IGNSS
International Global Navigation Satellite Systems Society Inc.

International Global Navigation Satellite Systems Society
IGNSS Symposium 2007

The University of New South Wales, Sydney, Australia
4 – 6 December, 2007

Precise Surveying with L1 RTK

Ian Iredale
Mapsoft & SAGEM / Australia
Ph: +612 9899 5845 Fax: +612 9680 3999 Email: ian@mapsoft.com.au

ABSTRACT

Historically, Real Time Kinematic (RTK) GNSS has been synonymous with dual frequency (L1/L2) receivers. Many dual frequency RTK receivers available in the market are using L1 only to provide a fixed solution, while L1/L2 is used to get a quick GNSS fix. With recent advancements in GNSS technology and the improved health and number of satellites, using a single frequency receiver is now a viable alternative to using a dual frequency receiver.

The ProMark3 RTK GNSS receiver is the first commercial single frequency RTK system in the world, which can initialise in as little as a few seconds time. This paper explores the real world application of this GNSS receiver. A number of surveys are conducted under different conditions to ascertain its usefulness and accuracy. Comparisons between it and dual frequency RTK receivers are made.

The receiver was used to perform actual surveys, under a wide range of conditions. The tests evaluate its performance with respect to the number of GPS satellites available, the quality of the GNSS site, the length of the differential vector, the performance of the supplied and third party radios and its performance using Sydnet. Float accuracies of better than 0.3 metres, claimed by the manufacturer are investigated.

The results were very encouraging. Under the right conditions, centimetre accurate results were obtained. The receivers take a similar time to dual frequency receivers to achieve a fixed solution. The licence free radios provided work over only short range and need line of sight conditions. Third party radios, however overcome these restrictions.

Single frequency RTK surveying provides an alternative solution to dual frequency. Provided eight or more GPS satellites are available, centimetre level results are available in similar or slightly longer times to dual frequency receivers. The ProMark3 receivers provide a very versatile solution, offering a navigation, GIS, post processed survey and GIS and RTK survey and GIS solutions, all in the one receiver. The weight and price of an on the pole setup is considerably less than for existing dual frequency solutions.

KEYWORDS: single frequency, ProMark3, L1, RTK, GNSS

1. INTRODUCTION

Magellan Professional released the single frequency ProMark3 RTK GPS receiver in August 2007. The ProMark3 has been on the market since late 2005 for post processed static and kinematic surveys. With a software upgrade and the addition of radio modems or a GSM/GPRS phone on the rover, it is now possible to use these receivers in RTK mode.

Single frequency RTK is not new. It has been in the domain of academia for quite a few years now. The problem has been how to obtain fixed solutions quickly without the use of both L1 and L2 frequencies. There are also a few commercial products currently available that claim L1 RTK accuracies of around 0.2 metres. The ProMark3 RTK is the first commercial receiver that claims L1 RTK accuracies of around 0.01 metres with initialisation times ranging from instantaneous to under 3 minutes in most cases. This accuracy is the same as that achieved by dual frequency RTK receivers. (ProMark3 RTK Brochure, 2007)

The aim of this paper is to road test the ProMark3 RTK receiver for the surveying industry. Is its performance sufficient to use in a professional survey environment?

The ProMark3 RTK GPS receiver has been put through its paces, to determine if it lives up to the hype promoted by Magellan Professional.

The effectiveness of the initialisation methods, supplied radios and the receivers performance on an actual survey is investigated. Generally the ProMark3 RTK GPS receiver lives up to expectations, although it was not possible to emulate the float accuracies claimed by Magellan Professional (ProMark3 RTK White Paper, 2007 p6).

Due to insufficient time, it was not possible to test all the features mentioned in the abstract. It is hoped that by the time the presentation is given, these features will have been tested.

2. L1 RTK SURVEYING

2.1 Overview of the ProMark3 Receiver

The ProMark3 receiver consists of a handheld GPS receiver which runs a Windows CE style operating system on a closed platform. The significance of the closed platform is that only software enabled by Magellan Professional will run on the receiver. This software includes, Microsoft Windows control panel, utility software, GIS and Surveying collection software for both post processing and real time work and FAST Survey. FAST Survey is a Magellan

Professional badged copy of Carlson’s SurvCE software, which is a GPS and Total Station data recorder program.

An external GPS antenna can be added via a cable and this provides more accurate results. It is optional for GIS projects and essential for Surveying projects. For RTK work, a radio is also connected via a cable to the handheld receiver. A mobile phone can be used instead of a radio to connect into a GPS CORS network.

The base and rover units are identical and are interchangeable if required. Generally the base is mounted on a tripod with a tribrach, tribrach adapter and possibly initialisation bar, whereas the rover is mounted on a fixed height pole. The pole may also be placed in a bipod for greater accuracy and so the pole can be left unattended.

The ProMark range of receivers have a history of being very easy to use and the software provided on the ProMark3 RTK is no exception. If surveyors are unable to assemble and operate this equipment then they are highly unlikely to be able to operate any other RTK gear.

Photograph 1. ProMark3 RTK GPS Receiver - Rover & Base

2.2 BLADE Technology

Magellan Professional claim to use a proprietary GNSS processing solution known as BLADE technology. BLADE uses both GPS and Satellite Based Augmentation System (SBAS) satellites to provide a quick initialisation with single frequency receivers (ProMark3 White Paper, 2007 p3). Magellan Professional claim that if the ProMark3 is reading the signal from 1 SBAS receiver the initialisation time will be improved by 50% and with 2 SBAS receivers by 75% compared with no SBAS (Press Release, 2007).

SBAS is a geostationary satellite system designed to improve the accuracy and safety of GPS aircraft navigation. Today most low cost bushwalking GPS receivers are capable of using the SBAS satellites to improve the autonomous accuracy of the receiver. SBAS systems exist in North America (WAAS), Europe (EGNOS) and Japan (MSAS). Using these systems, the benefit of the improved accuracy is available over most of the Northern Hemisphere. Unfortunately in Australia, SBAS cannot be used to improve autonomous accuracy.

The ProMark3 receiver does not use the DGPS part of SBAS, only the range and phase measurements. Because the SBAS satellites are stationary, there is no Doppler, so it is easier to use the data to resolve the integer ambiguities than that coming from a GPS satellite which is orbiting (email advice from Rob Leamon of Magellan Professional).

In Sydney, there are generally 2 Japanese satellites visible (PRN 129 and 137) at about 348º azimuth and 49º elevation. Whilst both satellites are nearly always visible, the ProMark3 seems to indiscriminately lock onto zero, one or both of them from time to time. Having said this it is generally the case that at least one SBAS satellite is being used.

2.4 Initialisation Methods

Standard dual frequency RTK receivers only use the “on the fly” initialisation method. In addition three additional initialisation techniques are provided on the ProMark3 RTK receiver.

These are in order of reliability and time:

1. Initialisation Bar. The initialisation bar is a 200mm long horizontal bar which is mounted between the tribrach adapter and the antenna. Using a quick release mechanism, the rover antenna can be placed on the other end of the initialisation bar. Despite the fact that the bar may be rotated in any direction around the base, rapid initialisation times are achieved, regardless of the quantity of available satellites due to the known length of the bar.
2. Known Point. By occupying a point which has been either previously occupied and logged during the survey, manually entered in the field or uploaded to the receiver in the office, very rapid initialisation times can be achieved in all but times of low available satellites or poor site location.
3. Static. Essentially this is an “on the fly’ initialisation, except the receiver is told that the antenna will remain stationary during the initialisation period. Provided the initialisation site is in a good location, initialisation times of under 3 minutes (and often much better) are generally achieved. This is very similar to the method used in the first generation of dual frequency receivers.

2.3 Differential Signal

The receivers come with a pair of identical radios that are directly powered from the receiver, conform to the IP65 standard and are interchangeable between base and rover. RTCM 3.1 corrections are broadcast from the base to the rover. The radios are licence free and as such are limited to 500mW at 869MHz in Europe and 902 to 928 MHz in North America (ProMark3 RTK Brochure, 2007). In Australia, the receivers come with the North American radios.

Under line of sight conditions, the radios have been tested and easily achieved the 1.6km range claimed by Magellan Professional (ProMark3 / ProMark3 RTK Reference Manual, 2007 p35). In very good conditions and with optimum locations for the base and rover radios, the maximum radio range achieved by Magellan Professional was 3 kilometres. This study is unable to confirm those claims. Finding a good location for the base station radio and mounting it as high as possible, is crucial to the range achieved. Where a ridge or housing blocks the signal, radio range can be as little as 300 to 400 metres. The longest non line of sight distance achieved with the radios during the tests was just over 1km. At this distance the radio signal was intermittent, with a fresh signal being received approximately every 5 seconds. The receiver is very sensitive to these changes in latency, rapidly changing from a float to fixed solution.

More powerful radios can also be used to increase this range, utilising the cable supplied with the ProMark3 radios (ProMark3 / ProMark3 RTK Reference Manual, 2007 p268). In this case spare batteries may be required for the ProMark3 to allow for the higher power consumption of the radios. The third party radios must have a maximum power 5v at 500mA to utilise the internal ProMark3 battery.

Alternatively a bluetooth capable mobile phone can be used via NTRIP connection or direct IP with a CORS network or other internet transmitted GPS data. It is preferable if the SBAS satellites phase and ranging are also broadcast to the ProMark3.

Magellan Professional claim maximum vector lengths of 10 kilometres at a horizontal accuracy of 0.01 metres + 1ppm (ProMark3 RTK Brochure, 2007). This is one of the areas where single frequency RTK receivers cannot match the longer vector lengths of dual frequency receivers. However, in most cases a maximum vector length of 10 kilometres is not a limitation to the surveyor. The accuracy at ranges beyond 1 kilometre have not been tested.

At the time of writing NTRIP and the alternative radio options were not tested. It is hoped that by the time the presentation is given, these options will have been tested.

2.4 Initialisation Times

Various testing of the initialisation times was conducted in Annie Prior Reserve in Glenhaven. This reserve has a clear area of about 20 to 30 metres radius. Trees of between 10 and 20 metre height surround this reserve. The base and rover were both placed in a central position in this reserve. A photograph of the park and GPS location is shown (see Photograph 2). A perfect base and rover location are often not available in real surveys. In clearer locations improved initialisation times could be expected.

The number of satellites quoted in this section, include both GPS and SBAS satellites.

Initialisation Bar – With 12 or more satellites, the initialisation time was always below 30 seconds. With 7 or more satellites, the initialisation time was always below 60 seconds.

Known Point – With 9 or more satellites, known point initialisation generally yielded times of from instantaneous to 10 seconds. With less satellites or in a worse position, known point initialisation often took many minutes.

Static – see Table 1 below. Of 64 initialisations only 5 (8%) took greater than 5 minutes. Initialisation times may vary in accordance with the number of available satellites. PDOP, baseline length, ionospheric acitivity and other factors. The Magellan Professional results are averaged for different situations.

On the Fly – not tested. Magellan Professional list this as being the slowest initialisation method.

Photograph 2. Annie Prior Reserve showing GPS location in red

Number of Satellites (GPS & SBAS)	Number of Initialisations (Test)	Initialisation Time (Test)	Initialisation Time (Magellan Professional)
8	5	2’50”	2’45”
9	17	2’07”	1’55”
10	9	3’44”	1’10”
11	16	1’45”	0’30”
12	11	0’27”	0’18”
13	6	1’37”	0’15”
14			0’10”

Table 1. Static Initialisation Times

The results for the 10 satellite case, included two readings above 5 minutes as well one reading just below 5 minutes, which resulted in the poor initialisation time for this number of satellites.

The results quoted by Magellan Professional represent 36 hours of testing in a totally clear environment (ProMark3 RTK White Paper, 2007 p10). These results are consistently better than the results obtained in an area with a few obstructions.

2.5 Performance on a real survey

The receivers were used to assist in the subdivision of a block of land at 19 Langford Smith Close, Kellyville. The land is marked red in aerial photographs (Photographs 3, 4 & 5). It is in a new subdivision area of cleared farming land and is suitable for performing RTK GPS surveys. The area surrounding the subdivision had numerous State coordinated survey marks (SCIMS) and Table 2 provides the results of this survey. The survey was carried out during a period of good satellite conditions.

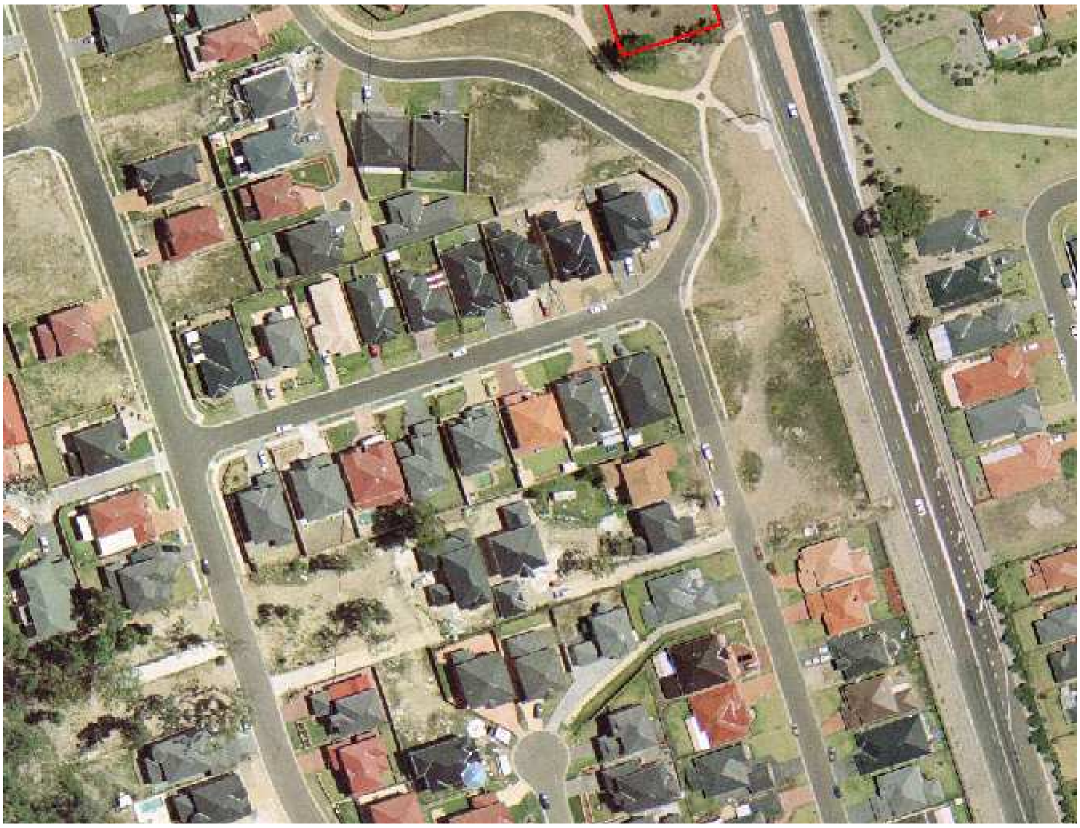
The base was set on a tripod inside the subject land. The rover was placed on a 2 metre pole with a bubble that had been checked for verticality before doing the survey. The pole was placed in a bipod and carefully levelled over each mark. Readings were taken for 30 seconds. Each mark was visited only once. The horizontal coordinates and heights obtained were shifted so that the mean of the differences equalled zero.

The results are very encouraging. Accuracies are very similar to that achieved using a dual frequency receiver.

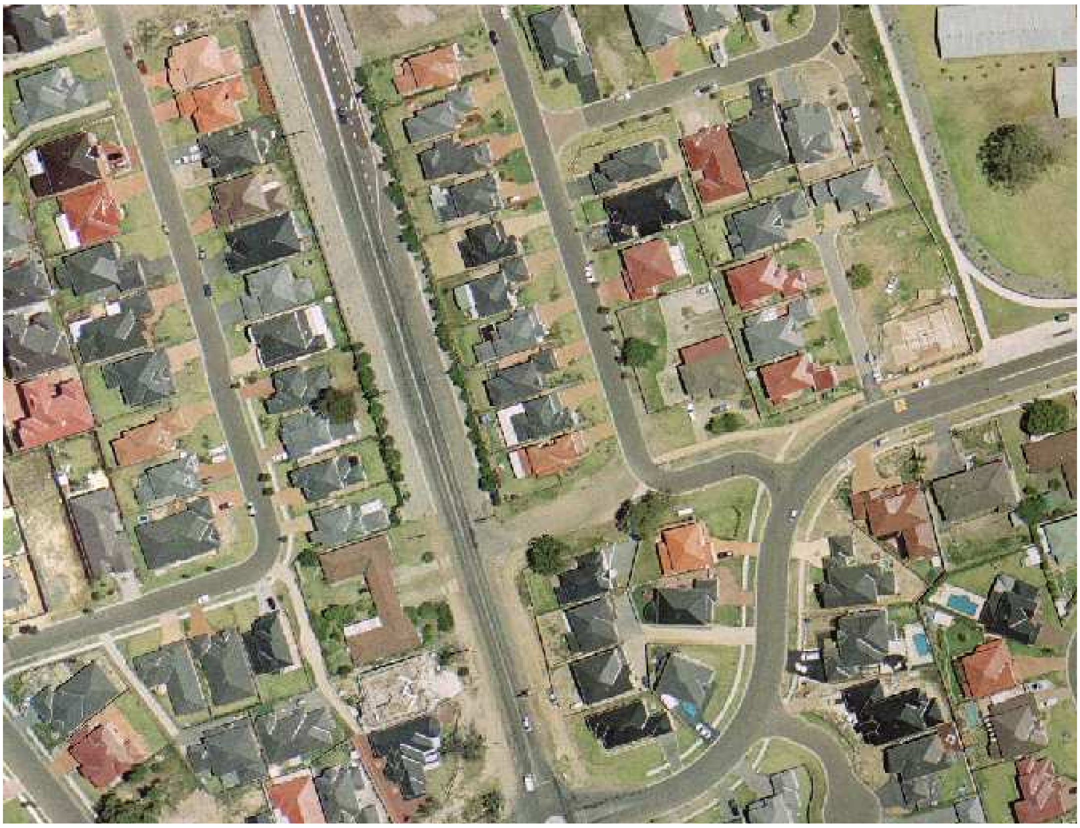
Mark	dE	dN	dH	Class & Order
PM 24973	0.009	0.017	-0.022	H: B & 2 – V LD & L4
SSM 112184	0.000	0.002	0.003	H: C & 3 – V: D & 4
SSM 112185	0.001	0.009	-0.006	H: C & 3 – V: D & 4
SSM 116818	0.009	0.011	0.006	H: C & 3 – V: LD & L4
SSM 122052	0.008	-0.008	0.010	H: C & 3 – V: LD & L4
SSM 122058	0.002	-0.014	-0.003	H: C & 3 – V: LD & L4
SSM 126294	-0.012	-0.007	NA	H: C & 3 – V: U & U
SSM 126295	-0.004	-0.009	NA	H: C & 3 – V: U & U
SSM 126296	0.013	0.007	NA	H: C & 3 – V: U & U
SSM 126417	-0.008	-0.009	0.001	H: C & 3 – V: LD & L4
SSM 126418	-0.008	-0.004	0.009	H: C & 3 – V: LD & L4
SSM 135617	-0.006	0.002	NA	H: C & 3 – V: U & U
MEAN	0.000	0.000	0.000	
SDEV	0.008	0.011	0.010	

Table 2. RTK results

Photograph 2. Kellyville survey (north area)



Photograph 3. Kellyville survey (central area)



Photograph 4. Kellyville survey (south area)

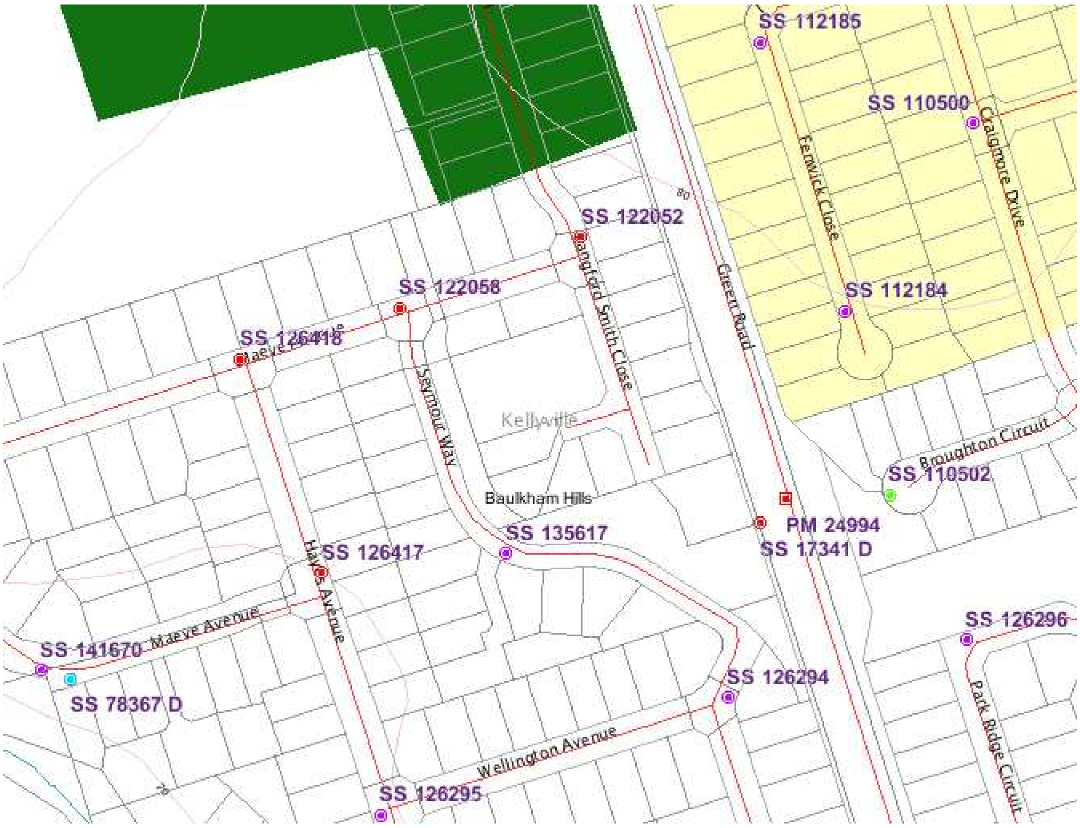


Diagram 1. Location of Survey Marks (north area)

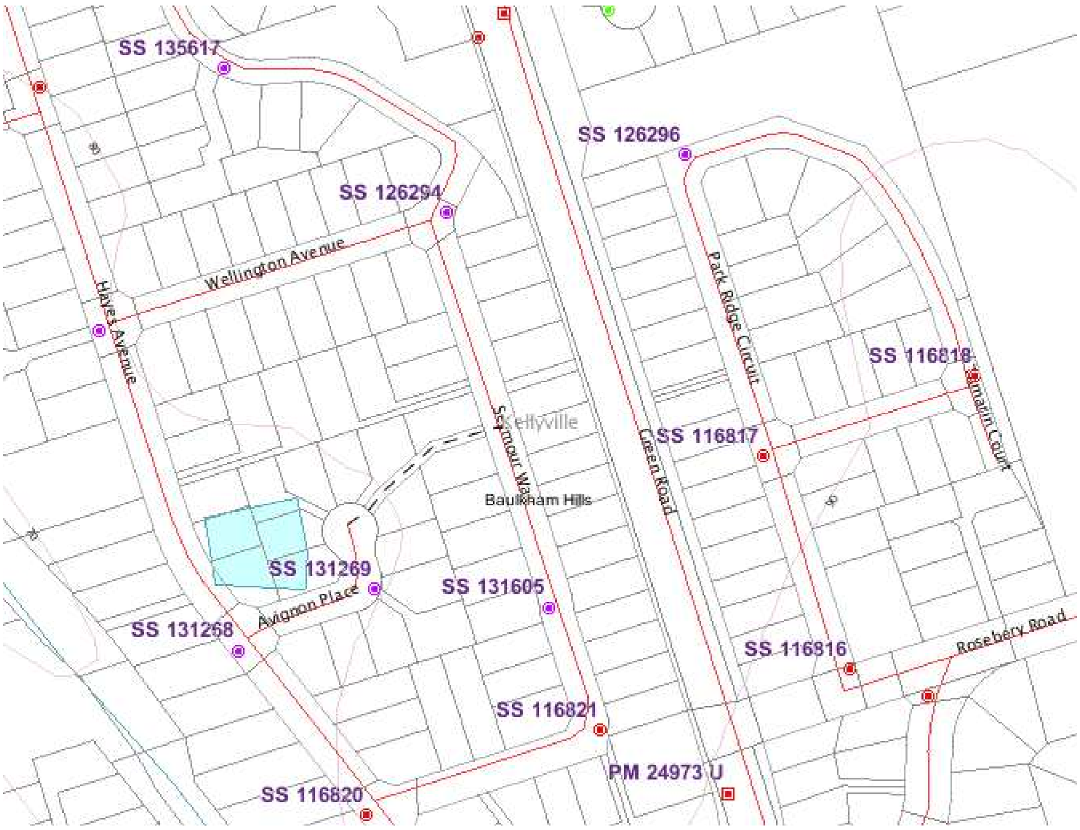


Diagram 2. Location of survey marks (south area)

As well as a test of the accuracy of the receivers, this exercise was used to document the time to achieve initialisation at each station. The status of the receiver shown in Table 2 was taken after the rover was levelled over the mark.

Mark	Status	Number of Satellites	PDOP
PM 24973	Fixed	13	1.4
SSM 112184	Fixed	11	1.9
SSM 112185	Fixed	11	2.0
SSM 116818	Fixed	12	1.9
SSM 122052	Fixed	12	1.6
SSM 122058	Fixed	10	2.1
SSM 126294	Fixed	12	1.5
SSM 126295	Fixed	12	1.5
SSM 126296	Fixed	12	1.9
SSM 126417	Fixed	12	1.6
SSM 126418	Fixed	11	2.0
SSM 135617	Fixed	13	1.4
8 other cadastral marks	Fixed	11-13	1.4-1.6
DH&W	Static 0’30” to fix	12	1.5
GIP	Static 2’07” to fix	11	1.5
DH&W	Static 0’58” to fix	12	1.5
DH&W	Static 0’35” to fix	8	2.3
DH&W	Static 0’11” to fix	12	1.9

Table 3. Initialisation Times, Satellites and PDOP

2.6 Float Solution Performance

Magellan Professional claim a float horizontal accuracy of 0.20 metres after 3 minutes occupation time (ProMark3 RTK White Paper, 2007 pp6-7). Tests were performed to check this accuracy and to also determine what vertical accuracies are achievable.

This claim is significant. With this level of horizontal accuracy, it should be possible to find survey marks in dense bush, without the need to run a time consuming and often difficult Total Station traverse.

The test was conducted at Annie Prior Reserve, Glenhaven, with the base located in the position shown in Photograph 2. The rover was located in the same reserve under trees about 43 metres to the north.

Test Number	dHOR	dVER	dXYZ
1	1.338	-0.22	0.258
2	1.478	-0.73	0.022
3	0.713	0.91	0.621
4	0.666	1.12	-0.056
5	0.244	-0.83	-0.134

Table 4. Float solution accuracy after a 3 minute occupation

None of the five tests achieved the horizontal accuracy claimed. Interestingly the 3D vector differences (dXYZ) appeared to be more stable and accurate, so a column was added to the table to display these. Unfortunately this will not assist in finding survey marks in areas where a “fixed” solution is not possible.

Magellan Professional were sent these results just before the deadline for this paper for comment. It would appear that their claim is for baselines longer than 1 kilometre and even up to 300 kilometres in clear sky conditions, although Magellan Professional have not tested baselines longer than 55 kilometres. An NTRIP connection or third party radios will be required to test baselines of this length. It is hoped that this claim may be able to be further tested by the time of the presentation.

2.7 Sydnet Test

Sydnet is a Continually Operating Reference System (CORS) which at the time of the test was operational at a beta level. It was possible to log in using one station only as a reference (ie a network solution is not possible).

The Sydnet test was carried out in the same location as the previous performance test in Kellyville. The vector length during this test was between 15.6 and 15.8 kilometres long. The system remained with a float solution for 25 minutes, whilst various State Survey Marks were visited. During this time a few unsuccessful attempts were made to obtain a fixed solution using the static initialisation method. After 25 minutes a fixed solution was obtained whilst occupying SSM 126417. A fixed solution was maintained until the end of the run on SSM 135617. After logging a fixed solution at this station, a known point initialisation was attempted. After six minutes of waiting without success a float solution was logged. The fixed results can be found in Table 5 and the float results in Table 6. Fixed solutions were all within the claimed horizontal accuracy of 0.01 + 1ppm. Vertical results were not so good, but NSW Lands Department itself has noticed some large vertical discrepancies. These results will be forwarded to them for their comment. This exercise enabled further testing of Magellan Professional’s 0.2 metre horizontal accuracy for long vectors in clear sky conditions. This time the accuracy was achieved in all but one of the tests. In 41 minutes, with 11 satellites visible for most of the time, 1.92Mb of data was downloaded from Sydnet.

Magellan Professional claim that long-range RTK (>10 km) with L1 only will require quite a long time to initialize or may not be possible (ProMark3 RTK White Paper, 2007 p2). Under these circumstances it was very pleasing to obtain a fixed solution after 25 minutes.

Mark	dE	dN	dH	Class & Order
SSM 122058	-0.007	-0.004	-0.078	H: C & 3 – V: LD & L4
SSM 126417	-0.016	0.000	-0.121	H: C & 3 – V: LD & L4
SSM 126418	-0.022	-0.004	-0.098	H: C & 3 – V: LD & L4
SSM 135617	-0.014	0.002	NA	H: C & 3 – V: U & U

Table 5. Sydnet Results Fixed Solution

Mark	Occupation	dHOR	dVER
SSM 126294	6 mins	0.418	NA
SSM 126295	3 mins	0.070	NA
SSM 126417	0 mins	0.016	0.233
SSM 135617 (Visit 1)	5 mins	0.194	NA
SSM 135617 (Visit 2)	6 mins	0.143	NA
SSM 135617 (Visit 3)	6 mins	0.064	NA

Table 6. Sydnet Results Float Solution

2.8 Versatility

The ProMark3 is a very versatile GPS receiver. Unlike most dual frequency units which can only be used for survey accuracy with a survey grade antenna, the ProMark3 is able to be used as a handheld receiver for navigation or GIS projects, with the external antenna for post processed centimetre level survey or sub metre level GIS projects, or in RTK mode for centimetre level survey and GIS projects. Survey and GIS software for both the receiver and office is provided as standard with the ProMark3. Software upgrades are freely provided for download from the Magellan Professional FTP site.

3. CONCLUSIONS

The ProMark3 RTK GPS receiver is a viable alternative to a dual frequency RTK receiver. Under good satellite conditions (11 or more GPS and SBAS satellites in view), the receiver provides similar performance to a dual frequency receiver. This is evidenced by the subdivision survey in Kellyville, where predominantly rapid on-the-fly initialisation was achieved.

In lower satellite conditions, the receiver's performance is slightly worse than dual frequency RTK and initialisation methods other than on-the-fly will need to be used. However even under these conditions, static initialisation times of under 5 minutes and generally less than 3 minutes, make the use of this receiver commercially viable, regardless of the number of satellites.

The float RTK accuracy needs to be further examined. However the usefulness of this feature to find survey marks in bushy areas may not be able to be realised.

ACKNOWLEDGEMENTS

The support of Viren Kalra from SAGEM Australasia for the loan of their equipment and Robert Leamon and Eric Guilloux from Magellan Professional for answering my questions was invaluable. I thank them sincerely for their efforts.

Whilst their support is acknowledged, it in no way influenced the findings in this paper and the results are a true and accurate reporting of the performance of the ProMark3 RTK GPS

receiver.

REFERENCES

Press Release - Magellan's BLADE™ GNSS Signal Processing enables Lower-cost, realtime centimeter accuracy (2007)

ProMark3 / ProMark3 RTK Reference Manual Rev D (2007)

ftp://ftp.magellangps.com/Land%20Survey/PM3/Manuals/PM3%20%26%20PM3RTK%20Reference%20Manual/

ProMark3 RTK Brochure (2007)

http://pro.magellangps.com/assets/datasheets/PM3RTK_Br(A4en)19Apr07.pdf

ProMark3 RTK White Paper (2007)

ftp://ftp.magellangps.com/Land%20Survey/PM3/Application%20Notes/PM3%20RTK%20White%20Paper.pdf