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Comparison of Dilution of Precision (DOP) in Multipath and Error free Environment using Single Frequency Global Positioning System

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Abstract— Global Positioning System (GPS) is a satellite based radio navigation system intended to provide highly accurate three dimensional positions and precise time on a continuous global basis. Usually, GPS accuracy is limited by several factors such as atmospheric, receiver and satellite based errors. Among them, Dilution of Precision (DOP) and multipath errors are very important to investigate the error for improving positional accuracy. In this paper, single frequency receiver data analysis in static mode is carried out. Using the GPS data, Horizontal Dilution of Precision (HDOP) results were presented. The presented preliminary results would be useful for developing suitable techniques for improving single frequency GPS positional accuracy by taking the HDOP errors into the consideration.

Index Terms— GPS, NMEA and HDOP.

I. INTRODUCTION

Global Positioning System (GPS) is developed and monitored by Department of Defense (DoD) USA in 1973. It gives position, time and velocity information. Initially it was developed for the defense and military applications but later it was made available for the civilian users also. The crude and sophisticated GPS receivers differ a lot in every aspect with introduction of the integrated circuit technology. Several external sources introduce errors into the position estimated by a GPS receiver. One important factor in determining positional accuracy is the constellation, or geometry, of the group of satellites from which signals are being received. DOP only depends on the position of the satellites (shown in Figures 1 and 2) how many satellites user can see, how high they are in the sky, and the bearing towards them. This is often referred to as the geometry. An indicator of the quality of the geometry of the satellite constellation is the Dilution of Precision or simply DOP. The computed position can vary depending on which satellites are used for the measurement. Different satellite geometries can magnify or lessen the position error. A greater angle between the satellites lowers the DOP, and provides a better measurement as can be seen from the cartoons of Figure 1, while a near proximity in the satellites enhances the DOP as shown in Figure 2. A higher DOP indicates poor satellite geometry, and an inferior measurement configuration, or in other words: the lower the value the greater the confidence in the solution. If four satellites are considered for position solution, then the linearized equations for their pseudo ranges can be written in the form of geometry of a matrix as

$$G=\begin{bmatrix} -x_1+x_u/p^1 & -y_1+y_u/p^1 & -z_1+z_u/p^1 \\ -x_2+x_u/p^2 & -y_2+y_u/p^2 & -z_2+z_u/p^2 \\ -x_3+x_u/p^3 & -y_3+y_u/p^3 & -z_3+z_u/p^3 \\ -x_4+x_u/p^4 & -y_4+y_u/p^4 & -z_4+z_u/p^4 \end{bmatrix}$$

Let H be the covariance matrix given by

$$H=(G^TG)^{-1}$$

Mathematically HDOP is defined as

$$HDOP=\sqrt{\sigma_e^2+\sigma_n^2}\,/\,\sigma=\sqrt{\sigma_x^2+\sigma_y^2}\,/\sigma$$

Where σ_x^2 and σ_y^2 denote the variances of x and y component of the position error, respectively..

σ_n^2 and σ_e^2 are the variances of north and east respectively.

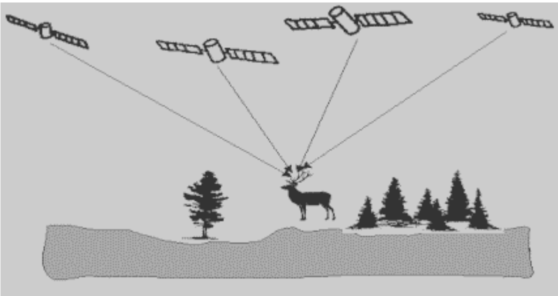

Figure 1. Good Dilution of Precision

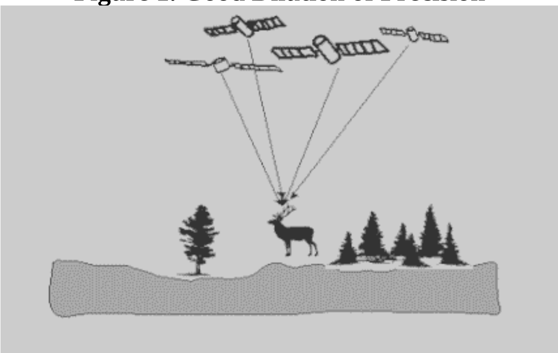

Figure 2. Poor Dilution of Precision

There are GPS receivers for different purposes such as military, geodetic surveying and time transfer (Parkinson et al, 1996). Single frequency GPS receiver receives L1 (1575 MHz) signals only. The positional information computed by the GPS module will be transmitted in a standard format called National Marie Time Electronics Association (NMEA) data format.

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The National Marine Electronics Association (NMEA-0183) standard defines electrical signal requirements, data transmission protocol, timing and specific sentence formats for a 9600-baud serial data bus (pcptpp030.psychologie.uni-regensburg.de). The NMEA has developed a specification that defines the interface between various pieces of marine electronic equipment. The standard permits marine electronics to send information to computers and to other marine equipment (www.gpsinformation.org).

II. NMEA SENTENCE FORMAT

NMEA is a standard protocol, used by GPS receivers to transmit data. NMEA output is EIA-422A which is a standard of Electronic Industries Alliance, but for most purposes one can consider it as a RS-232 compatible. The NMEA -0183 standard uses a simple ASCII (American Standard Code for Information Interchange) serial communications protocol. Each sentence begins with a dollar sign ($) and ends with a carriage return linefeed (<CR><LF>). Data is comma delimited. All commas must be included as they act as markers. Some GPS satellites do not send some of the fields. A checksum is optionally added (in a few cases it is mandatory). Following the $ is the address field aa ccc. aa is the device id. GP is used to identify GPS data. Transmission of the device ID is usually optional. ccc is the sentence formatter, otherwise known as the sentence name. Among the twelve NMEA strings received from single frequency GPS receiver, $GPGGA is most popular because it contains navigational data that is most commonly sought after. $GPGGA is the only string that reports latitude, longitude as well as altitude. The decode of GPGGA string received by a GPS receiver is shown in Table .2

Port	COM1
Bits per second [2400,4800,9600…….]	4800
Data bits	8
Parity bits	None
Stop bits	1
Flow control [XON/XOFF, Hardware, None]	Hardware

Table 1: Port settings

$GPGGA, 091459,1724.489,N, 07831.083,E, 1,03,3.9,0491,M, 01.9,M,, *6D	
GGA	GPS fix data
091459	Fix taken at 09:14:59 UTC
1724.489,N	Latitude 17 degrees 24.489 minutes, North
7831.083,E	Longitude 78 degrees 31.083 minutes, East
1	Position Fix Quality 0 = invalid 1 = GPS fix (SPS) 2 = DGPS fix 3 = PPS fix) 4 = Real Time Kinematics (RTK) 5 = Float RTK 6 = estimated (dead reckoning 7 = Manual input mode 8 = Simulation mode
03	Number of satellites being tracked
3.9	Horizontal Dilution of Position (HDOP)
491,M	Altitude in Meters, above mean sea level
01.9,M	Height of geoid (mean sea level) above WGS84 ellipsoid.
Empty field	Time in seconds since last DGPS update
Empty field	DGPS station ID number
*6D	The checksum data, always begins with *

Table 2: Decode of $GPGGA NMEA string from

III. RESULTS AND DISCUSSIONS

Understanding of GPS observables is very essential for the navigational applications. The significance of typical GPS observable variations is presented here. The results of GPS satellite information are provided to assess the receiver system performance. The data is acquired in static mode correspond to 26th November 2011, 09.00 hrs (UTC) at KLU (Geog. Lat. 16.26°N, Geog. Long. 80.37° E). Fig. 3 shows the receiver latitudinal positional variations.

The receiver position is estimated as Latitude: 16.26640 N. Fig. 4 shows the receiver longitudinal positional variations. The receiver position is estimated as Latitude: 80.37330 E. Fig.5 shows number of visible satellites. From the figure, it can be seen that most of time more than four satellites are visible. Fig.6 represents Horizontal Dilution of Precision (HDOP) results. DOP is an indication of the quality of the results that can be expected from a GPS point position (Hoffmann, 2001). It is a measure based solely on the geometry of the satellites.

Simulation results in multipath environment

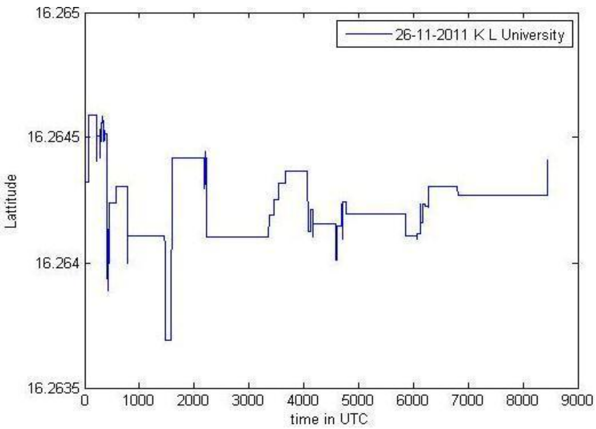

Figure 3: Latitudinal positional variations in multipath environment

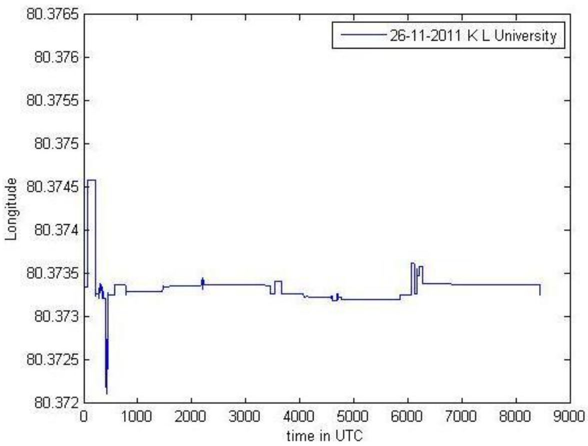

Figure 4: Longitudinal positional variations in multipath environment

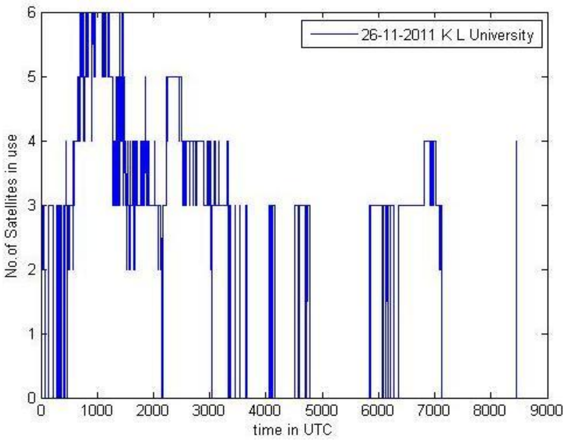

Figure 5: Number of visible satellites in multipath environment

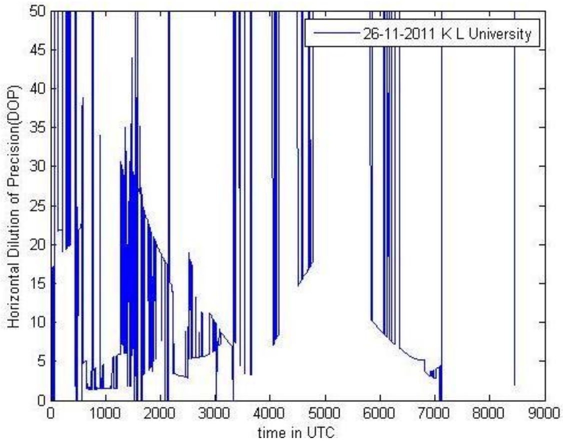

Figure 6: HDOP variations in multipath environment

Simulation results in Error free environment

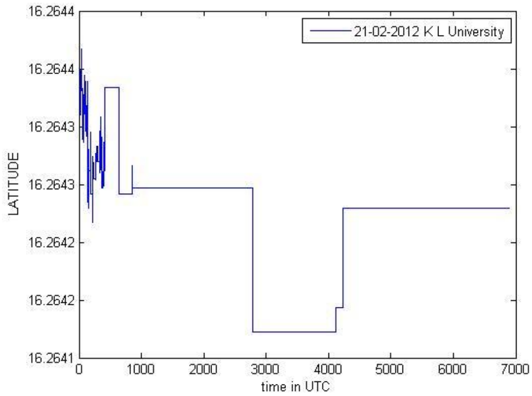

Figure7: Latitudinal positional variations in error free environment

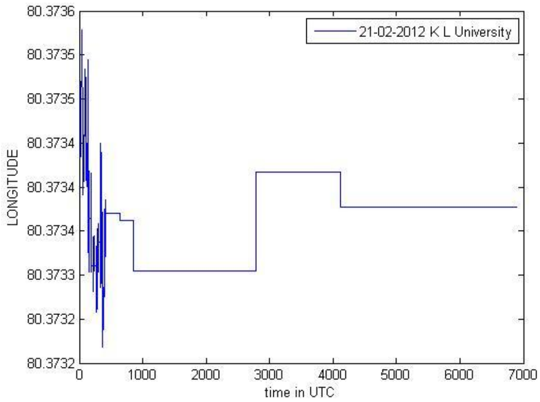

Figure 8: Longitudinal positional variations in error free environment

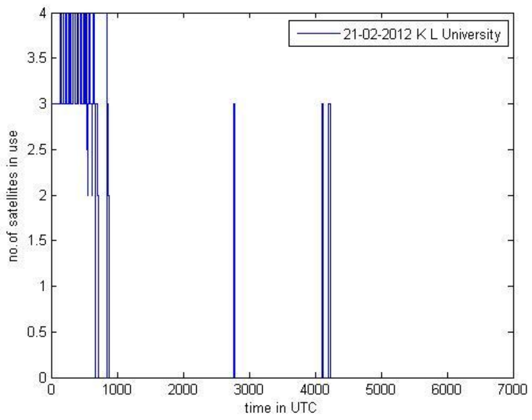

Figure 9: Number of visible satellites in error free environment

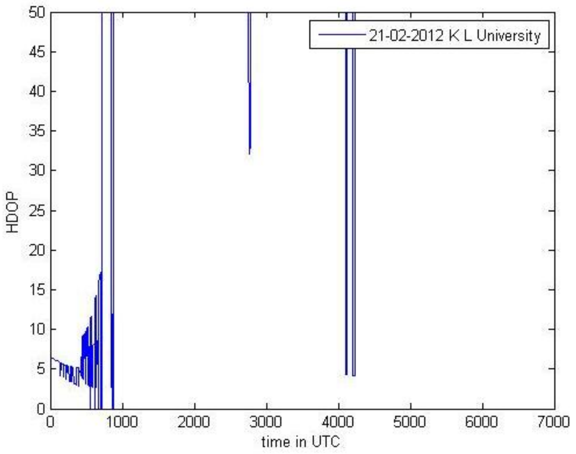

Figure 10: HDOP variations in error free environment

IV. CONCLUSION

The typical behavior of GPS observables are presented here. The GPS data acquired from the satellites is in NMEA format as it is compatible with present computer programs available. The outcome of this work is helpful in estimating the positional accuracy of the GPS receiver through the determination of satellite geometry.

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