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REVIEW ARTICLE

MEASUREMENT AND PREDICTION OF THE EFFECTS OF MULTIPATH ON THE GNSS RECEIVER POSITIONING ACCURACY IN A MULTI-GNSS ENVIRONMENT

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ABSTRACT

As urban areas demand position information for transportation, disaster management, and smart agriculture, Global Navigation Satellite System (GNSS) usage increases. However, multipath error sources from buildings and trees can degrade GNSS performance, posing a serious challenge to urban navigation systems. This study analyzed the impact of multipath on GNSS receiver positioning accuracy in three different reference coordinates (RC), namely (23.2547⁰N, 87.8468⁰E, -26.056m, RC1), (23.2544⁰N, 87.8470⁰E, -25.919m, RC2), and (23.2545⁰N, 87.8468⁰E, -17.599m, RC3), characterized as in-between 2 building walls (RC1), in-between building wall and trees (RC2), and open sky environment (RC3), within the vicinity of the GNSS Laboratory at the University of Burdwan, India, using a dual frequency Javad Triumph L S geodetic receiver. In this study, Signal Strength (C/No), Precise Point Positioning (PPP), Number of Satellites in View (NSV), Geometric Dilution of Precision (GDOP), 3-Distance Radial Mean Square (3-DRMS) position error, and Position Dilution of Precision (PDOP) were used as performance metrics to evaluate the position accuracy of the processed Rinex 2.11 data. The open sky environment (RC3) result showcases less than 4mm horizontal and 11cm vertical PPP accuracy in GPS and GPS+GLONASS hybrid modes of operation, indicating the best position for GNSS PPP when compared with the 15mm horizontal, 89cm vertical, and 27mm horizontal, 57cm vertical PPP accuracies of RC1 and RC2. Further analysis results show that the same RC3 has the highest C/No, maximum NSV, very low GDOP, and PDOP with the least 3DRMS position error of the measured constellations compared to the other two RC locations. Moreover, it was noticed that the multi-GNSS hybrid mode of operation technique adopted in this study mitigates the position error and enhances the GNSS receiver's positioning accuracy. Hence, this paper has significantly contributed to the study of multipath effects on GNSS receivers' positioning accuracy in different GNSS propagation channel scenarios.

KEYWORDS

Multipath, GNSS, Receiver, Positioning, Accuracy

1. INTRODUCTION

Multipath errors occur when a Global Navigation Satellite System (GNSS) signal is reflected off an object, causing a slight delay in signal arrival at the receiver, leading to incorrect position calculations (Nov Atel Inc, 2015). GNSS signals can be interfered with objects near the receiver antennas, leading to secondary propagation paths. This interference can distort the signal, especially in densely populated urban areas (Zheng et al., 2002). Despite increasing demand for position information, GNSS performance is easily degraded by multipath propagation, signal blockage, and non-line of sight reception, making position information and accurate navigation more challenging (Adewuni and Azeez, 2021; Ahmed et al., 2022). Forest canopy affects GNSS positioning accuracy, and attempts to improve it have not fully met researchers' needs for accurate coordinates in forests (Zimbelman and Keefe, 2018). Multipath sources are responsible for factors such as delayed signal, diminished carrier wave amplitude, reduced arrival angle, and altered polarization, which cause interference in code and phase correlation, thereby introducing errors in measurements. In addition, factors like humidity, sky concealment, and complex building structures also affect triangulation (Pirsiarash, 2017; Verma et al., 2019). Hence, this research was carried out to provide more information on the effects of multipath on the GNSS receiver's positioning accuracy in three different GNSS propagation channels characterized as open sky environment, building, and building with trees.

2. EXPERIMENTAL SETUP

Three GNSS reference coordinates aforementioned was created near the GNSS Laboratory Burdwan (GLB), and a Javad Triumph LS geodetic receiver antenna were placed consecutively in three RCs as shown in figure 1. The whole experimental setup and the data processing procedures are depicted in Figure 2. Dual-frequency Jipsrin data was logged and converted to the Rinex 2.11 file. The data was processed to obtain the C/NO of the GPS and GLONASS constellations. The converted data was uploaded to the Natural Resources of Canada (NRCan) website for PPP results. Further analysis was carried out on the constellation observation data to evaluate the level of multipath degradation of the satellite signals and the impacts on the GNSS receiver's positioning accuracy in each RC.

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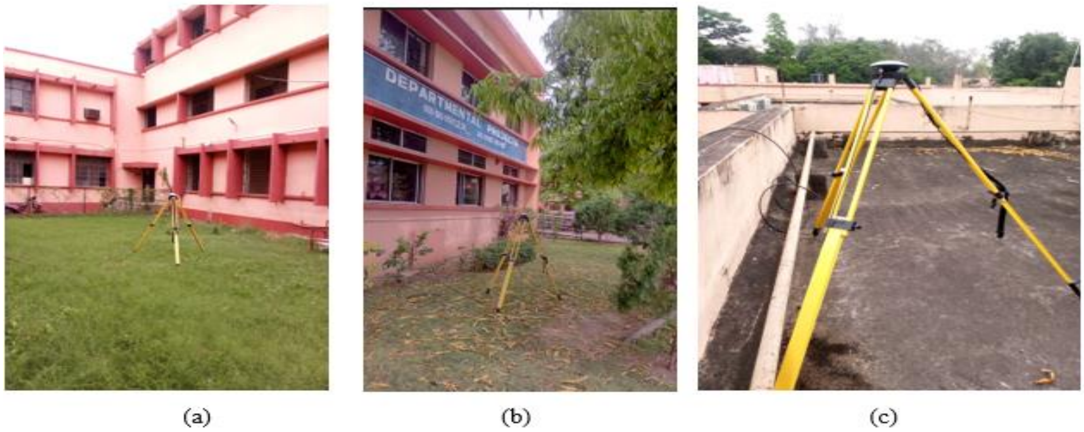


Figure 2: Experimental locations showing Antenna placed (a) in-between two building walls (b) in-between wall and trees (c) in an open sky environment.

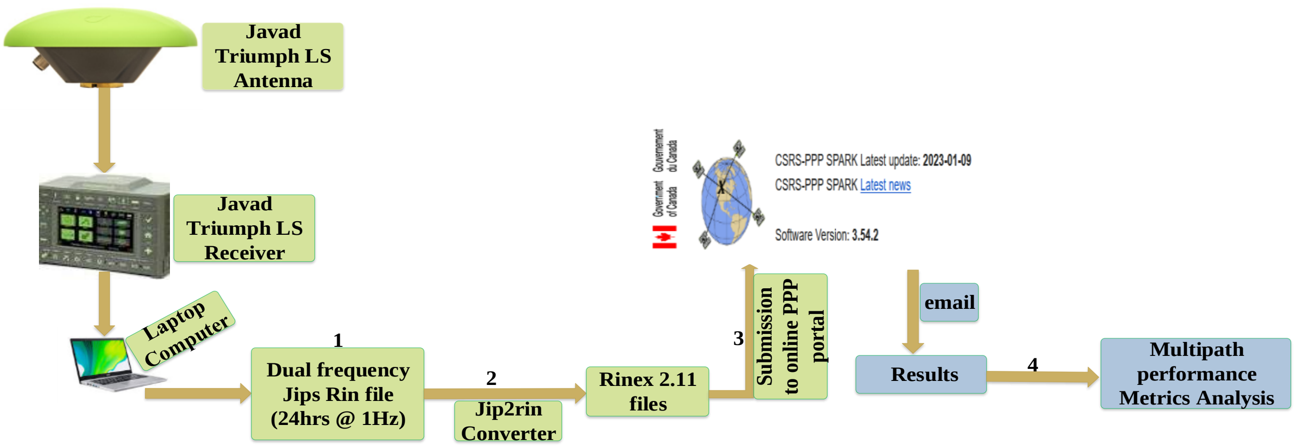
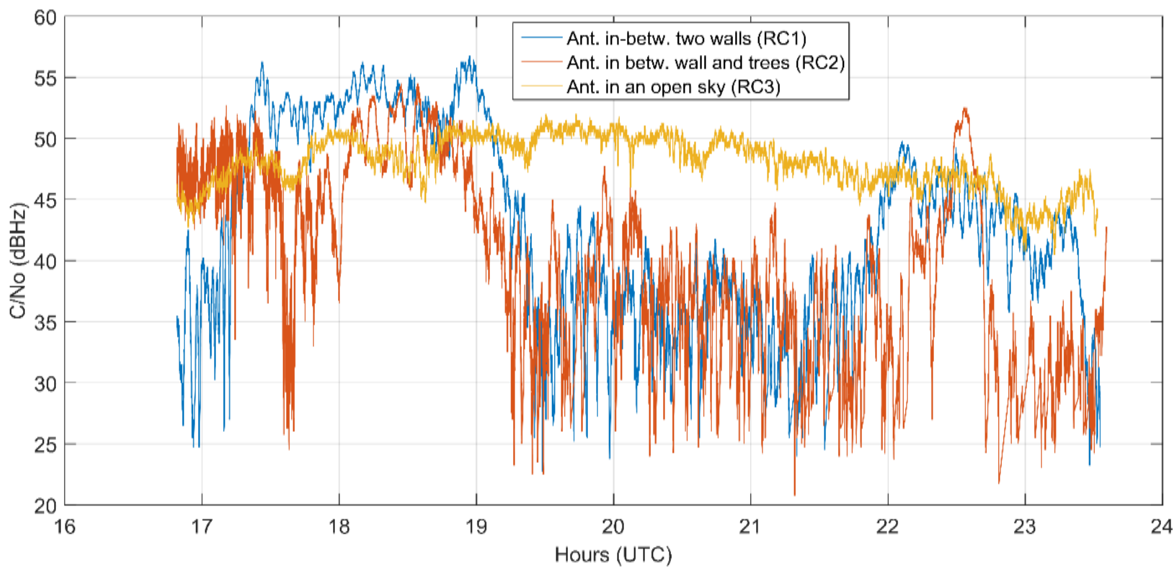


Figure 2: Experimental Setup for studying multipath effect on GNSS receiver's accuracy using Javad Triumph LS receiver at Burdwan University, India

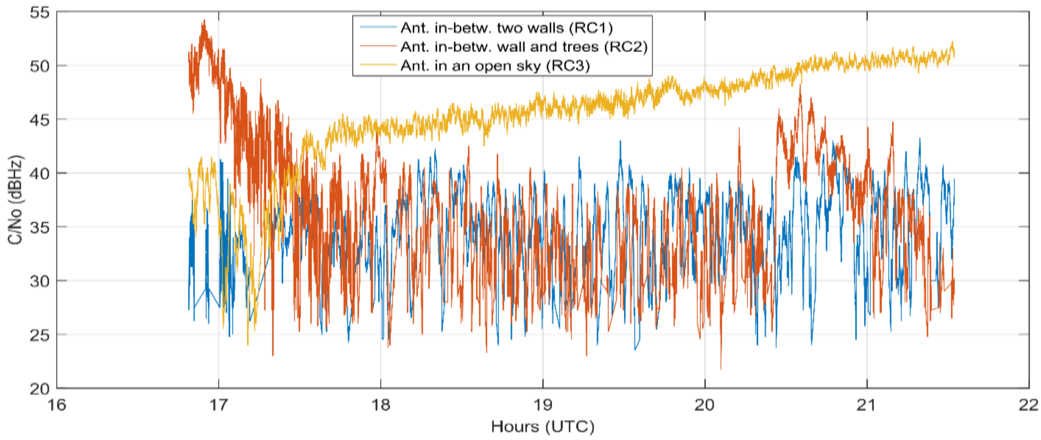
3. RESULTS AND DISCUSSIONS

3.1 Comparison of C/No of the GNSS Constellations at the three RC Locations

The study compares the results of the measured GNSS constellation's signal strength (C/NO dBHz) in the three RC locations, as shown in figures 3a and 3b. The C/NO obtained from GPS #32, #32, and #32 code frequency bands, showed the highest C/NO of 48.01 dBHz with a standard deviation of 2.12 in an open sky environment (RC3), the highest C/NO of 40.90 dBHz with a standard deviation of 7.14 when the antenna was in-between building walls and trees (RC2), and the highest C/NO of 42.81 dBHz with a standard deviation of 7.77 when the antenna was in-between two building walls (RC1) (CCRS-PPP, 2023). Likewise, the variation in C/NO of the GLONASS #7, #7, and #1 L1 code frequency bands measured, showed the highest C/NO of 45.68 dBHz with a standard deviation of 4.34 in the RC3 location, the highest C/NO of 37.34 dBHz with a standard deviation of 5.81 at RC2, and the highest C/NO of 34.89 dBHz with a standard deviation of 3.48 at RC1, respectively. Generally, this study reveals that C/NO in the three RC locations is higher and less fluctuating in an open sky environment, compared to the other two RCs influenced by multipath sources.



(a)



(b)

Figure 3: Variations of (a) GPS L1(#32, #32 & #32) (b) GLONASS L1 (#07, #07 & #01) Constellations Signal Strength (C/NO) in the three Locations

3.2 Position Accuracy Results of the three RC Locations

Table 1 shows the results obtained when the processed Rinex 2.11 observation files of each RC location were uploaded to the Natural Resources of Canada (NRCan) online service for precise point positioning and the position uncertainty results (95% confidence level) in GPS-only, GLONASS-only, and GPS+GLONASS hybrid modes of operation (Javad, 2023). It was observed that, below 4mm horizontal position accuracy and 11cm vertical position accuracy are achievable in GPS and GPS+GLONASS hybrid mode of operation a at 95% confidence level when the receiver antenna is placed open sky environment (RC3). It was also observed that below 15mm horizontal and 89cm vertical position accuracies were achieved in the GPS and GPS+GLONASS hybrid modes at a 95% confidence level, when the receiver antenna is placed in-between wall and trees (RC2). Moreover, below 27mm horizontal and 57cm vertical position accuracies were achieved in GPS and GPS+GLONASS hybrid mode at a 95% confidence level when the receiver antenna is placed in between two walls (RC1). These results imply that multipath sources worsen GNSS positioning accuracy, while an open sky environment gives better accuracy. Furthermore, the multi-GNSS hybridized mode of operation technique adopted (GPS+GLONASS) in the study mitigates the positioning error and enhances the positioning accuracy of the receiver in the three RC locations.

Table 1: NRCan online service PPP results for GPS, GLONASS and GPS+GLONASS multipath effects study at Burdwan university, India using Javad Triumph LS geodetic receiver.

		Position Uncertainty (95% Confidence Level), Geodetic ITRF 2020, m			
Type of Receiver	Antenna Location	GNSS	Latitude.	Longitude	Height
Javad Triumph LS	RC1	GPS	0.013	0.009	0.053
		GLONASS	0.069	0.149	0.377
		GPS+GLONASS	0.014	0.027	0.057
	RC2	GPS	0.012	0.015	0.089
		GLONASS	0.022	0.113	0.217
		GPS+GLONASS	0.009	0.008	0.058
	RC3	GPS	0.003	0.003	0.011
		GLONASS	0.004	0.007	0.020
		GPS+GLONASS	0.002	0.003	0.010

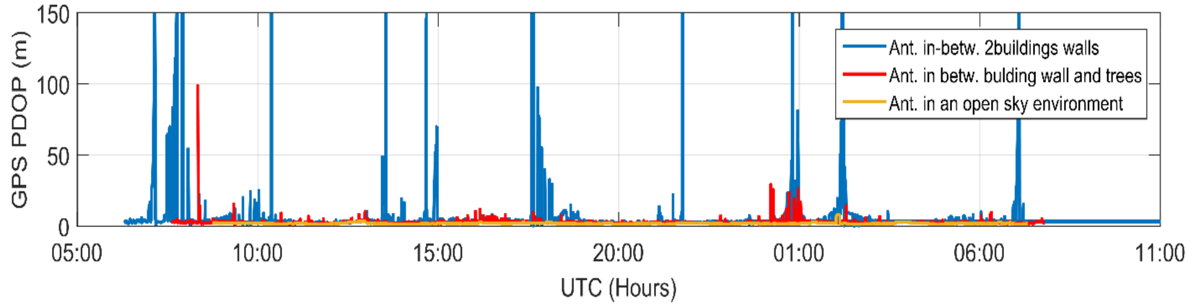
Further analysis on the effects of multipath on the GNSS receiver's positioning accuracy was carried out to complement the NRcan online service PPP results using maximum, minimum, and average values of Number of Satellite in View (NSV), Geometric Dilution of Precision (GDOP), and 3-Distance Root Mean Square (3DRMS) position error, and the results are shown in Table 2. It was witnessed that the open environment (RC3) has the highest average NSV in GPS-only, GLONASS-only, and GPS+GLONASS hybrid modes compared to the other two RC locations. Good GDOP is obtained when satellites are spread out in the sky. The lower the GDOP value, the better the accuracy. It was witnessed that the open sky environment shows the least average value of GDOP (better positioning accuracy) in GPS-only GLONASS-only, and GPS+GLONASS hybrid mode when compared with the other two locations (RC1 and RC2) that are characterized as severe multipath sources. Moreover, the 3DRMS position error observed in the three RC locations also shows that the open sky environment (RC3) has the least average 3DRMS position error when compared to the other two RC locations that are characterized by several multipath sources. These results also revealed that GNSS receivers' positioning errors are minimized in an open sky environment.

Table 2: GNSS –Multipath effects on Position accuracy performance metrics

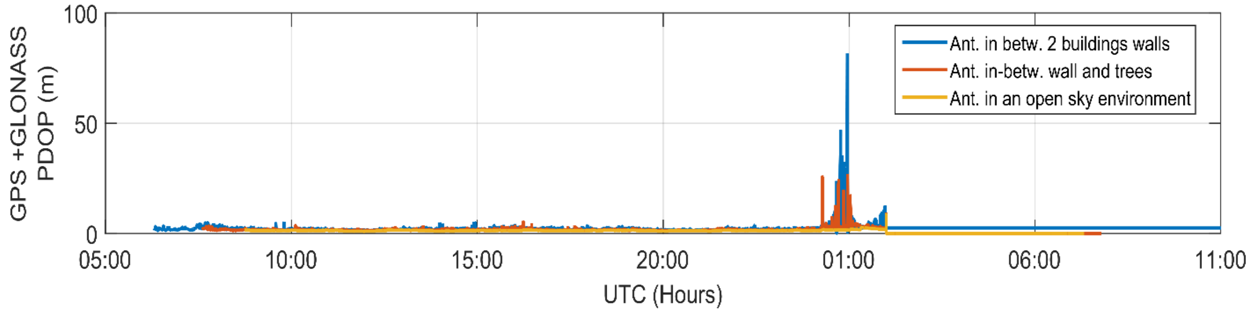
		GNSS Multipath Performance evaluation Metrics								
Antenna Location	GNSS	NSV			GDOP			3DRMS Position Error		
		Max	Min	Ave	Max	Min	Ave.	Max	Min	Ave.
RC1	GPS	8	4	5	15.0	2.6	6.02	7.4252	0.0053	0.0970
	GLONASS	5	4	4	15.0	2.7	7.89	9.7500	0.0383	0.3809
	GPS+GLONASS	14	5	9	10.8	1.7	3.03	5.5973	0.0022	0.0509
RC2	GPS	10	4	5	15.0	1.7	4.62	7.1393	0.0048	0.1271
	GLONASS	6	4	4	14.8	2.9	5.19	8.2033	0.0017	0.3198
	GPS+GLONASS	16	4	10	14.0	1.4	2.38	9.0995	0.0020	0.0526
RC3	GPS	11	6	8	10.3	1.5	2.25	9.6801	0.0021	0.0711
	GLONASS	8	6	7	3.7	2.2	2.41	9.7986	0.0039	0.5162

	GPS+GLONASS	18	10	14	3.10	1.2	1.63	8.1311	0.0022	0.0463

Figures 3a and 3b show the results of variations in position dilution of position (PDOP) values obtained with respect to time in GPS-only and GPS+GLONASS hybrid modes of operation in the three RC locations. The results show that the open sky environment has the least PDOP with respect to time of the two GNSS constellations considered. The PDOP in the open sky environment is minimal and appropriate for making decisions for GNSS applications, as depicted in the GPS and GPS+GLONASS scenarios compared to the other two RC locations. PDOP is higher when the RC is in-between two buildings, but the combination of the two constellations mitigated the PDOP.



(a)



(b)

Figure 3: Variation of PDOP with respect to time (a) GPS- only mode (b) GPS+GLONASS hybrid mode in the three RC locations.

4. Conclusion

Research on the effects of multipath on GNSS receiver positioning accuracy in multi-GNSS environments is needed due to the complex building and tree canopy structures in urban settlements. The study examined the impact of multipath on GNSS receiver position accuracy using a dual-frequency Javad Triumph L S geodetic receiver at three different remote sensing locations. Performance metrics like signal strength degradation, PPP determination, NSV, GDOP, 3DRMS position errors and PDOP were used to compare the receiver's accuracy. Results showed higher signal strength in open sky environments. The Open sky environments offer better positioning accuracy than multipath source locations, and the hybrid mode of operation enhances position accuracy. Maximum NSV, very low GDOP, and PDOP were achieved, and the least 3DRMS position error was obtained in open sky environments. The future work is to develop a GNSS multipath mitigation technique for environment characterized by multipath source like forest as navigation in such environment is inevitable.

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