Burka Award

Sponsored by: The Institute of Navigation

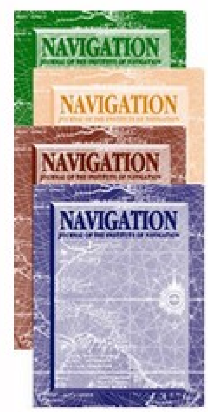
Purpose: To recognize outstanding achievement in the preparation of papers contributing to the advancement of navigation and space guidance.

Eligibility: Authorship of paper on navigation or space guidance published in NAVIGATION, the Journal of the Institute of Navigation.

Memorial: Given in Memory of Dr. Samuel M. Burka, a dedicated public servant who devoted a long and distinguished career to the research and development of air navigation equipment and reviewing technical material for official publications. He retired from public service in 1958 and died several months later.

Previous Winners:

2007: Dr. Chun Yang, Dr. Mikel Miller and Dr. Thao Nguyen
2006: Dr. Suneel I. Sheikh and Dr. Darryll J. Pines
2005: Dr. Mark L. Psiaki, Dr. Dennis M. Akos and Jonas Thor
2004: Dr. Christopher R. Carlson, Dr. J. Christian Gerdes and Dr. J. David Powell
2003: Dr. Donghyun Kim and Prof. Richard B. Langley
2002: Dr. Chan-Woo Park, Professor Jonathan P. How and Dr. Larry Capots
2001: Dr. James J. Spilker and Dr. A.J. Van Dierendonck
2000: Dr. John Betz and Dr. Kevin R. Kolodziejski
1999: Dr. Jean-Marie Sleewaegen
1998: Dr. Per Enge
1997: Siebren van der Werf
1996: Mats Brenner



The Institute of Navigation

Samuel M. Burka Award

is awarded to

Dr. Donghyun Kim

To Recognize Outstanding Achievement in the Preparation of a Paper
Contributing to the Advancement of Navigation and Space Guidance
"On Ultrahigh-Precision GPS Positioning and Navigation"
as Published in the Summer 2003 Issue of NAVIGATION,
The Journal of the Institute of Navigation

Presented June 2004

THE INSTITUTE OF NAVIGATION

Larry Hothem
President, The Institute of Navigation

Congratulations

Institute of Navigation Honorees

The Annual Awards Program is sponsored by the Institute of Navigation to recognize individuals making significant contributions, or demonstrating outstanding performance, relating to the art and science of navigation.

Nominations for these awards may be submitted by anyone, but all nominations must conform to ION® nomination guidelines.

Award recipients need not be members of the Institute. Details of the nomination process and nomination forms are available at www.ion.org.

The Institute of Navigation had the pleasure of honoring an outstanding group of contributors to the art and science of navigation at its 60th Annual Meeting held in Dayton, Ohio, June 7–9, 2004. The Institute extends its warmest congratulations to the recipients, its sincere thanks to all those who submitted nominations and its appreciation to the members of the ION® Awards Selection Committee who served so effectively in selecting the honorees.

Distinguished Service Award

Mr. Larry Hothem

In grateful recognition of his leadership and achievements on behalf of the Institute of Navigation.

Superior Achievement Award

Major Donald A. Aspden

For his meritorious achievements as MC-130P Navigator in Iraq combat operations and his innovations in developing and executing new, all-weather, low-level MC-130P navigation -procedures.

Dr. Samuel M. Burka Award

Dr. Donghyun Kim

For the paper with Prof. Richard B. Langley, "On Ultrahigh-Precision GPS Positioning and Navigation" published in the summer 2003 issue of NAVIGATION, The Journal of The Institute of Navigation, *Vol. 50, No. 2, pp. 103.*

Captain P.V.H. Weems Award

Mr. Karl L. Kovach

For extensive and continuous contributions to the development, operation, and utilization of GPS for the benefit of all users, military and civilian.

Tycho Brahe Award

Dr. John L. Junkins

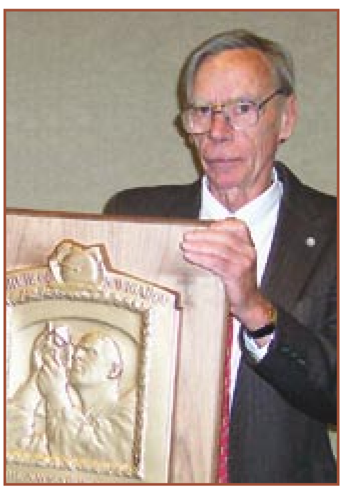
For significant contributions through research and teaching, to the fields of navigation, guidance and control, and for the invention of novel navigation sensors.

Norman P. Hays Award

Mr. Glen Gibbons

For service to the satellite navigation community through stewardship of GPS World *magazine.*

Thomas L. Thurlow Award



Dr. John G. Mark

For outstanding contributions to the advancement of navigation technology; in particular for the pioneering development and continuing improvement of strapdown inertial navigation systems.

Annual Award Nominations Encouraged

Members are encouraged to submit nominations for one or more of the following annual awards given by the Institute of Navigation for excellence in navigation.

- *Early Achievement Award*—for an individual early in his or her career who has made an outstanding achievement in the art and science of navigation.
- *Norman P. Hays Award*—for outstanding encouragement, inspiration and support leading to the advancement of navigation.
- *Superior Achievement Award*—for individuals making outstanding contributions to the advancement of navigation.
- *Thomas L. Thurlow Award*—for outstanding contributions to the science of navigation.
- *Tycho Brahe Award*—for outstanding achievement in space navigation.
- *Captain P.V.H. Weems Award*—for continuing contributions to the art and science of navigation.

Official nomination forms, along with brochures on the background and purpose of each award, are available from the ION National office by phone, 703-383-9688, or via the Web site at www.ion.org. Nominations must be received by February 21, 2005.

The awards and accompanying engraved bronze plaques will be presented at the ION's Annual Meeting, June 27–29, 2005, in Cambridge, Mass. The ION® urges you to participate in the nomination process so that a representative group of deserving individuals from the navigation community will receive appropriate recognition.

In addition to the above awards, the winner of the *Samuel M. Burka Award*—for outstanding achievement in the preparation of papers advancing navigation and space guidance—as chosen by the editorial panel of ION's journal, *NAVIGATION*, will be honored.

Address correspondence to Award Nomination Committee, The Institute of Navigation, 3975 University Drive, Suite 390, Fairfax, VA 22030, phone: 703-383-9688; fax: 703-383-9689; e-mail: membership@ion.org.

Kim and Langley Receive Prestigious ION Burka Award

At its National Technical Meeting in Dayton, Ohio, last week, The Institute of Navigation awarded GGE's Drs. Don Kim and Richard Langley the Burka Award for 2003. This award recognizes outstanding achievement in the preparation of papers contributing to the advancement of navigation and space guidance and is given for the best technical article appearing in *Navigation, the Journal of The Institute of Navigation* during the preceding year. Drs. Kim and Langley were recognized for their paper "On Ultrahigh-Precision GPS Positioning and Navigation" which appeared in the summer issue (Vol. 50, No. 2, pp. 103-116).

In their paper, Drs. Kim and Langley introduced an ultrahigh-performance GPS positioning and navigation system for gantry crane auto-steering. The system differs from conventional systems in terms of the positioning accuracy and precision it can achieve. A prototype of the system is in daily use at a large container terminal in Kwangyang Port, South Korea.

The award is given in memory of Dr. Samuel M. Burka, a dedicated American public servant who devoted a long and distinguished career to the research and development of air navigation equipment and reviewing technical material for official publications.

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On Ultrahigh-Precision GPS Positioning and Navigation

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Received September 2002; Revised June 2003

ABSTRACT: *This paper introduces an ultrahigh-performance GPS positioning and navigation system for gantry crane auto-steering. The system differs from conventional systems in terms of the achievable positioning accuracy and precision. Aside from ambiguity resolution and reliability, many error sources (such as phase wrap-up, antenna phase-center variation, instrumental group delay bias, receiver clock jumps, and residual tropospheric delay.) must be handled precisely to attain ultrahigh-precision positioning solutions. The paper also introduces an optimal interfrequency carrier-phase linear combination of the L1 and L2 measurements that can reduce the effects of quasirandom errors (that is, errors including significant low-frequency components and showing to some extent random behavior over relatively short intervals of time), such as multipath, diffraction, and ionospheric scintillation. A practical approach to estimating realistic receiver system noise is also introduced.*

INTRODUCTION

One of the many benefits of GPS is that it provides positioning solutions for a wide variety of users. By and large, there are two extreme kinds of GPS users — the traveler who is satisfied with positioning accuracies of a few tens of meters and the geodesist who struggles with those of a few millimeters. Such terms as "real-time," "kinematic," and "navigation" are usually associated with the traveler community of GPS users, while the geodesist community is generally familiar with such terms as "postprocessing," "static," and "positioning." Although they share the same GPS technology, the level of complexity of the hardware and software needed by these two kinds of GPS users is quite different.

Real-time kinematic (RTK) is a GPS technique pioneered by surveyors and geodesists for efficiently determining the coordinates of points with centimeter-level accuracy. GPS carrier-phase measurements must be used to attain the required positioning accuracies. Although the level of complexity of the hardware and software needed by the two kinds of GPS users is still quite different, this technique has gradually narrowed the distinctions between the two in terms of GPS applications. One good example is machine control using the RTK technique. Machine-control applications, such as a gantry crane auto-steering system, require positioning accuracies of better than a few centimeters with extremely high reliability in RTK mode.

The University of New Brunswick (UNB) has developed ultrahigh-performance GPS RTK software for gantry crane auto-steering. The UNB RTK system currently determines the position of the crane every 0.10 s (i.e., at a 10 Hz update rate commensurate with the dual-frequency data rate) with an accuracy of better than 2 cm and with extremely high reliability. Actually, there are two GPS receivers on each crane, so that the control computer on the crane can determine the crane's orientation as well as its position. This paper introduces new GPS technology for a gantry crane auto-steering system. Technical and scientific aspects of the system are discussed.

FUNDAMENTAL CONSIDERATIONS

One dilemma involved in developing a practical and fully operational RTK system is that correctly fixed ambiguities do not always guarantee positioning solutions with high precision at the level of a few centimeters because of errors in the carrier-phase measurements. One might be embarrassed by such a dilemma in real-world situations because in most GPS applications based on carrier-phase measurements, one's first interest is in resolving the integer carrier-phase ambiguities. Furthermore, one tends to believe that it is always possible to achieve positioning solutions with high precision at the level of a few centimeters once the ambiguities have been fixed correctly.

NAVIGATION: *Journal of The Institute of Navigation*
Vol. 50, No. 2, Summer 2003
Printed in the U.S.A.

APPENDIX B

To remove the nonrandom behavior of the observation time series, we use a differencing scheme in the time domain including the triple difference (TD; differencing consecutive double-difference observations after deleting cycle-slip spikes), quadruple difference (QD; differencing consecutive TD observations), and quintuple-difference (dQD; differencing consecutive QD observations). In this approach, we assume that the effects of any biases can be canceled in the differencing process, so that only the effect of observation noise (assumed as white noise) remains in the resulting time series. For example, consider the L1 carrier-phase dQD observable:

$$\dddot{\Phi}_1 = \dddot{\rho} + \dddot{s} + \dddot{\tau} - \dddot{I} + \dddot{b}_1 + \dddot{n}_1 + \dddot{\varepsilon}_1 \qquad \text{(B-1)}$$

where Φ_1 is the double-difference L1 observable; ρ is the geometric range; s is the satellite broadcast position error; τ is the tropospheric delay; I is the L1 ionospheric group delay; b_1 is multipath in the L1 carrier phase; n is the L1 ambiguities (in distance units); ε_1 is measurement noise of the L1 carrier phases (all double differentiated); and the notation "...." is the dQD operator. Using the one-dimensional Taylor series including higher-order time derivatives for each of the biases yields

$$S(t) = S(t_0) + S'(t_0)(t - t_0) + \frac{1}{2} S''(t_0)(t - t_0)^2 + \frac{1}{6} S'''(t_0)(t - t_0)^3 + R(t) \qquad \text{(B-2)}$$

where S represents each bias, and R is a remainder term known as the Lagrange remainder. Assuming that the observation time interval is $\delta(= t - t_0)$, we have the following dQD observable:

$$\begin{aligned} \dddot{S}(t_3) &= S(t_3) - 3 \cdot S(t_2) + 3 \cdot S(t_1) - S(t_0) \\ &= S'''(t_0)\delta^3 + \Sigma_R(t_3) \end{aligned} \qquad \text{(B-3)}$$

where $\Sigma_R(t_3)$ is the effect on dQD of the remainder R. Substituting equation (B-3) into equation (B-1) gives

$$\dddot{\Phi}_1(t_3) = \left[\sum_{\forall s} S'''(t_0)\right]\delta^3 + \sum_{\forall s}[\Sigma_R(t_3)] + \dddot{\varepsilon}_1(t_3) \qquad \text{(B-4)}$$

where

$$\sum_{\forall s} S'''(t_0) = [\rho''' + s''' + \tau''' - I''' + b_1''' + n_1'''](t_0) \qquad \text{(B-5)}$$

Equations (B-4) and (B-5) clearly show the relationship between the high-frequency components and the data rate in the differencing process. If the effects of the high-frequency components on the right-hand side of equation (B-5) are small enough to be ignored and/or the data rate ($1/\delta$) is high enough in equation (B-4), and if the effect of the second term on the right-hand side of equation (B-4) (i.e., the effect on dQD of the remainder R) is also small enough to be ignored, we can obtain the acceptable inference as

$$\dddot{\Phi}_1 \approx \dddot{\varepsilon}_1 \qquad \text{(B-6)}$$

As long as the differencing process satisfies equation (B-6), the fully populated variance-covariance matrix for the dQD observation noise $\dddot{\varepsilon}_1$ can easily be estimated using a number of dQD samples for each double-difference satellite pair time series:

$$\hat{\mathbf{Q}}_{\mathbf{dQD}} = \text{cov}\,[\mathbf{dQD}] \qquad \text{(B-7)}$$

where

$$\mathbf{dQD} = \begin{bmatrix} dQD_{1,1} & dQD_{1,2} & \cdots & dQD_{1,m} \\ dQD_{2,1} & dQD_{2,2} & \cdots & dQD_{2,m} \\ \vdots & \vdots & \ddots & \vdots \\ dQD_{n,1} & dQD_{n,2} & \cdots & dQD_{n,m} \end{bmatrix} \qquad \text{(B-8)}$$

and subscripts n and m stand for a sample number and a particular DD satellite pair time series number, respectively, and cov[·] is the variance-covariance operator. Since there exists a certain relationship between the original time series and the dQD time series as shown in equation (B-3), assuming that four consecutive L1 observations have the same variance, the fully populated variance-covariance matrix for the observation noise can also be estimated:

$$\hat{\mathbf{Q}}_{\mathbf{DD}} = \frac{1}{20}\hat{\mathbf{Q}}_{\mathbf{dQD}} \qquad \text{(B-9)}$$

Note that the size of samples should be determined to minimize bias in the estimates. In general, the larger the size of samples, the better the estimates will be.