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Preliminary Results on the Performance of Cost-effective GNSS Receivers for RTK

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Abstract

Global navigation satellite systems (GNSSs) is currently used in myriads of applications and at the same time internet-based applications are also growing. In case of GNSS, stand-alone, single receiver-based position solution accuracy may not be enough in many applications like automated transporting service, unmanned air vehicle, Geodesy and agriculture etc and GNSS mass market needs low cost high accurate position solution. Carrier phase measurement-based position solution is more precise than code-based measurement, but phase ambiguity is a problem in carrier phase-based measurement. Real time Kinematic (RTK) technique is a method where precise position solution can be obtained using Network Transfer of RTCM message through IP (NTRIP) protocol; here multiple signal messages (MSM) are also sent from the GNSS base station to the rover and Carrier ambiguity can be resolved. This research work focuses on the RTK performance of geodetic, survey-grade receivers and low-cost receivers and analysis on their comparative performances. Geodetic receiver uses its own algorithm to calculate RTK solution and for the low-cost receivers, an open-source GNSS data processing software, RTKLib has been used. A static survey is made and found that low cost receivers can provide sub meter level precision in RTK operation which may help in GNSS mass market application and solution development.

1. Introduction

Global Navigation Satellite System (GNSS) is being used in myriads of application, such as Geodesy, Geographic Information System (GIS), Agriculture, automatic transporting and Unmanned Air Vehicle (UAV) etc. For these applications the user needs to get precise position solution using GNSS. High-end, dual or tri frequency enabled, geodetic/ survey grade receivers can provide better accuracy over the low-cost receivers those are now readily available in the market at prices ranging between 25 to 100 USD. These cost-effective, small form factor and less power consuming GNSS modules may be the ideal components for mass-market use of GNSS. With the availability of such modules, researchers have shown interest in developing the low-cost systems with improved position solution accuracy. Carrier phase-based measurement is more accurate than that obtained using pseudo range [1]. But cycle ambiguity is an issue in carrier phase-based measurement. Much work has been done on LAMBDA method to resolve carrier phase ambiguity [2, 3] associated with double differencing the carrier phase between two simultaneous measurements (one of them serving as reference or as the base and the other as the rover) [4]. For this purpose, sending the carrier phase measurements from GNSS reference station (base) to the rovers are needed supported by proper communication method. In many cases, this is done utilizing RF over a radio link, but the method has limited coverage area depending on the hardware capabilities and cost. Radio Technical Commission for Maritime Services (RTCM) is a massage format for transportation of information from the GNSS base to the rover that consists of antenna description, system parameters, carrier phase measurement, pseudo range measurement and signal strength of reference station etc. [5, 6]. Use of Internet-based technology for this purpose is now being popular for long range coverage, ease of use and cost effectiveness; Network Transfer of RTCM messages via Internet Protocol (NTRIP) becomes increasingly popular method to provide RTK service using the Internet. NTRIP casters are available worldwide and users can access the RTCM with proper authentication. RTKLib is an open source program package which can calculate RTK solution using RTCM3 messages [7]. RTK solutions are of two types one is RTK Fix and another one is RTK Float [8]. If the ambiguity is integer value, it is called RTK Fix; if the ambiguity is float point number instead of an integer, then it is called RTK Float. And if the solution is only based on single receiver, then it is called single solution. Researchers are interested to analyze the performance of low-cost receivers incorporating the NTRIP method for ambiguity resolution. Better position accuracy can be obtained in RTK rather than DGPS and Standalone GNSS receivers [9, 10]. An experiment was done on SOKKIA GSR2600 dual frequency (L1/L2) receiver and radio signal receiving antenna, Trimble ProXR GPS receiver and Pocket PC with GPRS and Garmin eTrex low-cost GPS receiver and found NTRIP to be a cost effective technique [11]. An experiment is done on uBlox LEA 6T and found cost-effective precise positioning at centimeter level is possible using navigation-grade receivers [12]. An RTK experiment was done on Trimble system 5700 and uBlox LEA 4T [13].
India is good place to receive signal from multi-GNSS constellation and researchers are keen to explore the applicability and effectiveness of multi-GNSS in RTK for

both high end and low-cost receivers. In this research, our objective is to compare the RTK performance between multi frequencies, Geodetic-grade and single band, low cost receiver in multi-GNSS (GPS+GLONASS+Galileo) mode in short baseline using RTKLib.

2. Methodology

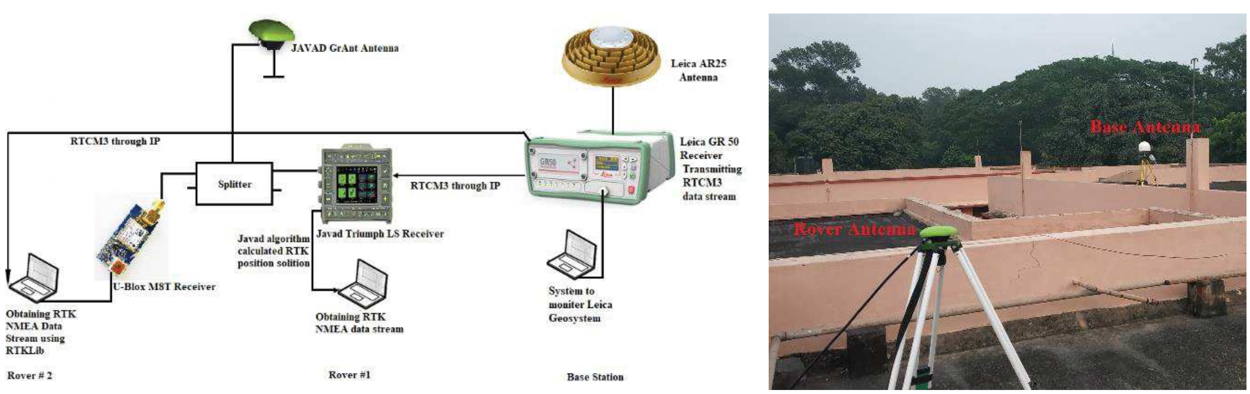
One base and one rover antenna are mounted under open sky within a very short distance. For this comparison purpose, GNSS signal from the rover antenna is fed into both the geodetic and low-cost receiver using splitter. A High end geodetic receiver ia used both as a NTRIP server and a NTRIP Caster. RTCM3 Multiple Signal messages (MSM) are transmitted from this base receiver through IP and both the geodetic and low-cost receivers are used to access the RTCM messages as NTRIP clients. Geodetic receiver can calculate RTK solution using its own algorithm and low-cost receivers calculate RTK solution using RTKLib [5] program packages. RTK based National Marine Electronic Association (NMEA) data stream are logged into PC for further analysis. RTK Fix and Float [8] solutions are used from appropriate NMEA data sentences [14]. The precision parameters, (viz. 2DRMS [Distance root mean square], CEP [Circle of Error Probable], SEP [Spherical Error Probable] and MRSE [Mean radial spherical error]) [15, 16] are calculated and obtained for the RTK position solutions, those are used to compare the position solution quality provided by both of the geodetic grade and the low cost receivers. The experimental setup, results and discussions are presented in the subsequent sections.

3. Experimental setup

Leica AR25 and Javad GrAnt antennas are used on the rooftop of The GNSS Laboratory Burdwan (GLB), The University of Burdwan, Burdwan, India as base and rover antennas respectively at a distance of 20 m (approx.) between two antennas. In the experiment, Leica GR50 is used as the GNSS base receiver with AR25 antenna that transmits RTCM3 messages and multiple frequency and channel code (L1C, L2W, L7Q, L8Q etc) measurements through IP [17]. Coordinate of base antenna is entered into the base GNSS receiver and the average position dilution of precision (PDOP) during the experiment is found to be around 0.6 in Multi-GNSS operation. A Javad Triumph LS is used as rover #1, which is a geodetic, high end receiver and uBlox NEO M8T module is used as rover #2, which is a low cost GNSS module. GNSS signal from the rover antenna is fed to both rovers through a GNSS signal splitter. Being a multi-frequency receiver, rover #1 can receive all GNSS frequency (L1, L2C, L5, E5a, E5b etc.) signals while the low-cost receiver can only use L1 frequency signal. The schematic and real snapshot of the base-rover connection is shown in fig. 1. Rover #1 can calculate RTK solution based on its own algorithm using most of all the RTCM messages, while RTKLib, used for rover #2 calculate RTK solution using only L1 (L1C) band measurements from RTCM3 as it is a single frequency band receiver. Obtained results from RTK NMEA data stream in static case is analyzed and the results are presented in the subsequent section.

4. Result and Discussion

Collected data are analyzed for solution capability of the rovers in RTK mode and the scatter plot of position is shown in fig. 2. It is witnessed that in case of rover #2 (uBlox) some points are scattered more in East-West direction in comparison to rover #1 in RTK operation; while in case of rover #1 (Javad), the RTK solutions are more precise, as expected. The precision level parameters are calculated and shown in Table 1. Maximum variation in longitude and altitude is more in rover #2 than that of rover #1; however, for the rover #2, the low-cost receiver module, the longitudinal variations remain well within a meter. It is observed that rover #1 provides either Fix or Single solution because the default setting of this receiver is to provide only Fix solution, but uBlox provides either Fix or Float solution. Rover #1 can fix ambiguity to integer maximum times rather than that of rover #2. It is also observed that, 2DRMS is in the order of centimeter for rover #1 and few centimeters for rover #2. And the 3D precision level is within cm level for both the receivers and the survey grade receiver provides one order better solution accuracy.



(a) (b)

Fig.1: (a) Schematic diagram of base rover connection; (b) Leica AR 25 and Javad GrAnt antenna under the open sky on the rooftop of GNSS Laboratory, The University of Burdwan, Burdwan, India.

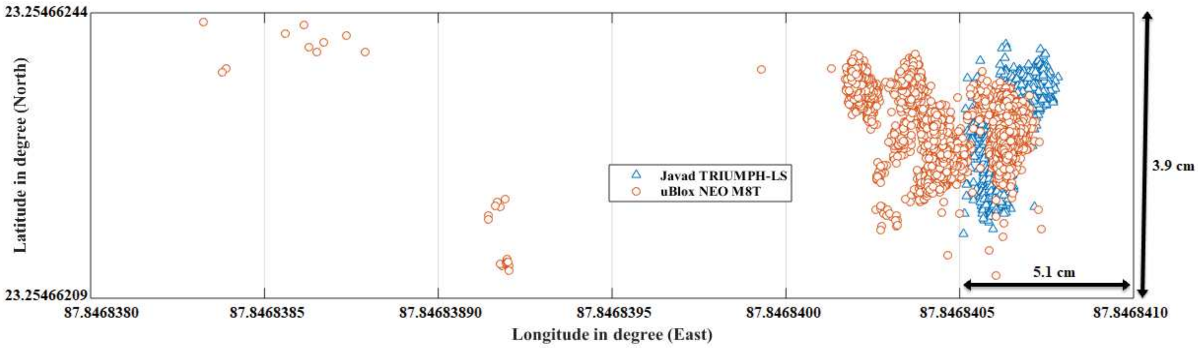


Fig. 2: Variation of RTK position solution for two different types of rovers in GPS+GLONASS+Galileo mode in static condition

Table 1 Comparison of precision level of RTK solution between Javad Triumph LS and u-Blox M8T receivers used as rovers in GPS+GLONASS+Galileo mode, observed from GLB, Burdwan, India. (Observation Time 11:38:18-14:18:39 UTC, 14 October 2018)

Receiver	Maximum Variation (m)			Fix	Float	Single	2DRMS (m)	CEP (m)	SEP (m)	MRSE (m)
	Lat	Lon	Alt							
Javad Triumph LS	0.0259	0.0282	0.0575	$99.97%	-	0.03%	0.0099	0.0041	0.0079	0.0098
UBlox M8T	0.0344	0.2461	0.3190	74.29%	25.71%	-	0.0332	0.0111	0.0147	0.0191

$ The default setting of Javad Triumph LS

5. Concluding remarks

This paper presents the initial results of the comparison of RTK based solution accuracy of low-cost GNSS modules in comparison to those obtained from survey-grade, geodetic receivers. It is noted that, good quality position solution is obtained from low cost receiver using RTK. It is possible to get sub meter level of accuracy from the low cost receiver in RTK using RTCM messages and RTKLib; this position solution slightly inferior to the solutions provided by the geodetic receivers. But the solution quality is acceptable and applicable in the systems where moderate to high precision is required in a cost-efficient way. On the other hand, the low-cost GNSS modules are of very small form factor and consumes very low power in comparison to the survey-grade GNSS receivers; all these attributes make these types of modules suitable for GNSS-based mass-market application and solution development in cost-effective way. Thus, the modules may be helpful in popularizing efficient and novel uses of GNSS in countries like India. The work presented here are preliminary and the studies have been made under open-sky, static condition with very short baseline distance between the base and the rover. Future studies would be extended to explore the performances of cost-effective antennas used in the rovers within real-life operational conditions having higher baseline distances. Other points of interest may be the effects of rover dynamics on solution accuracy and on performance of low-cost GNSS base stations operating with low-cost rovers in tandem. After this short-baseline study, performances in medium and long base line under constrained environment may be examined later. A detailed study would be helpful in developing GNSS based, cost effective application development in countries like India.

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