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Mixing Low-Cost GPS Receiver With Standard Surveying Receiver

Mustafa Subari
Centre for Geodesy and Geodynamic Studies
Faculty of Engineering and Geoinformatic Sciences
Universiti Teknologi Malaysia
80990 Johor Bahru, JOHOR DT
email: m.subari@fu.utm.my

Abstract

A GPS survey generally uses two or more GPS receivers. The normal trend is to use the same brand of receivers (or vendor) for data collections which will then processed through software supplied by the same vendor. Mixing different receivers, although theoretically possible through RINEX data formatting, are still not without problems. Even if it is to be done, normally the same 'standard' of receivers will be used. Mixing low-cost GPS receivers with standard surveying one will posed a more delicate challenge. Nevertheless, the economic potential of doing this exercise is great, for one, the use of low-cost receivers will enable cheaper expansion of receiver fleet within an organisation. At the moment, this exercise is only intended for the medium or intermediate accuracy type of applications. This paper discusses the technicality involved in this exercise, and results from an ASHTECH-ASHTECH and a NovAtel-ASHTECH 4 km baseline is analysed and presented.

1.0 INTRODUCTION

As part of an investigation carried out by the author in developing low-cost GPS surveying system for intermediate accuracy applications, this paper is trying to look into the feasibility of mixing low-cost GPS receiver with the 'standard' surveying-type receiver in a surveying environment. Specifically, the paper would like to look into the technicality involved and identify problems that may arise in doing such an exercise. The potential of doing the mixing is economically viable and promising, understanding that one of the major setback regarding the adaptation of GPS'technology in the surveying community is the high initial investment cost. This option would then enable cheaper expansion of the GPS hardware fleet within an organisation at a fraction of the normal cost, or for those who hasn't got one, would be able to build their GPS artillery with low-cost receivers while benefiting the availability of any active GPS station nearby (which generally operates surveying standard ones).

2.0 GPS SURVEYING - A ONE VENDOR SYSTEM

GPS surveying system (hardware and software) is considered as 'a package'. It requires specific GPS receivers to be use, following specific or pre-determined field observation procedures, and finally employing specific data reduction technique. It is a specific hardware, field work and software package. The field procedure might be 'standard' for a specific type of surveying work, but an immediate realisation one would noticed is that the hardware and the software are a specific 'vendor package' Namely, data observed by a brand A receivers could only be processed by brand A software. This is more obvious since the data collected is via the brand A 'proprietary' format which in turn will only be readable through brand A software.

It was quickly realised that a Receiver Independent Exchange (RINEX) data format is needed (Buetler et al. 1985) in view of the possibility mix use of different GPS receivers in large observation campaign. Until now RINEX has been accepted as a 'standard' output option for observation data in most GPS vendors. But this has not been without problems (Hendy et al, 1992), when although GPS vendors welcomed the move, albeit reluctantly, making their 'own version' of RINEX format.

3.0 GPS HARDWARE FOR SURVEYING - GENERAL NEEDS

GPS receivers for non-military positioning applications can be classified into two types describing their respective uses, namely the navigation and the surveying types. The navigation type receivers, are on the 'cheaper' end, utilising only the C/A-code measurements for position computations. These receivers generally output final reduced position values, which then little or no further processing can be done. The surveying type receivers on the other hand, are the more 'expensive' type, acquiring the carrier-phase data needed for the precise position computations.

Some of the characteristics for the surveying-type receivers can be further noted as follows;

- The surveying type receivers must be able to measure the integrated carrier-phase (or simply known as carrier-phase data) - it may only be a single frequency (L1), or dual-frequency (L1 and L2). Since C/A-code is the 'standard' feature, it might as well be retained. The precise codes, P1 and P2 is not 'really' needed in surveying. They are only an advantage, used in some of the ambiguity resolution techniques 'on-the-fly' (OTF).

- For 'long' data collection sessions, the receiver must have data recording capability (typically in the RAM format within the hardware) large enough to accommodate several surveying sessions, typically one to two hours each. All the intended data should be stored internally in the hardware and to be downloaded to an external media only when is needed.

- The receiver should also has 'some' operational features that are user selectable, for example the selection of the datarate and the elevation cut-off angle of the satellites. The option of datarate is very important in surveying, since long session observation is required, thus high datarate will results in too much of data. Typically datarate of between 15-60 second is appropriate.

4.0 GPS HARDWARE FOR SURVEYING - SOME ISSUES OF DISCUSSION

There are some issues with regards to the GPS receivers used for the ~~higher~~ accuracy surveying purposes that are worth to discuss in view of using GPS for the *intermediate accuracy applications*. Some of these issues has been regarded as the 'standard' norm in the GPS surveying practices. Among those issues are;

The use of dual-frequency instruments

It is known that the use of the dual-frequency instruments is for the purpose of ionospheric delay elimination, as well as an important aid for the ambiguity resolution technique. The dual-frequency approach in ionospheric elimination procedures is needed for longer station separation, in which the ionospheric delay is not common between the two stations, hence differencing technique will become ineffective. But for most surveying applications in the intermediate accuracy range, only short to medium baselines are involved (typically <15 km). For areas close to the Equator where ionospheric activity is most active, the baseline length would probably reduces to about 5 km.

- Number of tracking channel in the receiver has somehow created a *metos* in that the more channels you have, the better the result that you will get. In the mechanisation of a GPS receiver, the channels are used to track the satellites depending on the method employed. In most of the recently produced multi-channel type receivers, each channel is dedicated to track one satellite, as compared to the sequential or multiplexing type one, in which the same channel is used to track the satellites sequentially or alternately. The advantage of the multi-channel dedicated-type receiver is that, loss-of-lock due to the dynamic of the receiver will occurs the least. But for normal surveying usage, in which the receivers are in static mode, this difference then, would not be significant. The number of channel also tells the user the number of satellites that it can track at one time. With regards to this, many experiences have shown that, a good position fix can be obtained with six satellites (as we know, only four satellites are needed to have a position computed). Most of the time, the extras satellites are *not significantly* needed except for cases for example, where satellite obstructions is a problem.

The other development in the recent GPS receivers is on the high accuracy C/A-code measurements, utilising the so-called 'narrow correlator technology'. From about 2-3m accuracy, it is now known that measurement of the C/A-code can be made to a merely 20-30 cm, tenth fold better (Lachapell et al., 1993). With this accuracy, it might be useful to use the C/A-code measurement instead, for the intermediate accuracy type of applications. Furthermore, since code measurement is an unambiguous range measurement, hence, only shorter observation span is required.

5.0 LOW-COST GPS INSTRUMENTATION

Hardware

Low-cost GPS receivers are those priced well below the standard surveying-type ones. Generally priced around or less than RM10,000 a piece. These type of GPS receivers generally are the navigation-type ones with certain options enhancement. 'Cheaper' GPS receivers of the 'navigation-type' ones which only gives position fixes for a pre-set epoch, and does not provide raw-data measurements to the user, will not be considered in this study. Only those receivers which have the capability to output (and stored) the collected raw-data, enabling further data processing to be carried-out will be considered in this classification.

Rizos et al. (1995a) has identified some low-cost GPS hardware which have the potential to be used for the intended system. Most of these receivers are the navigation-type one with some of them having the capability of tracking phase or phase-related data, thus allowing the possibility of surveying use. They are further classified into several classes;

Class 1

- Instruments giving the same performance characteristics as "standard surveying" receivers, such as selectable data rate, and steered time-tags like the NovAtel GPSCard Series,

Class 2

- Instruments capable of outputting phase data at a fixed rate, with little further utility, such as the Magellan 5000PRO,

Class 3

- Instruments that measure phase-rate (Doppler), which could be used to construct a triple-difference type observable or integrated to construct a phase-like observation, such as the Trimble products: Acutime, Pathfinder, SV6.

One thing to note is that most of these receivers are in the OEM (Original Equipment Manufacture) or the PCMCIA (Personal Computer Memory Card International Association) format, hence although comparatively cheaper, they require a host computer to operate. But considering that standard surveying system also require a computer for data processing, this then should not be made a point of disadvantage.

Data Measurement

Some issues on the data measurements via these low-cost receivers need to be further understood. Among those are;

- Receiver independent data format - data measurements are made in their respective proprietary formats, but normally a manual is available in order to read understand them. A software is then needed to convert this format into a RINEX format.

- Fixed datarate - data are normally collected at a fixed unchangeable rate, most of the time the rate is high, typically 0.25-1.0 seconds. A program is then needed to sample out the required datarate.

- Data are not collected at discrete, well defined interval - for example the timetags might be in the sequence of 0.251012, 0.751013 and so on. Hence, a program is then needed to 'moved' the observation to the nominal timetags.

- No user controlled in the Input/Output (I/O) operations - such as setting the elevation cut-off angle. Hence, all available data are collected.

6.0 MIXING DIFFERENT GPS RECEIVERS - UNDERSTANDING BASIC ISSUES

In large surveying networks or campaigns, mixing receivers of different types are done in view of the economic considerations. Some technical issues has been identified. Among these issues discussed are (Clynch et al., 1989);

1. Data format

It has been the norm that receiver manufacturer used proprietary designed data format for their receivers and software. The idea has been purely business oriented, in that restrict the user to one vendor system. When different type of receiver are mixed, clearly, a standard data exchange format commonly understood by everybody is needed. Receiver Independent Exchange Format (RINEX) has been proposed (Gurtner et al., 1990) and used since then. It is now accepted as a *professional ethic* that vendors to supply program to convert their proprietary format data to RINEX format. But this exercise is not without problems, as Hendy et al. (1993) pointed out. For example; Some vendors corrected their timetag and measurement data with the computed clock error at every epoch, some do not; Some vendors internally smoothed their C/A-codes before outputting them out, some do not. Clearly, understanding what each vendors has done prior to their RINEX data, is necessary.

2. Receiver's clock and time tags

With regard to receiver clock and time tagging the observation data, Rizos (1994) pointed out three issues;

- All receiver should take observation to common-view satellites at epochs which are within 30 milliseconds of each other, to ensure that satellite errors cancel in between-receiver differencing.
- Receiver should be synchronised with each other at the microseconds level to ensure that all observation time tags are consistent with each other.
- All receivers should be "externally" synchronised to the satellite ephemeris (in general GPS time) at the millisecond level.

Point 2 and 3 can be easily met if the navigation solution (in which the receiver clock is solved for) is used to individually synchronise the receiver's clock to GPS time (better than 1 microseconds level can be achieved).

In an exercise of mixing receivers from different types, this has to be known, some receivers reset their clocks to GPS time but some do not.

3. Antenna-phase centre

The antenna-phase centre gives the correction to the physically defined antenna-centre point and the 'electrically defined' antenna-centre point. It comprises of an offset value and a variable value as a function of the azimuth and the elevation of the incoming signal (Gurtner et al., 1989). The offset values are normally made known by the manufacturer, thus necessary correction can be applied to the computed position. Short baseline observed by identical antenna type will cancelled both effect, since the satellites are more or less in the same directions. With different antenna type however, this is no longer valid. These values however, are normally in the few millimetres level.

7.0 MIXING LOW-COST RECEIVER WITH STANDARD SURVEYING RECEIVER

Apart from the basic issues discussed earlier, in carrying out the exercise of mixing low-cost GPS receiver with standard GPS receiver, some issues can be directly identified;

Data availability

- Data available for the processing would be restricted to the type measured on the low-cost receiver, which are at the most the C/A-code, the L1 Doppler and the L1 carrier-phase.
- Different receiver has their own 'distinct' way of data collection, thus a program is needed to 'convert' these datafiles into a RINEX format.

Data reduction software

- Data collected via the low-cost receiver might not be readily acceptable by the commercial (vendor specific) software or other third party software for two reason;
    - These software are generally meant for the high accuracy surveying type, thus using only the carrier-phase data
    - These software generally does not accommodate C/A-code solution or even the combined C/A-code and L1 carrier-phase solution

8.0 A TEST

A test has been carried out to implement this exercise on 6th September 1995. One baseline of about 4 km was observed for about two and a half hour session. The antenna on the UNSWs Mather pillar was having a split cable that was fed into an ASHTECH Z-XII and a NovAtel GPSCard receiver. The other receiver was also an ASHTECH Z-XII receiver, located at the SAGEM Australasia office in Alexandria, New South Wales. The datarate was 15 seconds. The ASHTECH Z-XII receiver, considered as the "top-of-the-line" class, collects all the observable, namely the C/A and P-codes, L1, L2 carrier-phases and L1 and L2 Doppler measurements. In the AS environment, the receiver claimed to be able to observed the Y-codes with its Z-tracking capability. The NovAtel receiver on the other hand is a single frequency GPS receiver, hosted in a desktop computer, collecting C/A-code, L1 carrier-phase and L1 Doppler only. With the test configuration, two identical baselines will be formed, the ASHTECH-ASHTECH baseline, which is the standard-surveying type baseline, and the ASHTECH-NovAtel baseline, in this case as the mix baseline.

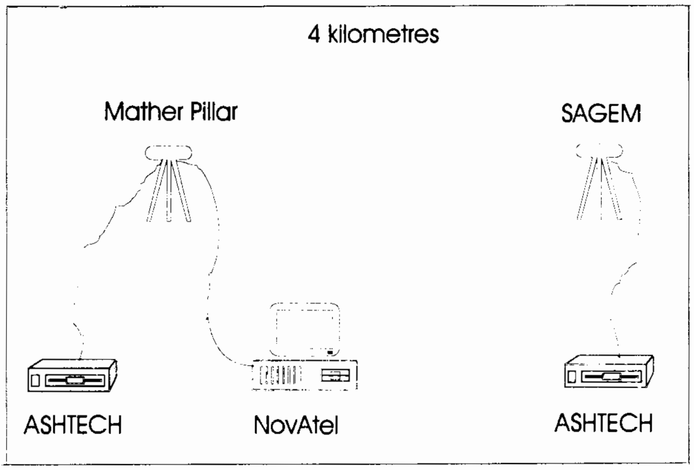

Figure 1: The Baselines configuration in the Test

9.0 THE STANDARD SURVEYING BASELINE

The ASHTECH-ASHTECH baseline (the standard surveying-type baseline) was processed using the GPPS^{tm} software, using the four solution type as indicated in the first column in Table 1. The DD ambiguity-fixed solution of the L1 carrier-phase is normally taken as the best solution, since it has got the shortest wavelength. Note that for a short baseline of this length, the ionospheric-free combination result is worst than the other results.

Solution	Baseline length (m)	Solution type
L1 carrier-phase	4055.957	DD ambiguity-fixed
L2 carrier-phase	4055.960	DD ambiguity-fixed
Widelane	4055.951	DD ambiguity-fixed
Ionospheric-free	4055.944	DD ambiguity-float

Table 1: GPPS^{tm} results

10.0 COMPARING THE STANDARD SURVEYING BASELINE AND THE MIX BASELINE

Data for both baselines (the standard surveying baseline and the mix baseline) were then processed using the in-house software (since the in-house software reads data in the RINEX format, the two ASHTECH datafiles were first converted to the RINEX format, then the timetag and observation data were corrected to the full second mark utilising the receiver clock corrections supplied by the receiver. The NovAtel data was already in full second timetag mark). The C/A-code measurements, the L1 carrier-phase measurements and the combined C/A-code and L1 carrier-phase measurements were processed. The results were given as in Table 2. The value in the bracket shows the difference between the result and the GPPS^{tm} L1 carrier-phase fixed solution (4055.957 m).

Solution	ASHTECH-ASHTECH Baseline	ASHTECH-NovAtel Baseline
C/A-code	4055.745 (-0.212)	4055.681 (-0.276)
L1 DD ambiguity-fixed	4055.960 (0.003)	4055.960 (0.003)
Combined C/A-code and L1	4055.929 (-0.028)	4055.929 (-0.028)

Table 2: Results of the standard-baseline and the mix baseline using the in-house software.

Note that from Table 2, the in-house software gives comparable results with the GPPS^{tm} software, with a difference of only 3 mm in the L1 DD ambiguity-fixed result. Interesting enough, the mix baseline also gives the same baseline length as the standard one! The C/A-code gives decimetre accuracy while the mixed C/A-code gives centimetre accuracy level. Clearly from the three solution results, comparable accuracy for both baselines type were obtained.

11.0 CONCLUDING REMARKS

Mixing low-cost receiver with standard receiver is an economically sound and technically viable practice. However, some technicality need to be look into. The major one is that concerning the software. Two level of software are needed, namely the pre-RINEX software and the data reduction software. The pre-RINEX software are those which includes data translating, 'pre-processing' and RINEX formatting. Generally, this has to be developed by the user. The data processing software to some extent, are commercially available, or even simply using software already owned by the user (most commercial software has the option of accepting RINEX file input). However, a third party data reduction software developed by user would be the ideal.

Lastly, benchmarking test should be carried out for such a combination, to reliably set the performance characteristic of it, in the sense of knowing what is the achievable accuracy and its level of reliability.

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Mustafa Din Subari

Dr. Mustafa Din Subari is a lecturer at the Faculty of Engineering and Geoinformatic Sciences, Universiti Teknologi Malaysia. He holds a B. Surv. in Land Survey from Universiti Teknologi Malaysia (1983), a M. Sc. in Geodetic Sciences from the Ohio State University (1987), and a Ph.D in GPS Surveying from the University of New South Wales (1996).