STUDY ON THE CERTIFICATING METHOD OF GPS DATA QUALITY

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ABSTRACT:

In Taiwan, there are more than one hundred GPS tracking stations maintained by Ministry of the Interior (MOI), Academia Sinica, Central Weather Bureau and Central Geological Survey. In the further, they may be instead of the GPS controlling points after giving the lawful status. In other words, the engineers don't need to survey on the reference points when they are surveying in the field. They only need to download the GPS data via internet and process the observations in their company. The precise coordinates of the unknown points will be obtained. Therefore, the data qualities of the tracking stations are more and more important.

In this study, six data quality indexes were adopted as follows: observations, cycle slips, multipath on L1, multipath on L2, clock offset and frequency stability. Besides, the relationships of the indexes and the positioning precision were found. The frequency stability of GPS receiver is the most important index, the cycle slip is the second index and the mutlipath is the third index. According to the results, the auto-analytical system of GPS data quality was established and the tracking stations were monitored. When the receiver got some problem or the station's environment changed, we hope to find and resolve the problems earlier to make sure the high data quality of the tracking stations. Moreover, we try to design a data quality verification to help users and let the engineers have more and more confidence when they use the data of GPS tracking stations.

KEY WORDS: GPS, Certificating Method, Data Quality, Positioning Precision

1. INTRODUCTION

GPS receivers are already being applied in geodesy, navigation and cadastral surveying in Taiwan. To maintain and ensure accuracy of positioning, an accurate and efficient system for calibrating the GPS receivers must be established (Lee et al., 2003). Because the GPS observations contain many errors, the relationship between GPS data quality and the positioning precision is very important (Chen and Yeh, 2002).

This study adopted five indices of GPS observations: multipath on L1 (*mp1*), multipath on L2 (*mp2*), observations by cycle slips (*o/slps*), clock offset (t_p) and clock stability (f_p). The relationship between the data quality and the precision of positioning was investigated, hoping to offer some comments for users, and to increase the accuracy and reliability of GPS positioning using the monitor of data quality.

2. INDICES OF DATA QUALITY

In this work, the indices of data quality are as follows (Yeh et al., 2002):

(1) *mp1*: Multipath on L1, measured in meters. The equation is expressed as

$$mp1 = P_1 - \left(1 + \frac{2}{\alpha - 1}\right)\Phi_1 + \left(\frac{2}{\alpha - 1}\right)\Phi_2 \qquad (1)$$

(2) *mp2*: Multipath on L2, measured in meters. The equation is written as

$$mp2 = P_2 - \left(\frac{2\alpha}{\alpha - 1}\right)\Phi_1 + \left(\frac{2\alpha}{\alpha - 1} - 1\right)\Phi_2 \qquad (2)$$

where P is the observation of pseudo range; and Φ is the observation of carrier phase. $\alpha = (f_1/f_2)^2$, where f_1 and f_2 denote the frequencies of L1 and L2.

(3) *o/slps*: This index is equal to observations by cycle slips.

(4) t_p: Receiver's clock offset, measured in seconds.

(5) f_p: Receiver's clock stability, measured in seconds.

The first three indicators were solved using Teqc software (UNAVCO, 2004), and the last two indicators were obtained using Bernese software (Beutler et al., 2001).

3. TEST DESCRIPTION

To decrease the incidence of common errors, six types of GPS receivers were chosen and configured at the Ultra-Short Distance Network of NML (National Measurement Laboratory, Taiwan) during three days. The testing receivers are shown in Figure 1 and the testing network is as depicted in Figure 2.

Six types of GPS receivers were set up at pillars TNML, NML3, NML4, NML5, NML6 and NML7 from Jan. 5 to Jan. 7, 2004. The sample rate was 30 seconds and the cutoff angle was 15 degrees. Because the measuring places of these receivers are very close, the errors (E.g. tropospheric delay, ionospheric delay) were considered to be approximately equal. The relationship between the quality of GPS data and the precision of positioning could be analyzed more easily.

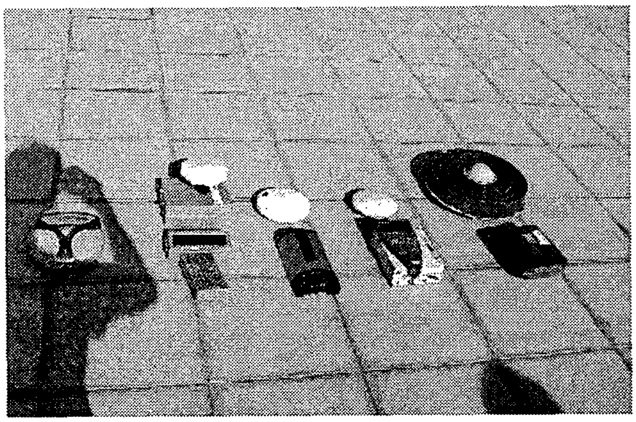

Figure 1. Types of testing receivers

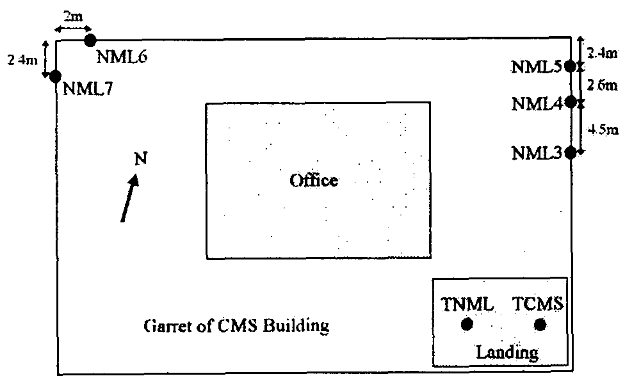

Figure 2. Ultra-Short Distance Network of NML

4. RESULTS OF DATA QUALITY

The GPS observations were calculated with Teqc software. Table 1 lists the average results of the first three indices. The experimental results show that type E is best and type C is worst in indices *mp1* and *mp2*. Additionally, types D & F are best and types A & C are worst in index *o/slps*.

Table 1. Results of the first three indices

Receiver's type	*mp1* (m)	*mp2* (m)	*o/slps*
A	0.33	0.35	**96**
B	0.18	0.20	1144
C	**0.89**	**0.62**	**80**
D	0.49	0.49	**3112**
E	**0.05**	**0.09**	2888
F	0.19	0.23	**3234**

In any case, to calculate the clock offset and clock stability, a GPS tracking station should be chosen as a standard (assuming that the clock offset and stability is approximately zero). In this work, IGS tracking station AMC2, which is maintained by U.S. Naval Observatory was selected, and the data were processed by Bernese 4.2 software. To obtain the exact clock offset and stability, the RNXSMT program was used to smooth raw data and detect cycle slips. When the GPSEST program was utilized to solve the ambiguity, RESRMS was used to reduce the worse data. Table 2 presents the average results of the last two indices.

Table 2. Results of the last two indices

Receiver's type	t_p (second)	f_p (second)
A	**9.01E-04**	1.29E-09
B	-6.76E-08	1.34E-09
C	-1.28E-08	1.33E-09
D	-1.74E-05	**1.27E-09**
E	**-5.04E-09**	1.34E-09
F	1.75E-07	**1.50E-09**

The experimental results show that type E is best and type A is worst in index t_p. Moreover, type D is best and type F is worst in index f_p.

5. RESULTS OF POSITIONING COORDINATES

After GPS data of stations TWTF (Taiwan), PKGM (Taiwan) and USUD (Japan) were downloaded from the internet. The coordinates of these three stations were constrained, and the relative static positioning was processed using Bernese software respectively as follows:

(1) Short distance: about 25 km, from TNML to TWTF.
(2) Middle distance: about 150 km, from TNML to PKGM.
(3) Long distance: around 2000 km, from TNML to USUD.

Figures 3 and 4 illustrate the maps of stations TNML, TWTF, PKGM and USUD. In these figures, TNML denotes the test place (Ultra-Short Distance Network).

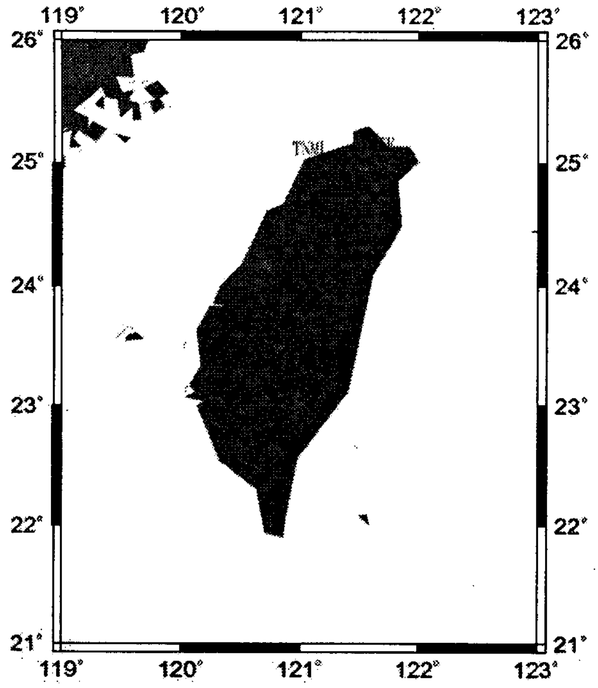

Figure 3. Map of station TNML, TWTF and PKGM

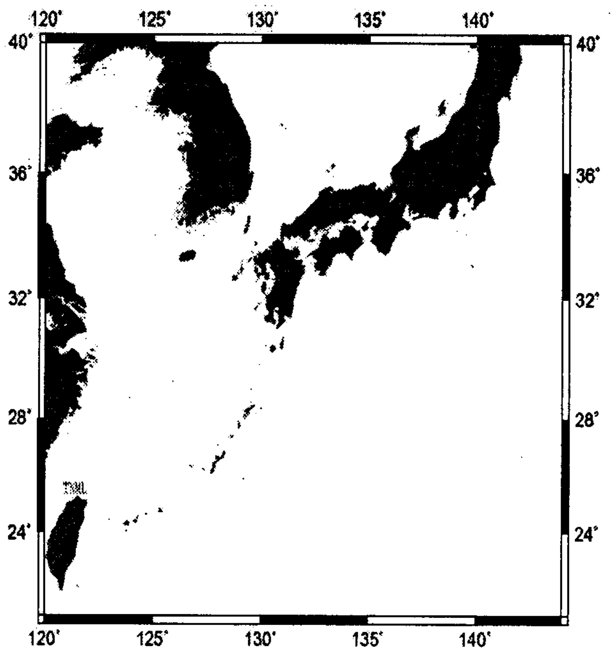

Figure 4. Map of stations TNML and USUD

Table 3 shows the results of short distance relative positioning. Table 4 presents the results of middle distance relative positioning Table 5 lists the results of long distance relative positioning.

Table 3. Results of short distance relative positioning

Receiver's type	N (cm)	E (cm)	h (cm)	Total (cm)
A	0.13	0.16	0.59	0.62
B	0.11	0.19	0.70	0.74
C	0.10	0.24	1.63	1.65
D	0.13	0.20	0.53	0.58
E	0.25	0.23	0.98	1.03
F	0.17	0.21	2.32	2.33

Table 4. Results of middle distance relative positioning

Receiver's type	N (cm)	E (cm)	h (cm)	Total (cm)
A	0.17	0.21	0.71	0.76
B	0.16	0.23	0.68	0.73
C	0.20	0.23	1.70	1.73
D	0.16	0.27	0.88	0.93
E	0.26	0.33	1.05	1.13
F	0.20	0.21	2.50	2.52

Table 5. Results of long distance relative positioning

Receiver's type	N (cm)	E (cm)	h (cm)	Total (cm)
A	1.05	2.09	3.44	4.16
B	1.02	2.13	3.13	3.92
C	1.04	2.18	4.31	4.94
D	1.01	2.26	3.77	4.51
E	1.10	2.34	3.53	4.37
F	0.95	1.66	5.27	5.61

6. CONCLUSIONS

Precision was evaluated with 4-hour repeatability of coordinates. The clock stability (f_p) was identified as a very critical factor for the positioning, in which a maximum error of 1.75 cm (the difference between type D and type F of short distance relative positioning) was found. Formula (3) can be applied to explain why clock stability is more important than clock offset (Leick, 1995).

$$\varepsilon = a_0 + a_1(t - t_{oe}) + a_2(t - t_{oe})^2 \quad (3)$$

where ε denotes the correction of clock; a_0, a_1 and a_2 respectively represent the clock bias, clock drift and clock drift-rate; t is the receiver's clock, and t_{oe} is the referential clock. Because ε is often applied to eliminate the clock error and can be logged by most of the GPS receivers, it is decreased when data are processed. However, the clock stability a_1 is not logged or modified, so it is very important for positioning.

Furthermore, cycle slips (*o/slips*) in which a maximum error of 1.02 cm (the difference between type B and type C of long distance relative positioning) was identified, was a second important factor for the precision of coordinates.

Moreover, clock offset (t_p) and multipath (*mp1* and *mp2*) effects did not critically affect the GPS results. Hopefully, the information presented in this study is helpful for GPS users when they decide to purchase any GPS receiver and to process GPS data.

7. REFERENCES

Beutler, G., E. Brockmann, R. Dach, P. Fridez, W. Gurtner, U. Hugentobler, J. Johnson, L. Mervart, M. Rothacher, S. Schaer, T. Springer, R. Weber, 2001. Bernese GPS Software Version 4.2, Astronomical Institute, University of Berne.

Chen, C.C., T.K. Yeh, 2002. A Study on Enhancing Precision of GPS Positioning Using the Short Range Distance Baseline Field, *Journal of Surveying Engineering*, American Society of Civil Engineering, Vol.128, No.1, pp.21~38.

Lee, C.W., T.K. Yeh, G.S. Peng, 2003. Traceability in Metrology and Uncertainty Evaluation of a Calibration System for GPS Receivers, *SPIE – The International Society for Optical Engineering*, August 3 - August 8, San Diego, California, USA, pp.410~418.

Leick, A., 1995. GPS Satellite Survey, Second Edition, JOHN WILEY & SONS, New York.

UNAVCO Inc., 2004. Teqc software, Boulder, Colorado, http://www.unavco.ucar.edu/. (accessed 20 Feb. 2004)

Yeh, T.K., C.S. Wang, C.W. Lee, 2002. Study on the Relation between the Quality of GPS Observations and the Precision of Relative Positioning, *Cadastral Surveying*, Vol. 21, No. 2, pp. 14~27. (in Chinese)