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ORIGINAL PAPER

TESTING OF GNSS MULTIPATH IN DIFFERENT OBSERVATIONAL CONDITIONS AT ONE STATIONARY STATION

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ABSTRACT

The aim of this paper is the analysis of temporal changes in multipath propagation errors on the pseudorange GNSS signal used for positioning, and its behavior during the calendar year (the quality of signal depends on e.g. foliage of trees, changes reflectivity surfaces due to rain or snow, etc.). The analysis was performed on data measured on a stationary point at Geodetic Observatory Pecný at Ondřejov, where one day was chosen as a constant time unit. Given the relatively highly unfavorable configuration of the experiment, RMS value of multipath is up to 60 cm on C1 and 40 cm on C2. These values vary with different weather conditions between 10 and 20 cm.

1. INTRODUCTION

The aim of the work was to analyze temporal changes of the impact of multipath propagation of GNSS pseudo-range signal used for positioning (determined via code pseudorange observations) during the calendar year, depending on weather conditions change (especially as a result of foliage of trees, changes in surfaces reflectance due to rain or snow, etc.). The analysis was performed on the sequences of one day data measured on a stationary point.

2. EXPERIMENT TEST OF MULTIPATH

2.1. DESCRIPTION OF THE EXPERIMENT

The experiment - long-term GNSS measurements to monitor changes in multipath propagation errors GNSS signal - was implemented at the field laboratory of the Research Institute of Geodesy, Topography and Cartography, v.v.i. - Geodetic Observatory Pecný in Ondřejov near Prague.

For measurements it was selected position, from which the view of the sky is limited by nearby buildings, structures, and particularly metal shed deciduous and coniferous woods. The following photos show the location of before-described obstacles in the area. The simple plan describes the distances to the biggest obstacle - the main building of the observatory.

Covering of the "sky plot" shows the Figure 2.

2.2. DATA

The Trimble SPS855 receiver with antenna Trimble Zephyr Model 2 was used for measurements in experiment to receive signals on two frequencies of GNSS navigation systems NAVSTAR GPS and GLONASS, however, only data from the NAVSTAR GPS were processed. The registration of meteorological data was concurrently performed (especially temperature, humidity and atmospheric pressure).

Basic measurement unit is one day (24 hours), which was determined with respect to maximizing the sky coverage data from the satellites from different directions. Because the NAVSTAR GPS satellites configuration is repeated with a period of 24 hours sidereal time, it makes no sense to extend the basic measurement unit for several days.

From the measured period (from winter to summer 2015) were selected measurement days, during which the situation in the surrounding obstacles is stable (e. g. permanent snow, rain etc.), and during which it was carried out photographic documentation of the state of the surface and the foliage of trees. Finally, it was selected 23 days for further analysis. The selected data including a description of the situation of surrounding obstacles summarized in the following Table 1 (DOY is the number of day in 2015).

2.3. PROCESSING OF THE MEASUREMENT

Measured data from GNSS technology - daily files - were tested in terms of multipath signals

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Table 1 Observation Conditions

DOY	Date	snow	leaves	message
037	6.2.2015	yes	no	part of day
041	10.2.2015	yes, melting	no	
043	12.2.2015	yes, partly	no	
044	13.2.2015	very small	no	
050	19.2.2015	very small	no	
062	3.3.2015	no	no	wet
065	6.3.2015	no	no	dry
069	10.3.2015	no	no	dry
077	18.3.2015	no	no	dry
083	24.3.2015	no	no	
086	27.3.2015	no	no	wet
089	30.3.2015	no	no	
092	2.4.2015	yes	no	
093	3.4.2015	yes	no	
105	15.4.2015	no	weak sprouting leaves	
107	17.4.2015	no	small leaves	wet
110	20.4.2015	no	young leaves	
114	24.4.2015	no	yes	
124	4.5.2015	no	yes	wet
125	5.5.2015	no	yes	wet
126	6.5.2015	no	yes	wet
127	7.5.2015	no	yes	wet
133	13.5.2015	no	yes	wet

(multipath) processed by software gNut-Anubis, which is being developed at Geodetic Observatory Pecný. Function of software is described in detail in (Václavovic and Douša, 2016).

Program gNut-Anubis (see e.g. http://www.pecny.cz/gop/index.php/gnss/sw/anubis/anubis-summary) calculated on the base of the GNSS RINEX set of measured data for a selected point in time: azimuth, elevation and multipath value for all satellites that were observed at this time. In our case, we focused on further processing only on GPS NAVSTAR satellites. In addition to the observation data file software still needs to calculate the appropriate navigation file.

Value multipath *MC* for frequencies *i, j, k* is

$$MC_k = P_k - L_i - \frac{2f_j^2}{f_i^2 - f_j^2}\left(L_i - L_j\right) \quad (1)$$

Value multipath on C_1 code is calculated according to the expression

$$MC_1 = P_1 - L_1 - \frac{2f_2^2}{f_1^2 - f_2^2}\left(L_1 - L_2\right) \quad (2)$$

and on the C_2 code

$$MC_2 = P_2 - L_2 - \frac{2f_1^2}{f_2^2 - f_1^2}\left(L_2 - L_1\right), \quad (3)$$

where P_i is the pseudorange, L_i is a "phase of carrier frequency", expressed in meters, and f_i is the corresponding frequency. Phase jumps ("cycle slips") for L_i are computed using linear combinations of L_4 (Melbourn-Wubbena) or L_6 - see (Václavovic and Douša, 2016).

Multipath calculation is as follows:

For a given number of epochs that are configured through parameters in gNut-Anubis software (in our case it was 20) is determined for a particular signal (e.g., MC_1) via linear combination (1), which mainly contains multipath. The number of epochs must be continuous without phase jumps and follows a desired epoch, which is related to the resulting value. The resultant value of multipath is given by the dispersion of the results of the linear combination (1).

In the following text we encounter the term "quadratic mean value" (abbreviated RMS or graphic "root mean square"), which is defined as follows: the quadratic mean m of n values of v is defined by the expression:

$$m = \sqrt{\frac{\sum_1^n v_i^2}{n}}\ . \quad (4)$$

Data processing into the final result was then carried out by the software:

- *Multi-anubis-GPS.for* which processes the results of the program-gNut Anubis and for a selected azimuth and elevation (step one degree) searches the maximum value (if the same azimuth, and elevation observed more satellites) multipath on each of the codes C1 and C2.
- *Multi-Anubis-GPS-10.for* that functions like a multi-program *Anubis-GPS.for* only seeks maximum and RMS multipath in a spherical trapezoid 10 x 10 degrees due clearer graphical interpretation of the results.
- "*Working software*" for combination of results of above mentioned software, results of it is "RMS" and maximum values "max".

Given the observational campaign was organized so that the south side of the forest and on the north side of the horizon was overshadowed by the building of the observatory was to select the observations decisive moments foliage of trees, snow cover and relative humidity. The results were shown in addition spreadsheet processing and graphically examples of multipath values for C1 and C2 are for DOY 037 in Figure 3. The complete set of images is subject of the research report (Kostelecký Jr. and Kostelecký, 2015).

2.4. SUMMARY RESULTS

The following Table 2 shows the numerical values of multipath in its entirety observed azimuth and altitude satellites. This is the maximum and the mean-square value (see above) for each day.

The following Table 3 shows the mean square value between two multipath somewhat extreme "conditions" of weather. Mean-square value is calculated on the grounds of destination "mean-square value of the effects of uncertainty" in determining the position of the code measurements. To calculate the differences were therefore selected days with different weather conditions.

Table 2 Average of multipath in the whole range of azimuths and elevations, mean square values (RMS) and the maximum of multipath for each day.

DOY	date	snow	leaves	message	C1 mean [cm]	C1 RMS [cm]	C1 max [cm]	C2 mean [cm]	C2 RMS [cm]	C2 max [cm]
37	6.2.2015	yes	no	part of day	52	61.5	501	35.1	39.8	465
41	10.2.2015	melting	no		53.3	61.7	299	36.4	41.1	349
43	12.2.2015	partly	no		52.3	62.2	447	36	41.8	504
44	13.2.2015	small	no		52.1	61.3	503	35.7	40.6	331
50	19.2.2015	small	no		51.9	60.4	373	35.9	40	303
62	3.3.2015	no	no	wet	55	62.5	323	38.1	42.9	461
65	6.3.2015	no	no	dry	53.6	63.9	553	36.9	41.3	305
69	10.3.2015	no	no	dry	53.6	62.5	515	37.1	42.2	317
77	18.3.2015	no	no	dry	54.3	62.8	308	37.5	41.8	403
83	24.3.2015	no	no		53.3	61.1	359	37.1	41.8	389
86	27.3.2015	no	no	rain	54.8	63.6	365	37.7	41.8	242
89	30.3.2015	no	no		56.9	65	395	37.9	41.4	301
92	2.4.2015	yes	no		55.5	63	412	37.6	41.6	278
93	3.4.2015	yes	no		54.5	62.8	329	36.7	40.2	233
105	15.4.2015	no	weak sprouting leaves		55.2	62.9	362	37.5	42.3	240
107	17.4.2015	no	small leaves	wet	53.4	61.4	280	35.6	39.2	292
110	20.4.2015	no	young leaves		54.6	62.8	363	37.8	43	435
114	24.4.2015	no	yes		51.8	59.5	346	35.5	38.4	181
124	4.5.2015	no	yes	wet	50.9	59.2	443	35.3	38.1	235
125	5.5.2015	no	yes	wet	50.6	57.8	410	35.4	39.5	363
126	6.5.2015	no	yes	rain	51.9	59.2	511	35.2	37.2	262
127	7.5.2015	no	yes	wet	52	58.4	268	35.3	38.3	227
133	13.5.2015	no	yes	wet	49.7	56.5	467	36.1	39.8	263

Table 3 Mean square value of difference (dRMS) in its entirety azimuths and elevations and the maximum mean values of the difference between two multipath periods (DOY1 minus DOY2).

DOY1 – DOY2	difference of states	C1 dRMS [cm]	C1 max [cm]	C2 dRMS [cm]	C2 max [cm]
037 – 038	no	11.4	100	10.5	95
037 – 065	snow/without snow	22.6	191	16.4	127
069 – 071	no	14.5	116	8.7	74
069 – 086	dry/wet	17.6	111	12.6	97
083 – 133	trees plane /leafed	13.4	104	15.3	112
104 – 105	no	11.0	64	15.3	156
124 – 125	no	11.0	47	12.3	131

3. CONCLUSION

The analyzed differences of the multipath propagation (multipath) between two, somewhat extreme climatic conditions show, that can be stated: the significant differences in multipath propagation are only in a specific direction to the satellites. The average values vary considerably less. Dependence on changing conditions (seasons) does not significantly change the value of multipath.

Given the relatively very unfavorable configuration of the experiment, the mean square value of the multipath *C1* is to about 60 cm and to 40 cm for *C2*. The dependence on the weather conditions varies between 10 and 20 cm.

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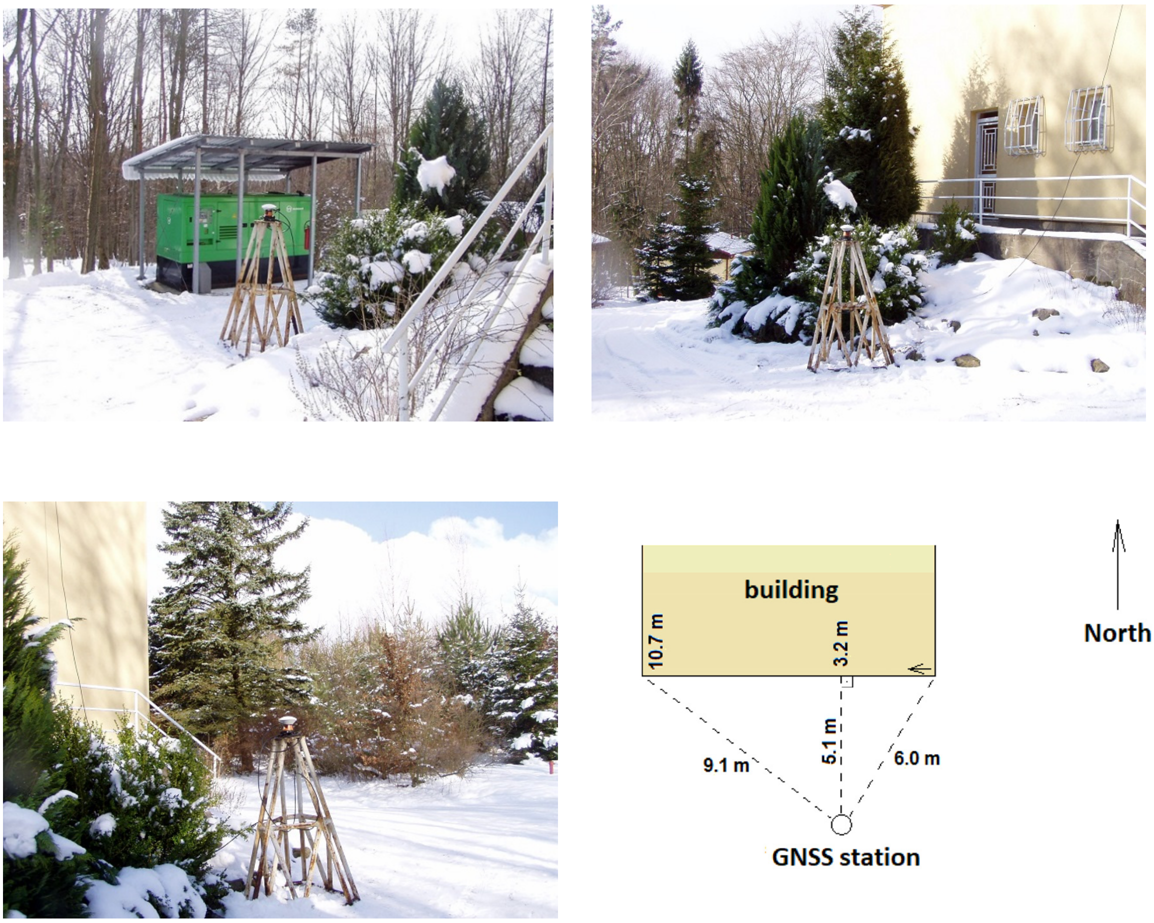

Fig. 1 Antenna location in the experiment - pictures left to right and down: a view towards SW, looking towards the north, looking towards the SE and the "situation".

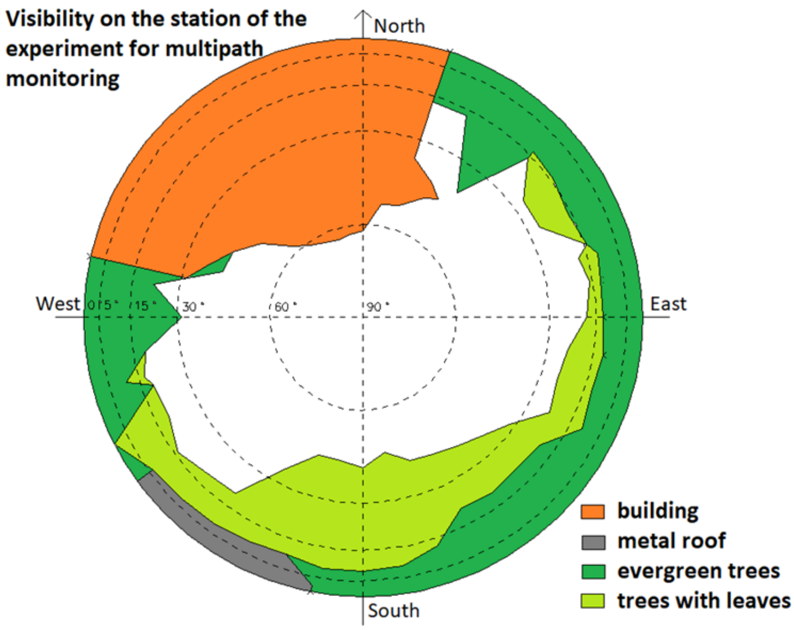

Fig. 2 Visibility charts of the sky plots on the station.

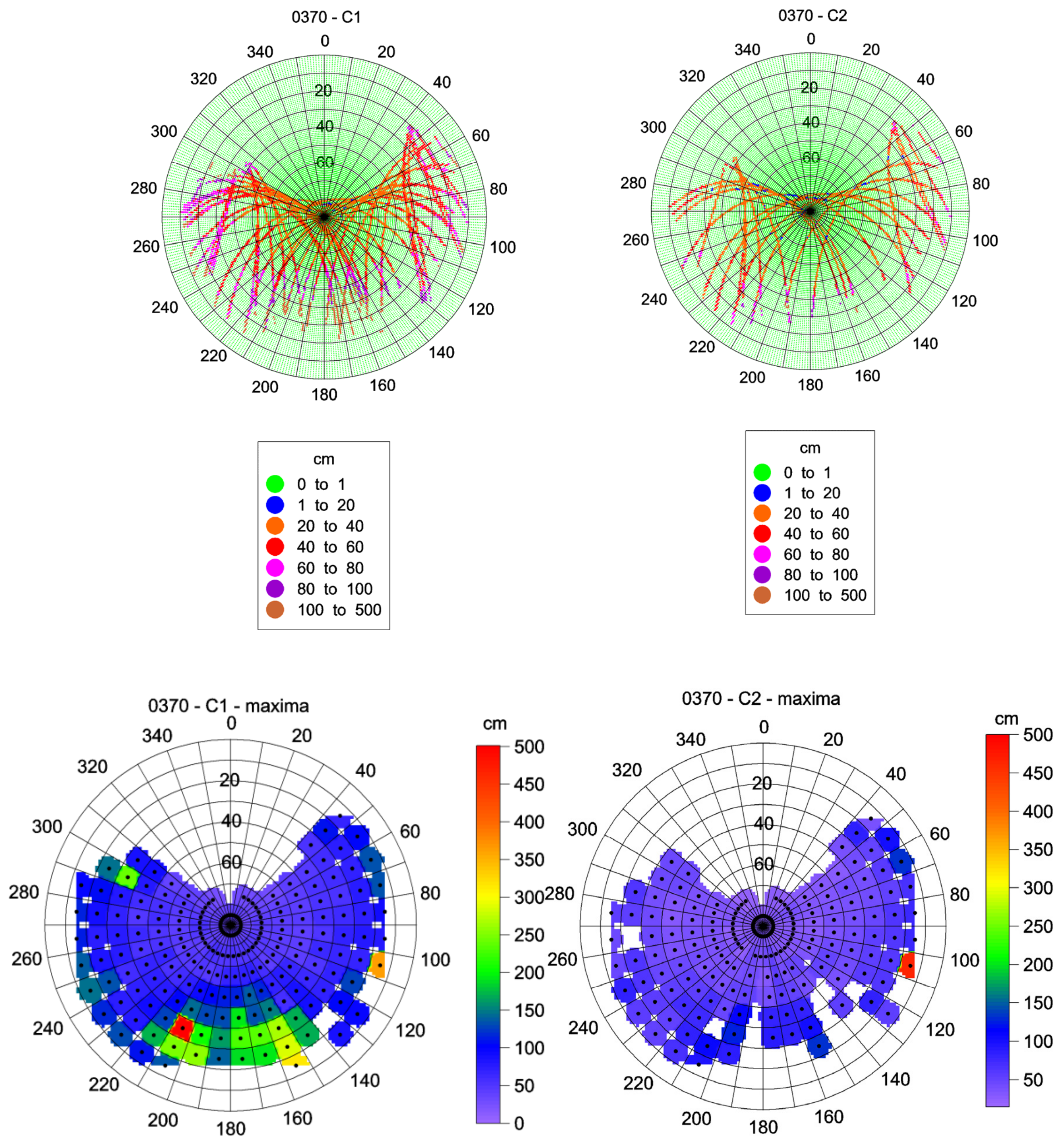

Fig. 3 Examples of detected multipath.