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Tomasz Szot
Gdansk University of Physical Education and Sport, Gdansk, Poland, tomasz.szot@awf.gda.pl

Marcin Sontowski
Gdansk, Poland, marcin.sontowski@gmail.com

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Evaluation of elevation parameter determination by Global Navigation Satellite Systems' sports receivers: A preliminary study

Tomasz SZOT[1], Marcin SONTOWSKI[2]

[1] Gdansk University of Physical Education and Sport in Gdansk, Poland; ORCID 0000-0001-8052-8531
[2] Gdansk, Poland

* Correspondence: Dr Tomasz Szot, e-mail: tomasz.szot@awf.gda.pl

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1. Introduction

Monitoring distance, time, speed, and other movement parameters has interested athletes, coaches, and scientists for decades [1], as this knowledge is essential for a valuable training process. For some disciplines, however, this monitoring poses a challenge, particularly when the competition area is expanding and the athlete is 'slipping out of reach' of measuring instruments.

When the first Global Navigation Satellite System (GNSS), the USA's NAVSTAR GPS, was made available to civilian users in the mid-1990s, it became clear that this technology would also find its use in monitoring physical activity [2]. The abolition of the deliberate reduction in the system accuracy in May 2000, the progress associated with the miniaturisation of equipment, the increase in computing capacity, and the launch of three more GNSSs (Russia's GLONASS in 2011, Europe's Galileo in 2016, and China's BeiDou in 2020) resulted in a significant increase in the popularity of GNSS receivers. Outdoor activities in the broadest sense, including sports and tourism, have also become beneficiaries of these receivers. An example of the trends can be observed in the changing sales profile of the industry's leading company, Garmin (garmin.com), in which the outdoor/fitness sector accounted for only 15% in 2009, with the last few years showing a steady share of over 50% [3]. Currently, the manufacturers of high-quality sports and recreational receivers usually rely on two systems, most frequently on GPS+GLONASS or GPS+Galileo), which enables faster determination of position coordinates, more accurate measurements, and better performance under difficult conditions.

Running is one of the most popular sports in which GNSS receivers are commonly used. In addition to the social aspect, manifested in comparison with other participants in the activity, what is important here is mainly the possibility of ongoing control of the level of commitment and effort based on movement parameters such as pace, distance, and elevation. The latter component, which is not very important in flat terrain running, is nevertheless becoming important in mountain running, as it has a key impact not only on the results achieved but also on the safety of the athletes.

GNSS receivers are specific measuring instruments because they determine geographical coordinates on the Earth's surface based on signals received from several navigation satellites located many thousands of kilometres above it, in space (e.g. GPS – approximately 20,000 km; [4]). The most popular devices, so-called code-based, intended for the general public and implemented in smartphones, cars, or sports and recreational devices, compute geographic coordinates and elevation based on the time shift between the codes generated by themselves and those received from satellites. The way the computations are performed, and the GNSS systems and their satellites are used, varies depending on manufacturers and models, hence the need to test them to identify the differences and assess their usability. Due to the geometric considerations, the vertical accuracy of these instruments is much lower than the horizontal accuracy.

Additional clarification is required to precisely define the 'elevation', which, in general terms, is the difference between the Earth's surface (adopted as the mean sea level, MSL) and a point above it (or, less frequently, below it). A typical sports GNSS receiver determines, by performing computations, the longitude and latitude as well as the so-called ellipsoidal height (Fig. 1). This height is the distance between the receiver and the surface of the rotational ellipsoid, i.e. a virtual surface described by the WGS-84 reference system. The vast majority of widely available sports and recreational code receivers provide this exact parameter as the 'height'. However, since the Earth's surface is highly variable, an additional theoretical concept of a geoid has been introduced into the field of Earth sciences, defined as a surface to which the force of gravity is perpendicular. A model of such a geoid, with high resolution and accuracy, is then used in land surveying, geological, geophysical and oceanographical works.

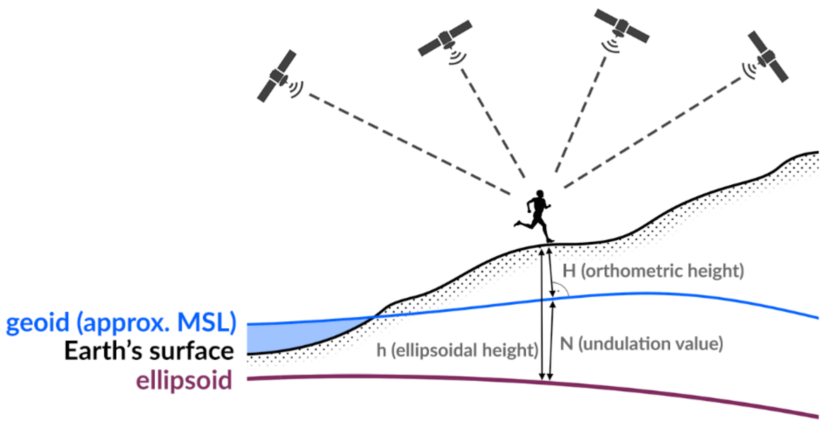

Figure 1. The relationship between orthometric height, ellipsoid height and geoid

The distance between the receiver and the geoid surface is referred to as the orthometric height. These quantities are described by the formula:

$$h = H + N \quad (1)$$

where: h – ellipsoidal height, H – orthometric height to the geoid; N – undulation value (the difference between geoid and ellipsoid) [5, 6]. If a GNSS receiver has downloaded (or is capable thereof) an accurate geoid model for a predetermined longitude and latitude, it is also capable of providing the user with height in relation to MSL. For a large portion of popular sports and recreational GNSS receivers, the solution to improving the elevation determination accuracy is the use of a barometric sensor which either operates automatically (when starting the activity) or is initiated by the user. Certain advanced models also have the ability to manually calibrate the starting point against the Digital Elevation Model (DEM) in place, but the type and accuracy of such terrain models, covering large areas of the world, are not provided by manufacturers. It is, therefore, worth noting that the reading (estimation) of a single height by a sports and recreational GNSS receiver will not be identical to the height known from topographic maps. This, however, does not affect the determination of relative indices. In the field of sports, the simplest indicator related to elevation is to determine the absolute elevation (Above Sea Level, ASL) or the relative elevation as the difference between elevations (e.g. between the end point and start point) or the so-called Elevation Gain (EG; also known as Total Elevation Gain, TEG).

An analysis of different methodologies for testing sports and recreational GNSS receivers shows that they can be classified into three groups. The simplest way is (1) to test a particular receiver in motion (or in a set of movement activities) specific to a particular discipline and then to relate the obtained values to the desired ones (e.g. total distance; [7, 8]). The second, more difficult way is (2) to determine a set of points (reference trajectory) and then to relate the position coordinate determinations acquired from the tested receiver to them. This identifies unit errors and presents them as relevant statistics [e.g. 9]. Neither (1) nor (2), however, provides an answer to the question of how accurate a receiver is while determining a single position coordinate and elevation. It is only possible when using the most advanced way of testing receivers (3), in which, for each point of the coordinates determined by the tested receiver, a reference point is established at the same moment in time and, obviously, in the same coordinate system. This way, however, requires accurate and precise GNSS receivers as well as the performance of complex computations [10–13].

This article analyses the determination of elevation by sports GNSS receivers intended for runners, thus complementing the range of the already existing methodologies to include a relatively simple evaluation methodology using Digital Terrain Models (DTM) for individual countries which, by feeding Geographic Information Systems (GIS), enable the performance of complex spatial analyses. These preliminary tests were aimed at determining the extent to which the adopted methodology, based on the aforementioned reference surface, would allow sports receivers to be distinguished in terms of determining the elevation parameter.

2. Materials and methods

2.1. Tested receivers

Three wrist-worn Garmin receiver devices (Forerunner 920xt, 935, and 945) were selected. At the time of their introduction to the market (in 2014, 2017 and 2019, respectively) they were the most advanced Forerunner series models. Each of them uses a barometer for elevation correction. The 920xt receives GPS and GLONASS signals, while the remaining ones also receive Galileo signals (Tab. 1), and it is worth noting that the user can choose either a single system (GPS) or GPS+GLONASS or GPS+Galileo setting (for triple-system receivers). The devices were set for receiving GPS+GLONASS with a recording frequency of 1/s and placed on the top part of a vehicle (Fig. 2).

Table 1. General specifications and settings of the receivers

FR	Release date	GNSS chipset	Barometric altimeter sensor	Recording frequency setting	Number of points recorded	
					Trial #1	Trial #2
920XT	2014	GPS, GLONASS	+	1/s	1126	584
935	2017	GPS, GLONASS, GALILEO	+	1/s	1126	584
945	2019	GPS, GLONASS, GALILEO	+	1/s	1126	584

Figure 2. The installation of sports GNSS receivers during preliminary tests

2.2. Reference surface

The Digital Terrain Model of Poland (DTM, also known as Digital Elevation Model, DEM) is a discrete (point based) representation of the topographic elevation of the land surface and is made freely available by the Head Office of Geodesy and Cartography of Poland (Pol.: GUGiK, www.gov.pl/web/gugik). The database text files contain point elevation values in a regular grid with a 1-metre mesh (ARC/INFO ASCII GRID format). The mean elevation error for the aforementioned model falls within a range of up to 0.2 m according to the statement in [14]). This meets the recommendations to which the reference system should be 10 times better than the accuracy of the device being tested [15]. Data package for both areas (Trial #1 and Trial#2) were downloaded in January 2022 (valid for the year 2011, latest files).

2.3. Testing protocol

The tests were conducted on two local asphalt roads with an even slope and road elevations of 47 m (Trial #1, a distance of 0.5 km) and 98 m (Trial #2, 1.3 km). The first of the distances was covered four times uphill and downhill (twice with a speed of 7 km/h uphill, 11 km/h downhill, and twice at 15/22 km/h), and the second one was covered twice uphill and downhill with speeds of 27/38 km/h. One-minute breaks were taken between individual passages, during which the vehicle did not move. Individual trials were selected from among the tracks recorded by the receivers in the GPX format (total of 1710 points of geographical coordinate determinations per receiver).

2.4. Calculation procedure

For each point of the geographic coordinates determined by the test receivers, a height resulting from the DEM used was determined using the GlobalMapper program (version 22). Both elevation data sets were then compared in a spreadsheet (Microsoft Excel) by computing the following measures: root mean square (RMS, associated with a probability level of 68%), mean elevation error, and total elevation gain (TEG) error. The latter measure is presented in the following form:

$$TEG\ [\%] = \left(\frac{\sum_{i=1}^{n} EGrec \times 100}{\sum_{i=1}^{n} EGpseudoref}\right) - 100 \quad (2)$$

where: EGrec – single elevation gain error specified by the tested receiver; EGpseudoref – single elevation gain error based on DEM for coordinates specified by the tested receiver, n – number of observations.

In the computations, an offset of 1.6 m was applied (the difference between the ground surface and the height at which the receivers were mounted on the vehicle).

3. Results

The aim of this part of the study was to determine the extent to which the reliance on the reference surface applied would allow receivers to be compared. This aim was achieved, and the obtained results are provided in Table 2.

Table 2. A comparison of the elevation determinations obtained by sports receivers during preliminary tests

Receiver	RMS [m]		Mean elevation error [m]		TEG error [%]	
	1st Trial	2nd Trial	1st Trial	2nd Trial	1st Trial	2nd Trial
Garmin Forerunner 920xt	12.9	2.5	-12.9	-1.6	+6.0	+11.1
Garmin Forerunner 935	20.8	19.2	-20.7	-18.6	+13.7	+9.5
Garmin Forerunner 945	7.0	8.2	-6.5	7.3	+9.8	+10.1

n – the number of points of coordinate determinations, providing the basis for computations

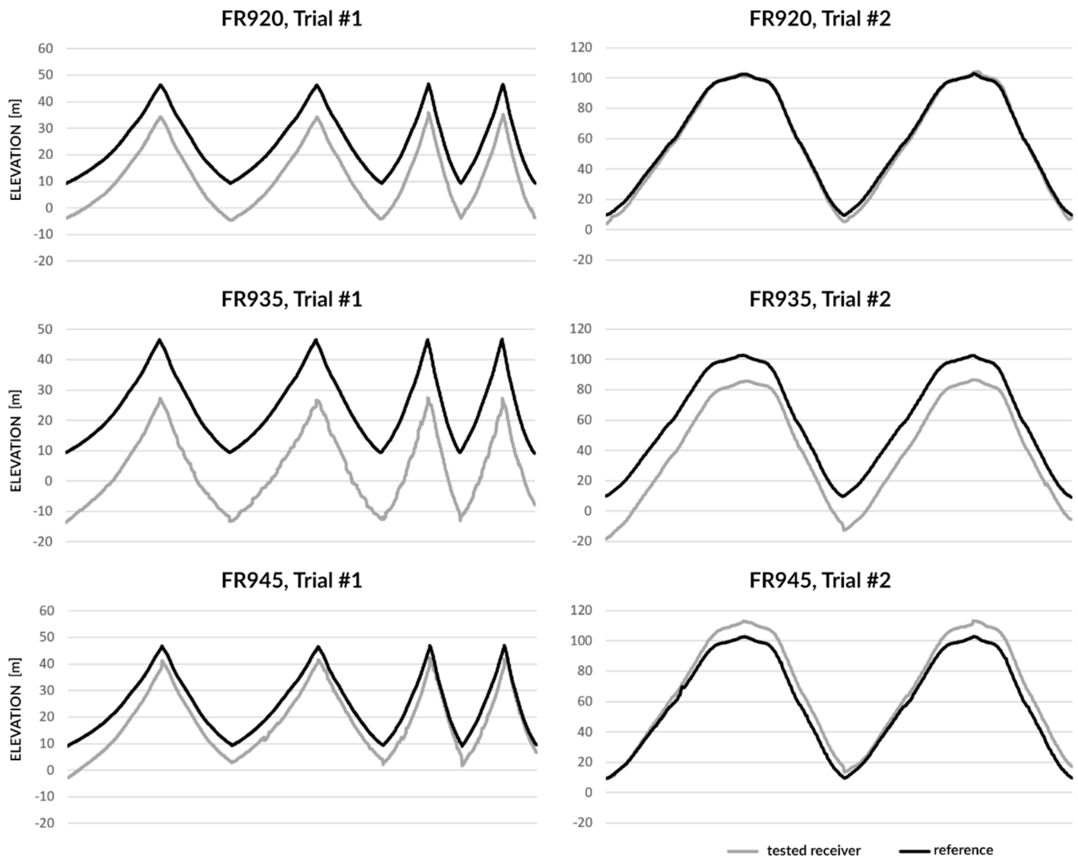

Figure. 3. The determination of elevation by the tested receivers (grey lines) in relation to the reference surface during the two trials (black lines).

During Trial#1, the best RMS score (7.0 m) was achieved by the latest receiver, the FR945, which also obtained the lowest mean elevation error value (-6.5), whereas it is worth noting that all the receivers underestimated the elevation. On the other hand, the lowest TEG error was noted for the device FR920xt (overestimation by 6.0%). During Trial #2, the lowest RMS score was achieved by the oldest receiver, the FR920xt (2.5 m), which also obtained the lowest mean elevation error value (-1.6 m). The TEG error value during this trial was similar for all three receivers, which overestimated them by 9.5–11.1%.

The characteristics of the recorded elevation readings by the tested receivers during all the trials are provided in Fig. 3. To improve the readability of the diagrams, the one-minute breaks described in the 'Testing protocol' sections were removed from them.

As can be seen from the course of grey lines, during Trial #1 (elevation difference of 47 m, lower speeds), all wearable receivers underestimated the values, with the FR945 coming closest to the reference surface. On the other hand, in Trial #2 (elevation difference of 98 m, higher speeds), the FR935 receiver underestimated the values, the FR945 slightly overestimated them (particularly at the top of the ascent and during the descent), and the FR920 came close to the reference values.

4. Discussion

The suitability of code-based GNSS receivers for monitoring human movement has interested researchers for many years. For the most part, these studies determine horizontal accuracy and, less frequently, vertical accuracy. Nevertheless, a review of the literature reveals such attempts as well. One study [16] analysed tourist receivers using static testing and related their elevation indications to reference points determined based on a digital total station and two nearby survey monuments. Another publication [17] documented the testing of bicycle receivers (TEG measure), and the elevation of the boundary points (only those two: at the beginning and end of the ascent) was determined based on an online mapping tool. On the other hand, the focus of Sánchez and Villena's interest [18] included GNSS receivers for runners and a smartphone, which were evaluated dynamically while analysing multiple variables. In this case, the local DEM, whose accuracy was not specified, was used as the reference surface.

The methodology for evaluating the determination of elevation by sports receivers presented in this article is based on the DTM/DEM of the territory of Poland. It is relatively easy to implement, as this model is freely available, up-to-date, and individual data packages can be developed in various programs (e.g. in the freeware QGIS). What is important, however, is that the national institution making this data available determined its mean error (0.2 m), which meets the general recommendations as set out, e.g. by the Institute of Navigation [15]. These assumptions enabled to conducting a dynamic test of three wearable GNSS receivers for runners and quantify the accuracy of the altitude component they determine. As can be concluded from the presented results (Table 2, Fig. 3), during Trial #1, the FR945 came the closest to the actual elevation (RMS = 7.0 m; mean error = -6.5 m), while during Trial #2, it was the FR920xt (2.5 and -1.6 m, respectively). On the other hand, when considering the TEG factor, all the receivers overestimated its total value, with the lowest error value noted again for the FR920xt receiver. Therefore, the applied methodology allowed the receivers to be distinguished and the measures that characterise them to be identified.

It would appear that as successive GNSSs have reached their full operational capability and as the systems and electronic devices used for their reception have become more and more advanced, newer receivers should perform better at determining the position coordinates and elevation than they did a decade ago. Even though this study does not unequivocally confirm it, this is true in most cases, particularly when it concerns devices dedicated to a particular activity or when determining position coordinates is carried out under difficult conditions (e.g. dense forests cover or deep valleys). On the other hand, it does happen that the 'GNSS receiver function' embedded in a device, when it is not its only primary function, is subject to other limitations (known only to the manufacturer), that affect the accuracy of the position coordinate determination. Such conclusions were drawn, for example, when examining smartphones, with the older receivers (Samsung Galaxy S4 and S5) exhibiting a higher accuracy of position coordinate determination than that of the newer ones, which has been confirmed by both dynamic [19] and static tests [20].

It is also worth noting that in the latest Forerunner series receivers (FR955 – 2022; and FR965 – 2023) Garmin introduced an innovative technology called Multi-Band, that has a significant impact on the quality of coordinate position determination. It uses multiple satellite systems on multiple frequency bands (L1/L5) at once and determines the optimal GNSS mode depending on the environment. Similar multifrequency-based technology had only been applied in the first smartphones a few years earlier [21], so it appeared quite quickly in the Forerunner series. Although the latest Garmin receivers with Multi-Band have not yet been scientifically tested, it is already known that in the case of smartphones, the additional L5 carrier frequency has a significant, positive impact on the accuracy of the position coordinates [22] and expands their area of application [23].

5. Conclusions and recommendations

As for this study, the main aim was to test a methodology. No further conclusions should be drawn regarding the accuracy of the position coordinate determination by the tested receivers. While objective values were obtained for individual measures, and the methodology allowed the receivers to be distinguished, the study itself is subject to certain limitations due to its preliminary, pilot nature. The first is the relatively small number of position coordinate and elevation determination points (Trial #1 – 1126, Trial #2 – 584). As wearable sports and recreational receivers do not offer a recording rate of more than 1/s, a longer test session is suggested. The second conclusion is that Trial #2 was conducted on a section of the road that mostly ran through a forest. It is known that the availability of a direct signal from satellites, rather than a limited or reflected signal, significantly improves the accuracy of GNSS receivers (which has been a subject of research, for example [24]). Thirdly, due to their 'running' nature, the receivers should be tested at speeds comparable to the runners' capabilities. The final comment concerns the receivers themselves: if the study aimed to determine the accuracy of a particular model, more than one unit would have to be gathered and tested.

The general recommendations include paying particular attention to receiver settings (GNSSs, recording frequency, latest firmware, etc.) and selecting reference surfaces (DTM/DEM) whose accuracy is precisely defined and meets the assumptions of high-value testing.

References

1. Fleming P, Young C, Dixon S, Carré M. Athlete and coach perceptions of technology needs for evaluating running performance. Sports Eng. 2010;13(1):1–18. DOI: 10.1007/s12283-010-0049-9
2. Schutz Y, Chambaz A. Could a satellite-based navigation system (GPS) be used to assess the physical activity of individuals on earth? Eur J Clin Nutr. 1997;51(5):338–339. DOI: 10.1038/sj.ejcn.1600403
3. Statista. Garmin revenue share worldwide from 2009 to 2022, by segment. Available online: https://www.statista.com/statistics/217905/revenue-distribution-of-garmin-by-segment/ (accessed on 18 September 2023).
4. GPS Standard Positioning Service (SPS) Performance Standard, 5th ed., April 2020. Department of Defense, U.S.A. Available from: https://www.gps.gov/technical/ps/ (accessed on 18 September 2023).
5. Li X, Götze HJ. Ellipsoid, geoid, gravity, geodesy, and geophysics tutorial. Geophysics. 2001;66(6):1660–1668. DOI: 10.1190/1.1487109
6. Meyer TH, Roman DR, Zilkoski DB. What does height really mean? Part IV: GPS heighting. Surv Land Inf Sci. 2006;66(3):165–183.

7. Portas MD, Harley JA, Barnes CA, Rush CJ. The validity and reliability of 1-Hz and 5-Hz Global Positioning Systems for linear, multidirectional, and soccer-specific activities. Int J Sports Physiol Perform. 2010;5(4):448–458. DOI: 10.1123/ijspp.5.4.448
8. Beato M, Coratella G, Stiff A, Iacono AD. The validity and between-unit variability of GNSS units (STATSports apex 10 and 18 Hz) for measuring distance and peak speed in team sports. Front Physiol. 2018;9(SEP). DOI: 10.3389/fphys.2018.01288
9. Specht C, Szot T, Dabrowski P, Specht M. Testing GNSS receiver accuracy in Samsung Galaxy series mobile phones at a sports stadium. Meas Sci Technol. 2020;31. DOI: 10.1088/1361-6501/ab75b2
10. Supej M. 3D Measurements of alpine skiing with an inertial sensor motion capture suit and GNSS RTK system. J Sports Sci. 2010;28(7):759–769. DOI: 10.1080/02640411003716934
11. Gløersen Ø, Kocbach J, Gilgien M. Tracking performance in endurance racing sports: evaluation of the accuracy offered by three commercial GNSS receivers aimed at the sports market. Front Physiol. 2018;9:1425. DOI: 10.3389/fphys.2018.01425
12. Szot T, Specht C, Dąbrowski PS, Specht M. Comparative analysis of positioning accuracy of Garmin Forerunner wearable GNSS receivers in dynamic testing. Measurement. 2021;183. DOI: 10.1016/j.measurement.2021.109846
13. Jølstad PAH, Reid RC, Gjevestad JGO, Gilgien M. Validity of the AdMos, advanced sport instruments, GNSS sensor for use in alpine skiing. Remote Sens. 2022;14(1):22. DOI: 10.3390/rs14010022
14. Digital Terrain Model (DTM) 2021. Head Office of Geodesy and Cartography Republic of Poland. Available from: https://dane.gov.pl/pl/dataset/2027,numeryczny-model-terenu-nmt (accessed on 18 September 2023).
15. Institute of Navigation. ION STD 101. Recommended Test Procedures for GPS Receivers (Revision C). U.S.A. 1997.
16. Wing MG, Eklund A. Elevation measurement capabilities of consumer – Grade Global Positioning System (GPS) receivers. J For. 2007;105(2):91–94. DOI: 10.1093/jof/105.2.91
17. Menaspà P, Haakonssen E, Sharma A, Clark B. Accuracy in measurement of elevation gain in road cycling. J Sci Cycling. 2016;5(1):10–12.
18. Sánchez R, Villena M. Comparative evaluation of wearable devices for measuring elevation gain in mountain physical activities. Proc Inst Mech Eng P J Sport Eng Technol. 2020;234(4):312–319. DOI: 10.1177/1754337120918975
19. Specht C, Dąbrowski P, Pawelski J, Specht M, Szot T. Comparative analysis of positioning accuracy of GNSS receivers of Samsung Galaxy smartphones in marine dynamic measurements. Adv Space Res. 2019;63:3018–3028. DOI: 10.1016/j.asr.2018.05.019
20. Szot T, Specht C, Specht M, Dabrowski PS. Comparative analysis of positioning accuracy of Samsung Galaxy smartphones in stationary measurements. PLoS ONE. 2019;14(4):e0215562. DOI: 10.1371/journal.pone.0215562
21. European Union Agency for the Space Programme. World's first dual-frequency GNSS smartphone hits the market, 2018. Available online: https://www.euspa.europa.eu/newsroom/news/world-s-first-dual-frequency-gnss-smartphone-hits-market (accessed on 20 January 2024)
22. Uradziński M, Bakuła M. Comparison of L1 and L5 GPS smartphone absolute positioning results. J Appl Geod. 2023;18(1):51–68. DOI: 10.1515/jag-2023-0039
23. Paziewski J. Recent advances and perspectives for positioning and applications with smartphone GNSS observations. Meas Sci Technol. 2020;31(9). DOI: 10.1088/1361-6501/ab8a7d
24. Wing MG, Frank J. Vertical measurement accuracy and reliability of mapping-grade GPS receivers. Comput Electron Agric. 2011;78(2):188–194. DOI: 10.1016/j.compag.2011.07.006

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