Influence of the Multipath Mitigation on Precise Positioning with Smartphone Raw GNSS Measurements

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ABSTRACT

The GNSS antenna is an interface between the GNSS satellites and GNSS receivers. With the rapid increase in demand of Location Based Services, GNSS is becoming a must have feature in the smartphones these days. With a quick test of smartphone equipped with GNSS, it is evident that although GNSS chip are more efficient as compared to the old generation chips, the integrated end results still suffer from a performance limitation. With the latest advancements like dual frequency chipsets from Broadcom BCM45577 (Shade & Madhani 2018), the positioning performance of the smartphones have significantly improved from several meter to decimeter meter level (Banville & Van Diggelen 2016). But, with the increasing precise positioning applications, the current smartphones still offer a limited accuracy (decimeter level) results. Multiple challenges faced by the smartphones designers are key factor in the performance glitch, with the main two being the antenna performance and the crosstalk within the smartphone platform itself (Moernaut & Orban 2009). Most of the handset designers are not GNSS or even RF experts, and rely on catalog components to provide GNSS and antenna hardware. Often unsuitable, cheap antenna are chosen or they are placed in the most unseemly positioning within the Smartphone casing. The handset designer faces several problems when incorporating a GNSS antenna. Cost efficient, omnidirectional radiation pattern are only few of those. As a GNSS engineer, we would prefer GNSS antenna to be far as possible from the transmitting devices like Bluetooth, Wi-Fi, FM etc. (Haddrell et al. 2010). Secondly, the performance of GNSS antenna itself is unacceptable. The point at which GNSS signal is received is called APC (Antenna Phase Center). The APC does not coincide with the physical phase center and keeps on changing with signal frequency, elevation, azimuth and intensity of the satellites (El-Hattab 2013). Hence, the mean positon of the varying electrical center must be determined for the calibration purpose. Additionally, the multipath is a second major problem in terms of GNSS positioning quality in smartphones. Cheap antenna in smartphones offers no or minimal multipath rejection capabilities (Haddrell et al. 2010). Waves suffering longer diffraction and reflection can be separated from the original signal due to the delay in arrival time. But, the waves which have minor reflection and diffraction distort the correlator function, thus degrading pseudoranges and carrier phase (Granger & Simpson 2008). In this paper, we propose a GNSS smartphone multipath mitigation (rejection) using state of the art choke ring platform. In this setup, the smartphone is mounted on geodetic pillars with choke ring platform underneath. Grooves likes structure is choke ring platform is well known from blocking or decaying the waves travelling parallel to the surface. The idea behind this technique is to decay the waves travelling from below or parallel to the ground plane. The GNSS raw measurements logged with the smartphone are used to perform RTK with another reference receiver within the small baseline.

Keywords: RTK, GNSS, carrier phase, choke ring platform, duty cycle, cycle slips

1. INTRODUCTION

The GNSS antenna in the smartphone is basically a 1 euros antenna with low multipath mitigation. In order to have a cm level accuracy with the smartphone, it is required that we should be able to determine the antenna phase center precisely and minimize the effect of multipath on the smartphone antenna. But, due to the poor quality of antenna, smartphone antenna calibration with the anechoic chamber is very tedious. However, the choke ring platforms has been studied and proved to be very effective again multipath originating from the surface just below the antenna. In this paper we presented two different approaches to enhance the quality of GNSS data from smartphone.

1.1 Approach 1 - Retransmission Scenario

In this setup a retransmission arrangement was performed Fig. 1. Where the signal from Roof top antenna was passed to a splitter. The signal before being passed to the splitter was amplified using a 30 dB amplifier for L1 and L5 frequency. The amplified signal was then passed to a Trimble NetR9 and to a helix antenna. NetR9 receiver used to log the GNSS antenna with L1 and L5 band, will be used as reference (base station) for performing RTK. The helix antenna with amplified signal was kept near to MI8 smartphone so as to minimize the signal received by MI8 directly from the satellite.

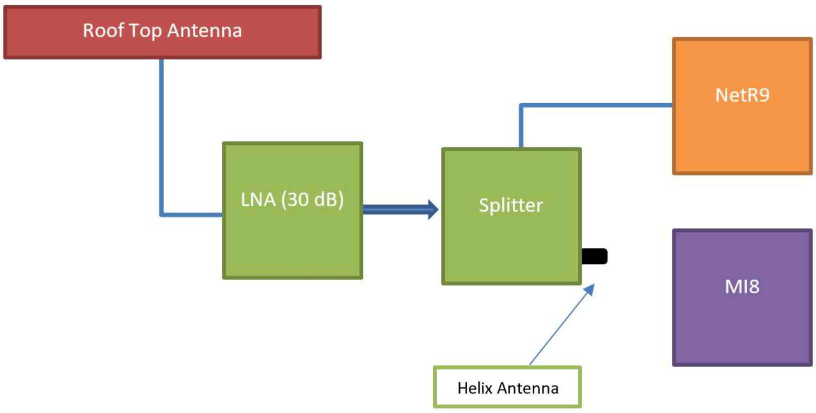

Fig. 1. Zero baseline setup.

The configuration parameters set in RTKLib are depicted in the table below. The configuration parameters Table 1 has been kept unchanged throughout the processing with other scenario (except for base station coordinate with setup 2). The other configuration parameters are set to default.

Table 1. Configuration parameters.

Parameter	Value
Positioning mode	Static
Frequency and constellation	L1+L5 and GPS only
Integer ambiguity res.	Cont.
Base station coordinates (roof top antenna: 61)	48 04 41.238610, 11 37 47.942650, 606.5840
Ionosphere correction	OFF
Troposphere correction	OFF
Satellite ephemeris	Broadcast
Filter type	Combined

1.1.1 Ground track

The ground track result from zero baseline setup using MI8 as rover and NetR9 as reference has an RMS value of E = 0.0024 m, N = 0.0035 m and U = 0.0031 m with the standard deviation of 0.0005 m,0.0008 m and 0.00012 m respectively Fig. 1.

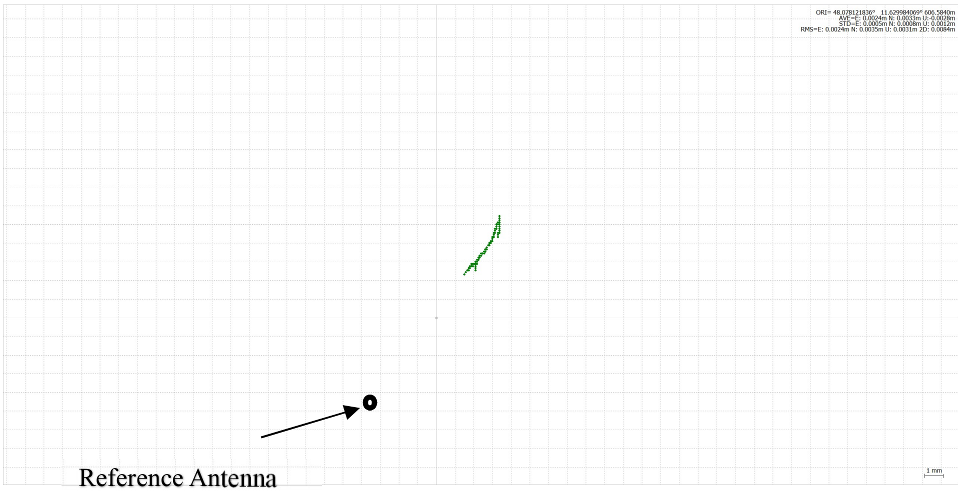

Fig. 1. Ground track.

1.1.2 Position accuracy

The position accuracy for the entire duration was stable and under mm level Fig. 2.

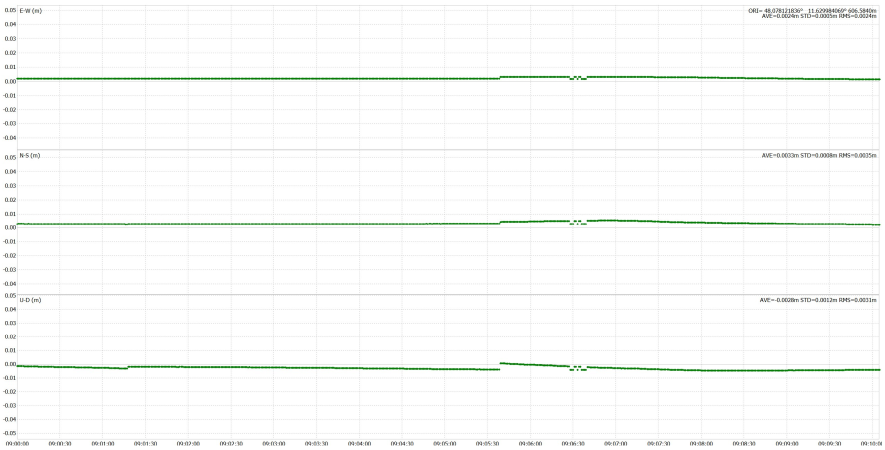

Fig. 2. Position accuracy with setup.

1.1.3 Ambiguity ratio

Due to the amplified signal scenario the number of satellite used for the RTK positioning with the smartphone were quite stable (# of satellites used were 7) Fig. 3. Secondly, the ambiguity threshold used for fixing the ambiguity was set to 3 (default). The ambiguity ratio results are quite promising with ratio above 3 throughout the measurement thus, resulting into 100 % ambiguity fix.

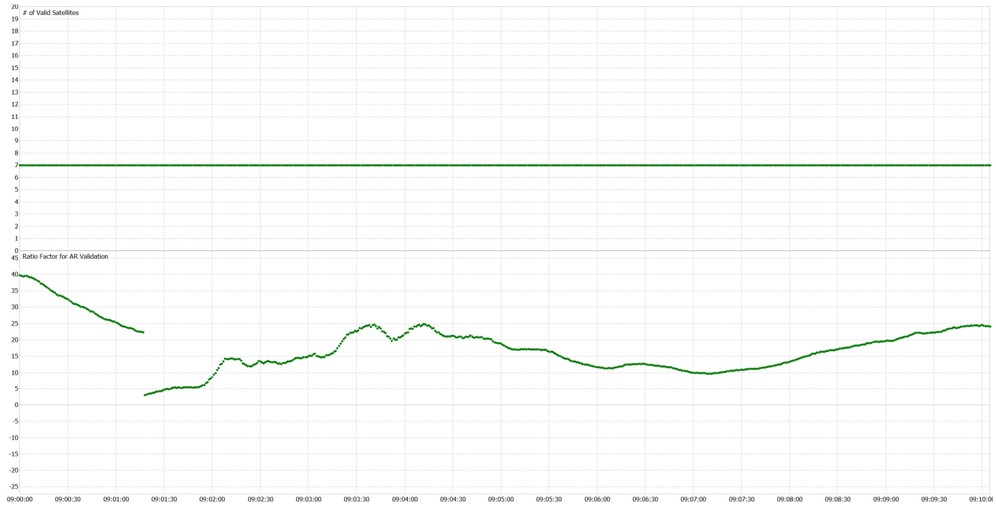

Fig. 3. Ambiguity ratio and No. of satellites.

1.1.4 Residuals

The code residual with RMS 1.80 meter and Carrier residual with RMS 4 cm as seen in Fig. 4.

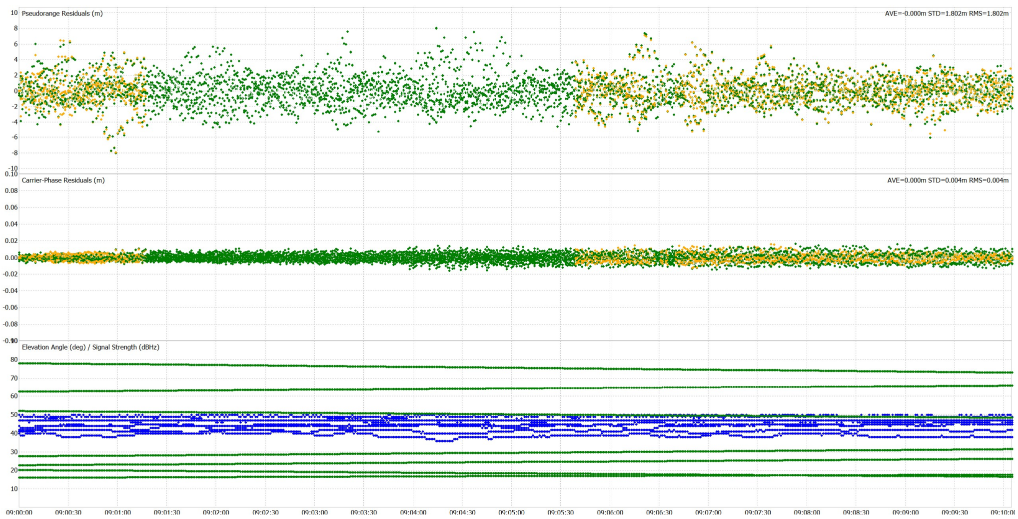

Fig. 4. Residual with zero baseline setup.

1.2 Approach 2 – Multipath Mitigation Using Choke Ring Platform

In this experiment, the smartphone is placed on the choke ring platform. The choke ring platform is one of the best design used to mitigate the multipath and reflected waves, which travel parallel to the surface. The choke ring platform used for the experiment is designed for L1 and L2 frequency.

The whole setup was then placed on the geodetic pillars Fig. 5. The coordinates of geodetic pillars are known with mm accuracy. The similar smartphone (MI8) was kept on another pillar without any choke platform underneath with the distance of approx. 20 meters. In order to perform the RTK, Trimble R10 was placed on the third pillar and was used as a reference station.

Fig. 5. Measurement setup with MI8 (Left: with choke ring platform, Right: without choke ring platform).

1.2.1 Analysis of GNSS raw measurements

Starting from the raw GNSS data analysis, the quality of data collected with the MI8 (with choke ring platform) is improved significantly as compared to MI8 without choke ring platform. The sky plot below Fig. 77 and 8, indicated the identical satellites which were recorded with both the smartphones. However, on the analysis of data quality with each satellite Figs. 9 and 10, it is clearly evident that the smartphone with choke ring platform has better observation data with less cycle slips. Specially, for satellites with high elevation, MI8 without choke ring still suffers high amount of cycle slips. To make sure, that the cycle slips are not the result of duty cycling, both the MI8 were set to ‘Full Raw GNSS measurement’, indicating duty cycle OFF.

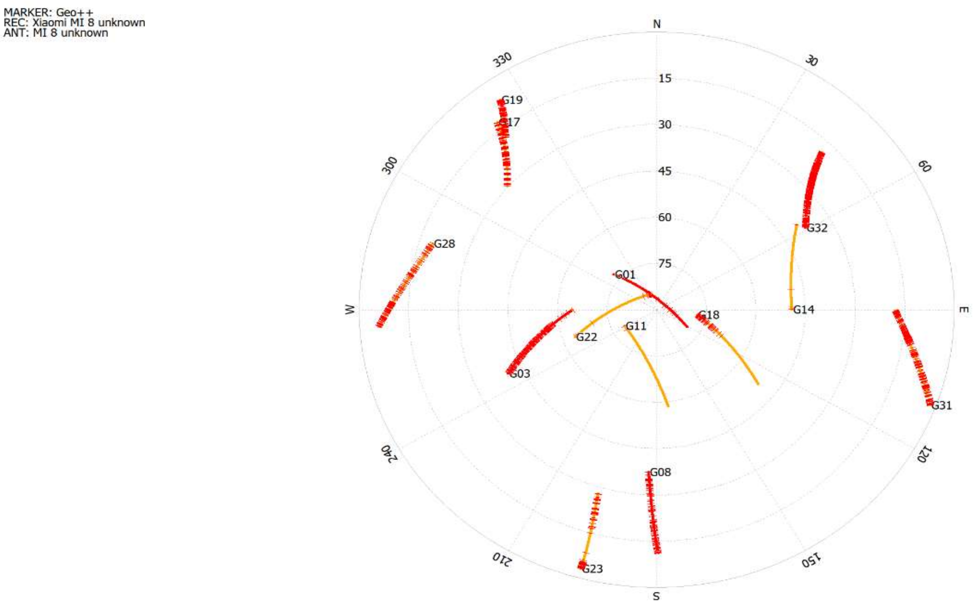

Fig. 6. Sky plot from MI8 without choke ring platform.

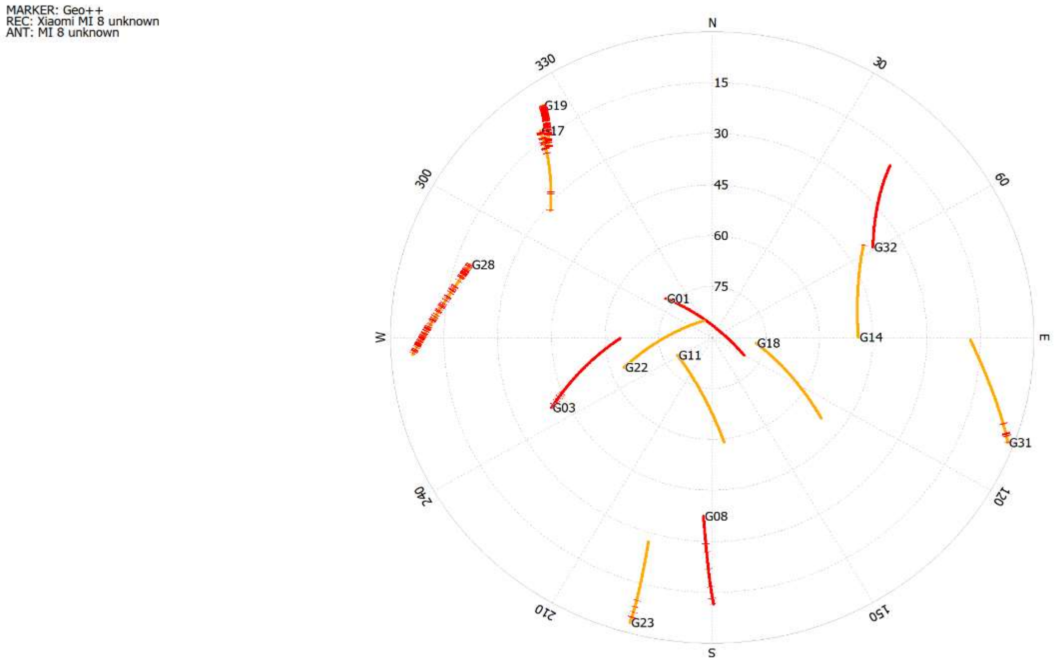

Fig. 7. Sky plot from MI8 with choke ring platform.

Fig. 8. Observation data with MI8 without choke ring platform.

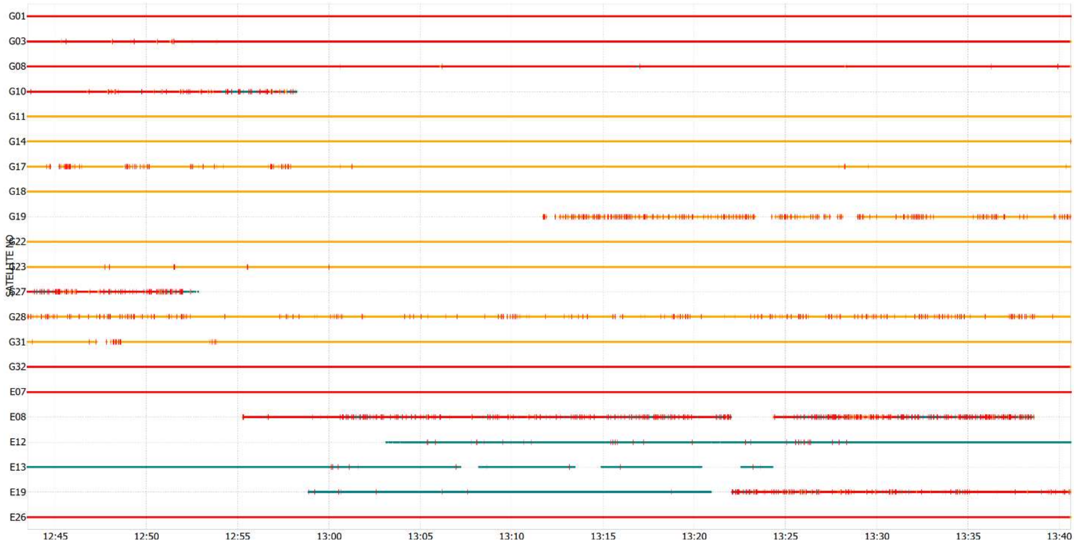

Fig. 9. Observation data form MI8 with choke ring platform.

The RTK position analysis of GNSS observation data without choke ring was performed first. The mean error in the positon w.r.t to true coordinates of pillar were calculated as 0.462 m, 0.0342 m and 2.921 m in x,y and z respectively see Fig. 10.

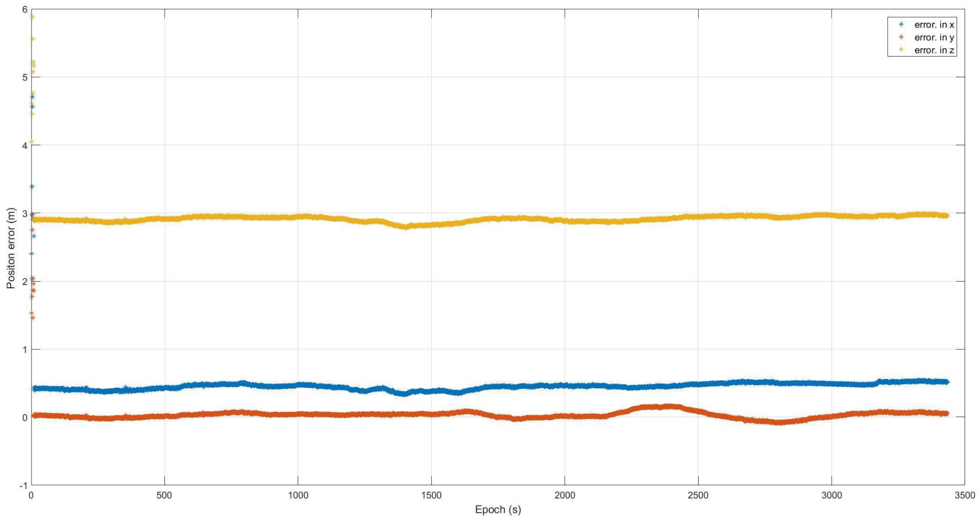

Fig. 10. Position error with MI8 without choke ring platform.

Position accuracy with the MI8 smartphone kept on the choke ring platform shows mean position error of 0.041 m, 0.0324 m and 0.0348 m in x, y and z respectively see Fig. 11.

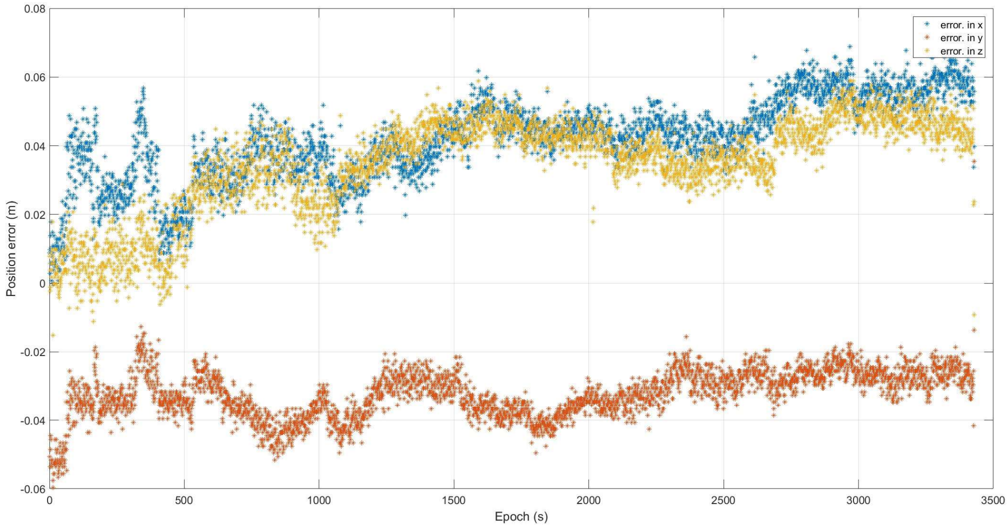

Fig. 11. Position error with MI8 with choke ring platform.

In addition the cm level accuracy, MI8 with choke ring shows 100 percent ambiguity fix in comparison to MI8 without choke platform which shows no fix ambiguities (only float solutions).

2. CONCLUSIONS

The new generation GNSS chips embedded inside the smartphone are much more efficient and precise in comparison to the GNSS in old generation phone couple of years back. Additionally, with dual frequency and multi constellation, convergence time has reduced from several minutes to seconds. Setup like retransmission and multipath mitigation with choke ring platform gives an evident proof that the smartphones provided with good GNSS signal quality, has a position accuracy within cm levels. In addition, with the android new feature to turn off the duty cycle, the quality of carrier phase is enhanced in terms of availability of more carrier phase data for performing RTK positioning Sharma.

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