POWERGPSÔ: A New Family of High Precision GPS Products

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BIOGRAPHY

Mr. Okamoto is the Manager of Research and Development at Sokkia Company, Ltd. He has over twenty years experience in GPS and survey equipment development. His specialization is the leadership of advanced development programs. He received his B.S. degree in Chemistry from Chiba University.

Mr. Miyahara is Chief Engineer for GPS Product Development at Sokkia Corporation. He has ten years of experience in the design of electronic products. His specialty is digital hardware design. Mr. Miyahara received his B.S. degree in Earth Sciences from the University of Toyama.

Mr. Ron Hatch is a principal at NAVCOM Technology. He is internationally known for his extensive contributions in satellite navigation over the last 35 years. His name appears on seven GPS patents. Recipient of the Instityte of Navigation's Kepler award in 1994 for his contributions to the advancement of GPS technology, Mr. Hatch received his B.S. degrees in Mathematics and Physics from Seattle Pacific University.

Mr. Tenny Sharpe is Manager of System Engineering at NAVCOM Technology. He has twenty years experience in the design and implementation of navigation systems and GPS user equipment. His specialties are leadership of advanced development teams, system design, navigation solution algorithms and software. Mr. Sharpe received his B.S. in Physics from Case Institute of Technology and M.S. in Computer Science from the University of California, Los Angeles.

ABSTRACT

A new family of high performance GPS receiver products has been introduced by Sokkia Corporation of Tokyo, Japan. This family of products, named the *POWERGPSÔ*. Professional Measurement System, is designed for use in applications requiring the highest accuracy and precision: static and kinematic surveying, real-time kinematic and GIS.

This paper provides an overview of the *POWERGPSÔ* product family with brief descriptions of the various models, their capabilities and target applications. Emphasis is placed on the innovative features of the core receiver technology, which enable the generation of GPS measurements of the highest quality. These features include:

- High sampling rate (80Mhz) and 3-bit analog to digital conversion of the down-converted GPS signal to allow precise code phase edge resolution.
- Proprietary multipath rejection techniques, which exploit the high sampling rate and precise digital sample resolution to yield pseudorange measurements of the highest quality.
- Proprietary cross-correlation algorithms which yield higher signal to noise ratios when tracking AS coded signals.
- A flexible digital signal processing channel architecture, which allows major functional blocks within the receiver to be assigned to track various combinations of the GPS signal as needed.

Sample results are presented illustrating the levels of performance achieved.

INTRODUCTION

The *POWERGPSÔ* product family is the result of a development program undertaken by Sokkia Corporation, Tokyo, Japan with support from NAVCOM Technology Inc., Redondo Beach, California. Sokkia, an established, worldwide provider of survey products, formed the initial product concept and initiated the product development in 1995. Since that time, all of the elements of the products and their accessories have been designed and implemented. The core GPS receiver modules, including custom digital processing ASICs and receiver control firmware, are of new design and incorporate innovative features, which allow the highest quality GPS measurements to be produced.

The *POWERGPSÔ* product family is comprised of five models divided among three categories of capability, which altogether cover a broad range of applications in the professional GPS market.

Figure 1 shows a "family portrait" with L1 and L1/L2 antennas and each of the models.

Different levels of capability are determined in each model according to the configuration of the auxiliary processor board used and the presence or absence of a built-in user interface.

Two of the models have built-in user interfaces. All of the models are compatible with Sokkia's SDR33 Electronic Field Book products, which provide a surveyor-friendly approach to control and data collection for GIS, electronic total stations, static, kinematic and RTK applications.

All of the models in the *POWERGPSÔ* family are based on the same GPS receiver technology with high rate sampling, proprietary multipath rejection technology and the SuperChannel™ architecture. They also all share the same intelligent power management technology.

Figure 1. The *POWERGPSÔ* Product Family

THE *POWERGPSÔ* PRODUCT FAMILY

The *POWERGPSÔ* product family is divided into three levels of capability. The first level is comprised of one model: the R100. This model is a basic GPS measurement engine. It requires an external controller and provides measurement outputs, real-time, code-based, dGPS positioning, 1PPS output, event input, internal power management and external power input.

The next level of *POWERGPSÔ* products includes two models: the R200 and R210. The capabilities added at this level are:

- data recording and file management (configurable from 4 Mbytes to 28 Mbytes),
- external, 10MHz oscillator input.

The model R200 requires an external controller. The model R210, shown in Figure 2, has a built-in keyboard and screen similar to the SDR33 platform, which enables on-board control of surveying operations.

Figure 2. The PowerGPS Model R210

The highest level of capability in the PowerGPS product family includes two models: the R300 and R310. These models have the added capability of full, real time kinematic (RTK) operation with on-the-fly ambiguity resolution.

The model R300 requires an external controller. The model R310, shown in Figure 3, is equipped with a built-in user interface based on touch-screen technology.

Figure 3. The PowerGPS Model R310

Observations recorded using all models in the *POWERGPSÔ* product family can be processed using Sokkia's full line of post-processing products including the Spectrum Survey and SpectrumGIS Windows-based software packages.

PowerGPS RECEIVER DESIGN

From the outset of the *POWERGPSÔ* development program, it has been Sokkia's goal to design a GPS receiver capable of producing the highest quality carrier phase and code pseudorange measurements. To achieve this goal, a number of innovative features were incorporated into the receiver design.

HIGH DIGITAL SAMPLING RATE

The *POWERGPSÔ* receiver digitizes the down-converted GPS signal at a sample rate of 80 MHz. This very high sampling rate allows precise code phase edge resolution and enables the use of advanced, proprietary multipath rejection techniques.

A 3-bit, symmetrical, analog-to-digital conversion is performed. Use of a 3-bit conversion minimizes the signal loss due to quantization inherent in the digitization process thus reducing noise to near the theoretical minimum.

MULTIPATH REJECTION TECHNOLOGY

The high sampling rate and 3-bit A/D conversion permit a more precise correlation between the received and internally generated code signals. Proprietary techniques, which exploit this improved mapping of the correlation curve are used to greatly mitigate the measurement errors caused by multipath. These techniques are collectively referred to as Compressed Multipath Rejection (CMPR). They are used to produce code pseudorange measurements of unparalleled quality enabling rapid and reliable on-the-fly ambiguity resolution.

FLEXIBLE SuperChannelÔ ARCHITECTURE

The dual frequency code and carrier tracking loops of the *POWERGPSÔ* receiver are organized into a series of functional blocks within the custom digital signal processing ASIC. These functional blocks, called SuperChannels™, implement all of the logic necessary to perform signal acquisition and to produce a complete set of observables for each GPS satellite being tracked.

As shown in Figure 4, a SuperChannel™ is subdivided into three sections: 1) an L1/CA section, 2) a P1(Y1) section and 3) a multi-purpose section which can be commanded to perform L2/P2(Y2) tracking or L2/CA tracking or L1/CA tracking.

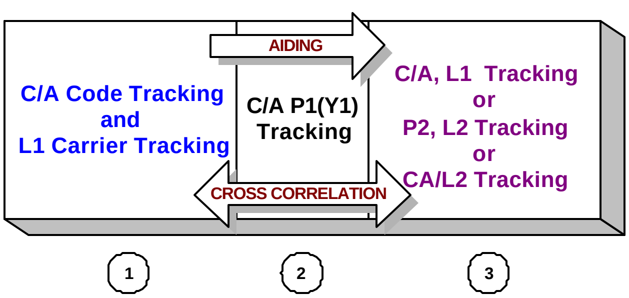


Figure 4. SuperChannel™ Block Diagram

Unlike most previous GPS designs, the SuperChannel™ architecture implements the high-rate loop filter computations, for both carrier and code tracking, within the custom digital processing ASIC. This offers several advantages:

1) High rate measurement outputs can be generated without excessive burdening of the microprocessor controller.

2) Numerical operations required by the tracking loops (aiding computations, accumulators, numerically controlled oscillators, etc.) can be optimized with respect to range and precision.

3) Tightly coupled aiding among the various loops is readily implemented including cross correlation techniques, which provide a higher level of sensitivity in the presence of Y-code (anti-spoofing or AS).

ANTENNAS AND RF/IF PROCESSING

Compact L1 and L1/L2 antennas have been newly designed for the PowerGPS Professional Measurement System. These antennas implement the following design criteria:

1) L1 and L2 phase center stability of ±1 millimeter.

2) Receptivity pattern, which balances sensitivity and ground plane multipath rejection.

The RF/IF front end of PowerGPS Professional Measurement System is comprised of custom filters, a RF ASIC and an IF ASIC. These components implement two completely independent signal paths for the L1 and L2 frequencies. Each signal path performs pre-selection filtering, signal amplification, automatic gain control (AGC), frequency down-conversion and analog-to-digital conversion.

A low noise phase-locked loop is included in the IF chip for local oscillator (LO) generation. The AGC is used to automatically maintain the optimum noise loading into the A/D converter over a wide range of input noise power conditions.

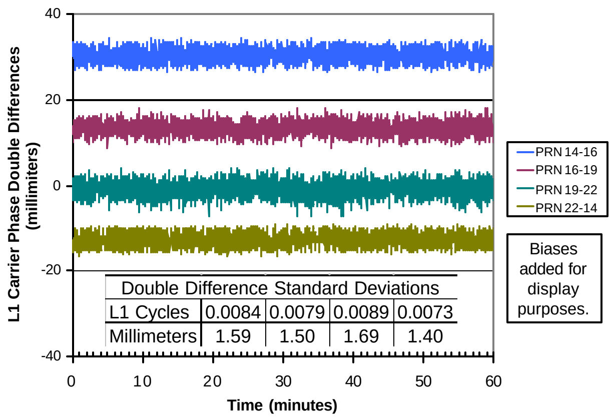
CARRIER PHASE MEASUREMENTS

All GPS precise positioning applications rely on the quality and integrity of the GPS receiver's carrier phase measurements. These include static and kinematic survey techniques as well as real-time kinematic (RTK) applications.

A common method used to evaluate GPS receiver phase measurement quality is the zero-baseline, double difference technique. This procedure involves processing integrated carrier phase measurements from two receivers running simultaneously attached to a common antenna.

Differences are formed at each measurement epoch between the same two satellites on each receiver and then between the two receivers. Since multipath and other common mode errors cancel in the double difference process, the result is a measure of the receivers internal carrier tracking noise performance.

Figures 5a an 5b show the results, for the L1 and L2 frequencies respectively, from a typical zero baseline, carrier phase double difference test for the *POWERGPSÔ* Professional Measurement System. The statistics shown in this figure indicate standard deviations of less than 1.7 millimeters for L1 and less than 2.2 millimeters for L2. This exceeds even the most demanding requirements for geodetic surveying.



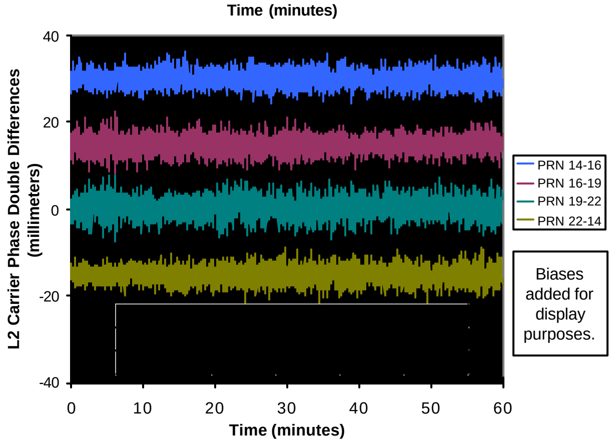


Figure 5a. L1 Carrier Phase Double Difference Results
Figure 5b. L2 Carrier Phase Double Difference Results

HIGHLY ACCURATE CODE MEASUREMENTS

For real-time kinematic (RTK) operation, on-the-fly (OTF) carrier phase ambiguity resolution begins with a differential code pseudorange position as its starting point. The more accurate this position is, the more rapid and reliable will be the OTF ambiguity resolution. The *POWERGPSÔ* Professional Measurement System has been designed with advanced, proprietary multipath rejection techniques, which yield code pseudorange measurements of unparalleled quality. These proprietary techniques, referred to collectively as Compressed Multipath Rejection or CMPR, are made possible by the high performance design features described earlier.

To evaluate the effectiveness of CMPR, compared to other GPS receivers, the test setup shown in Figure 6 was used. Simultaneous measurements from six different receivers, all connected to a common antenna, were recorded. Plots of the CA code pseudorange minus the L1 integrated carrier phase (CA code offset) versus time are shown in Figure 7. In the absence of multipath, the CA code offset varies slowly with satellite elevation and azimuth due to changing ionosphere delays. A smoothing filter with a time constant of 100 seconds was applied to the raw code offset before plotting to eliminate the high frequency code tracking noise.

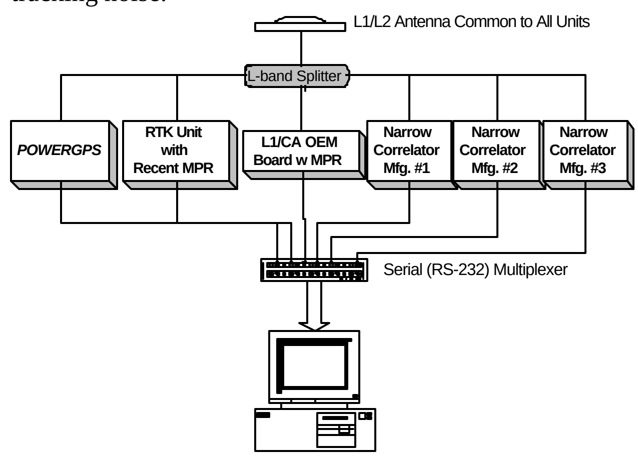


Figure 6. Test Setup for Comparative Tests

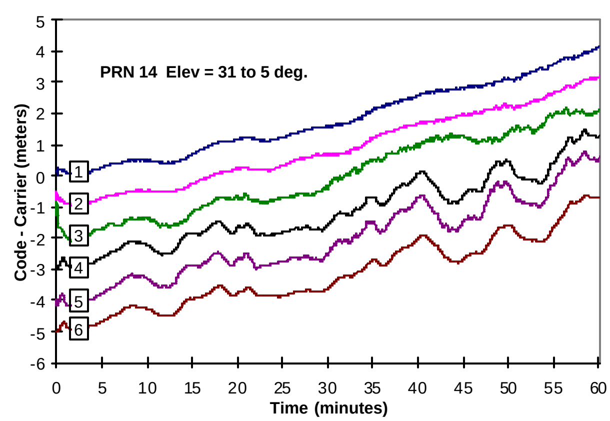


Figure 7a. Comparative Code Offset Results for:

1) *POWERGPSÔ* with CMPR
2) RTK unit with recent MPR technology
3) L1/CA OEM board with recent MPR
4) Narrow correlator Mfgr. #1
5) Dual frequency narrow correlator Mfgr. #2
6) Single frequency narrow correlator Mfgr. #3

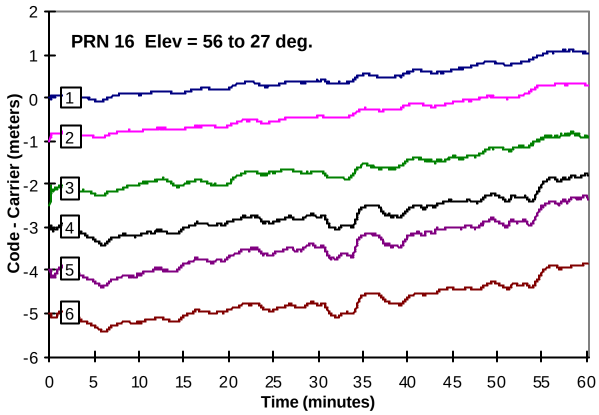


Figure 7b. Comparative Code Offset Results for:

1) *POWERGPSÔ* with CMPR
2) RTK unit with recent MPR technology
3) L1/CA OEM board with recent MPR
4) Dual frequency narrow correlator Mfgr. 1
5) Dual frequency narrow correlator Mfgr. 2
6) Single frequency narrow correlator Mfgr. 3

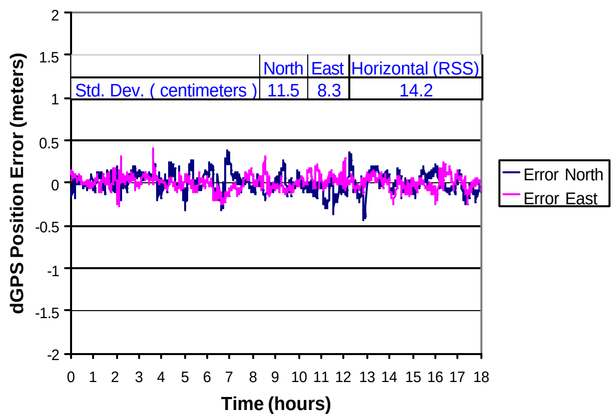


Figure 8. POWERGPS Differential Code Pseudorange Navigation Accuracy

Figures 7a and 7b show the effectiveness of the *POWERGPSÔ* CMPR technique in mitigating multipath. Only the highest capability, RTK survey unit with the most recent multipath technology showed performance approaching the *POWERGPSÔ*.

When units equipped with CMPR are used as both the dGPS reference station and remote navigator, the resultant differential, code pseudorange navigation achieves accuracy below 15 cm one sigma horizontal. Figure 8 shows an example of these results for an 18 hour test over a short baseline.

Differential code pseudorange accuracy at these levels greatly enhances the ability to perform rapid OTF ambiguity resolution and also provides an unprecedented level of performance for non-kinematic applications in GIS and related fields.

CONCLUSION

The key design features of the new *POWERGPSÔ* product family have been reviewed and their impact on generation of the highest quality GPS observables has been described. Sample data and results have been presented which illustrate the level of performance achieved by these products.