Emulating the Smartphone GNSS Receiver to Understand and Analyze the Anomalies in RTK Positioning using GNSS Raw Measurements

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ABSTRACT

With the release of Android N, Google announced the availability of GNSS Raw data from the mobile phone. This opens a broader perspective 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.

On one hand, error sources such as ionospheric error and multipath mitigation tend to degrade the quality of precise positioning in mobile phones. On the other hand, cycle slip introduced due to weaker carrier-phase signal makes the positioning in mobile phone code-phase dependent only. Now with the availability of GNSS raw data, researchers are getting the opportunity to analyze and develop new concepts to enhance the carrier-phase positioning into a mobile phone.

The approach presented in this paper is to emulate the smartphone and understand the effect of inducing noise in Pseudorange and Carrier phase artificially. The GNSS data recorded from smartphone directly cannot be manipulated to analyze the role of e.g. cycle slip in positioning accuracy quantitatively. Secondly, due to the hardware limitation, tracking inside the smartphone cannot be controlled which makes it difficult for researchers to play round with the GNSS data.

Based upon the statistical analysis performed on the code and carrier residual from the smartphone, a high quality GNSS data was degraded. Results presented in the paper clearly indicates that the degradation of positioning accuracy due to the presence of noise introduced in the Carrier phase and Pseudorange.

The first section gives user an understanding with state of the art positioning technique which is currently used in smartphones. Section 2 will give detailed description about data logging setup and techniques for inducing artifacts for emulating smartphone. In the following section results and analysis with different scenarios are discussed. In the final section paper will conclude the future possibilities and the extension of the work.

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STATE OF THE ART POSITIONING IN SMARTPHONE

The modern mobile phones offer the positioning accuracy up to 8-10 meters as shown in Figure 1 The availability of GNSS raw data to the user is still constrained by the direct access to the GNSS receiver embedded inside the mobile phone. Which limits the researcher to understand the effect of errors or biases in the measurement individually.

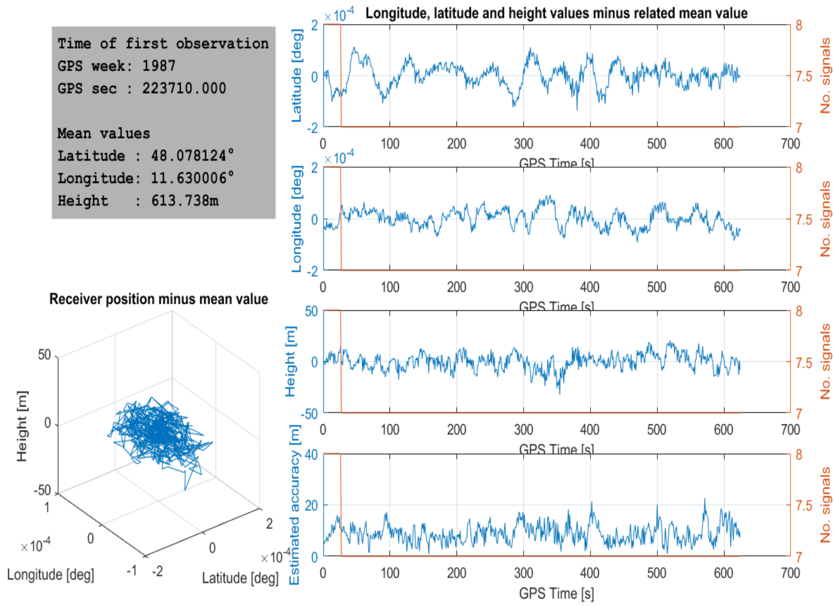

Figure 1: Single Point Positioning using GNSS raw data from mobile phone (Nexus 9, analyzed with the MuSNAT tool in SPP mode)

At the Institute of Space Technology and Space Applications, we are analyzing the feasibility of RTK positioning using the GNSS raw data from the smartphone. Initial results have been presented at the ION GNSS+ 2018 in Miami [1]. Our approach presented in that paper is based upon the analysis of the quality of GNSS raw data from the mobile phone and the anomalies introduced in the positioning results. We did observe on a Samsung S8 a number of features like code-minus-carrier drift, rather high pseudorange residuals as well as partly some high carrier phase residuals. The results were confirmed by other research groups and also Broadcom showcased in their presentation that issues like non-integer carrier phase ambiguities and carrier phase biases have been detected and will be corrected with future firmware updates [2]. Furthermore, the quality of GNSS raw data in the mobile phone is highly limited due to the poor quality of the GNSS antenna used on the mobile phone. Additionally, the interference introduced due to the design and placement of the GNSS antenna inside the mobile phone plays an import role in deciding the performance of the GNSS receiver. Finally, the "duty-cycle" option to save power has been discussed extensively by us and by the other researchers.

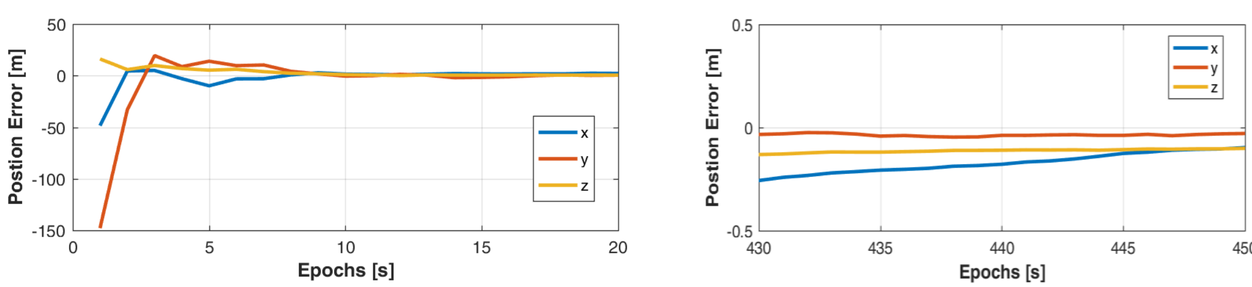

Figure 2: RTK Float Solution (LMSoft Software) showing postion accuracy before convergence (Left) and after convergence (Right)

Despite these difficulties, we found in our preliminary research, that an RTK float solution with Samsung S8 can be computed, even with "duty cycling" being activated by allowing a "carrier phase clock jumps" as shown in Figure 2. But, now is the time to get a deeper understanding of the impact of those various GNSS signal processing artifacts on RTK positioning. The research work includes the use of Android ISTA (GNSS/INS) logger for GNSS raw data logging, MuSNAT Receiver software for RTK positioning as shown in Figure 3. The analysis is based upon single (L1) frequency using GPS constellation only.

DATA LOGGING AND INTRODUCING ARTIFACTS

A. Performing the Data logging

In this new work for the deeper analysis of GNSS raw data and the impact of artifacts on RTK positioning, a zero base-line setup has been performed (see Figure 3). A standard rooftop antenna is used for the GNSS reception. The signal is then passed through the splitter which feeds the receiver software frontend and smartphone. Before being feed to the smartphone, the GNSS signal is amplified and passed to helical antenna. The raw GNSS data is then logged using the smartphone. The data is then analyzed with our RTKLIB based processing engine as well as with double difference analysis. In parallel, the raw GNSS signal is recorded for later processing with a software receiver.

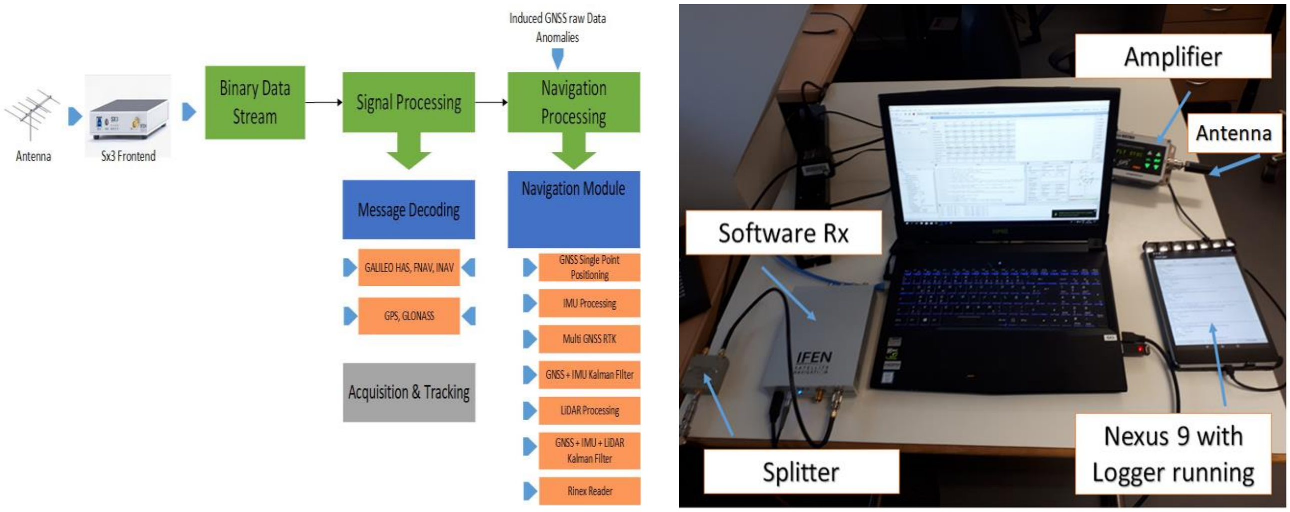

Figure 3: MuSNAT Receiver Software Flow (Left), Setup for Zero Baseline Test (Right)

In the second phase of the research, the MuSNAT Receiver software was used to emulate the GNSS Receiver embedded in the mobile phone. The idea behind this approach is to induce artificial artifacts such as degrading the quality of code and carrier phase, induce cycle slips. This analysis provides an efficient and effective mean to understand anomalies in the positioning accuracy using raw GNSS data due to the GNSS receiver inside the smartphone. We have the advantage to “enable” only one GNSS signal processing artifact at a time to precisely understand the impact of the RTK performance. The MuSNAT receiver is configured to emulate the GNSS chip present in smartphones based on publically available information [2]. RTK positioning is performed on a static scenario to analyze the quality of RTK fix using the software receiver.

B. Introducing the Artifacts

The GNSS data sample logged using the SX3 frontend is processed using the software receiver. The data quality for carrier phase and pseudorange is degraded by adding noise (white noise) based upon the analysis provided with the smartphone data. The average code and carrier residual from the smartphone and from emulated data has been shown in the table below.

Platform	**Code Residual (Average) in meters**	**Carrier Residual (Average) in meters**
GNSS data from Smartphone (S8)	3.9811	0.0035
Smartphone Emulated	3.8976	0.0024

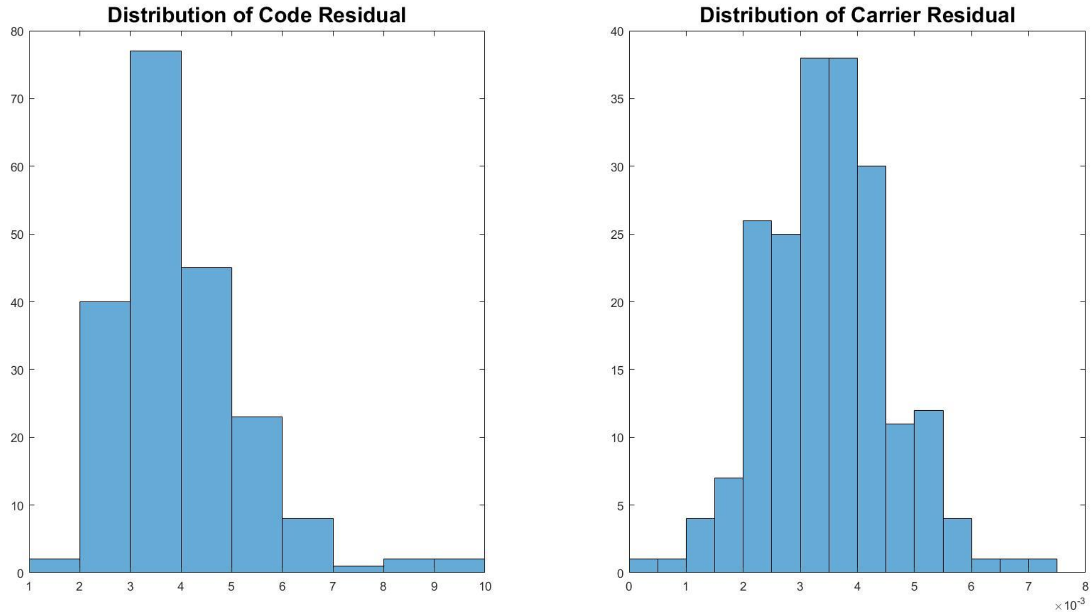

Figure 4: Distribution of Code and Carrier Residual with GNSS data from Samsung S8 with re-transmission setup

Additionally, to investigate the effect of degraded pseudorange, carrier phase and cycle slips, different models were implemented as shown in the Figure 5 . The satellites were chosen based upon the elevation angle. The satellites selected to add multiple, continuous cycle slips were low in elevation.

Figure 5: Emulation Scenarios, Scenario-1(top left), Scenario-2(top Right), Scenario-3(bottom left) and Scenario-4 (bottom right)

Figure shows different scenarios which were generated to emulate the GNSS performance of smartphones. **Scenario-0**, indicates the quality of GNSS raw data collected from the Samsung S8 with the re-transmission setup. Since, the data quality has been improved by enhancing the CNR of the GNSS signal received. GNSS data obtained with the setup (re-transmission) encounters few cycle slips. But, after certain epochs, the GNSS receiver inside the smartphone performs a duty cycle. This results into loosing tracking of all the satellites. **Scenario-1**, represents the high quality GNSS data logged using the SX3 frontend and is used to emulate the smartphone. **Scenario-2**, in this scenario random noise was added into pseudorange and carrier phase on satellite G17 after several epochs. Additionally, after few minutes of processing the data, cycle slips were added on every epoch for all the satellites to emulate duty cycling. Finally, in **scenario-3**, several cycle slips were added on satellite G08 and G17. Considering, G23, G28 and G31 being low elevation satellites, continuous cycle slips were added on each epoch.

RESULTS AND ANALYSIS

After logging the data with different above mentioned scenarios, RTK positioning was performed. Trimble NetR9 was used as a reference receiver. The carrier phase residual with Samsung S8 data (Scenario-0) were in really high due to high noise resulting into frequent cycle slips. The horizontal red line shows the average residual value. In Scenario-2, RTK was performed with high

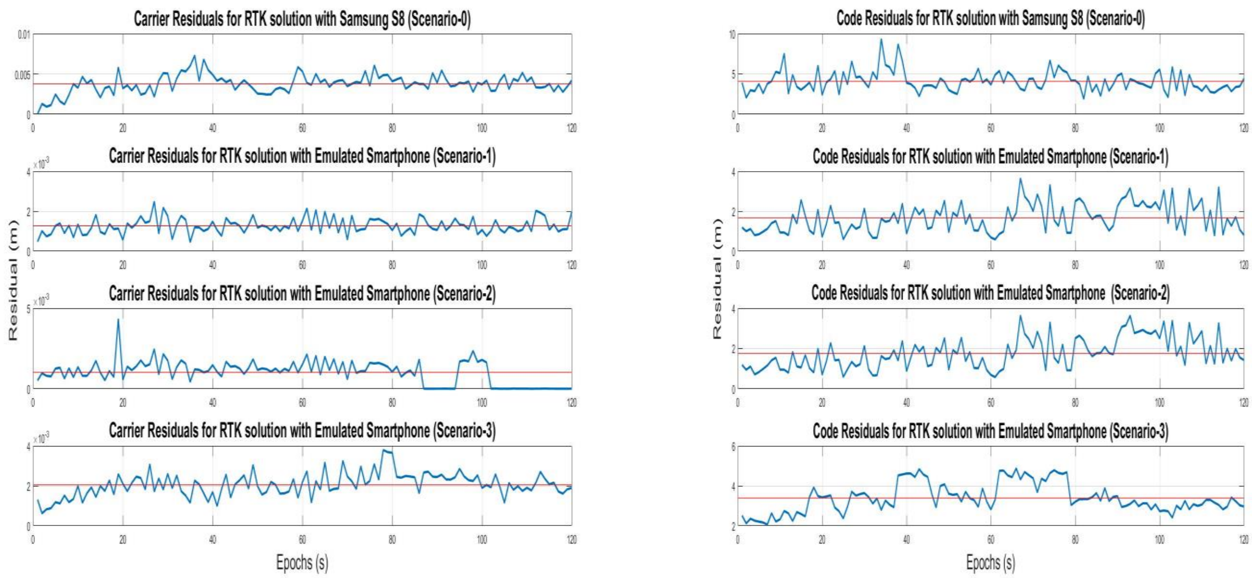

Figure 6: Code and Carrier Residuals

quality GNSS data with no cycle slips resulting into low residuals. In Scenario-2 and Scenario-3 artificial Pseudorange noise and carrier phase noise was added. Similarly, Code range residual with Samsung S8 (Scenario-0) is average 4.9 m average as compared to 1.9 m average with high quality GNSS data (scenario-1). In scenario-3, the code residual value tends to get higher once the duty cycle is emulated.

Due to the high code and carrier phase noise, GNSS data with Samsung S8 has no ambiguity fix. The ambiguity threshold is set to 3. In contrast, with high quality GNSS data (Scenario-1), 100 percent ambiguities were fixed with the positon accuracy up-to mm level. With Scenario-2, the ambiguity ratio tends to increase till the point tracking is lost due to duty cycle. Around epoch 90, the ambiguity ratio decrease drastically resulting into float solution, resulting into 77.5 percent fix solution.

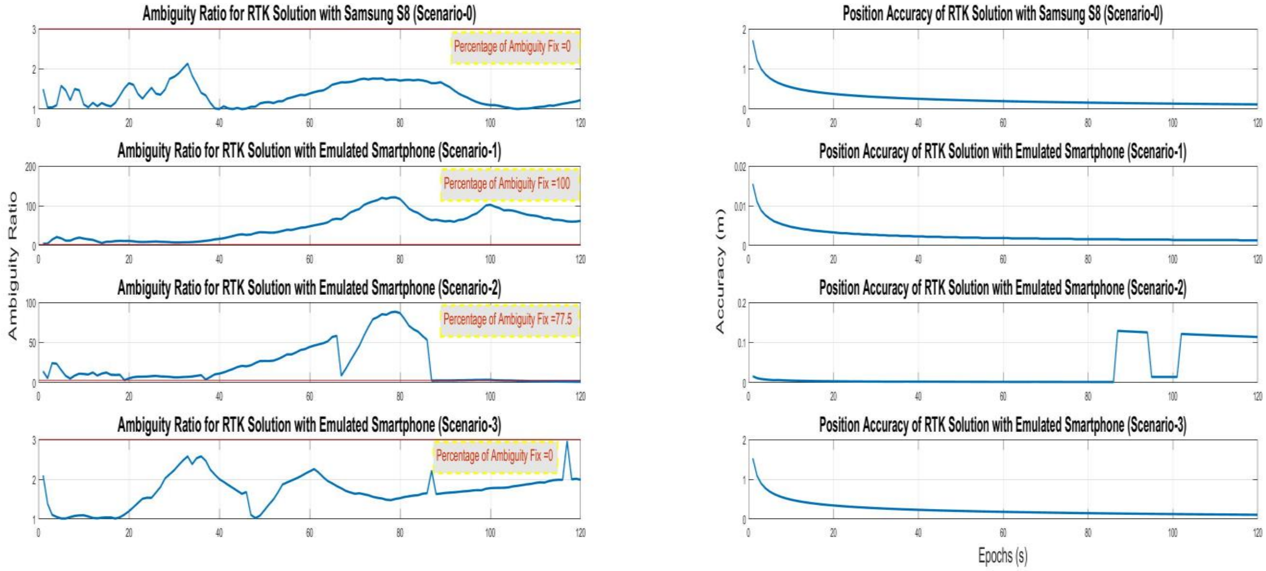

Figure 7: Ambiguity Ratio and Position Accuracy

During Scenario-3, several frequency cycle slips were introduced continuously, which in turns degrades the ambiguity ratio resulting into no fix solution. The quality of position accuracy in scenario-3 shows similar behavior as compared to Scanario-0.

CONCLUSION

The raw carrier phase provided by the phone is of moderate quality. The carrier phase residuals may range up to 10 centimeters is a major drawback for precise carrier phase positioning. Additional analysis however shows, that modeling the noise based upon statistical analysis is an optimum tool for analyzing the effect of noise on code and carrier phase. In this very case, additionally duty cycling in the smartphone makes RTK positioning almost impossible. The research also shows that the direct RTK processing is not feasible without the exclusion of solution validation or re-transmission setup to enhance CNR since, the quality of Pseudorange in such case is not adequate for RTK positioning.

II. References

[1] H. Sharma, A. Schütz and T. Pany, "RTK Positioning using Android GNSS Raw Measurements and Application Feasibility for the Trajectory Mapping using UAV's," in *ION GNSS+*, Miami, 2018.

[2] P. Madhani and S. Shade, "Broadcom: Android GNSS Measurements - Inside the BCM47755," in *ION GNSS+*, Miami, 2018.