Assessment of the Accuracy and Reliability of GNSS Measurements in RTK mode, Performed with Inclined pole, Applying Fuzzy Logic

Presented at the FIG Congress 2022
11-15 September 2022 in Warsaw, Poland

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1. Introduction

GNSS technology

-modernization of its features /space segment, civil signals and others/

-new model receivers /channels, weight, size, etc./

IT

-implement the latest trends in the equipment

- nowadays it's possible to complete the job faster and precisely

support of features. e.g. measurements with **inclined pole**

possibility for measurements of hard to access points

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1. Introduction

GNSS equipment nowadays

-much **better** performance;
-**improved** quality and reliability of the measurements;
-**acceptable results** via inclined pole.

How precise are the results?

is it "2.5cm accuracy in the inclination of 60°"?

What is the reliability?

answers **- not** by the human expert

assessment via Fuzzy logic

one single number –
rating

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1. Introduction

Topics studied here

-the **values** of the quality criteria;

-the **differences** in the quality at various angles of inclination of the pole;

-**analysis** of the results (numerical and graphical);

-overall **accuracy** results;

Is inclined pole a **good tool** for everyday geodetic practice?

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2. Procedure of the study

a) In the field

One point from the national geodetic network was measured in two different days;

The inclination angles - approximately **30, 60 and 90** degrees from the vertical line at the geodetic point.

The pole was oriented in the four world directions;

b) In the data processing

Geodetic measurements - processed in the controller;

The coordinates and $\sigma N, \sigma E, \sigma Z, PDOP, satellites\ used$ – exported and prepared for further analysis;

The last mentioned parameters - input in Fuzzy logic;

The rating value calculated for each measurement.

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3. Geodetic measurements – results and analysis

N	σN	σE	σZ	PDOP	satellites used	Tilt [deg]
573	15	12	27	1.4	29	00:45
1	16	18	26	1.19	30	24:49
2	17	28	26	1.19	30	42:38
3	21	38	29	1.29	28	68:29
4	21	12	27	1.24	29	23:38
5	31	14	33	1.27	28	52:13
6	40	16	37	2.06	27	77:45
7	15	18	27	1.24	29	25:56
8	17	29	30	1.24	29	52:07
9	20	36	34	1.27	29	80:49
10	21	13	27	1.24	29	29:53
11	29	15	30	1.4	28	56:06
12	34	17	31	1.4	26	74:43

Legend:

low value

high value

exception

Table 1 Quality results from the first part of the measurements

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3. Geodetic measurements – results and analysis

N	σN	σE	σZ	PDOP	satellites used	Tilt [deg]
573	15	12	25	1.35	30	00:39
1	15	27	25	1.35	30	22:22
2	17	41	25	1.35	30	44:49
3	26	52	31	1.88	27	78:45
4	20	12	25	1.48	30	20:43
5	28	13	26	1.35	30	48:51
6	36	15	30	1.35	28	80:16
7	16	15	26	1.35	30	22:36
8	17	25	29	1.35	30	52:50
9	19	32	33	1.5	29	81:31
10	20	14	26	1.39	30	26:36
11	27	15	28	1.45	30	49:09
12	36	17	32	1.4	27	73:35

Legend:

low value

high value

exception

Table 2 Quality results - second part of the measurements

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4. Graphical analysis of the results from conducted GNSS measurements

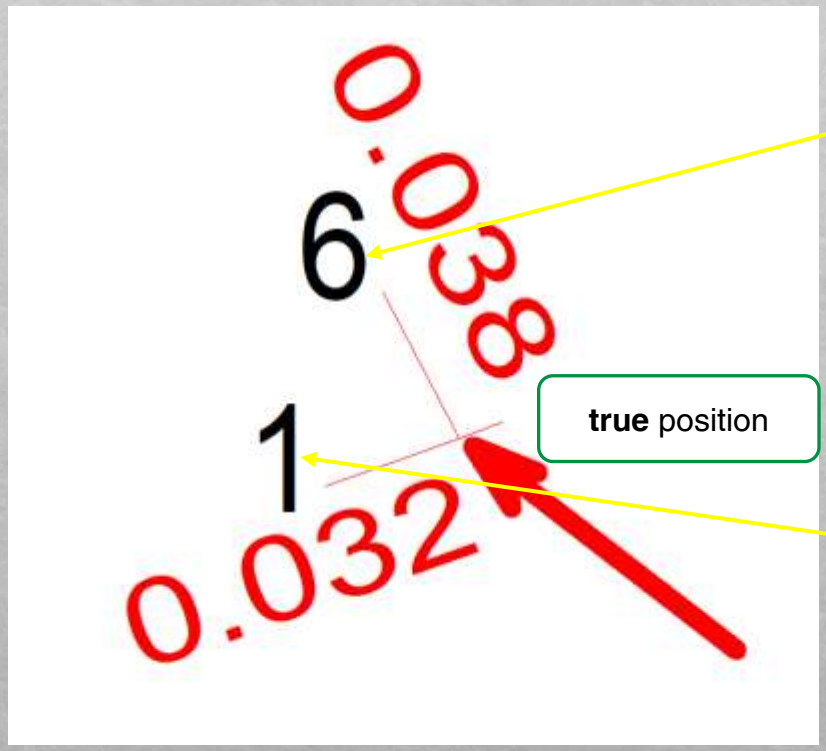

Fig. 2 Discrepancies in the plane - first part of the measurements

6 mm – almost **no practical difference** – at inclination of 30 or 90 degrees.

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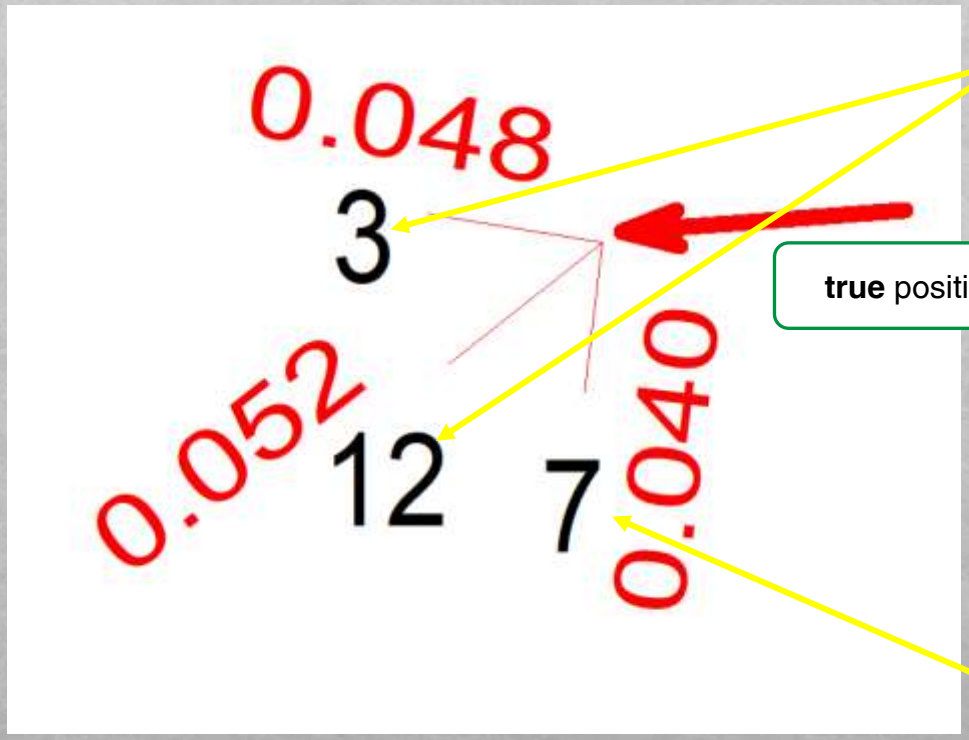
4. Graphical analysis of the results from conducted GNSS measurements



pole, inclined at 90 degrees

σZ=31;32 mm

true position

pole, inclined at 30 degrees

σZ=26 mm

Fig. 3 Discrepancies in the plane -second part of the measurements

significant discrepancies:

40 mm at **30** degrees;
from 48 mm to 52 mm at **90** degrees.

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5. Assessment of the overall quality and reliability of the GNSS measurements using Fuzzy logic

The variables – input in Fuzzy logic;

The rules for Fuzzy logic – created;

The rating value – calculated;

In this specific case, ***the bigger the rating value***,
the ***better is the overall quality*** of the relevant point determination.

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5. Assessment of the overall quality and reliability of the GNSS measurements using Fuzzy logic

Legend:

highest rating

direction of decrease

exception

N	inclination [deg]	rating
573	0	0.69
1	24	0.75
2	42	0.59
3	68	0.51
4	23	0.69
5	52	0.51
6	77	0.50
7	25	0.69
8	52	0.58
9	80	0.50
10	29	0.69
11	56	0.52
12	74	0.50

-the rating is **highest** - if the pole is **vertical**

exception - measurement N1

same results

up to **30** degrees and **vertical** pole

Table 3 First part of the measurements and their rating values

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5. Assessment of the overall quality and reliability of the GNSS measurements using Fuzzy logic

N	inclination [deg]	rating
573	0	0.73
1	22	0.60
2	44	0.50
3	78	0.48
4	20	0.63
5	48	0.54
6	80	0.50
7	22	0.73
8	52	0.63
9	81	0.51
10	26	0.70
11	49	0.55
12	73	0.50

Legend:

highest rating

direction of decrease

low rating

variations of rating at 60 degrees;

lowest rating at 90 degrees

Table 4 Second part of the measurements and their rating values

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6. Conclusion

From the numerical results it could be concluded:

-the **extreme values** of the rating are: min. 0.48 and max. 0.75;

-**small** variations of the rating between vertical and inclined up to **30 degrees** pole;

-**significant** differences [0.10-0.23] - in case the pole was inclined at angle up to **60 degrees**;

-**variations** in the interval [0.01, 0.12] -if the inclination angle was **increased** from **60 to 90 degrees**.

-for inclination angle of **90 degrees**, the rating was in the interval [0.48, 0.51].

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6. Conclusion

From the graphical information it could be summarized:

-if errors of e.g. 30 mm up to about 50 mm **aren't of importance** for the specific geodetic task, the differences in the overall quality between vertical and inclined pole **could be ignored**;

-if possible, the measurements to be performed via vertical pole in order **to be avoided** the compromise in the accuracy;

In case inclined pole is applied, this obviously **deteriorates** **the quality and reliability** of the GNSS measurements;

If the terrain conditions are hard or object is specific, **measurements** **still could be performed** with acceptable accuracy. Explicit attention should be paid to the reliability of the results, regardless to the angle of inclination.

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7. Outlook. Recommendations

Future work

-The necessary update of the relevant firmware could be done as the procedure and data processing of the measurements, conducted via inclined pole to be finalized without the required operator's intervention;

-Similar study could be performed during night time.

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USED SOFTWARE

Hi-Survey Road;
Vienna_fuzzy.

Thank you for your attention!

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