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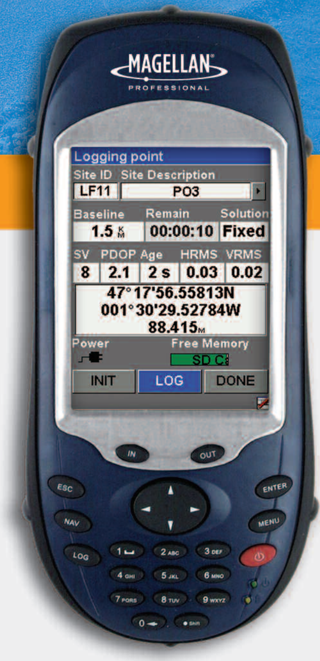
ProMark™3 RTK

White Paper



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1. Introduction

This paper describes standard and advanced features and performance of the new Magellan ProMark3 RTK positioning system.

ProMark3 RTK uses BLADE™, the Magellan technology that gives this new single-frequency system reliable RTK performance through the following key innovations:

- Flying RTK™
- GPS+SBAS RTK
- On The Fly (OTF), Known Point and Bar Initializations.
- Plug-and-play license-free radio modem for base/rover system use.
- Compatibility with RTK Network standards for rover-only use.
- Background logging of raw data for post-processing.

This paper demonstrates how these innovations can create a compelling performance/cost ratio compared to existing products and how Magellan can improve L1 RTK performance, leveraging its technology in order to improve the initialization time compared to “standard L1 RTK techniques".

Fig 1. ProMark3 RTK Base/Rover System deployed in the field

2. ProMark3 RTK Operational Environment

L1 RTK usually provides centimeter-level accuracy for a reasonable convergence time under the following conditions:

- Short, open-sky baselines less than about 10 kilometers.
- Quite low level of ionospheric and tropospheric residuals seen from base and rover.
- Sufficient number of common satellites seen from base and rover.

Magellan ProMark3 RTK is a single-frequency, 14-channel, dual-constellation (GPS+SBAS) system that enhances traditional L1 RTK performance:

What ProMark3 RTK can do:

- Deliver centimeter-level accuracy for short, open-sky baselines.
- Deliver decimeter-level accuracy for short, long, open and partly shaded baselines.

What ProMark3 RTK cannot do:

- Instant fix, even for short baselines, is currently not possible with L1 only.
- Long-range RTK (>10 km) with L1 only will require quite a long time to initialize or may not be possible.
- Partly shaded conditions can delay L1 RTK initialization time.

However, thanks to improved L1 processing technology, Magellan's ProMark3 RTK system introduces a new segment of the GNSS survey market defined by:

- Low-priced RTK system
- Small and light RTK system
- Handheld RTK system.

3. BLADE™: A Unique Magellan Technology for Quicker Convergence

BLADE™ (BaseLine Ambiguity Determination Engine) is a GNSS processing technique developed by Magellan that concentrates years of extensive experience in GNSS processing technology. In particular this new Magellan technology allows SBAS measurements to be used in the RTK processing. Additional GPS-like measurements are used by BLADE™, improving satellite geometry and allowing centimeter-level accuracies to be achieved in a shorter time compared to GPS-only algorithms.

BLADE Magellan's proprietary GNSS processing solution enables ProMark3 RTK to outperform other single-frequency RTK receivers and grants real-time performance in a lightweight handheld system. This white paper demonstrates how this exclusive technology drives rapid initialization, reliability and real-time centimeter-level accuracy to make the ProMark3 RTK a new reference for RTK surveying.

Fig 2. ProMark3 RTK Base

4. ProMark3 RTK Fixed Performance

RTK requires fixing carrier ambiguities in order to achieve a reliable centimeter-level position. Magellan's Blade™ technology, which is embedded in the ProMark3 RTK, uses SBAS ranging measurements in the RTK processing. This gives extra GPS-like measurements, which improve satellite geometry and allow centimeter levels of accuracy to be achieved faster than is currently possible with GPS only.

ProMark3 RTK fixed performance was evaluated using three different initialization methods:

- On The Fly (OTF)
- With initialization bar
- On a known point (KPI).

4.1 On-the-Fly Initialization

The RTK engine was reset every 300 seconds, and the following parameters were measured:

- Availability: the percentage of fixed trials over all the trials.
- Reliability: the percentage of correctly fixed trials over all the fixed trials.
- TTF (Time to Fix) for 50% of fixed solutions: the time within which 50% of the trials were fixed.

Table 1 shows the results for five open-sky baselines. Reliability was set to 99% and the processing mode used was kinematic. For each baseline, availability, reliability and TTF were evaluated with and without SBAS measurements.

Table 1. Open Sky Baselines, TTF

Test No.	Baseline length, meters	Number of Trials	Availability, %		Reliability, %		TTF, for 50% of fixed solutions, in seconds	
			Without SBAS	With SBAS	Without SBAS	With SBAS	Without SBAS	With SBAS
1	15	305	79.3	96.1	100	100	107	21
2	32	684	86.5	96.3	99.2	99.5	114	46
3	1215	282	85.1	95.1	100.0	100.0	132	58
4	2895	288	81.2	97.2	99.6	100.0	104	25
5	7256	281	75.4	87.9	99.1	100.0	155	58

These results show that ProMark3 RTK can provide very good open-sky performance. Reliability of over 99% was always met. The availability of SBAS improved the convergence time dramatically (it could be even more useful for difficult environments or shaded receivers). In all the cases, availability of SBAS reduced the Time to Fix by more than 50%. This is one of the main competitive advantages ProMark3 RTK has, compared to other single-frequency RTK systems.

4.2 Initialization on Bar

In addition to OTF ambiguity initialization, Magellan provides the option to initialize on a “kinematic bar”. This technique allows the receiver to fix the ambiguities within about 30 seconds in almost all cases.

The kinematic bar is an accessory that allows the rover antenna to be set level and precisely 20 cm from the base antenna. Because this baseline length is known, the rover is able to compute the ambiguities very quickly.

Table 2 shows the efficiency of this type of initialization. For this specific example where 224 trials were done, the kinematic bar initialization allows 100% TTF within less than 30 seconds.

Table 2. TTF Statistic, Initialization on Bar

Test No.	Baseline length, meters	Number of Trials	Availability, %	Reliability, %	TTF, for 50% of fixed solutions, in seconds	TTF, 50%, in seconds
1	20 cm (bar length)	224	100	100	27	27

4.3 Known Point Initialization (KPI)

For this test, the receiver was installed on a pole over a point with known coordinates. The known point can be chosen from a list of previously logged points, uploaded from GNSS Solutions software or entered manually.

After each measurement, the antenna receiver is put down to the ground in order to lose the GPS signal. Then, the pole is installed again on that point and a KPI initialization is done. Typical initialization on a known point was less than 20 seconds (See *Table 3*).

Table 3. Known Point Initialization Time to Fix

Test Number	TTF, in seconds	Number of satellites
1	5	8
2	9	8
3	4	8
4	7	8
5	7	8
6	20	8
7	19	8
8	20	8
9	44	8
10	15	7

5. ProMark3 RTK Float Performance

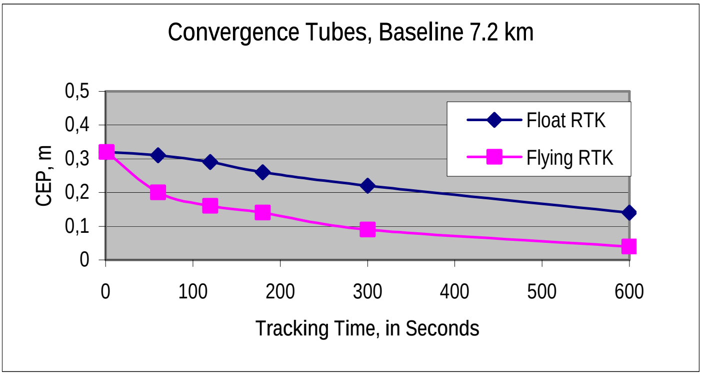
Instead of the standard Float RTK solution, Magellan has implemented the so-called Flying RTK™ mode. Flying RTK™ is a new Magellan technology that improves convergence performance compared to standard Float RTK.

In order to measure convergence improvements related to the Flying RTK™ technology, the following methodology was used:

- RTK process reset every 600 seconds.
- Convergence curves plotted for baselines of 30 m, 1.2 km and 7.2 km.

Fig. 3 below shows a comparison between Float and Flying RTK convergence for a baseline of 7.2 km in open sky environment.

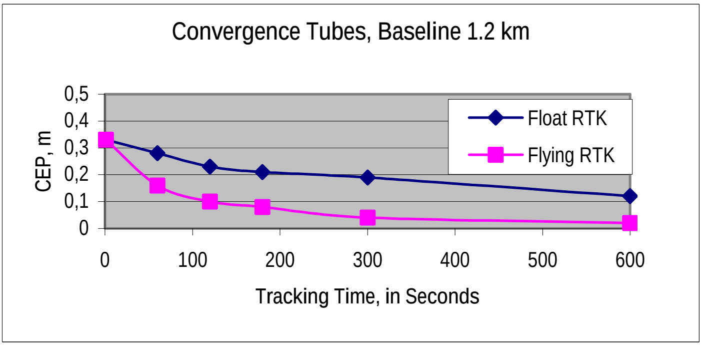
Fig. 3. Float Vs. Flying RTK Convergence (7.2 km Baseline Length)



In all cases, the Flying RTK™ solution improved the convergence time noticeably compared to conventional Float RTK.

Float RTK performance was typically 20-25 cm CEP after 300 seconds of tracking and 10-15 cm after 600 seconds of tracking. The Flying RTK™ technology improved the convergence time significantly, reaching the same accuracy in less than one third of the time for a 7.2-km baseline compared with standard Float RTK. Improvement was even better for shorter baselines (see below for a 1.2-km baseline).

Fig. 4. Float versus Flying RTK Convergence (1.2 km Baseline Length)



6. ProMark3 RTK Accuracy

6.1 Fixed Solution

Accuracy was tested with different configurations and different baseline lengths. The results presented here are field results obtained in an open-sky environment. Corrections were transmitted to the rover according to two different methods:

- Radio link between ProMark3 RTK base and ProMark3 RTK rover using Magellan radio modems. Baseline was 10 m.
- GPRS connected to a Z-Max Base station through Direct IP. Baseline was 2 km.

The positions computed by the ProMark3 RTK rover were compared to the same positions measured with a Z-Max and post-processed with GNSS Solutions.

Table 4. Fixed Solution Results

Test Results	10-m baseline (Radio link used between ProMark3 base and rover)	2-km baseline (ProMark3 rover connected to Z-Max base thru Direct IP mode)
Number of trials	213	129
Horizontal bias (mm)	8 mm	5 mm
Vertical bias (mm)	6 mm	10 mm
Horizontal Standard Deviation (mm)	5 mm	8 mm
Vertical Standard Deviation (mm)	6 mm	10 mm
Reliability	99%	99%

All these tests were done in automatic mode with On-the-Fly initialization. The results were all below 10 mm with more than 99% availability showing a very good quality of the solution compared with dual-frequency post-processed GPS.

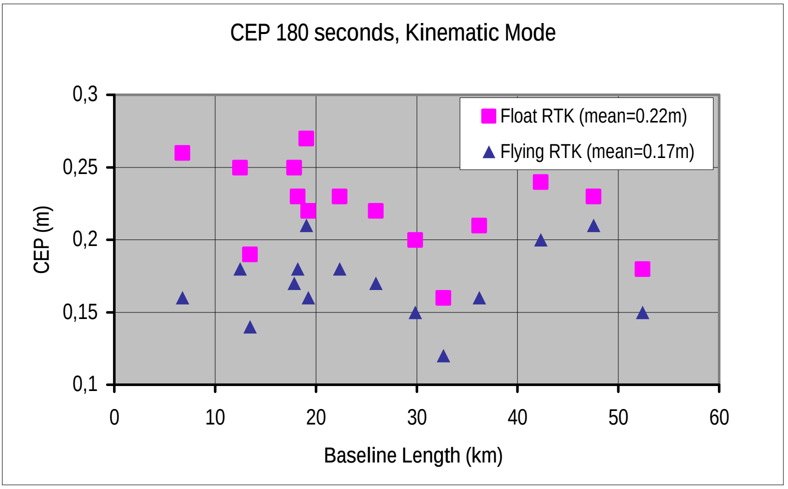
6.2 Float Solution

For baselines longer than 10 km, it is very difficult to achieve centimeter-level accuracy (fixing ambiguities) within a reasonable time using an L1 RTK system. In these conditions, only Float RTK solutions may be available. A Float solution may even be desired for such applications as mapping, using the ProMark3 mapping application.

The quality and performance of a float solution is therefore critical in many cases. BLADE™ RTK technology from Magellan allows Float/Flying RTK for longer baselines than standard L1 RTK solutions with decimeter-level accuracy. This section demonstrates that, when using the Flying RTK solution from Magellan, it is possible to get good decimeter-level performance for baselines much longer than 10 km.

Fig. 5 below shows CEP (50% horizontal) for Float and Flying RTK for 15 different baseline lengths. All figures correspond to 180 seconds (3 minutes) of cumulative RTK processing in kinematic mode.

Fig. 5. Float versus Flying RTK, CEP versus baseline length



Float convergence behavior was similar for baselines from 10 to 50 km. But in all cases, Magellan's Flying RTK algorithm can improve performance.

7. ProMark3 RTK Working in an RTK Network

Network RTK services have grown rapidly. NTRIP/GPRS connectivity allows a rover to easily connect to "optimal" reference stations. The main advantage of working with a GPS rover connected to an RTK network is that you mitigate the need to setup your own base station.

Commercial RTK Network services normally distribute L1/L2 data. The Magellan ProMark3 RTK system can request, receive, decode and apply RTK Network data for L1 RTK solutions. The ProMark3 RTK receiver supports most of the standard RTCM 2.x and RTCM 3.x messages.

In order to demonstrate ProMark3 RTK performance with RTK Network data, ProMark3 raw data as well as the raw correcting stream were recorded simultaneously. Having recorded these, ProMark3 RTK was run off-line to estimate TTF performance for different modes of operation.

Test summary is as follows:

- Duration: 3.5 days continuously
- Conditions: static, open sky
- Network: Orpheon, France (Leica Spider Net software)
- Protocol: RTCM 3.0
- Mean number of satellites from Network: 8.5
- Mean number of satellites tracked by ProMark3: 9.5
- Baseline: 10 km from nearest base
- RTK auto-reset: every 600 seconds.

During the test, we noticed that the Network sent data for about one GPS satellite less than the ProMark3 rover usually tracked. The Network uses an elevation cutoff angle of 10 degrees, which is usually good for L1/L2 rovers over long baselines.

At the same time, for L1 RTK usually working with baselines less than 10 km, low-elevation satellites could be very helpful. Moreover most real-time networks do not send SBAS data so the ProMark3 RTK cannot benefit from these valuable extra measurements. Nevertheless, ProMark3 RTK does work within these networks with certain limitations such as a longer Time to Fix.

We estimated standard TTF and fixed accuracy performance for the default (kinematic) and static RTK processing modes. The summary is given in *Table 5* below.

Table 5. Test Results in RTK Network

Processing mode	Number of trials	Availability of fixed solution during 600 sec	Reliability of fixed solution	Time to Fix (50%)	Horizontal accuracy (rms)	Vertical accuracy (rms)
Kinematic	250	84.2%	99.8%	65 sec	11 mm	16 mm
Static	250	89.7%	99.3%	54 sec	9 mm	13 mm

Both Time to Fix and accuracy performance with commercial Network are very good up to 10 km from a base, and they can be improved using the static processing mode.

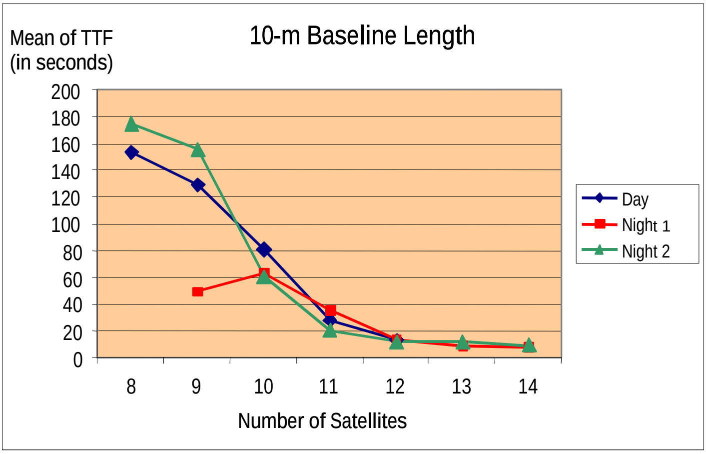
8. Sensitivity to Number of Satellites

In order to define the sensitivity of the ProMark3 RTK convergence time to the number of satellites tracked, the base and the rover were situated in an open-sky environment and connected through Magellan radios.

Fig. 6 shows the TTF versus the number of satellites received at the rover side. Condition of data collection was as follows:

- The three curves on the graph represent about 12 hours of recorded data per curve.
- A reset was sent automatically every 10 minutes, so the maximum TTF is 10 minutes. The points that were not fixed in that time are not taken into account in the graph.
- Measurements were done both at night and during the day.

Fig. 6. Mean of TTF versus number of satellites



It is clear that Time to Fix improves dramatically with more than 9 satellites and becomes very quick, less than 1 minute, for more than 10 satellites. ProMark3 RTK is very sensitive to the number of satellites available. This is why ProMark3 RTK has a significant advantage when using both GPS and SBAS satellites compared with any other single frequency system.

9. Conclusion

ProMark3 RTK is a unique product able to handle most types of survey needs from post-processing to RTK. The system even includes Mobile Mapping at no extra cost.

Using Magellan's BLADE™ technology, ProMark3 RTK benefits from the latest algorithms for processing single-frequency GPS and SBAS data. By using SBAS signals in processing, ProMark3 RTK is able to fix ambiguities in shorter times than standard L1 RTK engines.

For short, open-sky base lines, ProMark3 RTK can perform very efficient real-time surveys reaching centimeter accuracy in a few minutes. The addition of SBAS to GPS makes ProMark3 RTK able to lower the barrier of entry to RTK.

Survey features are supported by an easy-to-use and comprehensive user interface and are available through two different levels of application software, including FAST Survey.

White Paper

Magellan
Survey Solutions Contact Information:
In USA +1 408 615 3970 ▪ Fax +1 408 615 5200
Toll Free (Sales in USA/Canada) 1 800 922 2401
In South America +56 2 273 3214 ▪ Fax +56 2 273 3187
Email surveysales@magellangps.com

In Singapore +65 6235 3678 ▪ Fax +65 6235 4869
In China +86 10 6566 9866 ▪ Fax +86 10 6566 0246
Email surveysalesapac@magellangps.com

In France +33 2 28 09 38 00 ▪ Fax +33 2 28 09 39 39
In Germany +49 81 6564 7930 ▪ Fax +49 81 6564 7950
In Russia +7 495 980 5400 ▪ Fax +7 495 981 4840
In the Netherlands +31 78 61 57 988 ▪ Fax +31 78 61 52 027
Email surveysalesemea@magellangps.com
www.pro.magellanGPS.com

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