International Journal of Electronics and Communication Engineering (IJECEG)
Volume 2, Issue 1, January-June 2025, pp. 8-23, Article ID: IJECEG_02_01_002
Available online at https://iaeme.com/Home/issue/IJECEG?Volume=2&Issue=1
Journal ID: 1556-1522; DOI: https://doi.org/10.34218/IJECEG_02_01_002

COMPARATIVE ANALYSIS OF GEODETIC RECEIVER AND ANDROID SMARTPHONE PARAMETERS IN THE CONTEXT OF GPS, GALILEO AND QZSS CONSTELLATIONS

Poojari Krushika[1], Dr. A. Rajani[2], Dr. P. Naveen Kumar[3], Dr. Devadas kuna[4], Naraiah Rairala[5]

[1]Department of ECE, Jawaharlal Nehru Technological University, Hyderabad, India.
[2]Professor, Department of ECE, Jawaharlal Nehru Technological University, Hyderabad, India.
[3]Professor, Department of ECE, University College of Engineering, Osmania University, Hyderabad, India.
[4]Department of Electrical Engineering, IIT, Hyderabad, India.
[5]Ph.D Scholar, Department of ECE, University College of Engineering, Osmania University, Hyderabad, India.

ABSTRACT

Global Navigation Satellite Systems (GNSS) provides precise position, navigation and timing data (PNT) for global and regional satellite constellations. Geodetic GNSS receivers used for surveying and geospatial uses have the limitations of high cost and complexity. Compact, lower cost GNSS receivers/ modules, and handheld devices were commercially available for use later on. This paper presents a comparative analysis of signal strength measurements obtained from geodetic receiver and android smartphones across multiple GNSS constellations, including GPS, GALILEO and QZSS. The research aims to assess and compare the performance of geodetic receiver and android smartphones in capturing and processing signals from diverse satellite constellations with implications for positioning accuracy. The experimental methodology involves systematic data collection using single-frequency and dual-frequency android smartphones and the GPStation-6 receiver, situated at the Advanced

GNSS Research Laboratory (AGRL), Department of Electronics and Communication Engineering, Osmania University, Hyderabad. Both geodetic receiver and android smartphones are subjected to identical testing scenarios, capturing performance metrics such as satellite visibility, Signal-to-Noise ratio (SNR) for each satellite system. The Android smartphone recorded lower Signal-to-Noise ratios (SNR) in contrast to the geodetic receiver. The findings will contribute to advancing our understanding of the practical performance of these devices in realistic situations. Furthermore, the research may inform future developments in GNSS technology, enhancing the accuracy of positioning systems for a wide range of applications in India.

Keywords: GNSS, GPSTest, GNSS Logger, Android smartphone GNSS raw observations, static positioning, geodetic receiver, android smartphone receiver.

Cite this Article: Poojari Krushika, Dr. A. Rajani, Dr. P. Naveen Kumar, Dr. Devadas kuna, Naraiah Rairala. (2025). Comparative Analysis of Geodetic Receiver and Android Smartphone Parameters in the Context of GPS, Galileo and Qzss Constellations. *International Journal of Electronics and Communication Engineering (IJECEG)*, 2(1), 8-23.

https://iaeme.com/MasterAdmin/Journal_uploads/IJECEG/VOLUME_2_ISSUE_1/IJECEG_02_01_002.pdf

1. Introduction

Global Navigation Satellite Systems (GNSS) have revolutionized the way we navigate and understand our position on Earth. Google allowed access to GNSS raw measurements on smartphones and tablets using ‘Android 7.0’ in 2016 [5]. Among the notable GNSS constellations, Global Positioning System (GPS) operated by the United States with 32 satellites with carrier frequencies L1(1575.42MHz), L2(1227.60MHz) and L5(1176.45MHz), GALILEO managed by the European Union with 30 (22 current) satellites and the carrier frequencies are E1(1575.42MHz), E5a(1176.45MHz) and E5b(1207.14MHz) and the Quasi-Zenith Satellite System (QZSS) with 7 operating satellites designed primarily for Japan and the Asia-Ocean region with carrier frequencies L1(1575.42MHz), L2(1227.60MHz) and L5(1176.45MHz) [7].

High-precision GNSS data has been the domain of geodetic receivers. Here we use GPStation-6 geodetic receiver for comparative analysis of satellite visibility, signal strength. The GPStation-6 is a multi-frequency, multi-constellation GNSS receiver designed for high-accuracy positioning. The frequencies provided are GPS L1- coarse acquisition (C/A), L2-Precision code P(Y), L2C and L5, COMPASS QZSS, Galileo E1, E5a, E5b and L5. The GPStation-6 receiver is available in multiple configurations, including dual-frequency (L1 and L2; L1 and L5) and triple-frequency (L1, L2 and L5) options [7]. The Geodetic receiver is engineered for superior accuracy and reliability and equipped with advanced hardware and software to deliver precise positioning. Modern Android smartphones, featuring sophisticated GNSS chipsets, now offer multi-constellation support and enhanced signal processing capabilities.

Umberto Robustelli et al. (2019) have analyzed the positioning performance measurements using a Xiaomi dual-frequency android smartphone and compared to those of a geodetic receiver under two different scenarios in a multi-GNSS constellation environment [3]. Debipriya Dutta et al. (2020) have analyzed signal versatility, satellite geometry, precise positioning accuracy, and signal strength specifications using android smartphones in a multi-GNSS environment [1]. Jacek Paziewski et al. (2021) have analyzed smartphone's relative positioning in a multi-GNSS environment [9]. Farzaneh Zangenehnejad et al. (2023) have developed a tool called 'CSV2RINEX tool' and evaluated it's performance with other available android applications, namely GnssLogger and Geo++RINEX logger. Precise positioning performance is also analyzed using the newly developed tool [6].

2.Methodology

This paper presents initial findings on the effectiveness of widely accessible android smartphones to collect GNSS data. The study examined GNSS precise position solutions, satellite geometry, and signal strength values using android applications on commonly available smartphones in a stationary outdoor setting. The available smartphones from different manufacturers, as listed in Table 1, were used to retrieve multi-GNSS data simultaneously from the same location without relying on cellular service network support, with solutions derived directly from the GNSS chipsets embedded in the smartphones. These smartphones are capable of tracking GNSS signals in the L band from various constellations, including QZSS, GALILEO, GLONASS and GPS satellites. For comparative analysis with the smartphone data, we also use the geodetic receiver "NOVATEL-GPStation-6." This receiver can be upgraded in the field to meet specific performance requirements. The GPStation-6 receiver can trace all available GNSS constellations and satellite signals, including Galileo E1, E5a, E5b, GPS L1, L2, L2C, and L5, QZSS L1, L2C, L5, and GLONASS L1, L2 signals [8].

Table 1. Key characteristics of the Android smartphones employed for data collection

DEVICE	**SAMSUNG GALAXY S21**	**ONEPLUS 7**
Image		
Chipset	Qualcomm Snapdragon 888	Qualcomm Snapdragon 855
Operating System	Android 12	Android 10
Frequency	L1	L1/ L5

3. Data collection and Experimental setup

GNSS data from recent smartphones OnePlus 7, and Samsung Galaxy S21, were gathered near the Osmania University campus at a sampling rate of 1 second using the Android "GNSS Logger" (v3.0.6.4) and "GPSTest" (v3.10.3) for approximately 20 minutes on December 21, 2023. The smartphones were positioned in a relatively clear sky environment on the top of the ECE building at Osmania University, Hyderabad. Android applications GPSTest and GNSS Logger are used to capture GNSS data regarding user positioning and satellite details in the National Marine Electronics Association (NMEA) data format [3].

Both mobile applications commence simultaneously and record data continuously until we halt the logging process by clicking on the "stop log" button. GNSS NMEA data is captured concurrently for a duration of 20 minutes in an open-sky setting. The collected data is then stored in either the primary storage or backup storage of the smartphone. We can share the acquired data through email or WhatsApp in text format (.txt) as well as NMEA file (.nmea) format. The geodetic receiver is set in the necessary mode to operate and begins the logging process. The raw data can be extracted in .csv (Comma Separated Values) format. The latitude of the experiment location is 17.407^0 N and longitude is 78.517^0 E [2].

Figure 1. Mobile phones placed in an "open sky" environment

Figure 2. Mobile phones and antenna are placed in multipath free environment

Figure 3. GPStation-6 receiver, placed in AGRL Lab, ECE block, Osmania University

Figure 4. Clear view of Novatel GPStation-6 receiver

4. Results and Discussions

Satellite visibility, Signal strength variations parameters have been observed for multi-GNSS data collected for various satellite navigation systems like GPS, GALILEO and QZSS on December 21, 2023 for approximately 15-20 minutes. Each constellation's satellite visibility, signal strength variations, and parameters of smartphones, and geodetic receiver are discussed below in each section. The signal strength variations, satellites in view is plotted on the Y-axis of multi-constellation, while the X-axis represents local time in hours.

4.1. Satellite visibility in the context of GPS, GALILEO, QZSS

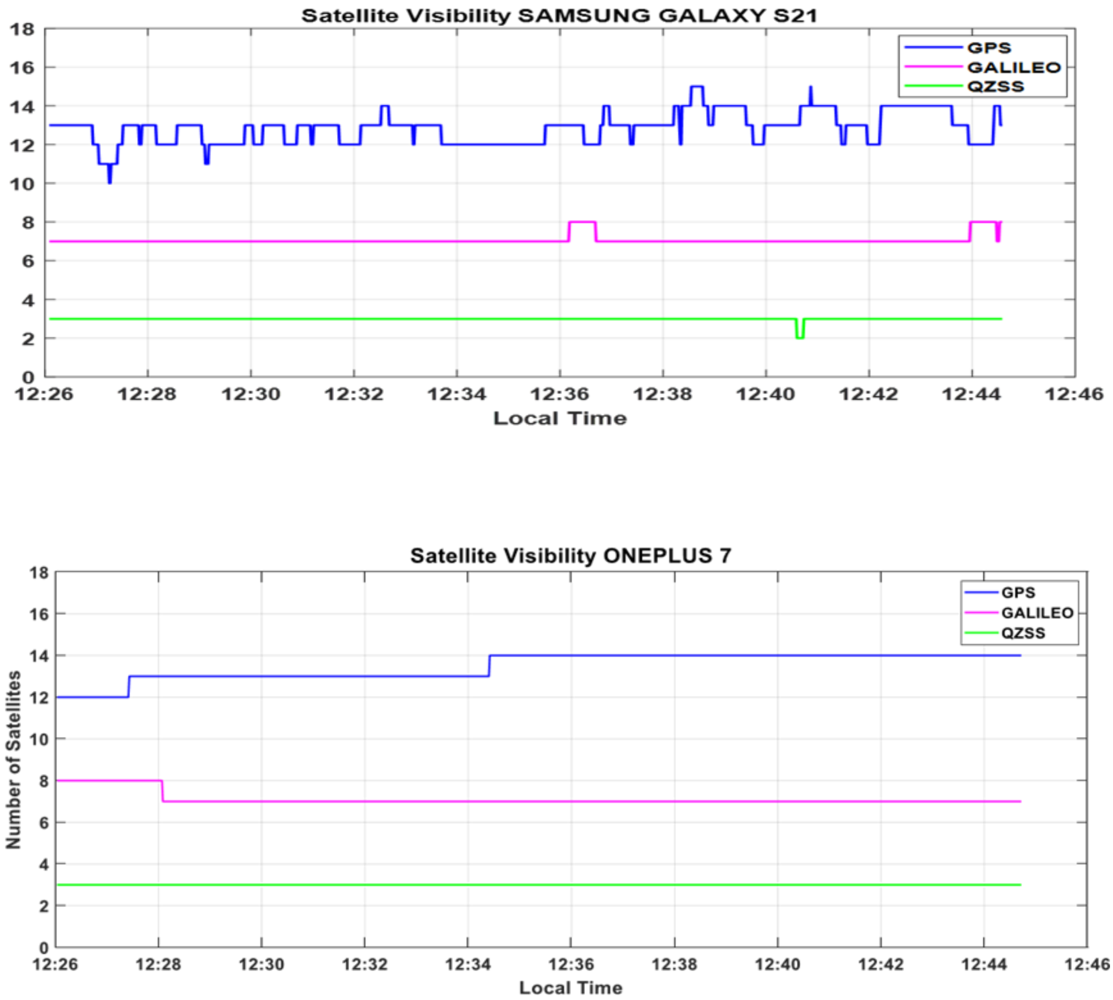


Figure 5. Satellite visibility of two smartphones, Samsung Galaxy S21 and Oneplus7

Figure 5. The plots show the satellite visibility of each constellation with respect to local time. Both the android smartphones are placed on the rooftop of the ECE block, Osmania University, Hyderabad. The experiment was carried out for 20 minutes in an ‘open sky’ environment in static conditions. One dual-frequency (DF) mobile and one single- frequency (SF) mobile are used for data collection and analysis, in our experiment.

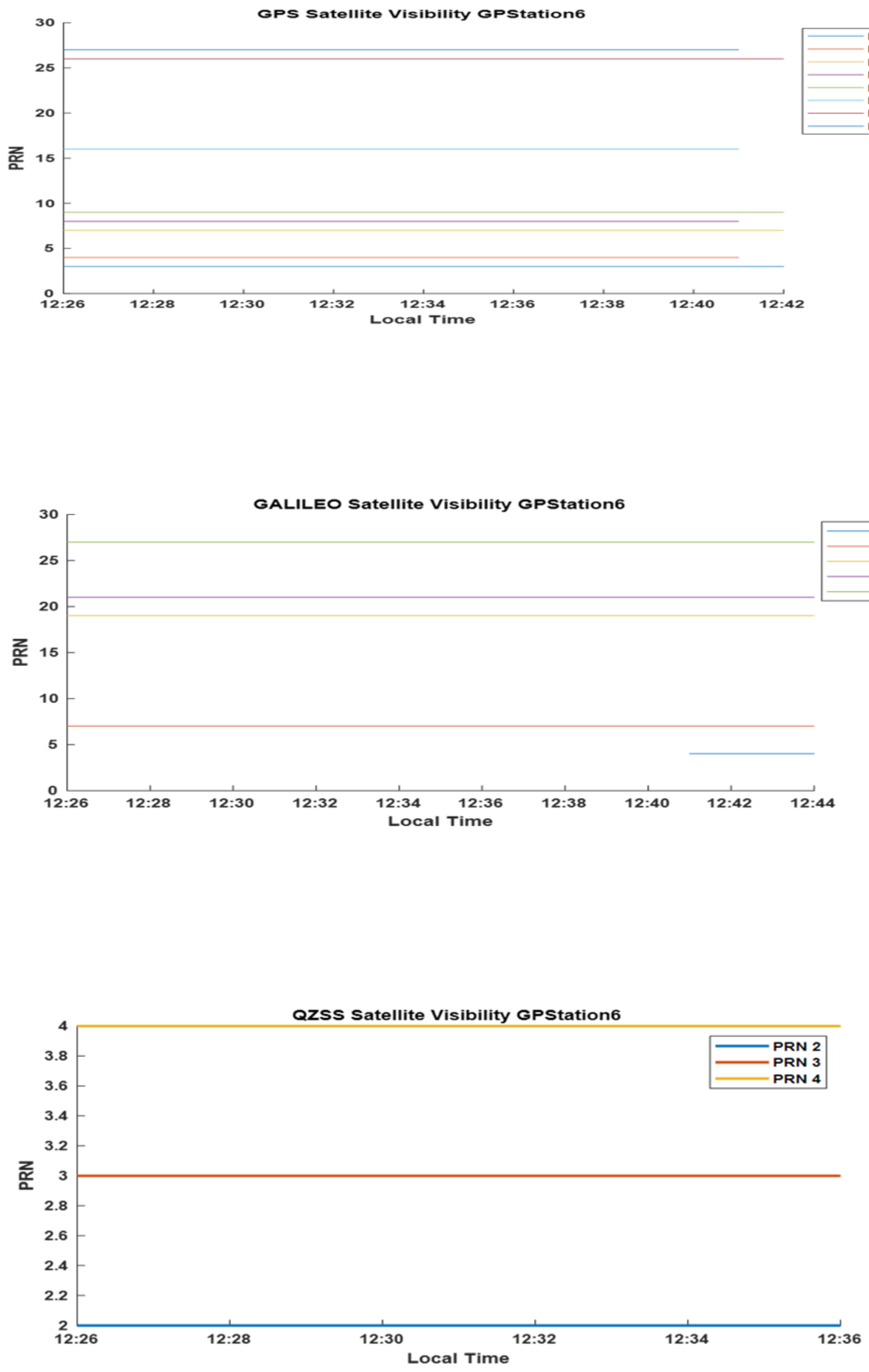


Figure 6. Satellite visibility of the GPStation-6 geodetic receiver of GPS, GALILEO, QZSS constellations

The smartphones used for analysis, namely the Samsung Galaxy S21 (SF) and OnePlus7 (DF) have received signals from all constellations considered for analysis. According to the data analyzed there were overall 11-15 GPS, 2-3 QZSS satellites, and 7-8 GALILEO satellites visible throughout the duration. Figure 6. indicates the plots for the geodetic receiver GPStation-6, which is placed at the AGRL laboratory. The receiver was kept in GLONASS mode to operate. Analyzing the plots, 8 satellites were visible for GPS, 5 satellites for GALILEO and 3 QZSS satellites were visible throughout the experiment duration. Both android smartphones and geodetic receivers rely on ephemeris data (information about the satellite's position and orbit) to determine satellite visibility. The overall analysis shows that satellite visibility for android smartphones were good when compared to geodetic receiver. Satellite visibility in Samsung galaxy s21 has much variation than in Oneplus7 in context of GPS, GALILEO, QZSS constellations.

4.2. Signal strength variations

The signal strength (SNR) represents the ratio between signal power and noise power (C/No) per unit bandwidth. It is essentially a solid indicator of GNSS SNR where a stronger signal has high SNR and a weaker signal has low SNR.

$$SNR = 10\log_{10}\left(\frac{Signal\ Power}{Noise\ Power}\right)\ \text{dB} \tag{1}$$

Where, Noise Power is measured in dB-Hz and Signal Power is measured in dBm

GPS signal strength variations of smartphones and geodetic receiver

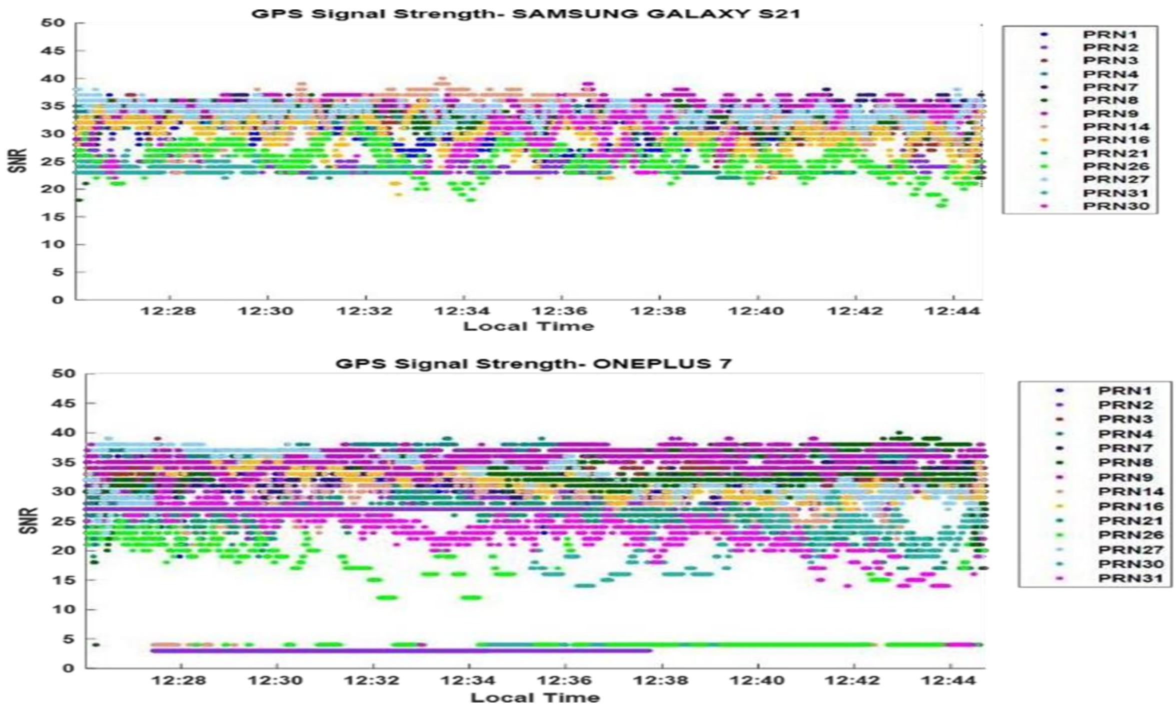


Figure 7. GPS Signal strength of Oneplus7 and Samsung galaxy s21

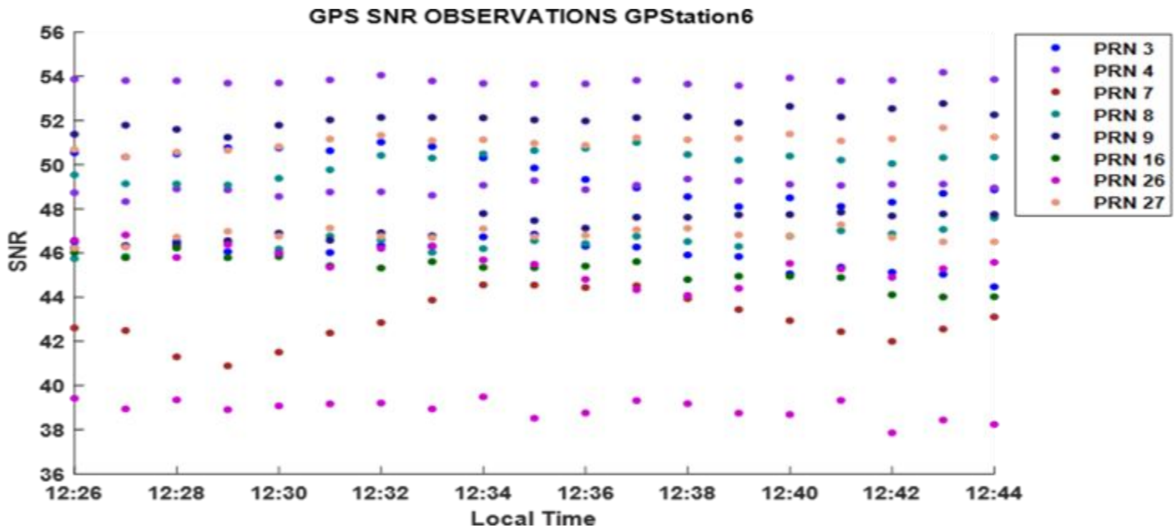


Figure 8. GPS Signal strength of GPStation-6 receiver

The signal strength variations are shown in the above plots with respect to local time. Observations were conducted using two GNSS smartphones: OnePlus 7, and Samsung Galaxy S21. The two devices have Qualcomm chipset. Figure 7. provides the SNR measurements for GPS signal for the two android smartphones. The GPS SNR ranges from 3– 40, and 16–40 for Oneplus7, and Samsung galaxy s21, respectively. The receiver graph is shown above in Figure

8. as the SNR ranges from 38-55 dB-Hz. These values are obtained from both smartphones (in airplane mode) and receiver simultaneously in static mode for 20 minutes duration.

GALILEO signal strength variations of smartphones and geodetic receiver

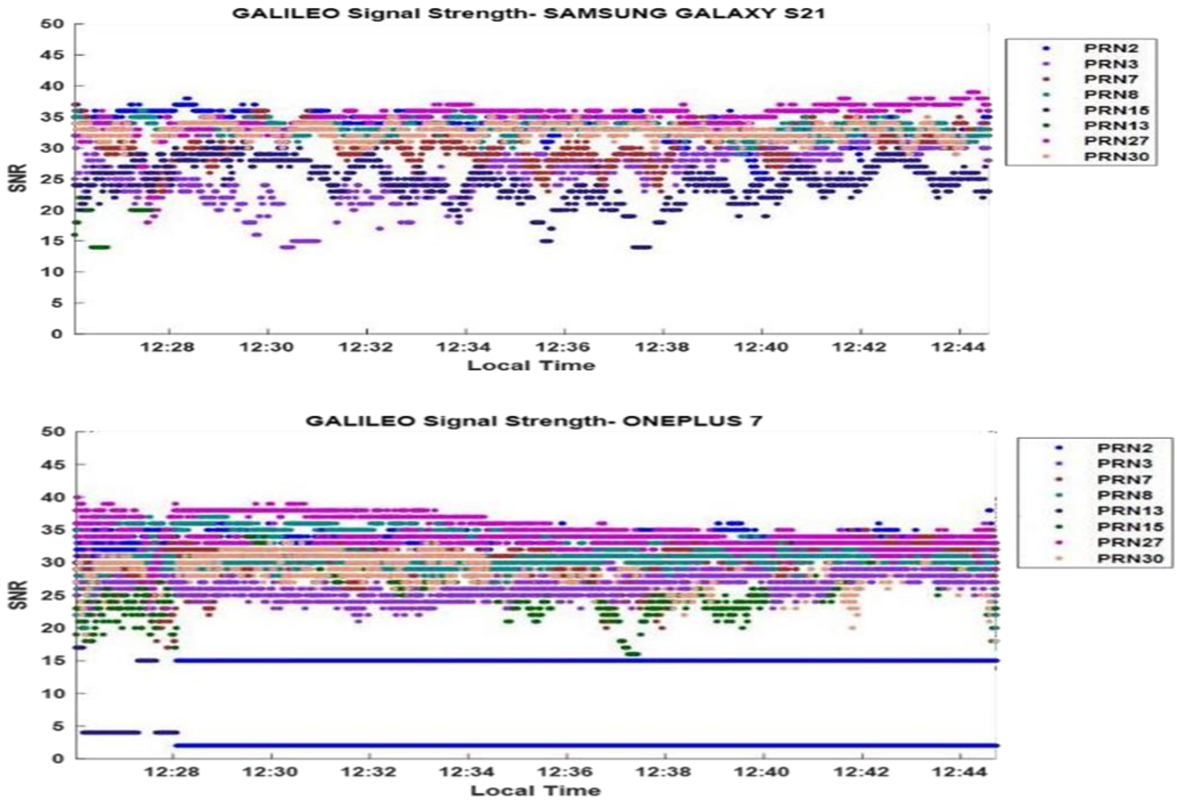


Figure 9. GALILEO Signal strength of Oneplus7, Samsung galaxy s21 android smartphones

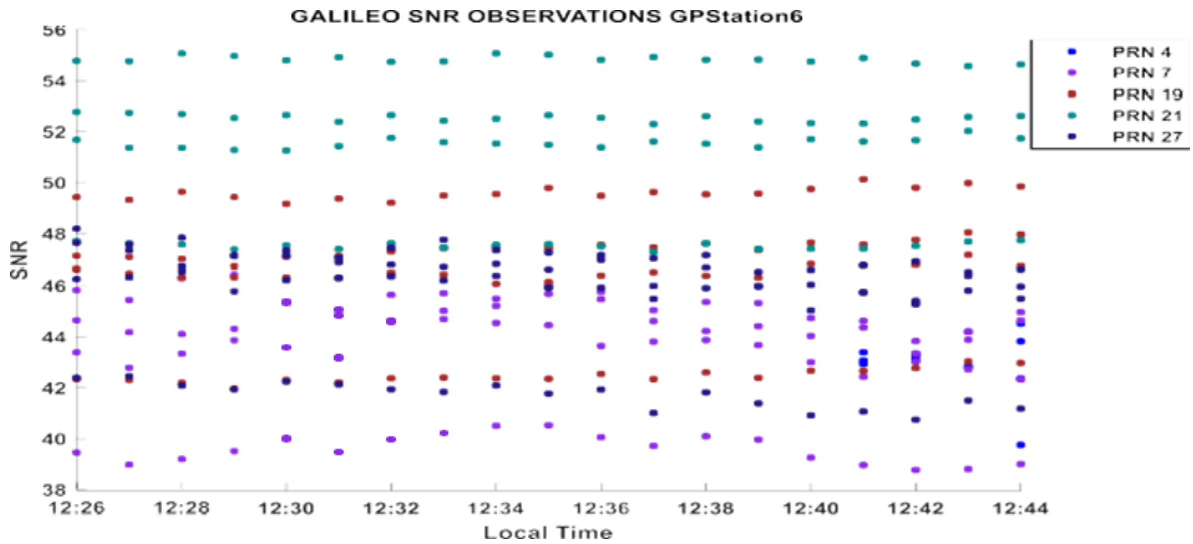
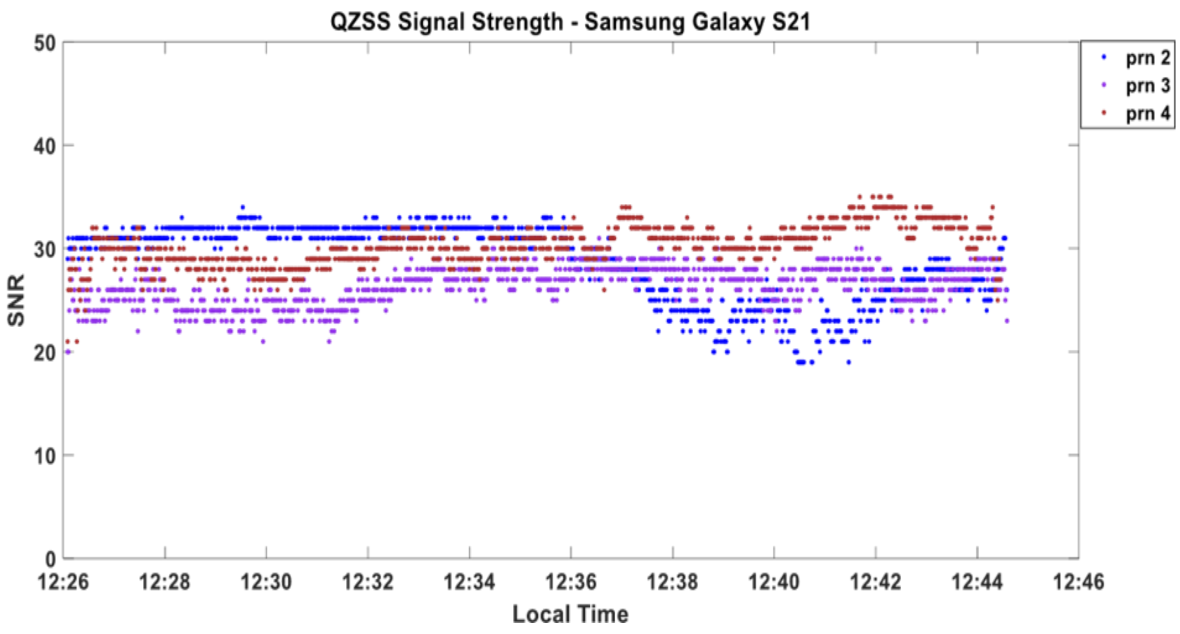


Figure 10. GALILEO Signal strength of GPStation-6 receiver

GALILEO SNR observations have been plotted using the data acquired. Figure 9. provides the SNR measurements for GALILEO signal for two android smartphones. The smartphone OnePlus 7 ranges from 2-40 dB-Hz, and the Samsung Galaxy S21 ranges from 13-39 dB-Hz approximately. The receiver graph is shown above in Figure 10. as the SNR ranges from 39-55 dB-Hz approximately. The graphs indicates that geodetic receiver has received strong SNR values better than android smartphones. Generally lower SNR is due to smaller antenna size and less advanced signal processing capabilities. Environmental factors such as user movement, obstructions and interference from other electronic components within the phone can significantly impact SNR. The SNR values can range widely, often between 20-30 dB-Hz in good conditions, but can drop significantly in urban environments or indoors. Geodetic receivers provide much higher positional accuracy, suitable for professional and scientific applications, while smartphones are adequate for everyday use where moderate accuracy is acceptable. SNR Values greater than 20 dB is considered as good quality, range of 10-20 dB is considered as moderate quality, less than 10 dB is considered as poor quality

QZSS Signal strength variations of smartphones and geodetic receiver



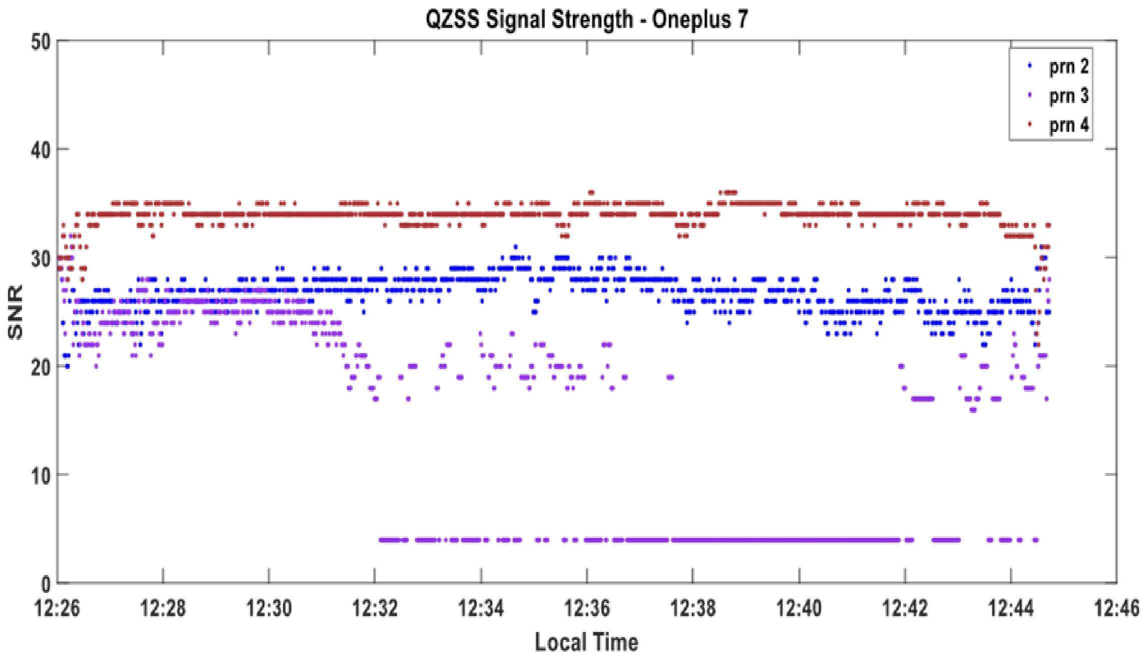


Figure 11. Variations of QZSS SNR with respect to local time in Samsung Galaxy S21, ONEPLUS7

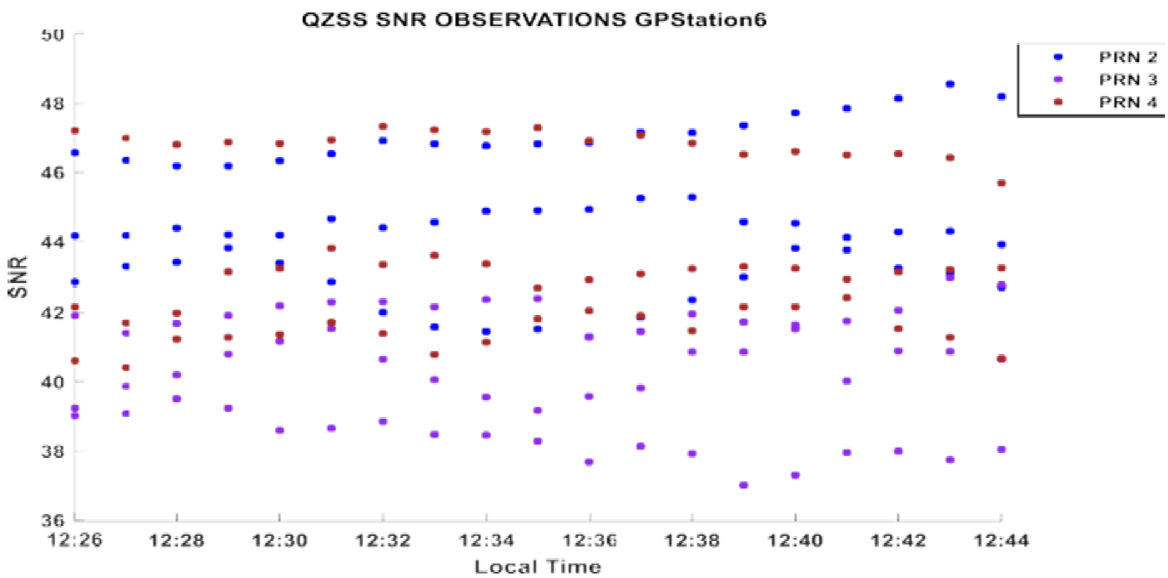


Figure 12. QZSS Signal strength of GPStation-6 receiver

QZSS SNR values have been recorded for two mobiles namely Oneplus7, Samsung galaxy S21. The mobile phones analysis is shown in Figure 11. and the QZSS C/N0 (SNR) ranges from 4-35 dB-Hz, 11-41 dB-Hz for Oneplus7, Samsung galaxy S21 respectively. The receiver analysis is shown above in Figure 12. and the SNR ranges from 37-49 dB-Hz. By looking at the figures briefly we can tell that lower level of SNR values have been recorded for android smartphones in comparison with geodetic receiver [1].

Table 2. SNR values of four smart phones of multi-GNSS constellation and receiver which is in single epoch (12:37:00pm, Local Time on 21-dec-2023)

Android smart phones and geodetic receiver	**GPS PRN- 21**	**QZSS PRN-4**	**GALILEO PRN-27**
OnePlus7 (DF)	26	35	33
Samsung Galaxy S21 (SF)	---	33	36
GPStation-6 receiver	---	47.13	48.19

The complete analysis of signal strength of android smartphones and geodetic receivers are shown individually for every smartphone and every GNSS constellation in each section. Table.2 indicates PRNs of multi- GNSS constellation of both android smartphones and geodetic receiver in a common single epoch. Table 2. has two PRNs namely, PRN-21 for GPS, PRN-4 for QZSS, PRN-27 for GALILEO. The data is collected by analysing the PRN values of two android smartphones data and geodetic receiver data. Both the android smartphones and geodetic receiver data are checked for common PRN values and the time considered must be same for all PRNs considered. The values in the table indicate SNR values of the dedicated PRN for each constellation at a common epoch. The empty boxes indicate that no SNR values have been recorded for the respective PRN at the time considered. By looking at Table 2. it is clearly visible that geodetic receivers have greater SNR values than android smartphones used. The GPS SNR value of OnePlus7 is 24 dB-Hz. Here no SNR values were recorded for Samsung Galaxy S21 and geodetic receiver. We considered PRN-4 for QZSS constellation and here the SNR value for geodetic receiver stands high when compared to android smartphones. When we consider only android smartphones for better SNR reception then OnePlus7 gets higher SNR value, 35 dB-Hz and Samsung Galaxy S21 remains least with 33 dB-Hz. PRN-27 is considered for GALILEO and the values for SNR have been recorded for a single epoch (12:37:00 Local Time). There is only slight change in SNR values between OnePlus7 and

Samsung Galaxy S21. The observation states that geodetic receiver has greater signal strength than android smartphones.

5. Conclusions

Geodetic receivers consistently outperform android smartphones in terms of signal strength and accuracy. They exhibit robust performance across all the satellite constellations studied, demonstrating high reliability in varied environmental conditions. In contrast, Android smartphones, while considerably more accessible and user-friendly, show limitations in signal strength. Despite all the limitations, modern smartphones have shown significant improvements in recent years, offering acceptable levels of accuracy for general navigation and consumer applications. Novatel GPStation-6 receiver is equipped with the GPS-703-GGG antenna. We explored how well devices handled signals from different constellations simultaneously. The overall satellite visibility for multi-GNSS constellations of android smartphones is finer compared to geodetic receiver. Through this comparative analysis we can conclude that signal strength of geodetic receiver is preferable than android smartphones. In conclusion, while geodetic receivers remain the gold standard for high-precision GNSS applications, Android smartphones are becoming increasingly capable alternatives for everyday positioning needs. As technology advances, integrating GNSS data with other sensors and systems (e.g., Internet of Things (IoT), 5G, 6G) will be crucial. Comparative analysis can guide the integration process and improve overall system performance. The choice between these devices should be guided by the specific accuracy requirements, environmental conditions, and user expertise.

Acknowledgements: I am indebted to Prof P. Naveen Kumar, Prof A. Rajani for their tremendous support and feedback throughout the research process. Finally, I thank Advanced GNSS Research Laboratory, Department of ECE, UCE, OU for providing the necessary facilities and resources to conduct my research successfully.

References

[1] Debipriya Dutta, Somnath Mahato., Soumyajit Raja., Souvik Ganguli., Sudip Verma., Anindya Bose. Android Smartphones for GNSS studies in Multi-Constellation Environment. 2020 National Conference on Emerging Trends on Sustainable

Technology and Engineering Applications (NCETSTEA), DOI: 10.1109/NCETSTEA48365.2020.9119916.

[2] Devadas Kuna, Naveen Kumar Perumalla., (2023). Assessment of android smartphones positioning in multi-GNSS/NavIC environment. Journal of Applied Geodesy. 17. 10.1515/jag-2022-0062.

[3] Umberto Robustelli, Valerio Baiocchi., Giovanni Pugliano (2019). Assessment of Dual Frequency GNSS Observations from a Xiaomi Mi 8 Android Smartphone and Positioning Performance Analysis. Electronics. 8. 10.3390/electronics8010091.

[4] Purfürst, T. Evaluation of Static Autonomous GNSS Positioning Accuracy Using Single-, Dual-, and TriFrequency Smartphones in Forest Canopy Environments. Sensors 2022, 22, 1289. https://doi.org/10.3390/ s22031289

[5] Pepe, M.; Costantino, D.; Vozza, G.; Alfio, V.S. Comparison of Two Approaches to GNSS Positioning Using Code Pseudoranges Generated by Smartphone Device. Appl. Sci. 2021, 11, 4787. https://doi.org/ 10.3390/app11114787

[6] Zangenehnejad, F.; Jiang, Y.; Gao, Y. GNSS Observation Generation from Smartphone Android Location API: Performance of Existing Apps, Issues and Improvement. Sensors 2023, 23, 777. https://doi.org/10.3390/s23020777

[7] GNSS frequencies, https://www.tualcom.com/gnss-frequency-bands-and-signals/.

[8] Novatel GPStation-6 receiver specifications, https://novatel.com/support/previous-generation-products-drop-down/previous-generation-products/gpstation-6-receiver

[9] Jacek Paziewski, Marco Fortunato, Augusto Mazzoni, Robert Odolinski; An analysis of multi-GNSS observations tracked by recent Android smartphones and smartphone-only

relative positioning results. Research Gate 2021. https://doi.org/10.1016/j.measurement.2021.109162

Citation: Poojari Krushika, Dr. A. Rajani, Dr. P. Naveen Kumar, Dr. Devadas kuna, Naraiah Rairala. (2025). Comparative Analysis of Geodetic Receiver and Android Smartphone Parameters in the Context of GPS, Galileo and Qzss Constellations. International Journal of Electronics and Communication Engineering (IJECEG), 2(1), 8-23.

Abstract Link: https://iaeme.com/Home/article_id/IJECEG_02_01_002

Article Link:
https://iaeme.com/MasterAdmin/Journal_uploads/IJECEG/VOLUME_2_ISSUE_1/IJECEG_02_01_002.pdf