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On Usability of Dual-frequency, Compact GNSS Modules for Long Baseline RTK

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Abstract

Global Navigation Satellite System (GNSS) Real Time Kinematic (RTK) is a popular technique for obtaining instantaneous high-quality position solutions. This manuscript presents the novel results on the usability of compact, low-cost, dual frequency GNSS modules with commercial GNSS patch antenna for RTK Rover applications instead of conventional geodetic grade, costly receiver-antenna combination. Using concurrent data from two such modules (uBlox ZED F9P and NTLab 104) and a uBlox antenna for short to long baseline lengths, the results establish the suitability of such modules for use as RTK Rovers. Up to a baseline distance of more than 200km, sub-meter level precision has been obtained in GPS+GLONASS hybrid operation. The results would be useful for the GNSS user community in cost and power efficient application development without dense Base station network.

1. Introduction

The evolution of multi-GNSS has paved the way for advancement of survey techniques offering varied solution precession qualities those include Singe Point Solution (SPS), Precise Point Positioning (PPP), Differential GNSS (DGNSS) and Real Time Kinematic (RTK). SPS offers quick position solution with meter level precession using a standalone receiver, while PPP uses data from a standalone receiver but involves longer time to provide much improved solution quality. DGNSS and RTK are differential positioning technique where more than one receivers are used; one of them is configured as the 'Base', the other is configured as the "Rover" that uses data from the Base to provide instantaneous precise position solution. Both for DGNSS and RTK, sending the measurement from the Base to the Rover(s) is needed over suitable communication channel. It is done either utilizing a RF link over radio that has limited coverage or using the Internet for transportation of data in Radio Technical Commission for Maritime Services (RTCM) format [1]. The later, Network Transport of RTCM via Internet Protocol (NTRIP), is now popular to provide RTK service [2].

DGNSS involves code-based measurements and offers decimeter-level precession solution for a few tens of km baseline distances between the Base and Rover [3-4]. For more demanding applications, RTK is used that depends on carrier phase-based measurement and is more accurate vis-à-vis the code-based measurement technique [5]. Carrier cycle ambiguity is an issue in such measurements, and much work has been done to resolve the carrier phase ambiguity [6-8]. Another advantage of RTK is the use of Internet based NTRIP, through which the baseline lengths can be increased up to larger distances.

Generally, geodetic grade, costly and bulky receivers are used for GNSS positioning including RTK. Currently, compact, multi-GNSS enabled, dual frequency receiver modules are commercially available whose SPS and PPP precession is comparable to that of the geodetic receivers with the clear advantages of cost, size and power requirements [9-10]. In this paper, an effort has been made to study the RTK performance of two dual-frequency, compact GNSS modules as Rovers operating for short to long baseline lengths. The result of the study would be useful for design and implementation of cost-efficient GNSS RTK-based applications for real-life applications.

In this study, a geodetic multi-GNSS receiver is configured as the base and two dual-frequency, compact multi-GNSS receivers are configured as RTK rovers. For short to long baseline lengths, Rover solution data is collected in standalone and hybrid GNSS operation modes. Experimental arrangement, results and discussions are sequentially presented in the subsequent sections; favorable results on usability of the compact, low-cost modules for RTK Rovers are found.

2. Experimental Setup and Methodology

A Leica GR50 multi-GNSS, survey grade receiver with an AR25 antenna under open sky is used as the Base on the rooftop of GNSS Laboratory Burdwan (GLB), The University of Burdwan, Burdwan; the precise location of the Base station is found out using online PPP service offered by Geoscience Australia (AUSPOS) [11]. Two compact multi-GNSS modules- an uBlox ZED F9P and a NTLab, concurrently connected to a uBlox multi-band active GNSS antenna through a 1×2 GNSS active signal splitter, are used as the simultaneous Rovers as shown in Figure 1. The modules are connected through USB ports to computers running the RTK processing software; the computers also provide the DC power to the modules. The uBlox F9P module can provide raw (.ubx) data output in GPS (L1 and L2), GLONASS (L1 and L2), Galileo (E1,

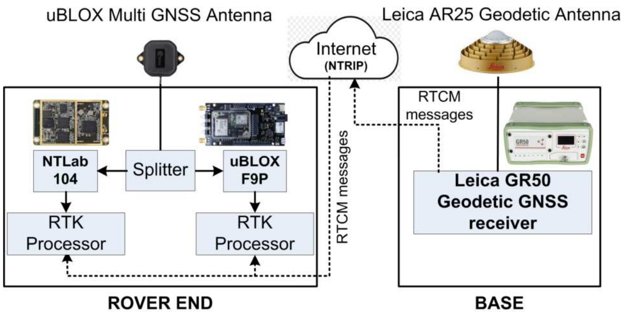


Figure 1. Experimental setup to study dual frequency, compact receivers' RTK performance for a maximum baseline distance of 220 km.

E5), BeiDou (B1 and B2) and QZSS mode; the EVB module has a size of approximately 4.7 cm×3.2 cm with a list price of around USD 300 [12]. The NTLab 104 provides raw data output in GPS (L1, L2/ L5), GLONASS (L1, L2) and NavIC (L5, S) mode, the EVB is of size 7 cm × 4.5 cm, with a list price of around 1000 USD [13]. Both modules can be operated with 5V DC.

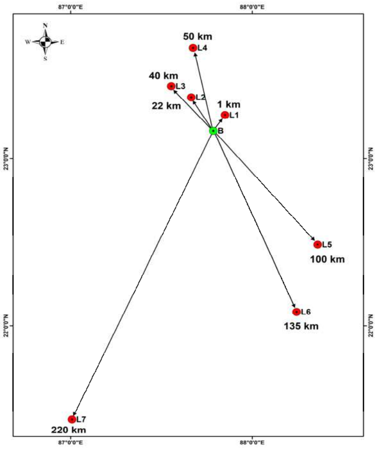


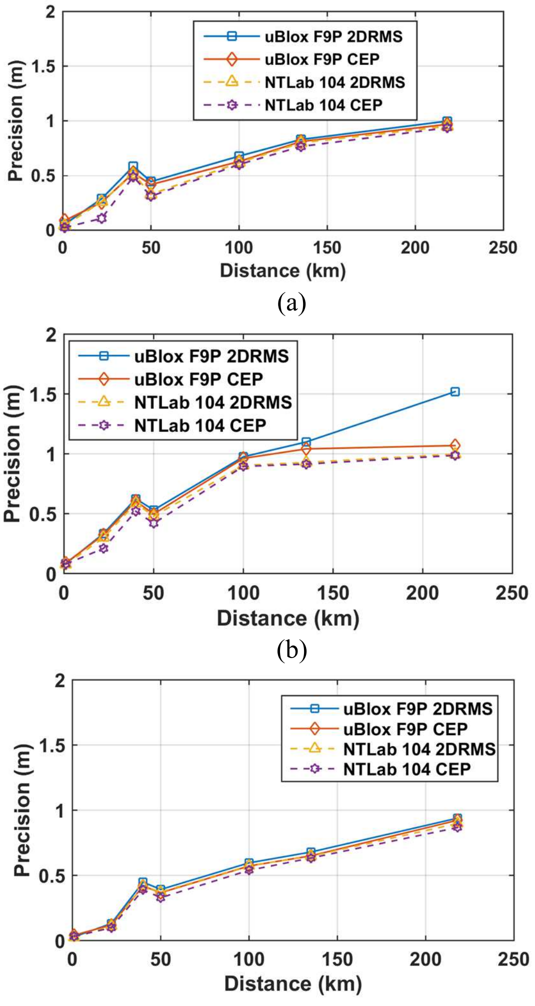
Figure 2. Different distance Base Rover RTK experiment as shown in the figure, Green dot shows the Base and Red dots show Rover Locations

Here, the Rover modules are sequentially operated in GPS, GLONASS and GPS+GLONASS hybrid mode for 1 hour @ 1Hz (3600 epochs) each at all the Rover locations. The RTKNAVI utility of RTKLib open-source GNSS data processing software package uses the local data from the Rover receiver together with the Base-transmitted RTCM3 Multiple Signal Messages version 7 (MSM7) messages to provide RTK position solution [14], which is available from the GLB Base station over NTRIP. The Base-Rover(s) combination is tested for baseline distances of 1 km, 22 km, 40 km, 50 km, 100 km, 135 km and 220 km as shown in Figure 2. The results on the RTK positioning performances are discussed in the next subsection.

3. Results

Concurrent RTK solution data collected from the modules operating in different GNSS constellation mode are analyzed for solution capability of the Rover modules. For the position solution provided by the Rovers, 2D Precision parameters- Distance Root Mean Square (2DRMS), Circle of Error Probable (CEP) and 3D parameters- Spherical Error probable (SEP) and Mean Radial Spherical Error (MRSE) are calculated following [15]. The results also include standard deviation of North, East and Up errors over the observation period, % of "FIX" type of RTK solution [2] and Time To obtain the First (RTK) FIX solution (TTFF). The precision parameters are shown in Figure 3 against the baseline distances and the other results are shown in Table 1.

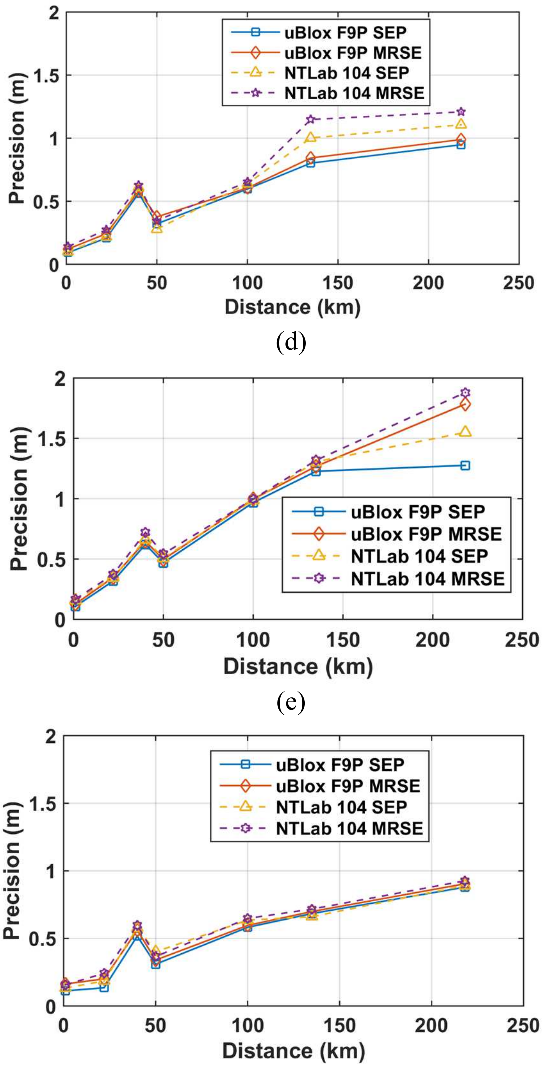
It may be observed from the Figure and Table that up to the baseline distance of more than 200 km, the horizontal (2D) precision is within 1 m and the 3D precision lies within 1.2 m level in GPS operation; whereas in GLONASS operation, horizontal precision is within 1 m and 1.5m for the NTL104 and uBlox F9P module respectively and the 3D precision is always better than 2m for both the receivers. In GPS+GLONASS hybrid operation, both 2D and 3D precisions always lie well within 1m; 0.5m precision is achieved up to a baseline distance of around 60km. The GPS+GLONASS hybrid mode provides better precision vis-à-vis individual GPS or GLONASS modes. Around the base-rover distance of 40 km, the values marginally increase due to the short to long baseline atmospheric model switch over in RTKLib [14].



(a)

(b)

(c)



(d)

(e)

(f)

Figure 3. RTK 2D precision parameters obtained from the compact dual-frequency modules for different baseline lengths in (a) GPS, (b) GLONASS, (c) GPS+GLONASS operation; and 3D precision parameters in (d) GPS, (e) GPS+GLONASS and (f) GPS+GLONASS operation

Variation of TFFS, RTK FIX solution percentage, average standard deviation of North, East and Up error for the two GNSS modules with increasing RTK baseline lengths in standalone GPS, GLONASS and hybrid GPS+GLONASS operation is shown in Table 1. It may be seen from Figure 3 and Table 1 that horizontal precision is slightly better for the NTLab 104 module, while 3D precision is somewhat better for the uBlox F9P module for GPS and GLONASS standalone operation. Both the modules perform equivalently in GPS+GLONASS hybrid combination for all the baseline lengths. Horizontal and 3D precision values are best obtained in GPS+GLONASS hybrid combination.

The results hint towards the marginally better operation of the NTLab 104 module in terms of FIX solution percentage and TTFF. The distance dependent increasing convergence time for RTK FIX solution can also be found out from the exercise, e.g., around 2½m, 4m and 8½m for baseline distances of 50km, 100km and 220 km respectively in GPS operation. Although the solution quality is better in GPS+GLONASS hybrid operation, the TTFF is found to be higher in this case. However, the exercise clearly shows the potential of using the low-cost, compact, dual-frequency GNSS modules as Rovers for obtaining sub meter precision up to long baseline distances.

4. Conclusions

This novel exercise presents the results of the studies on usability of low-cost, compact, dual frequency GNSS modules as Rovers instead of the conventional costly geodetic GNSS receivers for short to long baseline RTK. Based on the concurrent data from two commercially available compact modules used as Rovers, the results establish the suitability of such modules to be used as GNSS RTK Rover to provide sub meter precision up to a baseline length of more than 200km in GPS+GLONASS hybrid operation with clear benefits of cost and convenience. The results would help the GNSS user community in developing cost and power efficient, compact GNSS RTK Rovers that may operate without the need of dense Base station network that requires large financial resources. Future scope of work includes the use other GNSS combination for RTK, especially for the Indian region, where signals from all the global and regional navigation satellite systems are always available. Another important work would be to mitigate the degradation of solution quality around 40km baseline length through robust atmospheric correction algorithm.

5. Acknowledgements

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Table 1. Variation of Time to First Fix solution (TFFS), FIX solution percentage, standard deviation of North, East and Up errors of uBlox F9P and NTLab 104 dual frequency GNSS receivers with different RTK baseline lengths for GPS, GLONASS and GPS+GLONASS hybrid operation

Constellation	Distance (km)	uBlox F9P					NTLab 104				
		TFFS (s)	Fix (%)	Standard deviation of errors			TTFF (s)	Fix (%)	Standard deviation of errors		
				North	East	Up			North	East	Up
GPS	1	2	99.98	0.011	0.009	0.017	1	99.99	0.008	0.009	0.021
	22	72	63.46	0.012	0.016	0.018	69	64.10	0.009	0.010	0.020
	40	102	37.84	0.020	0.022	0.031	97	38.91	0.015	0.020	0.036
	50	138	18.59	0.013	0.015	0.020	136	18.62	0.009	0.013	0.022
	100	250	5.80	0.016	0.019	0.021	244	5.82	0.010	0.015	0.022
	135	336	3.02	0.025	0.020	0.030	327	3.09	0.020	0.017	0.033
	220	505	0.83	0.047	0.031	0.041	502	0.87	0.024	0.029	0.048
GLONASS	1	15	30.77	0.024	0.023	0.050	9	32.63	0.020	0.021	0.055
	22	119	5.21	0.025	0.022	0.079	111	5.99	0.022	0.025	0.088
	40	306	4.38	0.046	0.068	0.100	302	4.42	0.042	0.061	0.105
	50	374	3.54	0.029	0.025	0.082	367	3.88	0.023	0.025	0.090
	100	655	1.16	0.062	0.077	0.124	648	1.19	0.052	0.080	0.132
	135	686	1.08	0.073	0.091	0.201	679	1.10	0.059	0.087	0.207
	220	875	0.73	0.150	0.213	0.632	867	0.76	0.144	0.202	0.701
GPS+ GLONASS	1	6	99.99	0.009	0.012	0.013	3	99.99	0.007	0.008	0.018
	22	222	65.99	0.011	0.010	0.015	228	66.21	0.007	0.009	0.017
	40	289	38.60	0.018	0.016	0.019	280	38.74	0.012	0.014	0.022
	50	364	18.92	0.012	0.013	0.016	356	18.97	0.008	0.013	0.020
	100	629	6.24	0.017	0.014	0.022	617	6.31	0.011	0.013	0.026
	135	654	3.72	0.020	0.023	0.025	648	3.80	0.018	0.022	0.028
	220	810	0.97	0.097	0.113	0.033	803	1.05	0.089	0.100	0.038

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