

Japanese Aerospace Literature

This month: *The Global Positioning System*

A90-24408 Detection of a volcanic fracture opening in Japan using Global Positioning System measurements. SEIICHI SHIMADA, YUKIO FUJINAWA, SHOJI SEKIGUCHI, SHIRO OHMI, TAKAO EGUCHI et al., *Nature* (ISSN 0028-0836), Vol. 343, Feb. 15, 1990, pp. 631-633. 9 Refs.

Observations of crustal deformation associated with seismic swarm and sea-floor volcanic activity off the east coast of the Izu Peninsula, Japan, in July 1989, using a fixed-point GPS network are reported. These measurements are used to capture some rarely observed features of seismic and volcanic activity. GPS fixed-point measurements are used for the first time to follow the evolution with time of the crustal movements; such measurements provide a continuous uninterrupted record of deformation. The observations are supported by independent data from other sources, thus providing further evidence of the utility of the GPS.

A89-51305 In flight evaluation of GPS receiver using an aircraft with the stabilized video camera system. TAKAYUKI NISHI, *Proceedings of the 26th Aircraft Symposium*, Sendai, Japan, Oct. 19-21, 1988, (A89-51301 22-01). Tokyo, Japan Publications Trading Co., 1988, pp. 176-179.

This paper describes the result of the flight test for evaluation of the GPS receiver. A stabilized video camera reference system was installed on an aircraft (FA-300). Stabilized video camera reference system can be the system by which is estimated the accurate position of an aircraft for comparison with the position of the GPS receiver output. The accuracy of this reference system is approximately 20 m at an altitude of 3500 ft; this accuracy is superior to other reference system and provides enough value as reference of the GPS. The flight test of the GPS receiver was performed by using this reference system. As a result, the stabilized video camera reference system can be confirmed as an effective means for reference to the evaluating GPS.

A89-42790 Calibration of the delay time in the GMS/GPS time transfer receivers using portable reference receivers. TAKAO MORIKAWA, CHIHIRO MIKI, MAKOTO URATSUKA, EIJI KAWAI, MICHITO IMAE et al., *IEEE Transactions on Instrumentation and Measurement* (ISSN 0018-9456), Vol. 38, April 1989, pp. 661-664. 6 Refs.

The Communications Research Laboratory (CRL) of Japan and the National Measurement Laboratory (NML) of Australia have performed international time transfer using the Geostationary Meteorological Satellite (GMS) and the Global Positioning System (GPS) since 1986. The precision of the time transfer using GPS is 10 ns, while that using GMS is 20 ns. However, there has been a bias of 200 ns between the time transfer results of the two time links, which is mainly due to the estimation error of the delay time in the time transfer receivers. To improve this bias error, CRL developed a portable reference receiver (PRX) for the GMS time transfer to calibrate the delay time in the time transfer receivers. In November and December 1987, a calibration experiment was carried out by the PRX method for GMS and GPS between CRL and NML. As the result of the experiment, the bias was reduced from 200 to 75 ns and the accuracy of the time transfer between CRL and NML was significantly improved.

A89-42786 Development of GPS positioning system 'PRESTAR'. YUJI SUGIMOTO, NORIYUKI KURIHARA, HITOSHI KIUCHI, AKIHIRO KANEKO, FUMITAKE SAWADA et al., *IEEE Transactions on Instrumentation and Measurement* (ISSN 0018-9456), Vol. 38, April 1989, pp. 644-647. 9 Refs.

A precise relative positioning system using GPS, called PRESTAR, has been developed and is designed to give accurate relative position measurements, precise time synchronization, and precise orbit determinations. PRESTAR uses a high-gain beam antenna to obtain highly accurate range data through the high signal-to-noise (S/N) ratio of the received signal. It makes use of a beam antenna, necessitating a single channel sequential system. Its performance gives accurate relative position measurements, precise time synchronization, and precise orbit determinations have been demonstrated with a 55-km baseline experiment. Longer baseline positioning experiments and orbit determination experiments are being planned. The authors outline the PRESTAR system and some results of experiments.

A89-38203 Navigation, guidance and control subsystem of Space Flyer Unit. TOSHIMITSU NISHIMURA, YOSHIOKI KUBO, and TETSUO YAMAGUCHI, *Proceedings of the 16th International Symposium on Space Technology and Science*, Sapporo, Japan, May 22-27, 1988, Vol. 1 (A89-38031 16-12). Tokyo, AGNE Publishing, Inc., 1988, pp. 1299-1304.

The Space Flyer Unit (SFU), a small retrievable, reusable space platform, is reviewed, focusing on the development of the SFU navigation, guidance and control subsystem. The SFU configuration and operational sequence are described, and the requirements of the navigation, guidance, and control subsystem are listed. The subsystem components are discussed, including the Inertial Measurement Unit, the acquisition sun sensor, the pointing sun sensor, the GPS receiver, the reaction wheel and wheel drive, and the magnetic torquer. The operation of SFU in earth-pointing, sunpointing, and orbit control modes is examined. Also, consideration is given to the control modes, disturbance torques, stabilization of flexible solar arrays, and rendezvous strategy.

A89-38218 A precise position estimation of low-orbit satellites with least-square method using GPS signal. TOMOAKI ISHIFUJI, MINORU HIGASHIGUCHI, and KAZUO SHIMADA, *Proceedings of the 16th International Symposium on Space Technology and Science*, Sapporo, Japan, May 22-27, 1988, Vol. 1 (A89-38031 16-12). Tokyo, AGNE Publishing, Inc., 1988, pp. 1395-1400.

A method for making position estimates for low-orbit satellites using GPS signals and the least squares method is proposed. Simulations of typical low-orbit satellites are presented to demonstrate the duration of effective position estimation using more than 4 GPS satellites. The simulations are performed for a satellite at 500 km altitude and 30 deg inclination, 500 km altitude and 90 deg inclination, and 10,000 km altitude and 30 deg inclination. The results suggest that this method accurately calculates variations of satellite orbit parameters.

A89-38202 GPS-INS-STAR—A navigation system for the era of space autonomy. TORU TANABE, TOSHIKI KITAMURA, MASAYUKI IKEUCHI, TOSHIYUKI TANAKA, AKIRA AKASAKA et al., *Proceedings of the 16th International Symposium on Space Technology and Science*, Sapporo, Japan, May 22-27, 1988, Vol. 1 (A89-38031 16-12). Tokyo, AGNE Publishing, Inc., 1988, pp. 1293-1298.

Experimental validation of the GPS-INS-STAR hybrid navigation system concept is performed. First, an INS-STAR hybrid navigation system is constructed on the 3-axis motion table to verify the performance of its attitude loop. A GPS-INS hybrid navigation system is then installed on a car, and its translational performance is evaluated. Each result of the experiments is verified by theoretical analysis, and its feasibility for space application is evaluated. Through the experiments, the concept of the autonomous hybrid navigation is validated, and its potential in space autonomy is indicated.

A89-26745 Low cost multi-channel GPS receiver. RYOBUN TACHITA, KEN IKEDA, AKIO TERANISHI, JOHN H. PAINTER, and PHILIP S. NOE, *PLANS '88—IEEE Position Location and Navigation Symposium*, Orlando, FL, Nov. 29-Dec. 2, 1988, Record (A89-26701 10-17). New York, Institute of Electrical and Electronics Engineers, Inc., 1988, pp. 455-460.

An investigation was conducted on compact, multi-channel GPS (Global Positioning System) receivers. The code generator and correlation equipment were simplified, attempting to avoid downgrading the properties possessed by multi-channel receivers as much as possible, and the error-increasing factors caused by such modification were examined. As a means of simplifying the receiver hardware, phases with a unit of 1/8 chip were established in the code generator. Each channel was provided with a circuit for determining correlation, and the phase differences of the carrier and the code were measured by time division. It was confirmed that sufficient accuracy of measurement can be obtained even if such simplification is carried out.

A89-17770 Experimental validation of GPS-INS-STAR hybrid navigation system for space autonomy. TORU TANABE, MASATOSHI HARIGAE, and MASAYUKI IKEUCHI, IAF, 39th International Astronautical Congress, Bangalore, India, Oct. 8-15, 1988. 12 pp. 7 Refs., (IAF Paper 88-326).

The GPS-INS-STAR hybrid navigation system concept combines these three sensors using an error estimation filter. This paper presents the validation of the hybrid concept with experiments using three different configurations of GPS, INS, and STAR hardware: a INS-STAR hybrid system, a GPS-INS system, and a GPS-INS-STAR system. The results of the comparison of experimental results agreed with those of the theoretical analysis and confirmed the potential of the concept for space autonomy.

A88-16302 New integration scheme of GPS-INS hybrid navigation system for maneuvering spacecraft. T. TANABE, M. HARIGAE, and H. KOYAMA, *Automatic control in space 1985* (A88-16276 04-18). Oxford and New York, Pergamon Press, 1986, pp. 211-217. 5 Refs.

Integration schemes of the GPS with INS are considered. In the conventional navigation scheme, information from INS is usually used in the form of velocity-aiding signal to the receiver-tracking loops. In this paper, a new integration scheme is proposed which performs more effective information exchange so that it is more tolerant to RF interferences and unmodeled INS errors than the conventional scheme. These results are obtained from theoretical analyses and confirmed by computer simulations including GPS receiver dynamics.

A88-13092 International time transfers via GPS. KAZUYUKI YOSHIMURA, MAKOTO URAZUKA, MICHITO IMAE, CHIHIRO MIKI, TAKAO MORIKAWA et al., *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, No. 396, 1987, pp. 43-50. 26 Refs.

The principles and methods for international time transfer via the GPS are described along with the calibration technique and the design and efficiency of the GPS receiver. The characteristics of precision time transfer by direct and indirect methods are compared. Calibration techniques for delays by the atmosphere and the ionosphere are considered with reference to the precision of frequency and time transfer.

A88-13094 Flight test results for a GPS receiver in a helicopter and a business aircraft. TOSHIMICHI OKITA and AKIRA IGA, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, No. 396, 1987, pp. 57-62. 7 Refs.

Flight test results for the four-channel GPS receiver in helicopters and turboprop business aircraft are reported. No effect of the helicopter rotary wing on the GPS receiver was observed. A block diagram of the receiver is presented.

A88-13093 GPS receivers for air navigation. CHOGO SEKINE, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, No. 396, 1987, pp. 51-56.

The paper describes the design and characteristics of the GPS receiver for air navigation using the C/A code. Various functions of the GPS receiver are considered, including the singlechannel sequence, the high-speed single-channel sequence, and the five-channel sequence.

A88-13091 A clock error analysis of the GPS system. MICHITAKA KOSAKA, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, No. 396, 1987, pp. 37-43. 10 Refs.

The random clock error (RCE) for the atomic clock in the GPS is analyzed, and the calibration accuracy of the clock error is characterized using a polynomial model. A higher spectral density of the RCE is obtained for rubidium than for cesium. Expressions for the white noise, flicker noise, and integrated white noise for cesium and rubidium are presented.

A88-13090 GPS/INS hybrid navigation for aircraft. NAOHIRO YAMASHITA and HIROSHI KIJIMA, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, No. 396, 1987, pp. 29-36. 7 Refs.

The efficiency of the GPS/INS hybrid navigation system is evaluated by computer simulation. In the GPS the error was found to increase with maneuvering of the aircraft, while in the INS the error was found to increase with time. Future prospects for the hybrid system are assessed.

A88-13089 GPS application in space. MASAAKI MURATA, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, No. 396, 1987, pp. 22-29. 13 Refs.

The application of the GPS for space navigation is discussed. The characteristics of Landsat-D/GPS are examined, and GPS is considered with reference to the DMSP and MILSTAR. The advantages of direct satellite tracking techniques are noted.

A88-22605 Evaluation method of polynomial models' prediction performance for random clock error. MICHITAKA KOSAKA, *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090), Vol. 10, Nov.-Dec. 1987, pp. 523-527. 5 Refs.

In satellite navigation systems such as the Global Positioning System, clock error is one of the major sources of error in precise pointing. In order to remove clock error, it is modeled as a second-order polynomial and the

clock-error correction parameters are sent to users. However, a random clock error cannot be modeled as a second-order polynomial. Therefore, the time discrepancies due to random clock error must be taken into consideration for precise pointing. This paper proposes an analytical computation method for estimating the random clock error in the current system which makes use of the Allan variance characteristics of random clock error without random clock realization and a lot of simulation studies. Moreover, a numerical example based on the proposed method shows that the first-order polynomial model is better for predicting a random clock error than the second-order polynomial.

A88-13088 Civil aviation application of the Global Positioning System (GPS) and its issues. KOICHI KIMURA, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, No. 396, 1987, pp. 15-21. 17 Refs.

Recent trends in the utilization of the GPS for civil aviation are reviewed. Attention is given to GPS precision, the user equivalent range, and the probable error. The relationship between satellite radioposition determination and the GPS is examined.

A88-13087 A hybrid navigation system with GPS. TORU TANABE, MASATOSHI HARIGAE, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, No. 396, 1987, pp. 8-14. 15 Refs.

The design, characteristics, and performance of a hybrid navigation system using the GPS are described. The designs of the GPS-INS, GPS-STAR, and GPS-INS-STAR systems are discussed and compared. The performance of the GPS receiver with a digital signal processor is examined.

A88-13086 An overview of space and aircraft navigation. TATSUKICHI KOSHIO, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, No. 396, 1987, pp. 2-8. 12 Refs.

Recent developments connected with the utilization of navigation satellites for the GPS and for air traffic control are reviewed. Consideration is given to the airspace management system and to the operating principles of STAR GPS. The future prospects of navigation satellites are assessed.

A87-52974 Analysis of the geometric dilution of precision using the eigenvalue approach. MICHITAKA KOSAKA, *Journal of Guidance, Control, and Dynamics* (ISSN 0731-5090), Vol. 10, Sept.-Oct. 1987, pp. 509-512.

Geometric dilution of precision (GDOP) has been considered as a criterion for the selection of GPS satellites. The benefit of the eigenvalue approach is that the relationship between GDOP and observation directions can be expressed explicitly. In the present paper, this benefit is used to propose a novel geometric interpretation of GDOP by using an eigenvalue approach. Based on this interpretation, two simple methods of selecting GPS satellites are derived which do not need matrix inversion calculations.