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A Study on the Obtaining Navigation and Geo-Spatial Information Using WADGPS

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Abstract

Recently, a lot of interest focuses on DGPS with which it is possible to obtain 3D geographic information in real time. There are some methods to transmit corrected signals which use ground based systems as beacon, as well as wireless and TV broadcasting media. However, these methods require a large number of stations. Therefore, when the distance from station to user is increased, there is a range limit to the transmission of corrected signals. In order to solve these problems, WADGPS method using Geo-satellite is being investigated. In this study, static and kinematic tests were performed by using Satloc SLX WADGPS and Ashtech receivers. The results showed that SA was affected most among corrected signals of WADGPS; it was followed by ionospheric delay, tropospheric delay and satellite orbit errors. The accuracy of static observation was approx. ±1m on SA-on. This was ten times as accurate as that of absolute observation by common receiver on SA-off. In the SA-off, the accuracy of WADGPS can be improved further. The result of kinematic tests by WADGPS acted in concert with that of standard DGPS by C/A code. It was concluded that the application of WADGPS could improve considerably navigation and the construction of geographic information.

Keywords : *Navigation, WADGPS, GPS, DGPS*

1. Introduction

As a SBPS (Satellite-Based Positioning System), GPS of the United States and GLONASS of Russia are currently in operation, and Galileo of the European Union is under active development with a timetable of its full operation system by 2008 (C. Kee et al 1999, R. Lucas et al 1999, V. Ashkenazi et al, 1998). GPS is being researched and developed which is classified into Static GPS, Kinematic GPS and DGPS method according to a survey method, and into post-processing and Real-time processing according to a processing time of received data, but a recent trend is that the usefulness of Mapping/GIS and DGPS survey method in the field of navigation has been emphasized with their characteristic that a location measurement of relatively high precision is possible in a short time by removing errors of the same attribute included in a satellite signals between GPS satellite and a user (E. Kaplan, 1996, B. Pakinson et al 1996). Especially, because a database building of topography requires fast, precise and at the same time economic state-of-the-art techniques, demand for DGPS survey method will increase by degrees, and detailed researches are being continuously conducted to get accurate understanding and more improved results of DGPS survey method.

On the other hand, companies like OmniSTAR, Satloc, DCI are already providing commercial DGPS service worldwide using the medium of Geosynchronous Satellite and ground base stations (M. Whitehead et al 1998) and, with the importance of GNSS (Global Navigation Satellite System) being recently highlighted from enhanced safety of international private airlines, Satellite-Based Augmentation System is briskly being carried out by WAAS and LAAS of Federal Aviation Administration, MSAS of Japan, and EGNOS of Europe (R. Farnworth et al

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1998, J. Nieto 1999, R. Braff 1998, M. Abousalem 1997). Particularly, though the annulment of SA policy on GPS by the American government has brought huge benefits to transportation, first-aid treatment, resource exploration, recreation, tracking of various satellites, and time synchronization, DGPS technique is still of absolute necessity to the same extent as before the SA annulment in the fields such as survey, various navigation, precise farming, and resource exploration which all require precision.

Recently, Korea also set up 30 GPS permanent stations at an interval of 50 to 60 kilometers throughout the nation under the charge of local autonomous administrations, which, along with the existing internationally-certified GPS observatories, has laid the foundation for a national DGPS service, and thus DGPS application is increasing domestically and internationally.

2. Purpose and Method of the Study

Acquisition of topographical information should be based on fast, precise and also economic state-of-the-art techniques. The recent DGPS survey method is a positioning method based on various error correction of GPS satellites and, along with GLONASS and future Galileo system, is surfacing as a core of GNSS (Global Navigation Satellite System) as well as of precise positioning. So, in this study, I focused on applying various DGPS survey methods to navigation and acquisition of topographical information and then on examining their usefulness, for which, I first established the interpretational algorithm of absolute positioning and standard DGPS positioning, wrote a post standard DGPS program by Navigation solution, Pseudorange, and Carrier-Smoothing of Pseudorange and applied it to a test model, and then examined each interpreted result according to C/A-code Smoothing of absolute positioning, standard DGPS, and L1 Carrier using C/A code, and compared it with the result by Prism of Ashtech Company which is an existing commercial S/W. I examined, among SBASs that use as a medium stationary satellites which has recently been highlighted, especially WADGPS operating system of Satloc company which is providing WADGPS service using L-band communication satellite to the entire U.S. and part of Canada and South Africa, applied SLX receiver which can receive WADGPS correction signals and GPS signals simultaneously to a test model, and compared the result with the previous interpreted results.

Also, I intend to investigate the accuracy of absolute positioning by the Navigation solution and SLX receiver before and after SA annulment and examine the usefulness of various DGPS methods, and thus to energize the future national-level DGPS building.

3. Navigation Interpretation and Standard DGPS Algorithm

I set up the maximum application range of one cycle receiver to be an applying range of the program written for this study and made MATLAB after building basic algorithm for each interpretational method as seen below. I replaced detailed step-by-step interpretational algorithm below with documents for reference (G. Strang et al, 1997). In this study, I mainly described real-time Wide Area DGPS operating system by Satloc.

Navigation solution

It calculates satellite coordinates for each Epoch by applying Kepler's 16 orbit factors and correcting Sagnac effects, calculates Topocentric distance between a satellite and a receiver by means of error correction of the receiver's clock error included in Pseudorange and of iono- and tropo-delay, then forms an observation equation about Topocentric distance for each Epoch, and finally calculates the absolute location of the GPS receiver.

Post Standard DGPS solution

It calculates Pseudorange of each satellite from satellite coordinates calculated by correcting Kepler's 16 orbit factors and Sagnac effects at a reference station and from the reference station's coordinates that were exactly determined previously, and then calculates Pseudorange correction value on each satellite by calculating a distance gap with received Pseudorange. After calculating coordinates of each satellite at a mobile station in a previous way, it applies correction value of each satellite calculated at the reference station to received Pseudorange of each satellite and calculates three-dimensional coordinates of a receiver of the mobile station for each Epoch.

Carrier Smoothing Solution of Pseudorange

It applies to the 3-2 interpretational method the Carrier-smoothed Pseudorange value which was smoothed with Carrier by applying Pseudorange measurement value to Complementary Kalman Filter. The interpretation by smoothing, especially, has an advantage of considerably dissolving Multipath effects which are not eliminated by standard DGPS interpretation.

Satloc's WADGPS System

Satloc has provided WADGPS commercial correction service with RMS accuracy of horizontal and vertical components being 0.6 m and 1.2 m respectively to the entire U. S., Canada, and Mexico since May, 1997. The root of correction value is based on 15 observation networks set up throughout the U. S. as a 2 cycle Ashtech Z-II GPS receiver, and each observatory sends GPS observation data received at every second to 2 NCCs (Network Control Center, Reston VA, Scottsdale, AZ) through TCP/IP protocol Frame-relay communication links. The NCC processes data on Pentium-PC Network operated on Win-NT and calculates WADGPS correction value. This correction value, after being constructed as 750 bps data message and viterbi-encoded as 1500 bps data stream, is sent to L-band communication satellite of AMSC, and again, as Spot beam which has 3 overlapping parts, sent to the entire United States, southern Canada, and northern regions of Mexico.

Because the WADGPS applying experiment in this study was carried out before May 2nd in 2000, that is, before SA annulment, particularly WADGPS correction part about accuracy δ-process of satellite clock among SA error factors is emphasized. The Fast Clock Filter of Satloc is somewhat different from RTG clock filter developed by JPL in its method of approach where it first algebraically calculates receiver clock error and then calculates tropo-delay and satellite clock error simultaneously using Kalman filter.

In other words, Clock filter calculates SAmeas between Carrier-smoothed Pseudorange and a real distance from a receiver to a satellite which is calculated in consideration of ionosphere delay, satellite clock error, receiver clock error, and tropo-delay correction for each satellite observation value by the formula (1).

$$\begin{aligned} SAmeas = &\ True\_Range - PseudoRange - SV\_clock \\ &+ Receiver\_clock + Modeled\_Tropo \\ &+ Iono\_Delay \end{aligned} \qquad (1)$$

Here, the tropo-delay correction uses Niell Mapping Function. Detailed step-by-step contents of the core algorithm are replaced by documents for reference. And, although WADGPS base coordinate system is adopting ITRF94 coordinates, it is being used without any problem in terms of its practicalness, for the differences between ITRF94 coordinates and WGS84 coordinates coincide within WGS84 coordinates' own error.

SLX DGPS receiver, a combined type of GPS receiver and L-band receiver which is used to receive correction signals, receives WADGPS correction value signals and GPS signals simultaneously through one antenna, and GPS data are processed by built-in GPS receiver and WADGPS correction signals by L-band receiver. L-band receiver and GPS receiver are connected by serial port in the form of standard NMEA and RTCM message. L-band receiver S/W reorganizes State-space data transferred from AMSC satellite and user location information calculated by GPS receiver to Differential correction value which can be applied to a receiver. Especially, RTCM SC-104 type 1 is used to transfer WADGPS correction value to GPS receiver, in consideration of compatibility with other receivers, and it includes Zcount, PRCs (Pseudorange corrections), RRCs (Range rate corrections) and IODEs (Issue of data ephemeris) values.

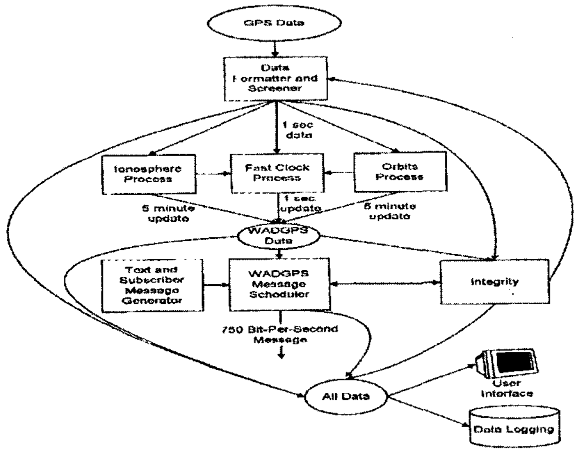

Fig. 1. The flow cart of Satloc's WADGPS correction signal.

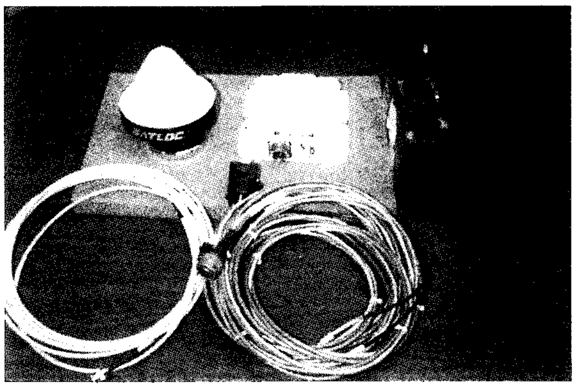

Fig. 2. Satloc's Real-Time SLX WADGPS antenna and receiver.

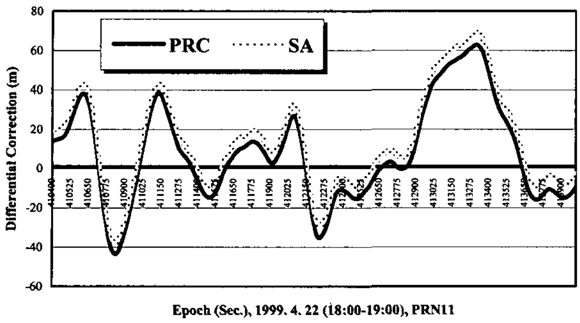

Fig. 3. Satloc's Real-Time SLX WADGPS antenna and receiver.

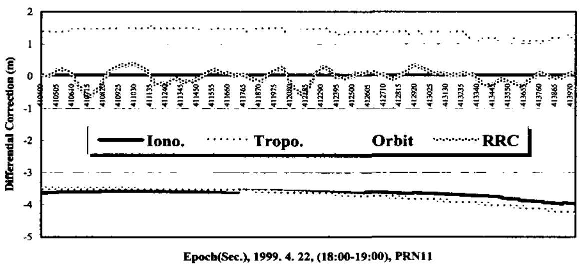

Fig. 4. Ionosphere, troposphere, orbit and RRC from Satloc's WADGPS correction signals information.

Figure 2 shows Real-Time SLX WADGPS antenna and receiver and Figure 3 illustrates correction value for SA and PRC out of one-hour correction data before SA annulment. Figure 4, especially, illustrates the result of analyzing ionosphere, troposphere, satellite orbit information, and RRC correction value out of correction information, at an interval of Epoch = 1 second, and it was revealed that SA is the factor that influences the most real-time WADGPS correction value and the next are in order of iono-delay, tropo-delay, and accuracy of satellite orbit power. Currently Satloc's service system is being effectively utilized for Aerial guidance for agricultural or other applications in the whole U. S. and part of Canada and South America, and for ground equipment Guidance, survey, and various GIS building.

4. Experiment and Interpretation

The site of the test model selected in order to examine the usefulness of absolute positioning and DGPS program which are written in this study and of WADGPS is Morse Field football ground in Harold Alfond Stadium of University of Maine Campus in downtown OldTown, Me., in the U. S., as shown on the upper left of Figure 5.

The distance between the lines in the football ground,

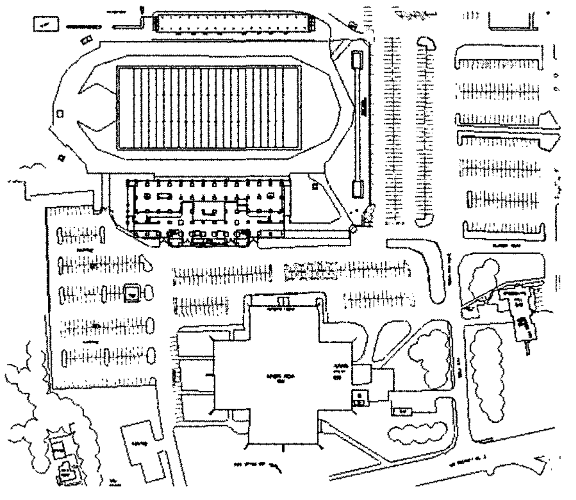

Fig. 5. Test Model.

20 lines in total, was 5 yards and the distance between the right and left goalposts from a datum of the starting point and the finishing point of vertical lines was 10 yards. Navigation Solution using C/A code and DGPS interpretational program by Carrier Code Smoothing and standard DGPS were written using MATLAB S/W respectively according to basic algorithm. Tracking Data for the distance line and the grid line in the football ground was acquired as each separate session using Ashtech's Z-II receiver and Satloc's SLX WADGPS receiver.

In tracking experiment by Ashtech receiver, the interval of saving signals was set for 2 seconds because of the limit of internal memory capacity of the receiver, and I moved on a straight course at a normal walking pace and, on a border part or at a turning point, proceeded after stopping for 5 second, as seen at Figure 6. In case of SLX receiver, coordinates were calculated at every second because WADGPS correction signals were renewed basically at every second, and each antenna of the two receivers used the same pole and an altitude was calculated correcting the height of the antennas. I extracted each C/A code pseudorange and L1 carrier for seven satellites (SV = 4, 5, 10, 13, 18, 24, 30), for which Cycle slip does not occur from the received data of each satellite acquired by Ashtech receiver, unlike other satellites at the same altitude of more than 30 degree for which Cycle slip is possible due to stands and roof structures that are set up on the south of the Stadium, and used the data as input data for Navigation Solution, standard DGPS, and Code Smoothing of Carrier, and then calculated the result of three-dimensional Tracking. Also, I analyzed the result of real-time Tracking test about the distance line and the grid line in the football ground using Satloc's SLX DGPS receiver, and compared and examined each interpreted result on the basis of the result processed by Ashtech's Prism, a commercial S/W.

Figure 6 is the look of the Track of the football ground calculated by Navigation Solution program and Figure 7 and 8 are the results of standard DGPS by C/A code and Smoothing DGPS of C/A code by L1 carrier respectively. The results by Ashtech's Prism S/W are shown at Figure 9 and 10 each. While the result of C/A single positioning Tracking at Figure 6 is that the shape of Stadium is almost impossible to make out due to error of correction model, and Noise, the result of standard DGPS using C/A code at Figure 7 shows it was able to calculate tracks better than the commercial program at Figure 9 does. According to the DGPS interpreted result by C/A code L1 smoothing at Figure 8, it is reproducing the more lifelike look of the Stadium compared to the DGPS result only by C/A code, and showed tracks which correspond with the interpreted result by Prism at Figure 10.

Especially, in order to compare each interpreted result by absolute positioning using C/A code, standard DGPS, and C/A-code Smoothing of L1 Carrier written

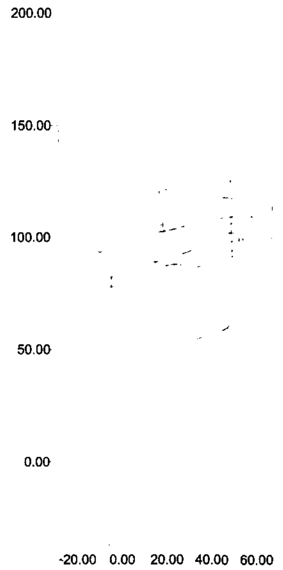

Fig. 6. C/A Single Positioning

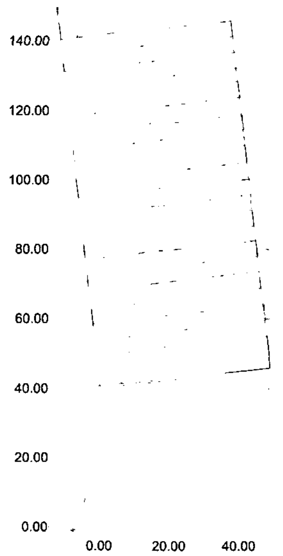

Fig. 7. C/A-DGPS

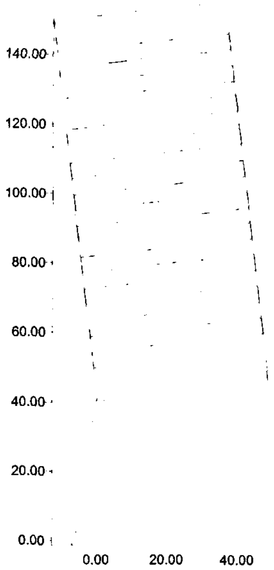

Fig. 8. C/A-L1 : DGPS

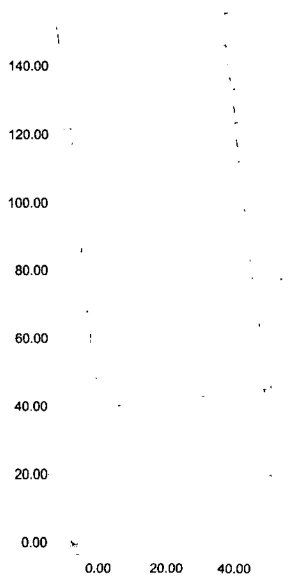

Fig. 9. C/A-DGPS (Prism)

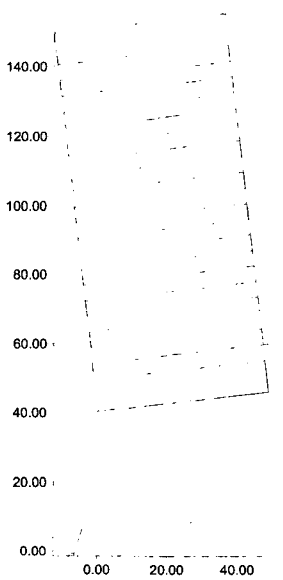

Fig. 10. C/A-L1sm (Prism)

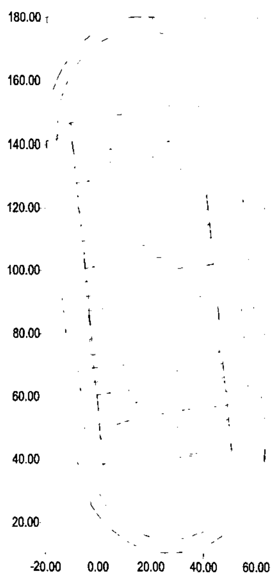

Fig. 11. SLX WADGPS

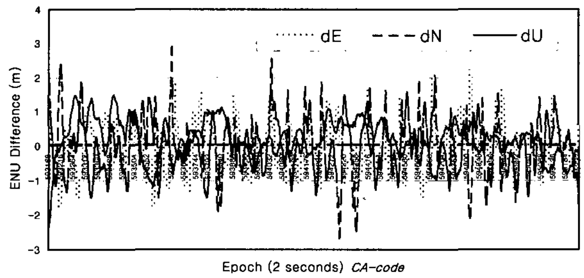

Fig. 12. E, N, and U Deviation from Prism S/W (CA only).

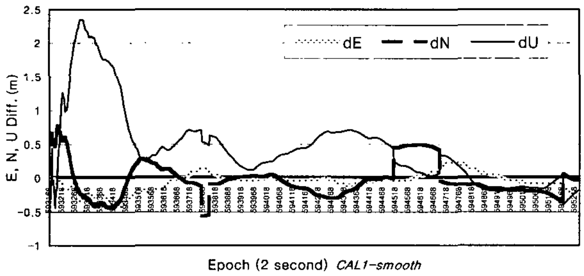

Fig. 13. E, N, and U deviation from Prism S/W (C/A-L1 sm).

in this study with the result by Ashtech's Prism which is an existing commercial S/W, I compared and examined the results of Figure 7 and 8 on the basis of the interpreted result of Figure 10 in the directions of E, N, and U for each Epoch. Figure 12 shows the deviation of E, N, and U directions in case of DGPS using only C/A Code, and the average deviation of the three directional components was within ±1 m.

Figure 13 shows coordinate deviation for each Epoch of DGPS result which was Smoothing processed complementing C/A Code with L1 Carrier, which, showing ±0.5 m average deviation except the earlier Up direction deviation, reveals that it, when Smoothing processed, produces remarkably better results than when Code is simply used, and especially I was able not only to verify the reliability of the S/W written in this study but also to confirm the usefulness of DGPS.

Figure 11 shows the result of tracing the football ground and adjacent tracks simultaneously by SLX WADGPS receiver. Though, in an experiment by SLX receiver, direct comparison for each Epoch is impossible because it is not done simultaneously with Ashtech receiver, it shows tracks similar to standard DGPS result (Figure 7) by C/A code written in this study.

For testing the accuracy of Satloc-WADGPS, we examined the accuracy of the absolute positioning by Ashtech receiver and SLX receiver (Figure 14, 15). The results of point positioning using Ashtech

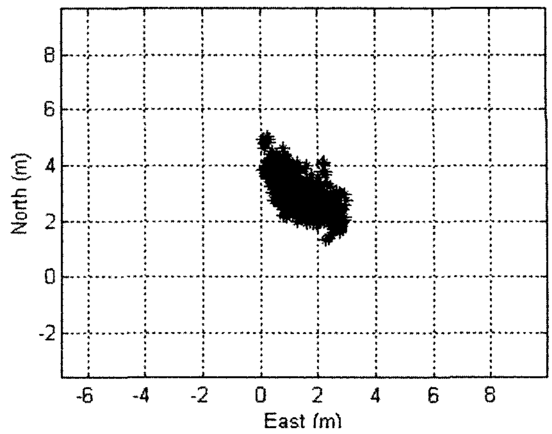

Fig. 14. Point Positioning (2D-plot Ashtech).

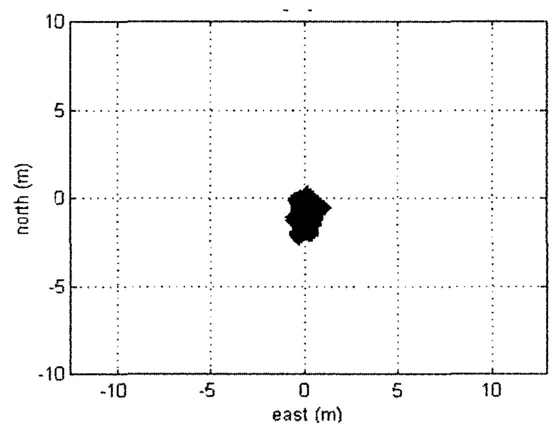

Fig. 15. Point Positioning of SLX WADGPS.

receiver was ±2 m and SLX WADGPS was ±0.6 m.

So, I could find that WADGPS is appropriate for a speedy topographical information building that does not require a high degree of accuracy, and that it can be utilized very effectively particularly in the ground, maritime and aerial navigation field.

5. Conclusion

After writing out an interpretational program of absolute positioning and DGPS method, applying it to a test model, and then comparing the result with the interpreted result of WADGPS and Prism S/W and examining it, I draw the following conclusion.

1. From interpreting the results after analyzing algorithm of absolute positioning, standard DGPS and Smoothing DGPS method and drawing up programs for each of them then applying them to a test model, I could get results that correspond to a commercial S/W.

2. The DGPS interpretation result by L1 smoothed

C/A code presented better Tracking result than the DGPS result by C/A code, because it was able to correct even the influence of Multipath.

3. The real-time WADGPS interpretation result about this test model presented the Tracking results which correspond to standard DGPS results by C/A code, and WADGPS will be able to be utilized in the field of navigational topographical information building.

Reference

1. Bradford W. Parkinson, James J. Spilker Jr. (1996). Global Positioning System : Theory and Applications Volume I, II.
2. Changdon Kee and Chulsoo Pyong, (1999). A Solution of a Natural Way to Implement WADGPS in East Asia : Decentralized WADGPS. ION GPS '99:211-220.
3. Elliott D.Kaplan (1996). Understanding GPS Principles and Application. Artech House.
4. Gilbert Strang, Kai Borre (1997). Linear Algebra, Geodesy, and GPS. Wellesley Cambridge Press.
5. Jorge Nieto, Joaquin Cosmen, Ignacio Garcia (1999). Interoperability Test Analysis between EGNOS and MSAS SBAS Systems. ION GPS '99:221-231.
6. Michael L.Whitehead, Gary Penno, Walter J.Feller, and Ivan C.Messinger (1998). A Close Look at Satloc's Real-Time WADGPS System. GPS Solutions, 2(2):46-63.
7. Mohamed A.Abousalem (1997b). Performance Overview of Two WADGPS Algorithm. GPS World:48-58.
8. R. Lucas, Daniel Ludwig (1999). GALILEO : System Requirements and Architectures. ION GPS'99:2097-2101.
9. Rick Farnworth, Edward Breeuwer and Andrew Watt (1998). EGNOS Operational Test and Validation for Civil navigation - User Requirements - ION GPS '98:147-155.
10. Ronald Braff (1998). Description of the FAA's Local Area Augmentation System (LAAS). Journal of Navigation, 44(4):411-423.
11. V Ashkenazi, G Hein, D Levy, P Campagne (1998). GNSS SAGE : SATNAV Advisory Group of Experts. ION GPS '98:1097-1101.