	93	89,4	82,9	71	42
7	580	580	47,7	21,2	26	35	106,9	80,5	75	0
8	250	248	21,4	58,1	33	25	80,6	117,3	83	78
9	160	140	21,8	54,8	34	60	81,0	114,1	80	13
10	140	130	16,5	55,1	57	85	75,8	114,4	8	39
Σ(1-10)	4985	4968	249,8	397,2	385	527	842,0	989,8	684	454
11	160	140	14,0	56,4	43	13	73,2	115,6	91	62
Section according to	5145	5108	263.8	453.6	428	540	915.2	1105.4	775	516
L =0.5 km n = 11 pcs	+37			-189.8 -189,912		-112		-190.2 -189.941		+259 +29

The results of all field measurements, including those obtained during the construction of a closed levelling course, are summarized in Table No. 2.

4 Conclusion

As a result of the analysis of research carried out by German, Russian and Finnish metrology laboratories, the following results were obtained:

- not one of the methods considers the peculiarities of the influence of the vertical refraction of the surface layer of the atmosphere on the results of leveling the CN.

- the influence of vertical refraction of the surface layer of the atmosphere on the results of high-precision leveling of the central layer at positive and negative temperatures of the surface layer of the atmosphere is not taken into account.

As a result, there is a need to conduct a number of studies on the improvement of the I and II class leveling methodology, including the study of the refraction effect that occurs in the lower layer of the atmosphere. Considering these conditions, it is necessary to improve the leveling monitoring program at the stations.

On the basis of theoretical and practical research, a number of problems were solved based on the practical importance of using a modern digital level in the performance of high-precision leveling work of I and II classes and based on the research results.

1. In high-precision leveling, it is possible to reduce the impact of errors as a result of the analysis of the existing tracking program;
2. Due to the significant improvement in the technical characteristics of modern digital levels, it is necessary to propose a new value of permissible errors in class I leveling;
3. In the process of performing leveling of the first class on a digital level, increasing the number of measurements, monitoring programs were developed, as a result, a reduction in systematic error was achieved.
4. Based on the results of the research, the method of performing class I leveling with a "digital level" was improved, taking into account the effect of refraction in the near-earth layer of the atmosphere.

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