Data Acquisition Experiment using NovAtel Dual Frequency GPS Receiver

Dhiraj Sunehra
Jawaharlal Nehru Technological University Hyderabad, Andhra Pradesh, India

Abstract

The advent of very large scale integration (VLSI) technology has led to the use of powerful microprocessors within the GPS receivers with reduced size. This led to the integration of both the instrument and data acquisition system together. Out of the various commercially available GPS receivers, dual frequency receivers are the most sophisticated and most expensive. In this investigation, a NovAtel make DL-4plus dual frequency GPS receiver is used. Brief description of the hardware and software aspects of the GPS receiver are presented along with the experimental details of antenna installation and its site selection. The results of data acquisition and various error corrections obtained from the receiver are highlighted.

1. Introduction

In 1990, there were only few GPS receivers available in the commercial market. However, in the past two decades the Global Positioning System (GPS) technology has made a remarkable development in the field of navigation and communication. The advent of VLSI technology made it possible to construct a GPS receiver with just a single integrated circuit allowing reduction in power consumption, size and cost. There are many types of GPS receivers available for different applications such as military, geodetic surveying and time transfer [1]. Among the commercially available GPS receivers, dual frequency receivers are the most sophisticated and most expensive. Although these receivers differ in their design, construction and capabilities, they share a number of common principles in their operation. One such GPS receiver is the NovAtel make, DL-4*plus* dual frequency GPS receiver available at Research and Training Unit for Navigational Electronics (NERTU), Osmania University, Hyderabad. This receiver is a high performance, high accuracy, GPS receiver with fast data update rates and built-in integrated memory (Compact Flash Card) for data acquisition. Data acquisition is an important aspect for real time display of GPS information through a user interface. Modern GPS receivers include various graphic user interface (GUI) based software for data acquisition. Various aspects of installation, data acquisition and utilization are described in this paper. The data acquisition experimental results of typical GPS observables such as GPS position, dilution of precision (DOP), pseudorange, carrier phase, signal strength, and measurement of various error corrections obtained from the receiver are presented.

2. Hardware aspects of NovAtel DL-4plus GPS receiver

A dual frequency GPS receiver (DL-4*plus* RT2W) of NovAtel make is installed at the Research and Training Unit for Navigational Electronics (NERTU), Osmania University, Hyderabad. The DL-4*plus* is a 24-channel dual frequency GPS receiver and is capable of receiving and tracking the L1 C/A Code, L1 and L2 carrier phase, and L2 P-Code (or encrypted Y Code) signals. This receiver is enriched with Patented Pulsed Aperture Correlator (PAC) technology and a powerful microprocessor. It provides multipath-resistant processing and excellent acquisition and re-acquisition time. The front view of the receiver is shown in Figure 1. The front panel includes a LCD display, user interface keypad for fast configuration of the receiver, an integrated memory (Compact Flash Card) and the power up button. The receiver has the facility to log GPS data into the flash card or a personal computer [2]. This receiver has been installed at a suitable location on the terrace of NERTU building.

Figure 1. Front view of DL-4*plus* GPS receiver

The NovAtel GPS receiver consists of five major components: (i) GPS Card (OEM4-G2 Card), (ii) Enclosure, (iii) GPS Antenna (Model: GPS-702), (iv) Power supply, (v) Data communications equipment. The receiver card obtains filtered and amplified RF signal from the active antenna through a coaxial cable. The RF section translates the RF signal to an IF signal, which is used by digital section later. The digital section consists of an analog-to-digital converter, a 32-bit system processor, memory, control and configuration logic, signal processing circuitry, and serial peripheral devices. The digital section receives a down-converted, amplified GPS signal which is digitized and processed to obtain the position, velocity and time information. A multipath resistant antenna (GPS-702) is used with DL-4 receiver. The GPS-702 is an active antenna comprising an LNA and is designed to operate at the GPS L1 (1575.42 MHz) and L2 (1227.60 MHz) frequencies [3]. The GPS antenna converts the electromagnetic waves transmitted by the GPS constellation into RF signals. The RF and power specifications of the antenna are given in Table 1.An enclosure is used to protect the GPS Card from environmental exposure and RF interference.

Table 1. RF and power specifications of GPS-702 antenna

Specification	Details
RF	
3 dB pass band	L1: 1575 -15/+30 MHz
	L2: 1228 -15/+30 MHz
Gain at zenith (min)	L1: +5 dBic
	L2: +2 dBic
LNA gain (typical)	27 dB
Polarization	Right-hand circular
Noise figure (typical)	2.0 dB
L1-L2 differential propagation delay(max)	5 ns
Nominal impedance	50 Ω
VSWR	≤ 2.0 : 1
Power	
Input voltage	4.5 – 18.0 V DC
Current (typical)	35 mA

The DL-4*plus* receiver gets an input supply voltage from a 12V DC adapter operating from 220V, 50Hz mains. A PC or other data communications equipment is necessary to communicate with the receiver and, if desired, to store data generated by the receiver.

3. Receiver site selection experiment

Installation is a very important aspect for operating any electronic radio system efficiently. The DL-4*plus* GPS receiver has been installed at a suitable location on the terrace of NERTU. An unobstructed site is selected for antenna installation to ensure the optimal performance of GPS receiver. A 15 ft height concrete pillar has been constructed on the terrace of NERTU building to ensure a good visibility of satellites and minimize the error due to multipath.

The antenna position determination was made through data quality check analysis using Translations, Editing Quality Check (TEQC) tool [4]. The main aim of the TEQC editor is to do data pre-processing from different manufacturers data. Using TEQC commands, the data quality check is made on the GPS data collected for a period of about 24 hours, at three different locations on different days. The brief details of the quality check parameters at three locations, viz. Location 1, Location 2 and Location 3 are given Table 2. From the table, it can be observed that 'Location 1' has the lowest multipath error when compared to other two locations. The average multipath error on L1 frequency (MP1) is 0.37 m and that on L2 frequency (MP2) is 0.45m. This location 1 is identified as the suitable location for setting up the antenna.

3.1. Installation details of lightning arrestor

Electrical and electronic equipment, including GPS receivers can get damaged due to lightning energy entering their circuit directly or by some other path. These equipment can be protected to a considerable extent from damage by installing a Lightning Arrestor. Lightning Arresters provide a means by which lightning currents may enter or leave the earth without passing through the circuitry to be protected. The equipment can be protected from lightning using metallic lightning rods that extend from a point above the top of the GPS antenna to the ground. The lightning arrestor has a sharp edge on the top side and the bottom side is attached to a long thick copper strip that is taken down the building. The lower end of the copper strip is properly earthed. When lightning occurs and hits the rod, current flows down to the earth through the copper strip. To protect the GPS antenna from severe lightning storm, a lightning arrestor is also installed over the NERTU building.

Table 2. Data quality check analysis using TEQC tool

Description of parameter	Location 1	Location 2	Location 3
Time of start of data file	Mar 16 2007 18:01:00	Feb 05 2007 18:00:00	Feb 21 2007 18:00:00
Time of end of data file	Mar 17 2007 18:29:00	Feb 06 2007 18:30:00	Feb 22 2007 18:30:00
Antenna geodetic coordinates (WGS-84)	N 17° 24' 28.84" E 78° 31' 05.95"	N 17° 24' 28.85" E 78° 31' 06.12"	N 17° 24' 29.0" E 78° 31' 4.9"
Antenna height	467.3276 m	461.4825 m	594.82 m
Data sampling period	60.0 s	30.0 s	60.0 s
Total number of satellites visible during the observation	30	30	30
Receiver tracking capability	12 SVs	12 SVs	12 SVs
Moving average multipath error on L1 frequency, MP1	0.372223 m	0.362965 m	0.729130 m
Moving average multipath error on L2 frequency, MP2	0.450014 m	0.609920 m	0.904827 m

The earthing is provided through a copper-strip wiring, (Length: 75 ft approx., 1”×6 mm dimensions) and an earth pit (dimensions: 3×3×5 ft) with an earth piping length (5 ft) are used. To increase conductivity in the pit coal and salt are added. Occasional watering helps to maintain good conductivity. The antenna setup with the lightning arrestor on the top of the concrete pillar is shown in Figure 2.

Figure 2. GPS Antenna with lighting arrestor setup for DL-4*plus* GPS receiver at NERTU

4. Receiver Data logging setup

Various graphic user interface (GUI) based software are provided with the receiver to set-up and monitor its operation. These include the control and display unit (CDU) software, DL-4 tool and Convert 4 software. The DL-4*plus* receiver is connected to a personal computer (PC) through serial communication ports COM1, COM2, and AUX. The COM1 port supports the standards of more flexible USB interfacing, RS-232 and RS-422. The communication is established with the receiver by issuing necessary commands using the CDU or DL-4 tool software loaded in the PC. These can be used for acquisition of raw data through the ports of the receiver. Once installed, the GPS receiver is ready for data logging in stand-alone mode. In this mode, each data logging session is stored in a single file on a compact flash memory card. Later, this file can be transferred to a PC using DL-4 tool software for post-processing. In the interfacing mode, the data will be stored on a PC. The acquired raw GPS data can be converted into either ASCII, binary or Receiver INdependent EXchange (RINEX) format using the Convert software utility. The data logging setup of the NovAtel DL-4*plus* GPS receiver is shown in Figure 3.

5. Data Acquisition and Processing

To achieve higher accuracy the receiver uses PAC technology which uses a combination of low noise ranging measurements and a very narrow correlation window. This significantly reduces the effects of multipath interference and distortion [5].

Figure 3. Data logging setup of DL-4*plus* GPS receiver

Multipath is more commonly considered to be the reflections due to surfaces surrounding the antenna and can cause an error of about 1-5 m in code phase measurements and about 1-5 cm in the carrier phase measurements [6]. Excellent acquisition and re-acquisition times make it possible to operate the receiver in very high dynamics environments and where frequent interruption of signals is expected. As the application of GPS technique extends from high precision navigation positioning to scientific research such as ionospheric space research, there is an increased need for accurate and efficient L_1/L_2 data processing. Data acquisition and processing can be done using software tools. These tools provide many windows with radio button that tell the receiver, the type of data and data rate to be collected and location of the data to be stored (for example the Compact Flash Card) etc. Among the available tools, CDU provides a user friendly GUI tool. The windows in CDU such as Constellation , Channel tracking status , Position , Plan, INS Position, Velocity and Attitude, Velocity, Console, ASCII logs window and Logging control windows are used to control the operation and displays the status information of the receiver. The displayed information facilitates various applications of the system. Among the available windows, some of the control and status windows and their features are briefly described in Table 3. The functionality of the receiver can be expanded through NovAtel's Application Programming Interface (API) option. The Application Program Interface (API) allows developing specialized C/C++ applications. This receiver is also capable of receiving Satellite based Augmentation system (SBAS) correction signals and supports real-time Differential GPS.

Table 3. CDU tool control and status windows

1. Constellation Window

Displays information about total number of satellites being tracked along with Pseudo Random Noise (PRN) numbers. Also provides Azimuth, Elevation, and Signal to Noise Ratio (SNR) of the selected PRN.

2. Channel Tracking Status window

Displays the following information:

- Specific PRN being tracked by the particular processing channel of the receiver.
- Pseudorange measurement values in meters for a selected channel.
- Time duration for which the signal is continuous without cycle slips.
- Other option such as Doppler, residuals, signal to noise ratio are also displayed.

3. Position window

Displays the following information:

- The user's position (latitude, longitude and height).
- The four PRN numbers of satellites used for estimating the position. Also the constellation of selected satellites to which they belongs viz. GPS or GLONASS.
- The receiver's date and time (GMT and local).

6. Results and Discussion

The typical GPS parameters such as position, velocity, elevation and azimuth angle of the tracked satellites, Dilution of Precision (DOP), signal strength on the L1 and L2 channels are displayed on the menu of CDU. The visual representation of graphical displays of satellite information is provided to assess the receiver system performance.

Figure 4 shows the receiver position variations with 5 m scale. The data acquired correspond to 23rd February 2007, 00:22:19 hours local time (LT) at NERTU. The receiver position is estimated as Latitude: 17°24'29" with ±1.4 m error residual, Longitude: 78°31'04" with ±1.27 m error residual and Height: 440.465 ± 4.89 m. It provides both GPS time and local time.

The visual representation of all visible satellites (9) is shown in Figure 5. This panel gives information about current position of satellite in terms of azimuth and elevation angle. The lowest mask angle supported is 5°. It means that satellites above 5° elevations will only be tracked by the receiver.

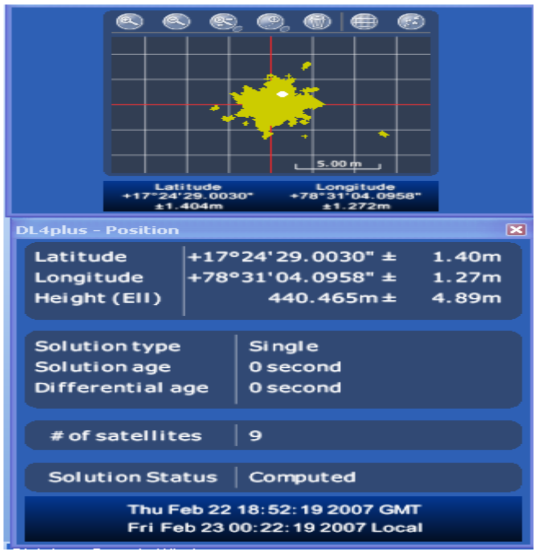

Figure 4. Position and plan window

Figure 5. Satellite constellation window

The satellite signal strengths at a particular epoch of all visible satellites (L1C and L2Y) are shown in Figure 6. For better position estimation, the SNR should be more than 35 dB-Hz. It is observed that the maximum SNR is 50 dB-Hz for SV23, and the minimum SNR is 28 dB-Hz for SV11. It is also observed that L1C signal strength is always more than L2Y signal. The receiver is also capable of tracking SBAS signals as well.

The DOP variations such as Horizontal DOP (HDOP), Position DOP (PDOP), Vertical DOP (VDOP), Time DOP (TDOP) and Geometric DOP (GDOP) are shown in Figure 7. The lower the DOP, the better is the positioning solution. The estimated DOP values are less than 3, which signifies that good satellite geometry is available for precise receiver position estimation. The position DOP is estimated as 2.25. The common feature of DOP variations is that the observed VDOP (2.07) is more than HDOP value (0.88).

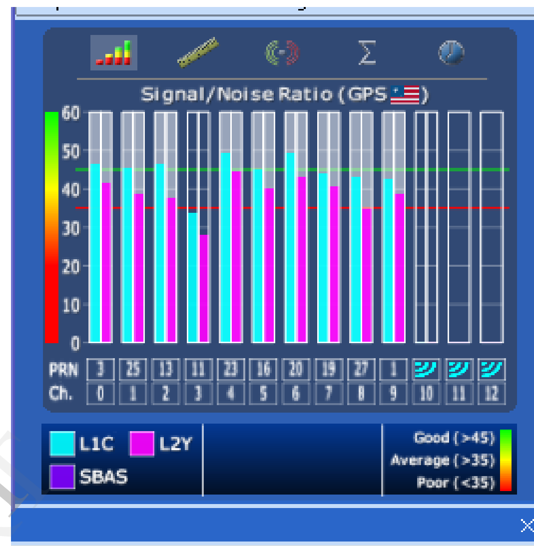

Figure 6. Satellite signal strength indicator window

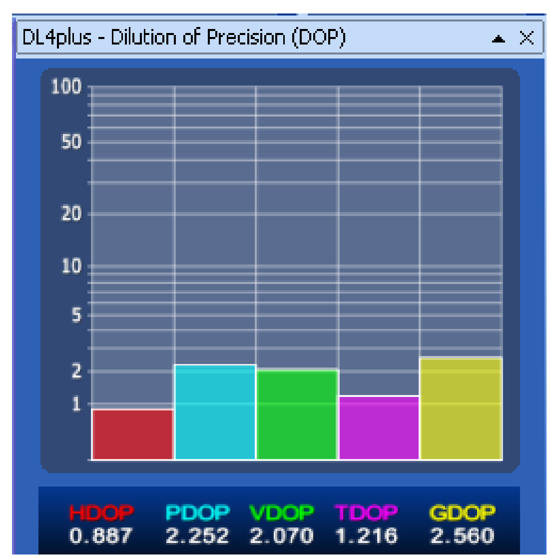

Figure 7. DOP window

Table 4. Various error corrections obtained from DL-4plus dual frequency GPS receiver (01:28 hours, November 1, 2008)

S.No	Description	PRN 9	PRN 17	PRN 26	PRN 28
1.	Satellite Position X, Y, Z (m)	16938727.8614 5996485.5465 18961451.1464	-2790515.8175 15013712.3055 21769274.2591	22111527.7448 11140848.0847 -10808589.1810	-10167850.8146 22708537.3862 9190562.0378
2.	Elevation angle (degrees)	20.4	37.8	11.6	46.7
3.	Azimuth angle (degrees)	314.9	19.1	232.6	79.2
4.	Satellite clock correction ($\times 10^{-3}$m)	6791.550	11989.847	2978.371	-7000.299
5.	Ionospheric correction (m)	0.850036728	-0.111887872	5.581921149	-0.451142433
6.	Tropospheric correction (m)	6.691570681	3.811760665	11.354929012	3.213716681

6.1. Measurement of Various GPS Error Corrections

The DL-4plus GPS receiver can log several parameters including ionospheric, tropospheric and satellite clock corrections for all the satellites in view at a particular epoch. Table 4 lists the various corrections for four selected GPS satellites along with their position in earth-centered earth-fixed (ECEF) coordinates, elevation and azimuth angles at 01:28 hours local time on November 1, 2008. It may be observed that the ionospheric and tropospheric path delays are higher for satellites with lower elevation angle. This is due to the larger path travelled by the signals in the propagating medium. Even though the observations are taken during the daytime, ionospheric delay corrections show lower values than the corresponding tropospheric delay corrections, and are sometimes negative also. This is due to the effect of differential instrumental biases (interfrequency biases) of the satellites and the receiver on the ionospheric delay estimates. The effect of instrumental biases is specific to dual frequency GPS receivers, which are an essential component in any satellite based augmentation system (SBAS). The estimation of these differential instrumental biases is necessary for accurate estimation of ionospheric delay [7].

7. Conclusions

An attempt is made to assess the performance of a dual frequency GPS receiver system. Site selection is very important in the installation of a dual frequency GPS receiver. For this an experiment is carried out and the antenna position is determined through data quality check analysis using TEQC tool. The significance of installation in a multipath free environment is highlighted. The average multipath error on the L1 frequency is obtained as 0.37 m and that on L2 frequency is found to be 0.45 m. During pre-monsoon and monsoon periods lightning is very common in the Indian region. If the lightning strikes the equipment it will completely damage the costly equipment. So, erecting a lightning arrestor with the antenna is beneficial. The typical behaviour of various GPS observables is presented. The acquired data from the receiver would be useful for ionospheric TEC analysis.

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