Qualitative Analysis of Smartphone GNSS Raw Measurements and Effect of Duty Cycling on the RTK Positioning

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BIOGRAPHY (IES)

Himanshu Sharma is a Research Associate at the Institute of Space Technology and Space Applications (ISTA). He received his Bachelors in Technology (B. Tech) degree in the field of Electronics and Communication from the Maharishi Dayanand University, Rohtak, India. He accomplished his Masters in Science (M.Sc.) in the field of Communications and Signal Processing from Technical University of Ilmenau, Thuringia, Germany. His research interests are Precise GNSS Positioning and Signal Processing. Currently, He is involved in the project focused on RTK positioning using the mobile phone GNSS Raw Data.

Andreas Schütz is a Research Associate at the Institute of Space Technology and Space Applications (ISTA). He received his Bachelors and Masters in the field of Geodesy and Geoinformation from Technical University Munich, Germany. His research focuses on Precise GNSS Positioning and Receiver Technology, as well as Integrity and Sensor Fusion. He is currently involved in a project regarding RTK/IMU coupling on smartphones and PPP IMU coupling for automotive applications.

Prof. Thomas Pany is with the Universität der Bundeswehr München where he leads the satellite navigation unit LRT 9.2 of the Institute of Space Technology and Space Applications (ISTA). He teaches navigation focusing on GNSS, inertial sensors and aerospace applications. His unit investigates signal design, GNSS transceivers and high-integrity multi-sensor navigation (inertial, LiDAR) and is also developing a modular UAV-based GNSS test bed. He has a PhD from the Graz University of Technology and used to work for IFEN GmbH where he created the SX3 software receiver. He authored around 200 publications including one monography and received five best presentation awards from the US institute of navigation.

ABSTRACT

With the release of Android N, Google announced the availability of GNSS Raw data from the mobile phone. This opens up to the broader prospective for research, analysis and enhancement of the positioning quality in mobile phones. With increasing applications based upon augmented reality, e-banking, e-health, etc., there is a rapid increase in the demand for precise positioning using the existing architecture of mobile devices.

But, the quality of carrier phase raw data is not adequate for the substantial RTK (precise positioning). Artifacts in smartphone GNSS antenna, environmental degradation and cycle slips are few of the major issues to be addressed for reliable carrier phase positioning in the smartphone. The code range residual with static retransmission setup are very noisy in comparison to carrier phase residual. This results in invalid positioning solution with wrong ambiguity fixing. Disabled duty cycling shows a considerable improvement in the positioning accuracy. Relatively higher code residual in Samsung S8 and Nexus 9 are contributing factor for non-fix ambiguities in RTK using these two smartphones. The RTK positioning is feasible with the raw GNSS data from the smartphone, but only float solutions are reliable. With the new series of GNSS chips, around 42% ambiguities were fixed. Improved error modeling and efficient Kalman Filter tuning must be performed in order to enhance the RTK positioning accuracy.

INTRODUCTION

With the introduction of GNSS raw measurement from the mobile phones. There is a huge interest in the scientific community to enhance the positioning accuracy of smartphone. Due to the limitation in the GNSS smartphone antenna embedded inside, researchers are keen to improve the position accuracy by better error modelling and Kalman Filter tuning. The transmitted satellite signal are circular polarized, but the receiver antenna in the smartphone is vertically polarized. This lead to a decay of -3 dB to -9 dB in signal strength. The carrier phase positioning requires continuous tracking of the satellites in order to estimate integer ambiguity. But, features such as duty cycling, which were introduced in the smartphone to achieve higher battery usage, leads to the deactivation of GNSS satellites tracking in smartphones periodically. Thus making RTK positioning strenuous in smartphones. The rapidly increasing demand of higher position accuracy, a promising solution is a must.

With the availability of GNSS raw data from the mobile phone, there is a growing interest in analyzing the quality of raw data and its feasibility for precise positioning. The research work focused in the paper is highly dedicated in analyzing the quality of GNSS raw data and its RTK performance analysis.

The approach presented in the paper showcase the quality of GNSS raw data, and its feasibility to perform RTK solution. The Analysis has been performed using three smartphones Nexus 9, Samsung S8 and Xiomi MI8. Since, Nexus 9 has an additional feature of "deactivated duty cycle", which will be used to analyze the effect of duty cycling on positioning accuracy and its effect on RTK positioning. The paper demonstrates the quality of RTK solutions in post-processing. In order to analyze the quality, a static retransmission setups was performed. The analysis is based upon single (L1) frequency using GPS constellation only.

MEASUREMENT SETUP

The raw GNSS data logging for the analysis was performed using the GNSS/INS logger developed at the Institute of Space Technology and Space Applications (ISTA). The ISTA logger is an android based application capable of logging GNSS and INS (Accelerometer, Gyroscope and Magnetometer) data from the embedded sensors in the smartphone. The analysis presented in this paper has been performed using the most advanced (in-terms of GNSS) smartphones available in the market. The characteristics feature of the smartphones are mentioned in the table below.

Model	Manufacturer	Pseudorange	Carrier phase	Duty Cycle
Nexus 9	HTC	Yes	Yes	No
S8	Samsung	Yes	Yes	Yes
MI8	Xiaomi	Yes	Yes	Yes

In the first phase of data logging, mobile phone are placed in the vicinity of re-transmitting antenna (helex). The raw GNSS data was logged for the duration of approx. 7 minutes. The signal from roof top antenna is passed to a splitter and then feed into the reference receiver and the rover. Before feeding the signal to the rover (smartphones), the signal is amplified and fed to retransmission antenna. The idea behind this setup is to compensate for the poor signal reception of the GNSS antenna embedded in the mobile phones and override GNSS signal coming from the satellite directly with low CNR. The description of the setup is shown in the figure below.

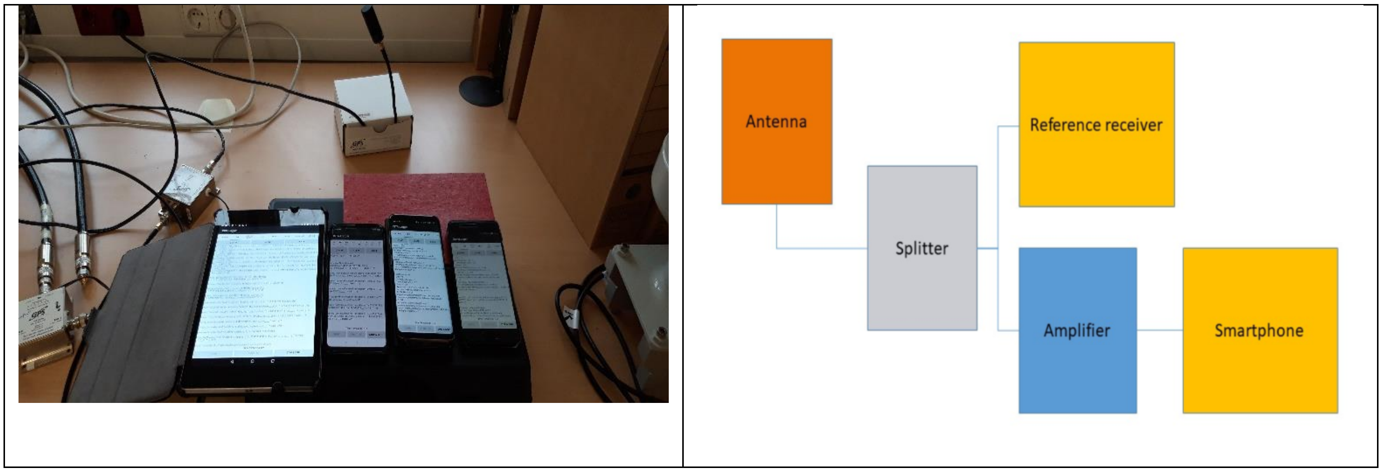

Figure 1: Zero baseline Retransmission Setup

The logged raw GNSS data is then processed with the MuSNAT receiver Software. The MuSNAT receiver has an integrated navigation module capable of performing single point positioning and RTK positioning. The navigation module has an integrated RTKLib for performing RTK positioning.

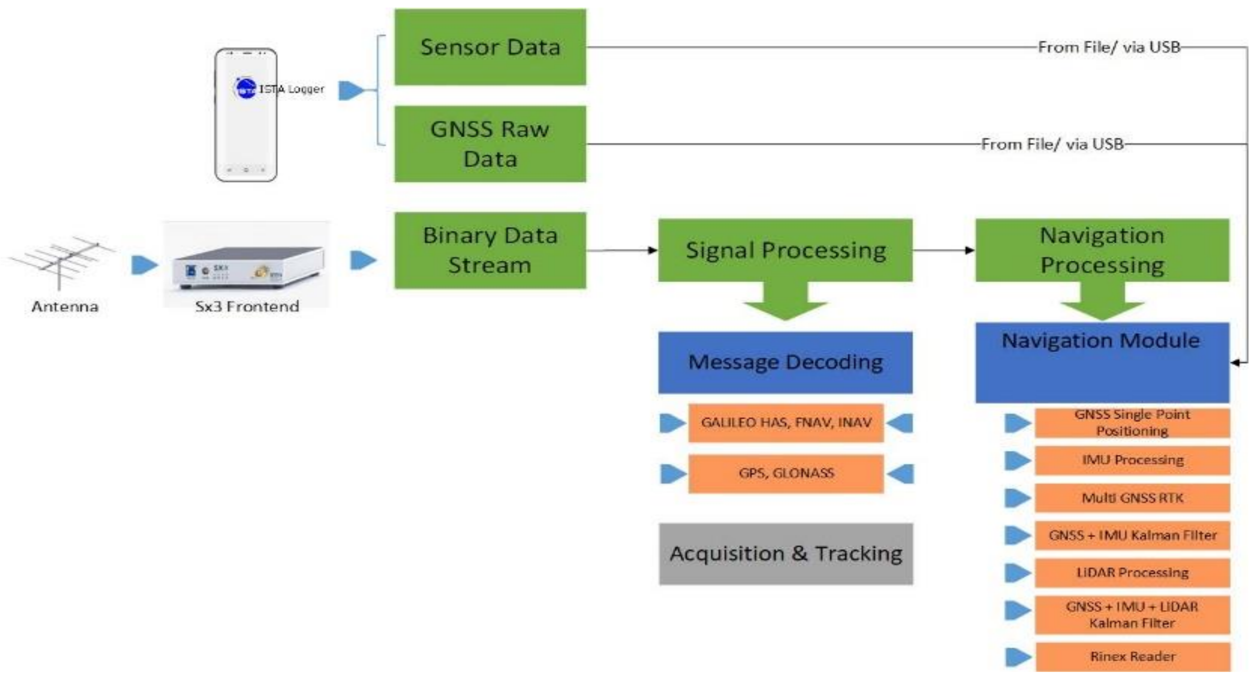

Figure 2: MuSNAT Receiver Software flow

The detailed setup parameter has been explained in the tables below.

Baseline	Zero Baseline
Ambiguity fixing Threshold	3
Ambiguity Resolution Technique	LAMBDA, Continuous
Constellation Type	GPS Only
Frequency	L1 Only
Rover	Smartphone (Nexus 9, Samsung S8, Xiaomi MI8)
Reference	Trimble NetR9
Atmospheric Correction Model	No
Amplifier	30 dB
Retransmission Antenna	Helix

STATIC RETRANSMISSION ANALYSIS

The CNR received through the smartphone antenna is shown in the Figure 3. The receiver have more than 4 satellite with CNR above 45 dB-Hz. The cycle slips detected in the observation data is represented with a LLI flag indicator in the Rinex observation data. Raw data shown below indicates a cycle slip detected to carrier phase at L5 frequency.

```
> 2018 10 24 12 48 24.9995970  0 18
G01  22592332.83600     53222.31900     -3176.422          45.524     22592326.53700     316479.85600     -2372.011          42.705
G03  20417024.06500     14325.81300      -858.817          48.023     20417022.86100      83268.45610      -640.878          48.421
```

The cycle slips in the observation data of nexus 9 is shown in Figure 3. The duty cycling in Nexus 9 is by default deactivated. This results in continuous tracking of satellites for the complete duration. The cycle slips are due to the various reasons such as multipath, reflection, fading etc. of carrier phase.

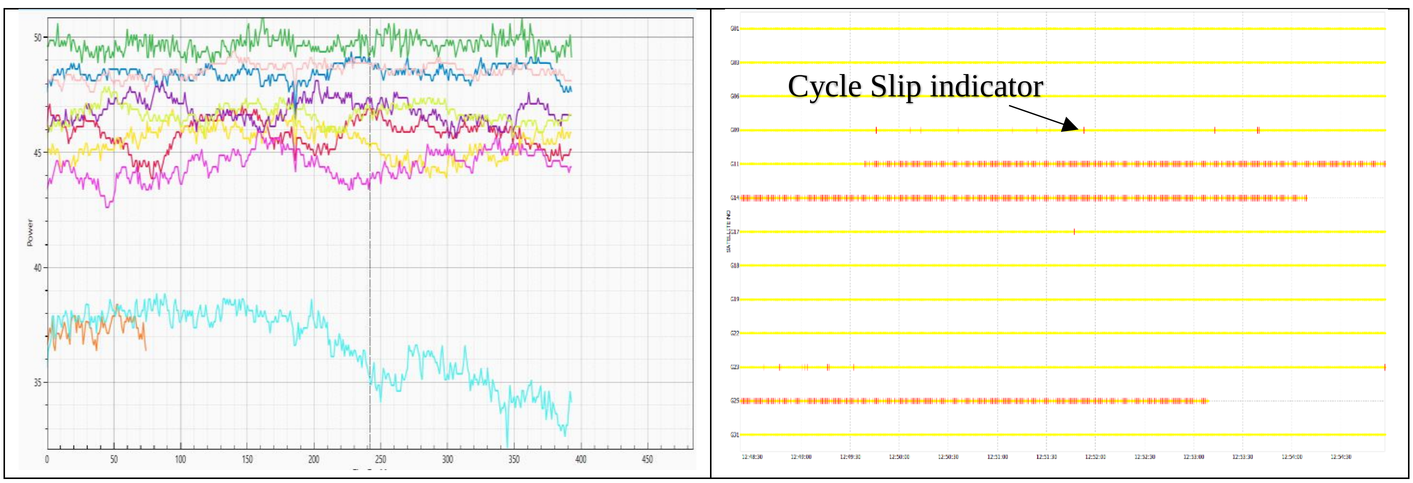

Figure 3: CNR (Left) and Cycle Slip (Right) for Nexus 9

The CNR and the cycle slips in Samsung S8 also shows similar characteristics (see Figure 4). But, after approx. 5 minutes of recording, the duty cycle occurs and the tracking of all satellites is lost. Thus, resulting into cycle slips on all the satellites simultaneously.

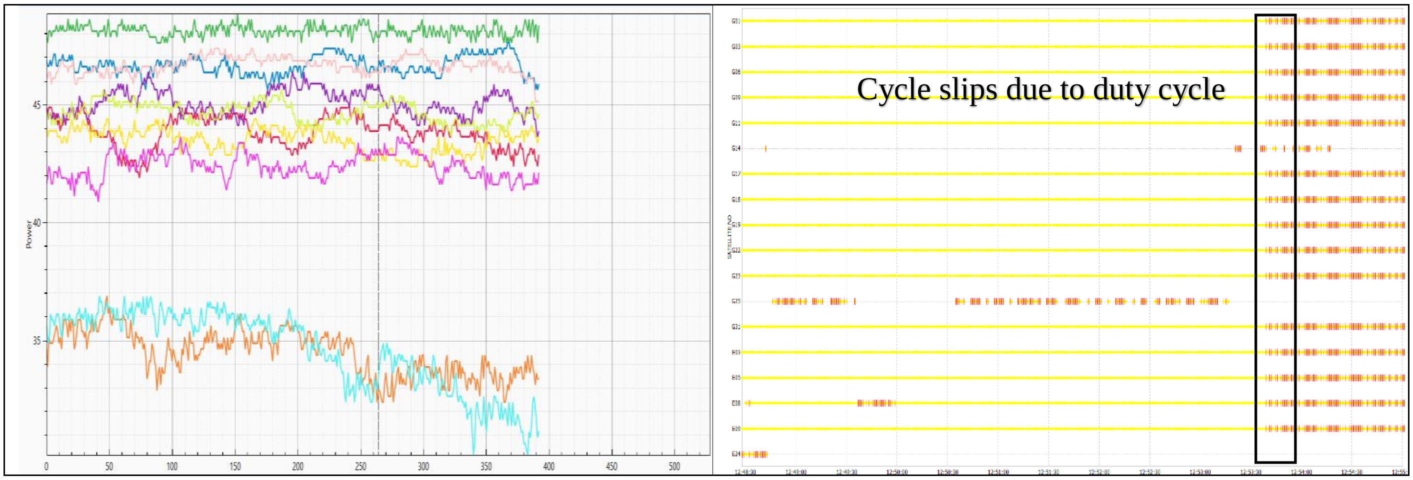

Figure 4: CNR (Left) and Cycle Slip (Right) for Samsung S8

The CNR plot for the Xiomi MI8 represented CNR for dual frequency (L1 and L5) simultaneously (Figure 5). The Xiomi MI8 is acquired with BCM47755 dual frequency GNSS chip from Broadcom. Due to the higher CNR and better visibility of satellites, there are only few cycles experienced.

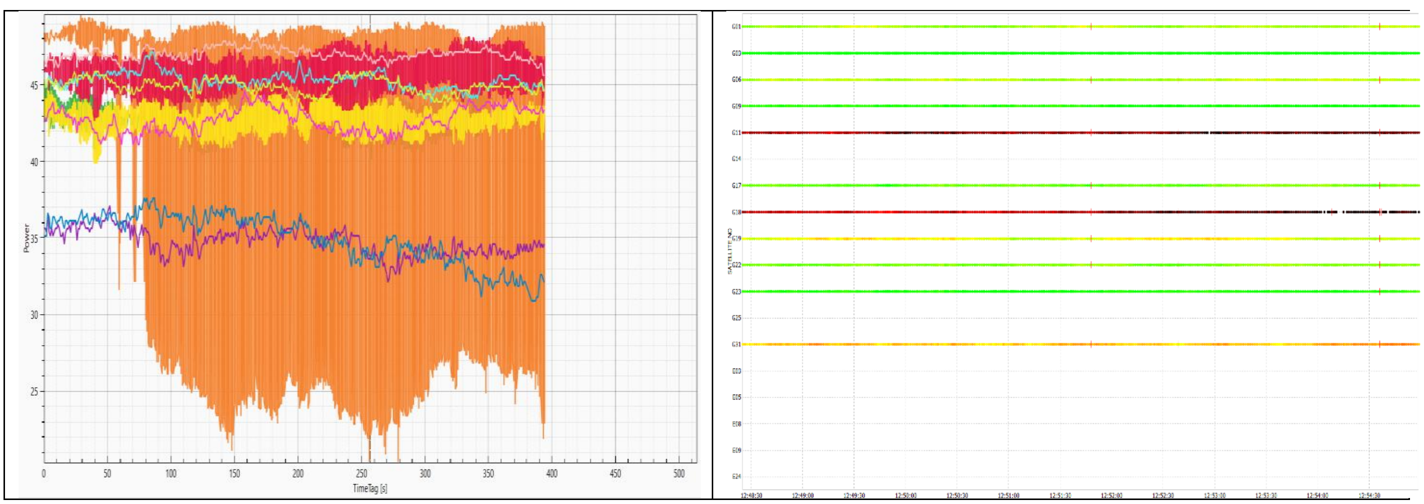

Figure 5: CNR (Left) and Cycle Slip (Right) for Xiomi MI8

The average code residual measured are 4.19 m, 3.95 m and 2.63 m for Nexus 9, S8 and MI8 respectively (see Figure 6). The code residual with MI8 is relatively low in comparison to Nexus 9 and Samsung S8.

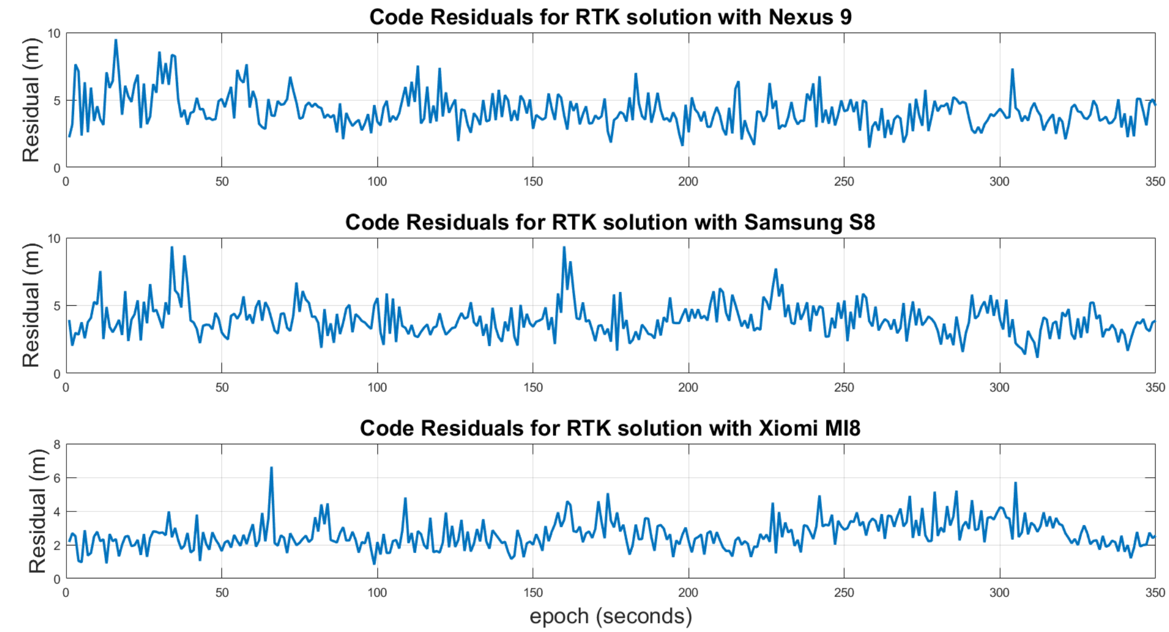

Figure 6: Code Residual with different Smartphones

The average carrier phase residual measured are 0.0056 m, 0.0032 m and 0.0051 m for Nexus 9, S8 and MI8 respectively as shown in the Figure 7.

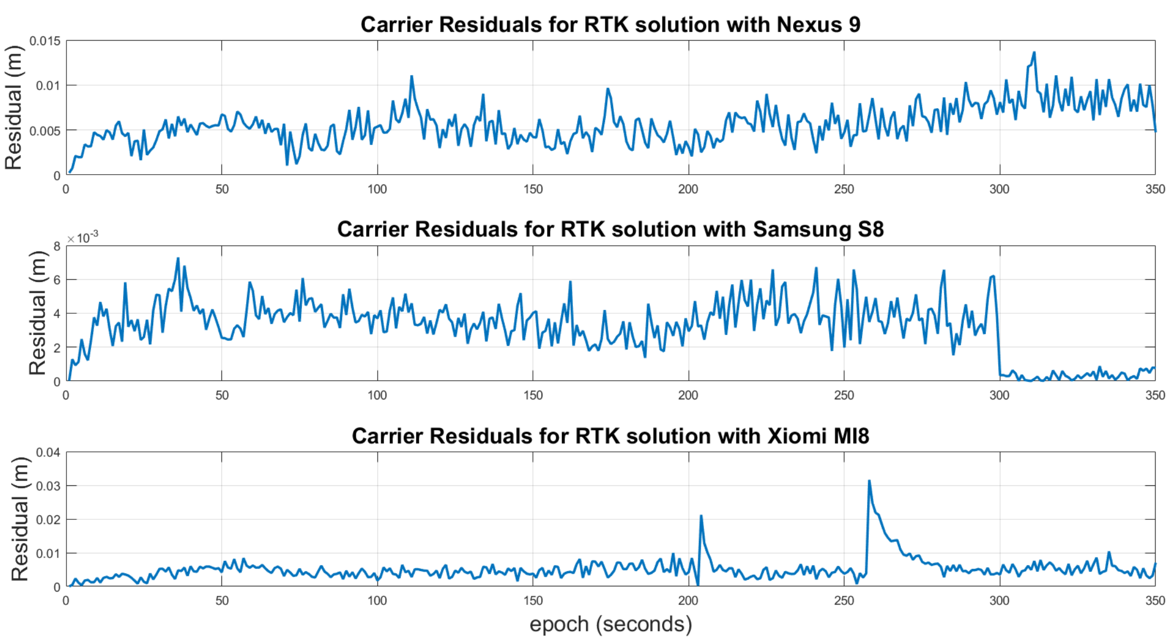

Figure 7: Carrier Residuals with different Smartphones

The ambiguity ratio threshold is set to 3. The RTK solution from Nexus 9 and Samsung S8 has no ambiguity fixes. Whereas, RTK solution with Xiomi MI8 has 42.57 % ambiguity fixed as shown in Figure 8.

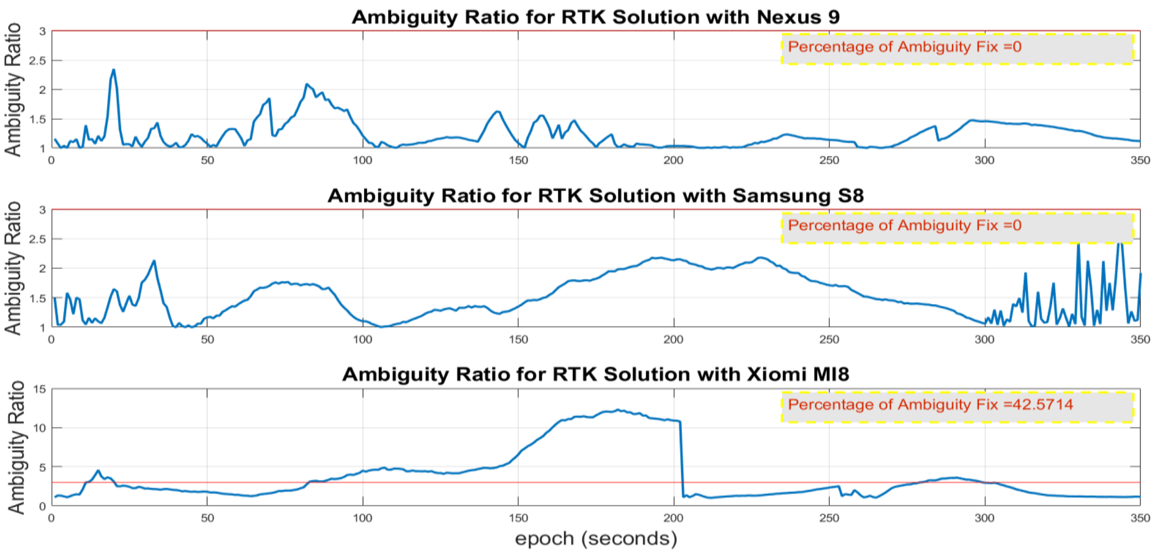

Figure 8: Ambiguity Ratio for RTK solution with different Smartphones

The positioning accuracy converges over a period of time. This is due to the fact that small cycle slip present is the carrier phase are detected and corrected by MuSNAT receiver. But, cycle slips introduced due to duty cycle (at approx. 300th epoch) (see Figure 9) in Samsung S8 degrades the positioning accuracy. Due, to the correct ambiguity fixes in MI8, the position accuracy converges to approx. 0.017 m within first 12 seconds.

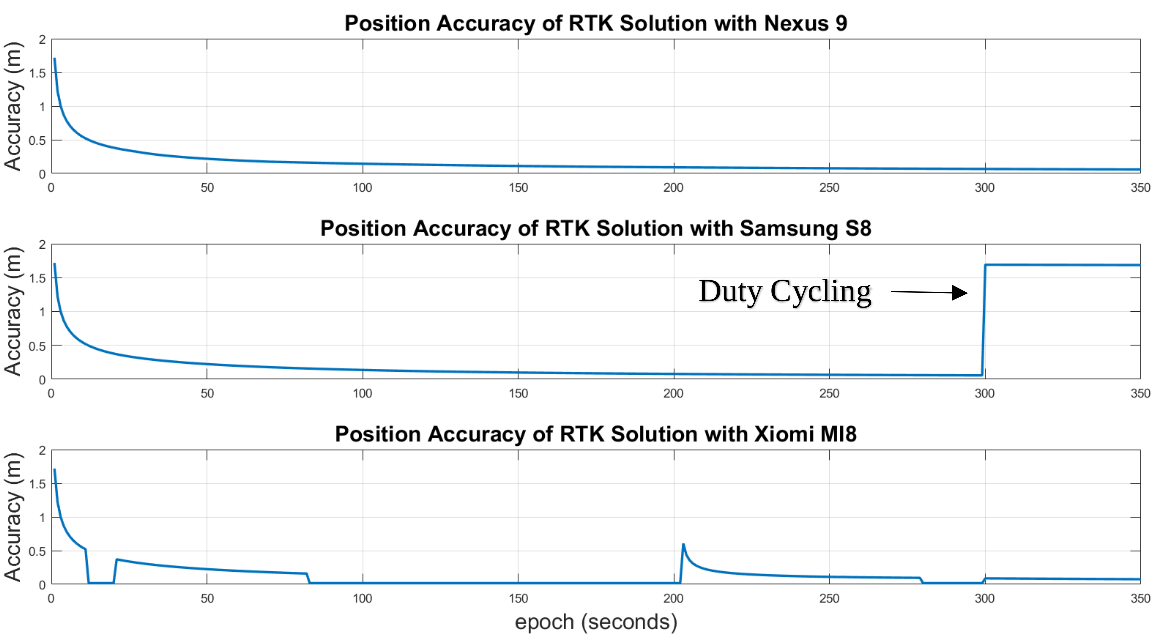

Figure 9: Position Accuracy for RTK solution with different Smartphones

In order to analyze the accuracy corresponding to latitude, longitude and height (see Figure 10). A reference position coordinates of roof top antenna were measured using NetR9 receiver. These true coordinate were used to measure to the error in the position coordinates measured using smartphone GNSS raw data as shown in the equation below.

$$\Delta Latitude = Latitude_{True} - Latitude_{measured}$$

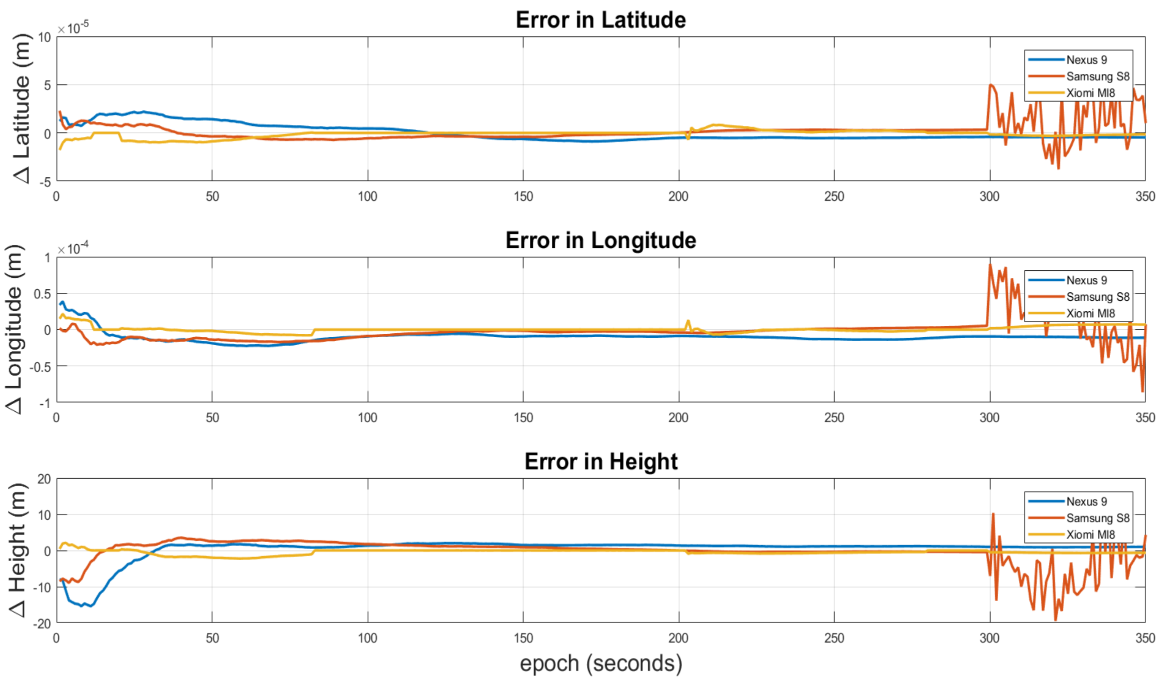

Figure 10: Position Accuracy in Latitude, Longitude and Height for RTK solution with different Smartphones

CONCLUSION

The duty cycle really degrade the RTK positioning solution. However this time, by exploiting an advantageous measurement setup yielding relatively consistent data, the RTK float solution became very stable until cycle slips occurred. The float position was maintained with respect to the reference coordinates within a meter until signal loss.

The raw carrier phase provided by the phone is of moderate quality. The carrier phase residuals may range up to 10 centimeters and "Duty Cycling" is a major drawback for precise carrier phase positioning. However, using techniques such as linear combination, larger cycle slips can be corrected. This will enhance the ambiguity fixing using the dual frequency RTK positioning. The results presented in the research are the preliminary analysis on the feasibility of RTK positioning using GNSS raw from the mobile phone. The research shows that the direct RTK processing is not feasible without strengthening the signal. Additional, duty cycle, higher code residual and multiple cycle slips due to multipath deteriorate the accuracy of RTK positioning.