PPP Potential of a Compact, Low-Cost GNSS Receiver's Module in a Low Latitude Region: A Case Study at the Lautech GNSS Laboratory, Nigeria

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Abstract: Precise point positioning (PPP) for global positioning systems (GPS) is being utilized for many scientific and commercial applications, and the Global Navigation Satellite System (GNSS) world is quite excited about it. With the PPP technique, the GNSS can accurately determine the geolocation of any point. PPP commonly involves the use of expensive geodetic GNSS receivers, which can hardly be afforded by GNSS researchers. Hence, this paper presents the PPP potential of a compact, low-cost GNSS receiver's module in a low-latitude region: a case study at the Lautech GNSS Laboratory (LGL). A compact, low-cost uBlox ZED F9P GNSS module was used to log GNSS multi-constellation data for 24 hours for some days in February, May, and July, 2024 respectively. The PPP solutions obtained from the final International GNSS Service (IGS) product through the Natural Resources of Canada (NRcan) online service for GPS-only and GPS+GLONASS hybrid mode of operation show that below 5 mm horizontal position solutions and below 20 cm vertical coordinate position solutions are achievable in GPS-only and GPS+GLONASS hybrid modes of operation in low latitude regions using a compact, low-cost uBlox ZED F9P GNSS module. The results imply that a compact, low-cost GNSS receiver is a potential GNSS receiver for PPP solution accuracy and can be used for PPP geodetic applications or GNSS-based applications in low-latitude regions like Nigeria. Its low power consumption is an added advantage.

Keywords: Low-cost, GNSS-receiver, Potential, Low, Latitude, Region

1 Introduction

The Global Navigation Satellite System (GNSS) has revolutionised various sectors including geospatial sciences, transportation, agriculture and disaster management [1]. Among the advancements in GNSS technology, the Precise Point Positioning (PPP) technique has gained significant attention due to its ability to provide high-accuracy positioning without the need for a network of reference stations [2]. Achieving such precision has been associated with high-cost GNSS receivers which limits their accessibility and applications particularly in developing regions [3]. However, the emergence of compact, low-cost GNSS receiver modules presents a promising opportunity democratise access to high-precision positioning technology [4]. This study focuses on evaluating the PPP potential of low-cost GNSS receiver modules in low-latitude regions with specific case study conducted at the Lautech GNSS Laboratory (LGL) in Nigeria. Low-latitude regions pose unique challenges for GNSS applications due to ionospheric effects that can significantly impact signal quality and positioning accuracy [5]. Therefore, accessing the performance of low-cost GNSS receivers in such environments is crucial for determining their viability and potential benefits. The importance of this study lies in its potential to make high-accuracy GNSS positioning more accessible and affordable especially in regions where financial resources and technological infrastructure are limited. Leveraging low-cost GNSS receivers can support broad range of applications like precision agriculture, urban planning, environmental monitoring and

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disaster management which can lead to significant socio-economic benefits enhancing the capacity for informed decision-making and efficient resource management [6]. In this context, the LGL provides an ideal setting for this case study, offering the necessary infrastructure and expertise to rigorously evaluate the performance of these compact, low-cost GNSS modules. The findings of this study will contribute to the growing body of knowledge on low-cost GNSS technologies, highlighting their capabilities and limitations in challenging low-latitude environments. Summarily, this research aims to demonstrate the feasibility of adopting low-cost GNSS receivers for high-precision applications by fostering greater innovation and development in GNSS-based technologies in Nigeria and similar regions.

2 A Brief Explanation on GNSS PPP

Precise Point Positioning (PPP) is a highly accurate satellite navigation technique used to determine the precise location of a single GNSS receiver, relying solely on the measurements from the receiver and satellite orbit and clock data [7]. Today, GNSS Precise Point Positioning (PPP) is being used for numerous scientific and business purposes, and it has attracted unparalleled enthusiasm from the GNSS world [8]. PPP is a computationally efficient method which employs high-accuracy satellite orbits and carrier phase measurements to offer centimetre-level positioning solutions. It uses a single receiver to provide homogenous positioning quality in a consistent global frame by removing simultaneous observations at the reference and rover receivers. The accuracy of PPP is further enhanced through the use of precise satellite ephemerides and clock corrections, often provided by services such as the International GNSS Service (IGS). These corrections are essential for reducing the errors inherent in the GNSS measurements and achieving the high precision required for applications like geodesy, surveying, and Earth observation [9;10]. PPP, despite its advantages, is limited by long convergence times, limiting its use in real-time GNSS applications. However, it has gained interest and widespread adoption in government, academic, and commercial sectors for position, navigation, and timing applications [11]. PPP's rigorous error modelling results in minimal difference between accuracy and precision, with residual biases typically at centimetre level [12]. Unlike traditional Differential GPS (DGPS) methods, which require a network of reference stations, PPP can achieve centimetre-level accuracy globally without the need for nearby reference stations [13]. The PPP technique is particularly beneficial for positioning and navigation in remote areas where continuously operating reference stations (CORS) infrastructure is not accessible [14].

3 GNSS PPP using Compact uBlox ZED F9P GNSS Module at LGL, Nigeria

In this study, Compact, low-cost, multi-constellation, dual-frequency uBlox ZED F9P GNSS module is used for PPP positioning study at LGL, Nigeria to examine its PPP potential in low latitude region.

3.1 uBlox ZED F9P GNSS Module

The description of the GNSS module used in this study is as shown in the Table 1.

Table 1. Compact, Low Cost uBlox ZED F9P GNSS Module used for the PPP Study

Manufacturer/Model	Module Picture	Accustomed GNSS Multi-Constellations	Frequency of Operation	Size (mm x mm)	Cost
uBlox ZED-F9P		GPS, GLONASS, GALILEO, BEIDOU, SBAS	GPS L1, L2 GLONASS L1, L2 Galileo E1, E5 Beidou B1, B2	32x22	383 USD

4 Experimental Set up for Data Collection

The experiment was set up at LGL, (8.17054400°N, 4.26892783°E, 403.411m) located in the Department of Pure and Applied Physics Laboratory complex, Ladoke Akintola University of Technology, Ogbomoso, Nigeria. A static mode real-time multi-constellation GNSS data were logged using a uBlox ZED-F9P dual-frequency GNSS module together with a uBlox multiband GNSS patch antenna as shown in Figure 1. In this set up, the antenna was placed on the top of a pole in an open sky setting at a height of about 403 metres above sea level. The uBlox ZED-F9P GNSS module employed in this case can be used for both standalone and Real-Time Kinematic (RTK) purposes. The GNSS module was connected to a computer's USB port, which also provides the module with required power supply. Dual frequency GPS, GLONASS and GPS+GLONASS hybrid mode data were collected for 24 hours for selected days in the months of February, May and July 2024 respectively. The reason for repeating the experiment in different month of the year is to check the validity of the PPP results obtained. The data collected through the uBlox module were logged using the uBlox logger software (u-Centre version 24.02). The Rinex 3.05 observation data file obtained was converted to Rinex 3.03 file for the GPS, GLONASS and GPS+GLONASS hybrid mode of operation and were uploaded individually to Natural Resources of Canada (NRcan) online service for precise point positioning (PPP) results which were received via email.

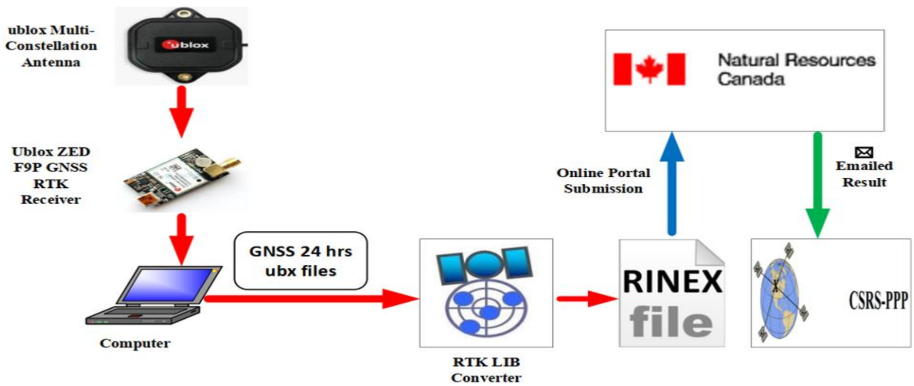

Fig. 1. Experimental setup for studying PPP performance of uBlox ZED F9P Module at LGL, Nigeria

5 Results and Discussion

Table 2 represents the PPP solution results of final IGS product obtained through NRcan online PPP service using the compact, low-cost uBlox ZED F9P GNSS module for data acquisition in GPS-only, GLONASS-only and GPS+GLONASS hybrid mode of operation for one and two days in the months of February, May and July, 2024 respectively. It was observed that below 5 mm horizontal position solution is realizable in GPS and GPS+GLONASS hybrid mode and that below 20 cm vertical coordinate is also realizable using compact, low-cost uBlox GNSS module in Low latitude region. The results imply that compact, low-cost GNSS module (uBlox ZED F9P) is a potential GNSS receiver for PPP accuracy research in low latitude region since the PPP performance gives desirable and acceptable horizontal and vertical PPP solution in the region. The low-cost, light weight, low power consumption of the compact, low-cost uBlox ZED F9P GNSS module is an added advantage in some of the low latitude region where regular and stable power system is a serious challenge.

Table 2. Results for GNSS PPP for LGL, Nigeria using GNSS compact, low-cost uBlox ZED F9P module

Data collection date	Position Uncertainty (95% Confidence level) Geodetic ITRF 2020, m								
	Latitude (North)			Longitude (East)			Ellipsoidal Height (Up)		
	GPS	GLONASS	GPS+GLONASS	GPS	GLONASS	GPS+GLONASS	GPS	GLONASS	GPS+GLONASS
13/02/2024	0.009	0.065	0.007	0.014	0.138	0.010	0.054	0.146	0.035
19/05/2024	0.004	0.016	0.003	0.007	0.055	0.006	0.025	0.053	0.019
20/05/2024	0.005	0.021	0.004	0.007	0.074	0.005	0.027	0.076	0.020
06/07/2024	0.005	0.026	0.004	0.008	0.074	0.007	0.031	0.075	0.023
07/07/2024	0.017	0.183	0.013	0.035	0.422	0.028	0.085	0.630	0.077

6 Conclusion

This paper studied the potential of compact, low-cost GNSS module for GNSS PPP solution in low latitude region at the LGL, Nigeria using compact, low-cost uBlox ZED F9P GNSS module. The PPP solution results obtained on different days in different months of the same year 2024 show that the compact, low-cost GNSS module (uBlox ZED F9P) is a potential GNSS receiver module for GNSS PPP solution in low latitude region. The GNSS module has proved to be suitable and efficient in GPS-only and GPS+GLONASS hybrid mode of operation with 95% confidence level in low latitude region for mm or sub-cm accuracy in horizontal coordinates and below 20 cm accuracy in vertical coordinate. Therefore, compact, low-cost GNSS module (uBlox ZED F9P module) has the potential for being explore for GNSS PPP solutions and other GNSS RTK applications in low latitude region, its low-cost, and very low power consumption is an added advantage for GNSS applications exploration in the low latitude region.

The future work will involve studying the potential of other modules from different manufacturers on different constellations in low latitude region and also investigating the impact of the data logging frequency on the PPP solution.

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