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Current DGPS Techniques and Flight Applications

Mohd Meraj Uddin[1], Dr. Shah Aqueel Ahmed[2]

Research Scholar, Mewar University, Rajasthan[1]

Principal, M.M.A.N.T.C., Malegaon, Maharashtra & Research Supervisor, Mewar University, Rajasthan[2]

Abstract: This paper provides a summarisation of current DGPS techniques in flight applications. Differential GPS (DGPS) was meant for the needs of positioning and distance-measuring applications which is essential for higher accuracies which stand-alone Precise Positioning Service (PPS) or Standard Positioning Service (SPS) GPS could not deliver. This paper elaborates the characteristics of various DGPS systems and comparison of their strengths and weaknesses in flight applications.

Keywords: Differential GPS (DGPS), flight applications

I. INTRODUCTION

In comparison to the long and medium range at present, higher correctness can be given by the Satellite navigation system. There are a lot of various methods which are built that can give precision which are as good as the landing systems at present, as far as GPS is concerned. Providing the review of present DGPS methods and flight functions is the objective of this paper. To match the requirements of locating and distance-measuring functions which need the exactness at above par level in comparison to stand-alone Precise Positioning Service (PPS) or Standard Positioning Service (SPS) GPS's ability to provide, Differential GPS (DGPS) was created. There is usage of control or reference receiver in DGPS at an identified position so systematic GPS blunders can be calculated and with the help of the benefit of spatial correlation of blunders, those blunders can be eliminated from the calculation taken by moving or the remote receivers which were situated in same locality. Diversity of executions has been defined so the DGPS system can be impacted. The objective here is to distinguish different DGPS systems and then make a comparison in their fortes and flaws in the flight applications. There are two general groups of differential GPS systems which can be recognized: Ones which depend mainly on code calculations and ones which depend mainly on carrier phase calculations. Much precise exactness is acquired with the help of carrier phase but solution has to face integer vagueness and cycle slips. Just when cycle slip arises, it should be fixed and integer vagueness should be measured again. Pseudo range solution is comparatively strong but has low accuracy i.e. 2m to 5m. It never faces the cycle clips and thus no reinitialisation is required there.

II. DGPS CONCEPT

In the Figure 1-1, DGPS architecture can be seen where the system comprises of a Reference Receiver (RR) which is situation at an identified position which was examined in the past and one or more than one DGPS User Receivers (UR) are involved too. Reference Station (RS) is the term given to the combination of RR antenna, differential correction processing system and data link equipment. UR (mobile receivers) makes use of the calculations from RR so the basic blunders can be eliminated. If this is to be achieved then the UR should employ a subset or same set of satellites as reference station at the same time. To abandon the basic blunders, DGPS positioning equations are put into words. Signal path deferrals via air, satellite clock and ephemeris blunders are few of the basic blunders. Common satellite blunders are left over system blunders, for PPS users, which are usually situated in PVT (Position, Velocity and Time). For SPS Users, Common satellite blunders which are usually impacted by larger Ionospheric propagation blunders than SPS comprised of purposely added blunders from Selective Availability (SA) which are eliminated from US-DOD policy at present. The blunders which are distinctive to every receiver like receiver calculation noise and multipath cannot be eliminated without extra recursive processing so the average, leveled or clean solution can be obtained [1].
Use of different DGPS methods is made where data generating will be done, subjected to the exactness anticipated. If the outcomes needed are real-time outcomes then there is a need of data link. Data can be gathered and generated afterwards for the applications which do not have a real-time requirement. Accuracy requirements normally determine about the calculations and algorithms made in use. At the moment SA was on, real-time PPS DGPS comprised of a lower data rate in comparison to SPS DGPS as rate of change of nominal system blunders was not faster than rate of change in SA. User and Reference Station should be making use of similar service, PPS or SPS, in any situation.

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As parameters are not impacted by propagation of signal or distance to (or) from satellite, clock and frequency biases for a specific satellite would look similar to every user. Satellite clock and frequency bias will be common error elements for the Pseudo-range and delta-range calculations and they will not be similar to the users as they are situated at different positions and will comprise of relative velocities of satellites. Signal propagation deferral is actually a basic blunder for the receivers who are situated in one position but the blunder slowly de-correlates and converts into being liberated as distance between receivers elevates. In all the three scopes of satellite ephemeris, there are blunders. Because of that, some portion of blunder would look as a common range blunder while some portion will stay a left over ephemeris blunder. The part which is left over is usually tiny in size and does not affect much for the same observation angles to satellite.

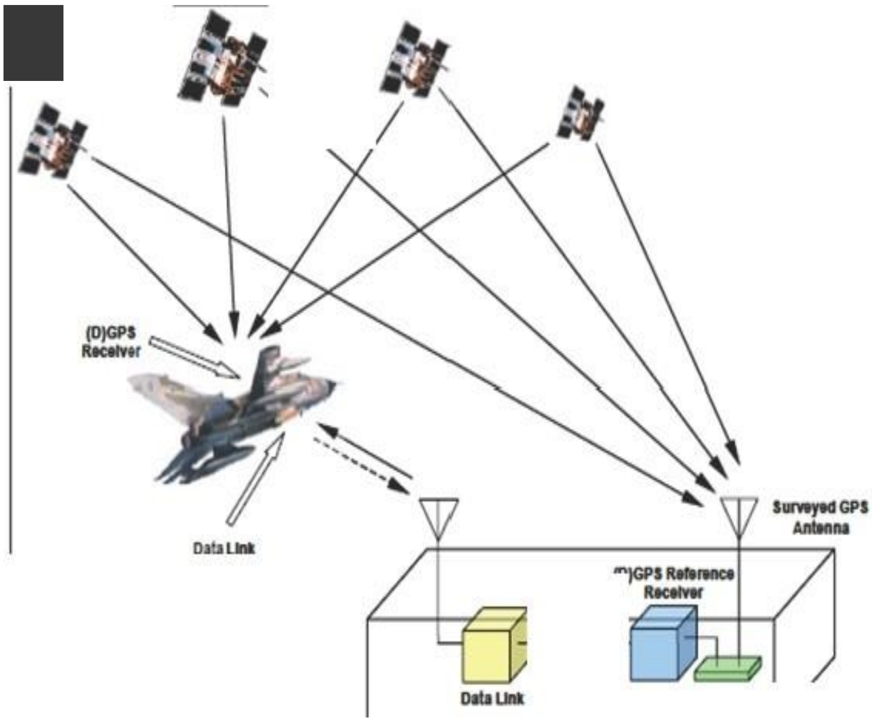

Figure 1: Typical DGPS Architecture

Radio Technical Commission for Maritime Services (RTCM) Special Committee-104 built the approved standard for SPS DGPS [2, 3]. Standards are mainly planned for the real-time functional usage and cover a broad extent of DGPS calculations. Many of the SPS DGPS receivers are well-matched with RTCM SC– 104 differential message formats. Radio Technical Commission for Aeronautics (RTCA) have created DGPZS standards as well for the special Category-I (CAT – I) accuracy method with the use of range-code differential. RTCA document DO-217 comprises of the standards and the document is planned just for the limited usage till the time an international standard is built for accuracy method [4].

III. DGPS IMPLEMENTATION TYPES

Two main variants of differential calculations and equations are there and one of them is on the basis of ranging-code calculations whereas other is on the basis of carrier-phase calculations. Various methods are also there to execute data link feature. DGPS systems can be developed so they can help in restricted region from one reference station or can make usage of a network of different reference stations and special design algorithms so cogency of DGPS method over a broad region can be expanded. Outcome shows that too many variations of possible DGPS system executions are there which make use of combinations of such design functions.

Ranging-Code Differential GPS: To measure psedorange or position corrections for UR, ranging-code differential method makes use of pseudorange calculations of RS. RS measures pseudorange corrections for every satellite which can be seen by removing true extent measured by examined location and identified orbit parameters from calculated pseudorange. After that, suitable correction for every satellite is chosen by UR receiver which it traces and then the correction which is calculated is removed from pseudorange. Corrections are just calculated by removing calculated location from examined location if RS gives location corrections instead of pseudorange corrections. Easiness of measurements is the benefit of making use of location corrections. There is a minus point too which is that the

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reference and user receivers should make use of the similar set of satellites which may be achieved by organizing the selection of satellites between Reference Receiver and User Receiver or by having Reference Station calculate a location correction for every the combinations of various satellites. Because of all this it is supple and well-organized so it can give pseudorange corrections instead of location corrections. RTCM SC- 104, NATO STANAG 4392 and RTCA DO-217 formats are on the basis of pseudorange instead of location corrections. The Rate of change of corrections is measured too in real-time systems which make it easy for user to spread corrections to the time where they are made use of to the user position solution and that lessens the effect of data inactivity on exactness of system but never removes it completely. After nearly 2minutes, SPS corrections turn into completely uncorrelated SPS corrections with user calculations. The corrections which are implied after 2 minutes might generate the solutions that are not more exact than stand-alone SPS GPS. For 10 minutes or more under the slow transformation ionospheric situations, PPS corrections can stay correlated with user calculations. Post-mission and real time dispensation are two methods of pseudorange data dispensation. There is a benefit of choosing post-mission solution over real-time which is that it gives more precise outcomes as user can look for the errors with ease and evaluates the leftovers of solution. There is a minus point of post-mission solution too which is that the outcomes do not arrive at that point only, it takes time. Double difference pseudorange is usual algorithm of ranging-code DGPS post-processed solution. Below are mathematical models for single and double difference observables which are being created.

a. Single Difference between Receivers

Possible pseudo range calculations between two receivers (k. l) and two satellites (p, q) are displayed in Figure 1.2. Satellite clock and Satellite orbit blunders will be eliminated if pseudorange 1 and 2 are differenced. SA will be lessened too and will be eliminated entirely if signals conveyed to every receiver are produced at same time. Leftover blunder from the SA is not the issue for post-processed positioning but it can be easily made sure that differencing is done between pseudoranges detected at same time [5]. If there are atmospheric blunders, they would be decreased remarkably with single differencing.

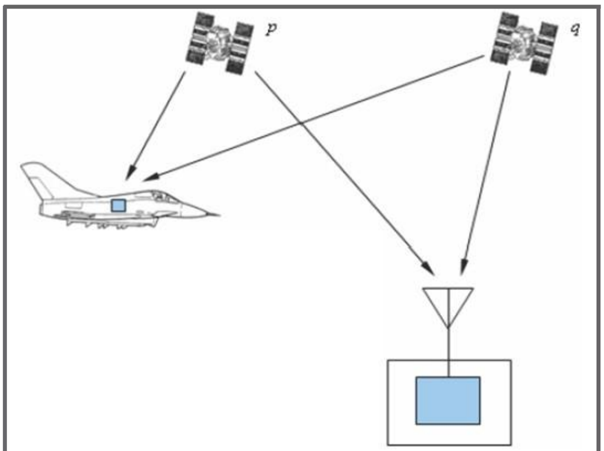

Figure 2 Pseudo range Differencing

Basic mathematical model for single difference pseudo range observation is as follows

$$P_k^p - P_l^p = \rho_k^p - \rho_l^p - \left(dt_k - dt_l\right)c + d_{k,p} - d_{l,p} + d_{k,p}^p - d_{l,p}^p + \Delta\varepsilon_p \quad (1.1)$$

Where Pi p is pseudorange measurement, ρip stands for geometric space between stations and satellite, dti stands for receiver's clock offsets, di, p stands for the receiver's hardware code delays, di p,p stands for multipath of codes, Δε p stands for calculation noise and c is velocity of light. Equation (1.1) signifies single difference pseudorange observable between receivers. Another kind of single difference in addition to (1.1) is called between-satellite single difference.
Supposing that co-ordinates of station k are known and difference in clock drifts is one known, four unknowns are there in equation (1.1). Therefore the four satellites are needed to deliver four single difference equations so the unknowns can be solved. On the often basis, single differences which has code observations is made use in relative navigation [6].

b. Double Difference Observable

Differences are made between receivers and satellites with the use of every pseudorange in Figure 1-2. By taking two between-receiver single differences and differencing between two satellites, double differences are created. The process gets rid of every satellite reliant, receiver reliant and numerous atmospheric blunders if distance is not much between two receivers. Equation which is formed is:

$$P_k^p - P_k^q - P_l^p - P_l^q = \rho_k^p - \rho_k^q - \rho_l^p - \rho_l^q + d_{l,p}^j \quad (1.2)$$

where $d_{i,p}^{j}$ stands for complete influence of multipath.

Three unknowns can be seen in the equation (1.2); co-ordinates of station l. To decipher for unknowns, minimum four satellites are needed so the minimum number of three double difference equations are created. With the use of propagation of errors law, it can be seen that double difference observables are two times the noisy as pure pseudoranges [5]:

$$\sigma_{DD} = \sqrt{\sigma_P^2 + \sigma_P^2 + \sigma_P^2 + \sigma_P^2} = 2\sigma_P \tag{1.3}$$

Even though they are noisy, they are precise as numerous blunders are eliminated. It should be noted that the multipath stays there as it cannot be shown and is not reliant for each receiver.

A. Carrier-Phase Differential GPS

With the use of carrier-phase calculation method, difference between carrier phases can be calculated at RR and UR. To eliminate satellite and receiver clock blunders, double-differencing method is implied. Difference between phase calculations at UR and RR for one satellite is first difference which removes satellite clock blunder that is common to both the calculations. For the second satellite, the procedure is the same and is done again. By deducting first difference for first satellite from first difference for second satellite, a second difference is created which removes both receiver clock blunders that are common to first difference equations. The procedure is then done again for two pairs of satellites which lead to three double-difference calculations which can be answered for difference between reference station and user receiver positions. Fundamentally, it is a relative positioning method and thus the user receiver should be aware of reference station position so the exact location can be calculated. Below there is discussed a lot more about such procedures where different observation equations are shown.

a. Single Difference Observable

Immediate phase difference between two receivers and one satellite is the single difference. The single differences between two satellites and one receiver can be described too. Phase difference between two receivers A and B, and satellite i am given with the use of basic definition of carrier-phase observable shown in equation (A.23) of Annex A:

$$\Phi_{AB}^{i}(\tau) = \Phi_{B}^{i}(\tau) - \Phi_{A}^{i}(\tau) \tag{1.4}$$

and can be expressed as:

$$\Phi_{AB}^{i}(\tau) = \left(\frac{f}{c}\right) \cdot \rho_{AB}^{i}(t) + \Phi_{AB}^{i}(\tau) - N_{AB}^{i} \tag{1.5}$$

where $N_{AB}^{i} = N_{B}^{i} - N_{A}^{i}$. Hence, with four satellites i, j, k and l:

$$\Phi_{AB}^{i}(\tau) = \left(\frac{f}{c}\right) \cdot \rho_{AB}^{i}(t) + \Phi_{AB}^{i}(\tau) - N_{AB}^{i} \,;\; \Phi_{AB}^{k}(\tau) = \left(\frac{f}{c}\right) \cdot \rho_{AB}^{k}(t) + \Phi_{AB}^{k}(\tau) - N_{AB}^{k} \,;$$

$$\Phi_{AB}^{j}(\tau) = \left(\frac{f}{c}\right) \cdot \rho_{AB}^{j}(t) + \Phi_{AB}^{j}(\tau) - N_{AB}^{j} \,;\; \Phi_{AB}^{l}(\tau) = \left(\frac{f}{c}\right) \cdot \rho_{AB}^{l}(t) + \Phi_{AB}^{l}(\tau) - N_{AB}^{l} \,.$$

b. Double Difference

By deducting two single differences calculated to two satellites i and j, double difference is created. Basic double difference equation is:

$$\Phi_{AB}^{ij}(\tau) = \Phi_{AB}^{j}(\tau) - \Phi_{AB}^{i}(\tau) \tag{1.6}$$

which simplifies to:

$$\Phi_{AB}^{ij}(\tau) = \left(\frac{f}{c}\right)\rho_{AB}^{ij}(t) - N_{AB}^{ij} \tag{1.7}$$

where $N_{AB}^{ij} = N_{AB}^{j} - N_{AB}^{i}$, and only unknowns are double-difference phase uncertainty N_{AB}^{ij} and receiver co-ordinates. Local clock blunder is differenced out.

Therefore, the double difference observation equation can be written as [7]:

$$\frac{\partial\Phi}{\partial X_A}dX_A+\frac{\partial\Phi}{\partial Y_A}dY_A+\frac{\partial\Phi}{\partial Z_A}dZ_A+\frac{\partial\Phi}{\partial X_B}dX_B+\frac{\partial\Phi}{\partial Y_B}dY_B+\frac{\partial\Phi}{\partial Z_B}dZ_B$$
$$+\frac{\partial\Phi}{\partial N_1}dN_1+\frac{\partial\Phi}{\partial N_2}dN_2+\frac{\partial\Phi}{\partial N_3}dN_3...+\frac{\partial\Phi}{\partial C}dC+...=\left(\Phi^O-\Phi^C\right)+v \tag{1.8}$$

where:

X_A, Y_A, Z_A	=	Co-ordinates of Receiver A;
X_B, Y_B, Z_B	=	Co-ordinates of Receiver B;
N_1, N_2, N_3	=	Integer Ambiguities;
C	=	Tropospheric Factor;
$\left(\Phi^O-\Phi^C\right)$	=	Observed minus Computed Observable; and
v	=	Residual.

Unknown receiver co-ordinates can be calculated from equation (1.8). Although, it is compulsory to calculate carrier phase integer uncertainties, that is, integer number of all the wavelengths between receiver and satellites. Such integer uncertainty can be solved if it starts with mobile receiver antenna inside a wavelength of reference receiver antenna in some of the measuring functions. Both of the receivers begin with same integer uncertainty so there is no difference. After that, phase shift which mobile receiver experiences is integer phase difference between two receivers. Reference and mobile receivers can resolve for uncertainties on their own as a portion of initialization procedure for the various applications where it is not practical to put reference and mobile antennas at one place with each other. There is one method which is to position mobile receiver at the place which has been examined before. Therefore, with this, initial difference is not always zero but can be determined with ease. It is necessary to solve for integer uncertainty at unidentified position or in motion or both for a few applications. Here in this situation, solving for integer uncertainty normally comprises of removing the solutions which are not right until the time when right solution is observed. If we have to keep initial number of candidate solutions small, then a fine initial approximation of position can be of good help [8]. The calculations which are dismissed in the process from additional satellite signals are implied so the correct solution can be separated. Such search methods require just a number of seconds or maybe a few minutes so they can perform and can have the remarkable computer processing strength. “Kinematic GPS (KGPS)” is a name given to this form of carrier-phase DGPS method. Sometimes the carrier track or phase lock on satellite face the interruptions which are cycle slips and because of them there is a loss of integer count, then initialization procedure should be done again for that satellite. There are many reasons for the interruptions (cycle slips) which can be physical barrier of antenna or immediate quickening of user platform. If receiver does not gather dismissed calculations from the additional satellites to keep up position solution, then output data flow might face interruptions (cycle slips) too. Once an exact position solution is preserved then the re-initialization for satellite which was lost can be sudden or nearly sudden. Creating a strong and speedy technique of initialization and re-initialization is a main barrier which the designers of real-time systems come across that has a safety critical function like aircraft precision method. There is an explanation of the methods to solve the uncertainties in the real-time and post-processing applications along with information regarding cycle slips repair methods are observed in references [9-17].

DGPS Datalink Implementation: The implementation of the DGPS depends on the type of data link used so it can be used in several ways. No data link is one of the simplest ways. When it comes to real-time application, the measurement is stored either in the receiver or on suitable media so that it can be processed at a later time. In order to achieve surveying accuracy, by the use of precise ephemeris data, the data must be post-processed. The precise ephemeris data is only available after the survey data has been collected. In a similar manner, the effort and the cost may be unnecessary to maintain a real-time data link. In spite of that, the real-time output which is at low-precision can be useful to confirm whether the test is progressively properly or not even if the accuracy of the results will be enhanced later. From the reference station to the users, unlinking of the differential measurements or correction can be done in real-time. When it comes to serving a large number of users in real-time, the above technique can be used. The encryption of the uplink can be done for proprietary commercial services and the military purposes and also, to restrict the use of DGPS signals to a selected group of users. The transmission of the differential corrections can be done at different frequencies. There is a trade-off system between the update rate of the corrections and the range of the system but the satellite data link is the exception. The following table incorporates the number of frequency bands, the rate at which the corrections could be updated with the use of standard RTCM SC-104 format [2, 3, 20] and the range.

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Table 1: DGPS Datalink Frequencies

name	Description	DIS
DGPS	CIA code pseudo range	1-Sm
PDGPS	P code pseuclo range	0.1-I m
VPDGPS	Addition of dual band carrier phase	5-30cm
UPDGPS	Above with integer ambiguities resolved	<2cm

An uplink can be the DGPS signal or a separate receiver or a transmitter system can be superimposed on a GPS-link L-band ranging signal. The uplink can act as pseudolite or a pseudo-satellite which can deliver the ranging signal and also, through the RF section of the user receiver, the DGPS data can be delivered. In a similar way, the transmission of GPS navigation can be done. If we talk about the advantage then the availability of the position solution can be increased by the use of addition signal(s) and also, one of the crucial advantages is the decrease in the carrier-phase initialization time. The system has a very short range which is a few kilometers at the most and this is due to the complexity of the RS and URs. The two factors responsible for this are the line of sight restriction and the low-power to avoid interference with the real satellite signals (i.e., if the GPS satellite signal is overpowering then pseudolite can become a GPS jammer). There is one more option available for the users to the RS or the other central collection point i.e., a downlink option. In this case, the calculation of the differential solutions can be done at a central location which is often the case for test range applications. For the test range applications, the information is not used aboard the vehicle rather it is where precise vehicle tracking is desired. The downlink can be of the following:

- It can be the satellite tracked plus the position data.
- It can be the measurement of the delta range and the pseudo-range.
- It can be an intermediate frequency which is translated from raw GPS signals.

With respect to the user equipment, the translator method can be expensive. Hence, it is often used in munitions testing. Munitions testing are where the user equipment may be expandable. For more information about the application, you can refer chapter 4.

Local Area and Wide Area DGPS: Using a single RS, the accuracy is a DGPS solution is enhanced which degrade with distance from the RS site. This decrease occurs due to the increase in the difference among the user receiver ephemeris, the reference, Ionospheric and the tropospheric errors. Within a distance of 350 km [20], it is likely for errors to remain highly correlated. The systems which are often limited by the data link to an effective range of around 170 km are usually called Local Area DGPS (LADGPS). Wide area DGPS (WADGPS) systems are the systems which compensate for accuracy degradation over a large area. WADGPS generally make a use of reference receivers. These reference receivers are coordinated in order to provide DGPS data which is valid over a wide coverage area. In order to broadcast the DGPS data via satellite, these kinds of systems are designed. Although there are more feasible ways like a network of ground transmission sites. To derive the appropriate tropospheric and ionospheric corrections for the user receivers which are appropriate for its location, the user receivers must make use of the special algorithm. For use of commercial aviation, WADGPS systems are transmitted from geostationary satellites and few countries like The United States, Japan, Europe, Canada, and Australia either have developed or are planning to deploy it. GPS like ranging signals can also be provided by the satellites. Clock corrections require the user to derive ionospheric corrections from an ionospheric model or dual-frequency measurements. So other nations may provide these corrections to participate in the trend followed by the above-mentioned nations. From multiple reference stations via satellite, there are some commercial DGPS services that broadcast the data and such systems remains a group of LADGPS but not the WADGPS systems. The reason behind is that the network is not formed by the integration of the reference stations. Therefore, as soon as the distance from the individual reference sites increases the accuracy of the user degrades.

IV. DGPS ACCURACY

The result of the DGPS is the accuracy of the of the order of about 1 meters and it is demonstrated by the controlled tests and recent extensive operations use of DGPS. C/A code pseudo range, as the only observable, is used in many recent applications of DGPS with achieved an accuracy of 1 to 5 meter in real-time. While other applications use both carriers phase observables and pseudo range (C/A or P-code). Ultra-Precise DGPS (UP GPS) and Very Precise DGPS (VPGPS) take the advantage of precise dual band P-code pseudorange and carrier phase observables. Also, these are the state-of-the-art ASTHTECH packages, which are capable of On-The-Fly ambiguity resolution. Various techniques are developed by the ASHTECH which are capable of achieving high accuracy at the cost of increased complexity.

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Table 2: ASHTECH Classification Scheme of DGPS Techniques

Name	Description	DIS
DGPS	CIA code pseudo range	1-Sm
PDGPS	P code pseudo range	0.1-I m
VPDGPS	Addition of dual band carrier phase	5-30cm
UPDGPS	Above with integer ambiguities resolved	<2cm

Below is the discussion of DGPS error sources which also incorporates comparison between DGPS error budgets and non-differential GPS.

V. DGPS ERROR SOURCES

The following are the major sources of error affecting stand-alone GPS (see Annex A):

- Satellite Clock Drift;
- Selective Availability Errors (only SPS applications).
- Ephemeris Error;
- Ionospheric Propagation Delay;
- Multipath;
- Receiver Noise and clock drift; and
- Tropospheric Propagation Delay

With the possible improvement provided by DGPS and the estimated magnitude of the error sources, the following table summarizes the above-mentioned stated error sources:

Table 3: Error Sources in DGPS

Error Source	Stand..\Jone (m)	DGPS(m)
Ephemeris	S-20	0–1
Ionosphere	IS-20	2-3
Troposphere	3-4	I
Satellite Clock	3	0
Multipath	2	2
Receiver Noise	2	2
Selective Availability	so	0

The error which is coming from multipath depends on the site and the values mentioned in Table 1-3 is an example. Table 1-3 do not contain the receiver clock drift as it is corrected in the standard solution and treated as an ample parameter. Also, it is significantly added to differential errors. The correction of the receiver noise errors and multipath cannot be made by the DGPS.

The following are the strategy adopted in order to correct GPS errors and induced biasing:

- Selective Availability Errors: the main concern of these errors is to the SPS users. With the exception that they are found to be of larger magnitude and have the ability to change frequently, they are similar to the naturally occurring clock errors and ephemeris. A three-dimensional error is the epsilon error. Hence, as a common range error, the part of the error will appear and part will remain a residual ephemeris error. The size of the residual portion is generally small for similar look angles to the satellite; the impact of the residual portion remains small. As a frequency and time bias, the dither error appears which a common error to all receivers is also. Distance from the satellite or the signal propagation does not have any effect on this error. A residual clock error will be a result of any delay between the time of use at the user receiver and the time of measurement at the reference station and this is because of the frequently

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changing nature of this error. The design of the SPS DGPS systems depends the rapid rates to minimize this effect and on the rate-of-change term in the corrections.

- Ionospheric and Tropospheric Delays: the compensation is complete when the respective signal path to the satellite, for users near the reference stations, is close together. With the increasing distance between the RS separator and the user, the distance between the different tropospheric and ionospheric paths to the satellites increased so much that the tropospheric and ionospheric delays are not common errors now. Thus, the atmospheric delay correction's effectiveness decreases with the increase of the distance between the user receiver and the RS.

- Ephemeris Error: the effective compensation cannot be achieved if the error has a large out-of-range component (e.g., 1000 meters or more due to an error in a satellite navigation message). Even then, if the distance between the user receiver and the reference receiver is small, the error will be small.

- Satellite Clock Error: The rate of change of this error is even slower than the SA dither error with the exception that it is not in the situation of satellite failure. Until the time both user receivers make use of the same satellite clock correction data, the error is completely compensated for all practical purposes.

With the increasing distance from the reference station, the error budget is determined for an SYS DGPS system is shown in Table 1-4.

Table 4: SPS DGPS Errors (ft) with Increasing Distance from the Reference Station

ERRORSOURCES	ON:\I	100 NM	500 1	1000N:\I
Space Segment: Clock Errors	0	0	0	0
Control Segment: Ephemeris Errors	0	0.3	1.5	3
SA	0	0	0	0
Propagation Errors:				
Ionosphere	0	7.2	16	21
Troposphere	0	6	6	6
TOTAL(RMS)	0	9.4	17	22
User Segment:				
Receiver Noise	3	3	3	3
Multipath	0	0	0	0
UERE(RMS)	3	9.8	17.4	22.2

As the above-mentioned content, the distance between the RS and the user location is one of the factors which is responsible for the correlation of the errors experienced. With the increase in the separation between the RS from the users, the significant difference can be experienced at the ionospheric and tropospheric sites. Similarly, the increase in the separation also means that by the RR and UR, ephemeris error's different geometrical component is seen which is commonly referred to as "Spatial Decor relation" of the atmospheric errors and the ephemeris. In general, for a user within the range of 350 km of the RS, the errors are highly correlated in nature. Imagine the distance is greater than the 250 km, in such cases; the better results can be obtained by the user which is due to the use of correction models for ionospheric and tropospheric delay [18, 27]. Since the differential correlations incorporate the multipath errors and the RR noise and become the part of the error budget of the users and also, the multipath errors and the receiver noise can be lowered so the in the DGPS implementation, the correspondent error components can be experienced. If we talk about the other type of error in real-time DGPS positioning system then the data link "age of correction" is one of them, which came into existence because of the latency of the transmitted corrections (i.e., at epoch t 0 + Dt, the transmitted corrections of epoch t0 arrive at the moving receiver). Since they were not analyzed under various SA/AS conditions so these corrections are not the correct ones which result in the slight offset of the coordinates of the UR

VI. INTERGRITY ISSUES FOR AIRCRAFT NAVIGATION

In order to use the system as a supplementary mean of aircraft navigations, at the moment, the only certified are the satellite navigation systems. When the GPS is integrated with the other navigation system, then it is the only certified system for aircraft navigation which is contrary to the system used in these days. The reason behind is the integrity rather than the accuracy. As per the US Federal Radio navigation Plan Within the navigation system, the installation of a monitor function is required in order to detect the increasing error above a threshold level. Also, this case can be seen

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in the form of the ground segment within the GPS system. However, the order of the time to alarm (TTA) is in order of several hours for this system and for the cruise, this time is too long because the requirement of the TTA for the cruise is 60 seconds. For stand-alone GPS integrity, several methods were proposed and their practical implementation is also done. A well-known aviation application and a developing family of one of that implementation, incorporates so-called Receiver Autonomous Integrity Monitoring (RAIM) techniques. You can find the more details about the RAIM techniques in the references [4, 22]. Apart from increasing the accuracy of the GPS positioning, DGPS enhances integrity which is done by compensating for anomalies in the navigation data message and the satellite ranging signals. In the ranging-code DGPS correction message, the range rate and range are provided which can be compensated for ramp and step type anomalies in the individual satellite signals but it can be done until the maximum is crossed by the corrections or the rates allowed in the correction formats. The two major steps are taken if the corrections are found to be increased above a certain limit, firstly, a warning is sent to the user by placing a "do-not-use" bit patterns in the corrections (as defined in STANAG 4392 or RTCM SC-104 message formats) which is done to not to allow user to use that particular satellite and secondly, by the omission of the corrections for that satellite.

VII. DIFFERENTIAL GLOBAL POSITION SYSTEM AUGMENTATION SYSTEMS

To increase of the levels of accuracy, integrity and the availability of DGPS-based navigation/landing systems, lots many methods were developed which supports both Ground-Based Augmentation Systems (GBAS) and Space-Based Augmentation Systems (SBAS) in which the broadcasting of various signals is done by the geostationary satellites (INMARSAT-3) and computation is done through a ground network of Integrity Monitoring Stations and transmitted from a dedicated Earth Station. The examples of SBAS are the European Geostationary Navigation Overlay System (EGNOS) and the American Wide Area Augmentation System (WAAS). The following are the points which are broadcasted by the geostationary (GEO) satellites in case of WAAS:

- Corrections of clock, ephemeris, ionospheric for each SV (to increase Accuracy);
- GPS utilises Warning (Integrity Signals); and
- Ranging Signals (to have a increase in Availability)

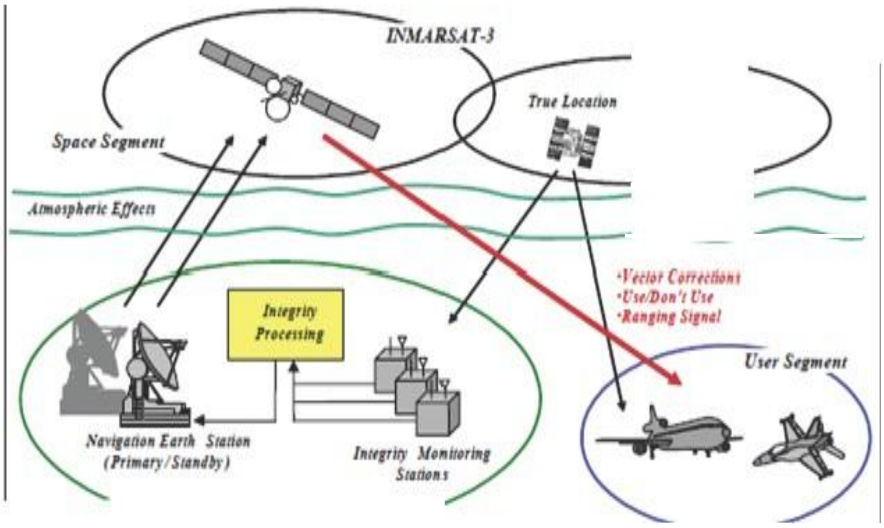

Figure 3: Wide Area Augmentation System

In order to have precision approach capability (3-dimensional guidance) for Category 1 approaches, WAAS is designed and incorporates the following availability:

- In the Rest of U.S. it is available but is less than 95%; and
- Greater than 95% Available in the majority of Continental US (CONUS);

The following availability is specified for those approaches which are en-route through non-precision:

- 50% of Continental US is better than 99.9% Availability; and
- Rest of U.S.is available, but less than 99.9%.

At CONUS, WAAS services are offering the Vertical Protection Level (VPL) which is shown in figure.

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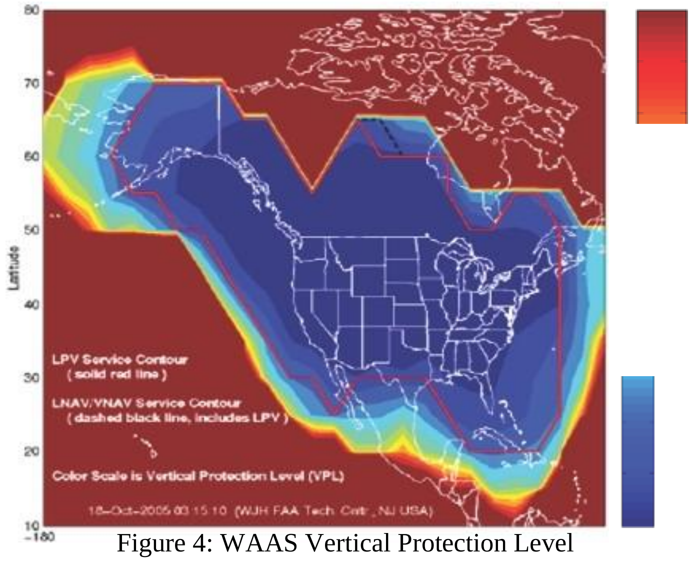

Figure 4: WAAS Vertical Protection Level

The Aim of LAAS (Figure 1-5) is to provide category II and III Precision Approach (PA) at the airports where it require the capability and CAT-I PA is available at those facilities where WAAS PA is not available.

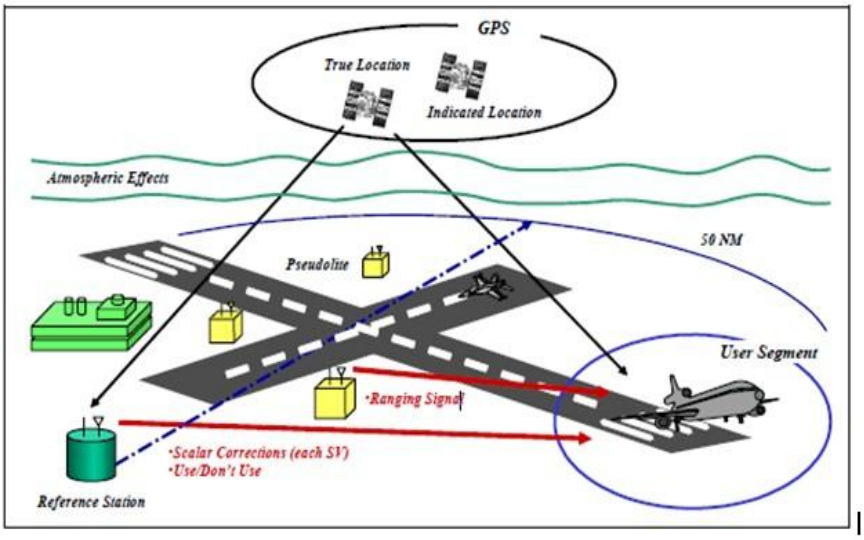

Figure 5: Local Area Augmentation System

The Local Reference Station broadcast the following things:

- GPS utilises Warning (to increase Integrity); and
- Scalar Corrections (to have a increase in Availability).

The implementation of Local Pseudolites Broadcasting (LPB) is done with the available additional ranging signals for very high accuracy and increased availability [31].

VIII. CONCLUSIONS

DGPS provides a good position, velocity and time reference solution for the flight applications.

Code-range DGPS are sufficient to:
- At various environmental or meteorological Condition Performs test missions over wide areas.
- Obtained aircraft present position which is as accurate as those of radar tracking systems;
- Optical trackers provides effective backup for some applications;
- During test missions aircrew workload is reduced by imposing few limitations to test missions;
- Data processing time is reduced when compared to other reference systems; and
- The test activities have been speed up.

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