The Assessment of GNSS Measurements from Android Smartphones

Kaishi Zhang, Fangtan Jiao and Jianwen Li

Abstract Android, the most popular smart operating system with an approximately 86% market share, has been able to support devices in exporting GNSS raw measurement. Taking an example of Huawei P9 smartphone, the paper mainly illustrated the way to obtain GNSS raw measurements on Android OS platform. Moreover, the quality of the satellite signal, the accuracy of GNSS measurements obtained from Android smartphone were analyzed. It can be approved that under good observing conditions, the mean Carrier-to-noise Ratio (CNR) of the satellite signal received by smart mobile devices with Android operating system can usually reach above 25 dBHz, the pseudorange noise of each satellite is about 8–12 m, and the cycle clip ratio of carrier phase measurements is extremely high, the carrier phase range noise can be within 0.006 m when no cycle slip. Compared with common GNSS geodetic receivers, due to the smartphone's hardware, the CNR is lower, and the quality of measurements needs to be improved.

Keywords Android · Pseudorange · Carrier phase · Carrier-to-noise ratio

1 Introduction

"Android", the name of the humanoid robot in the science fiction L'Eve Future written by French author Auguste Villiers de L'lsle-Adam, which represents the most popular smart operating system now. In 2003, Andy Rubin founded Android

K. Zhang · J. Li (✉)
Zhengzhou Institute of Surveying and Mapping, Zhengzhou, Henan Province, China
e-mail: zzljw@126.com

K. Zhang
e-mail: cashzhang1995@163.com

F. Jiao
TSINGHUA University High School, Beijing, China
e-mail: jiaowh0927@163.com

J. Sun et al. (eds.), *China Satellite Navigation Conference (CSNC) 2018 Proceedings*, Lecture Notes in Electrical Engineering 499,
https://doi.org/10.1007/978-981-13-0029-5_14

Inc. and began to research and develop the intelligent operating system. In 2005, Google Inc. acquired Android as well as its R&D team. In November 2007, Android operating system was roll-out, and a global Open Handset Alliance composed of 34 software, hardware and telecommunication enterprises was established to develop open standards for Android devices. In 2008, Google released the initial version of Android, approved by the US Federal Communications Commission. As the system continued updating and optimizing, Android has been widely accepted by customers. By the first quarter of 2017, the market share of Android has reached about 86% [1].

The early version Android can export the location such as longitude, latitude and altitude with GNSS controller, and provides the related application program interface (API) to obtained location. However, due to the commercial confidentiality requirement of the manufacturer, the operating system encapsulates the variables of GNSS measurements, so that it is impossible for developers and users to obtain the GNSS measurements. In 2016, the Android Nougat system was released by Google Inc. added the APIs to export the available GNSS raw measurements, which brought a chance to get the pseudo-range and carrier phase measurements to achieve precision positioning by the mobile phone.

At present, the Android smart mobile devices that support the output of GNSS raw observations include HUAWEI's Honor 8 and 9, HUAWEI's P9 and P10, HUAWEI's mate 9, Samsung's S8, Google's Pixel and Nexus 6P, 5X phones and Nexus 9 tablets. The main feature of those device is listed in Table 1 [2].

This paper briefly introduces the Android system library about GNSS raw measurements and APIs to obtain measurements. Moreover, it assessed the measurement data collected by Huawei P9 smartphone in Carrier-to-Noise Ratio(C/N0), Pseudorange Noise, Ranging Precision and Cycle Slip.

Table 1 Comparison between compatible devices

Model	Pseudorange rate	Accumulated delta range	Satellite constellation
Honor 9	√	√	GPS/GLONASS
S8 (Exynos)	√	√	GPS/GLONASS/Galileo
S8 (QCOM)	√	×	GPS
P10	√	√	GPS/GLONASS/Galileo/ BDS
P10 Lite	√	×	GPS
P9	√	√	GPS/GLONASS/BDS
Pixel	√	×	GPS
Nexus 6P	√	×	GPS
Nexus 9	√	√	GPS
Nexus 5X	√	√	GPS

2 Location Libraries and GNSS Raw Measurements

Compared with the earlier versions, new classes had been added into the Location library in Android Nougat, such as GnssMeasurement class, GnssNavigation class, GnssClock class and so on.

The GnssClock class, which represents a measurement of the receiver's clock, mainly contains the timestamp information. As Android is developed based on the Linux kernel, the clock set in Android devices can be classified into the Real Time Clock (RTC) and the System Clock. The System Clock is a "software" clock to users. The RTC is a "Hardware" Clock (HWClock), which runs independently from the operating system. The RTC is maintained by an integrated circuit in the smart devices. In the previous version of Android, developers and users cannot obtain HWClock timestamps as it is encapsulated. The GnssClock class provides methods to get HWClock, so the developers can compute the GPS time of Android devices.

GnssMeasurement class mainly contained raw measurements and computed information, such as Constellation Types, Carrier Frequency, Space Vehicle ID, Carrier-to-Noise Ratio, Received Satellite Time, Pseudorange Rate, Accumulated Delta Range, etc. And GnssNavigationMessage class contained a GNSS satellite Navigation Message. These classes is indispensable to compute pseudorange and carrier phase measurements so as to position precisely on Android devices.

3 Quality Assessment

With a NovAtel GNSS receiver set together, a Huawei P9 (EVA-AL10) smartphone was adopted to collect measurements on the rooftop station in Zhengzhou, Henan Province, without electromagnetic interference detectable and obstacles above 10° of elevation angle around. The data during 15:44:37–00:15:17, Nov. 11th, 2017 (GPST) was selected as the sample with 1 s interval, 30,642 valid epochs and 227,831 valid measurements.

3.1 Carrier-to-Noise Ratio

As shown in Fig. 1, in good observing condition, the Carrier-to-Noise Ratio of signal received by Huawei P9 mainly distributed within 20–35 dBHz.

As shown in Fig. 3, the CNR of signal from G30 satellite decreased as the elevation angle of satellite descend. Referring to the observation data, the mean CNR value is 28.88 dBHz. When the elevation angle was below 30°, the CNR was under 25 dBHz. And it reached above 30 dBHz only with a elevation angle over 40°. However, in the same condition, the mean CNR value of NovAtel DL-V3 receiver was 44.64 dBHz (Fig. 2).

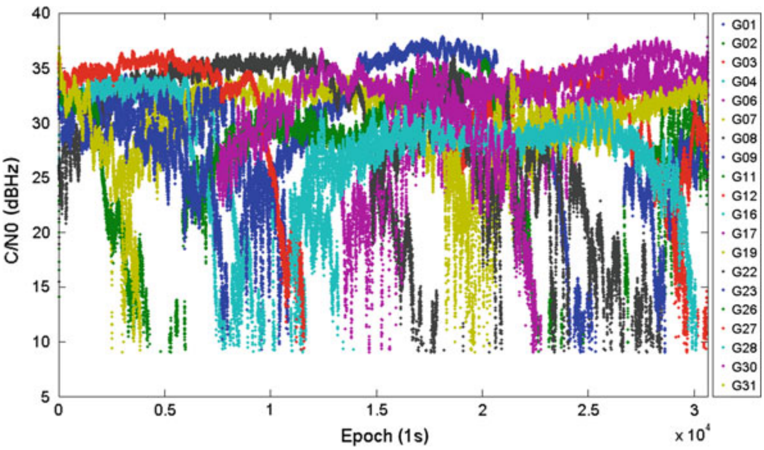

Fig. 1 Distribution of C/N0 on Huawei P9

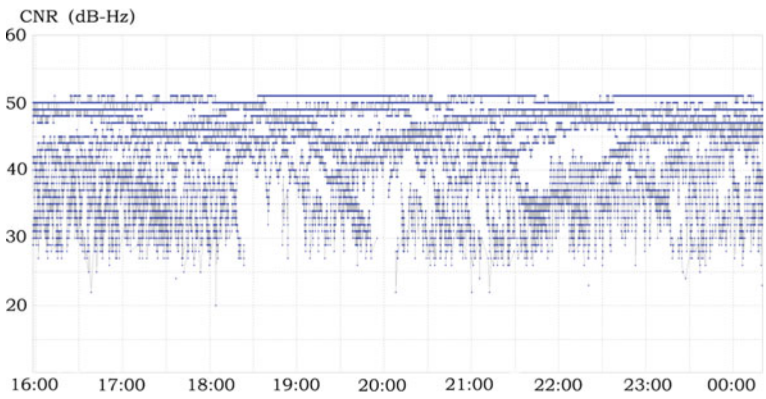

Fig. 2 Distribution of C/N0 on NovAtel receiver

3.2 Pseudorange Measurements

3.2.1 Theoretical Pseudorange Noise

Pseudorange noise is one of the key point of the quality assessment for navigation devices. Since PN code ranging is achieved by accurate tracking of PN code, the noise of code tracking is the decisive factor of range measurement. The principles were shown as follow.

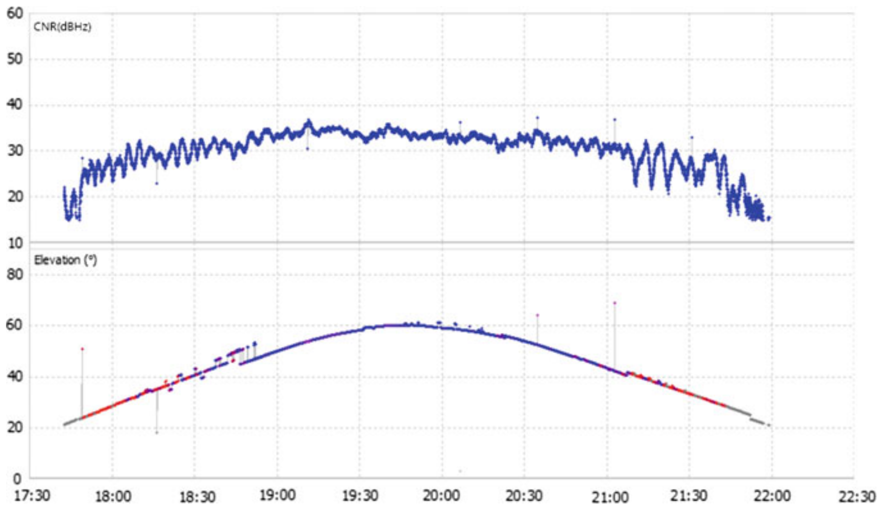

Fig. 3 C/N0 and elevation (G30)

$$\sigma^2_{CELP} = \frac{K_1}{C_s/N_0} \tag{3.1}$$

$$\sigma^2_{NELP} = \sigma^2_{CELP}\left[1 + \frac{K_2}{C_s/N_0}\right] \tag{3.2}$$

$$K_1 = \frac{B_L(1 - 0.5B_LT)\int_{-\beta_r/2}^{\beta_r/2} G_s(f)\sin^2(\pi f\Delta)df}{(2\pi)^2\left(\int_{-\beta_r/2}^{\beta_r/2} fG_s(f)\sin(\pi f\Delta)df\right)^2} \tag{3.3}$$

$$K_2 = \frac{B_L(1 - 0.5B_LT)\int_{-\beta_r/2}^{\beta_r/2} G_s(f)\cos^2(\pi f\Delta)df}{T\left(\int_{-\beta_r/2}^{\beta_r/2} fG_s(f)\cos(\pi f\Delta)df\right)^2} \tag{3.4}$$

C_s/N_0 is Carrier-to-Noise Ratio; σ^2_{CELP} is the tracking error of coherent delay-locked loop; σ^2_{NELP} is that of noncoherent delay-locked loop. Most of GNSS receivers adopt the noncoherent delay-locked loop. And K_1, K_2 are the coefficients which is related to loop bandwidth B_L, integrate time T, filter bandwidth β_r, Code correlation interval Δ. $G_s(f)$ is the normalized power spectral density with infinite bandwidth, and $\int_{-\beta/2}^{\beta/2} G_s(f)df = 1$ [3]. Referring to the equation above, it is obvious that when CNR gets higher, the code tracking error increases as the range noise reducing.

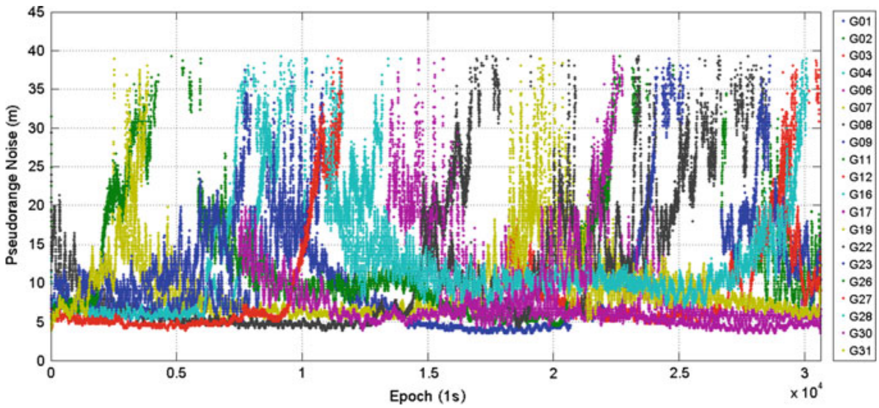

Fig. 4 Distribution of pseudorange noise

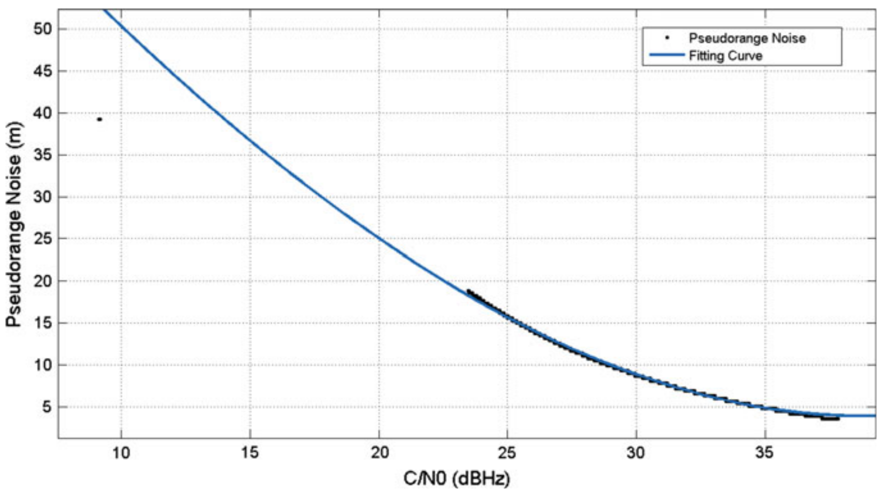

Fig. 5 Fitting curve: pseudorange noise and C/N0

As shown in Figs. 4 and 5, the range noise of Huawei P9 distribute from 5 to 40 m. The mean theoretical value of pseudorange noise is about 10.76 m. Comparing the theoretical pseudorange noise with CNR, it can be approved that the noise value reduces as the CNR values rises.

3.2.2 Pseudorange Noise in Practice

In terms of the pseudorange measurements computed, the polynomial fitting method was used to get the pseudorange noise with each 120 adjacent measurements divided into one segment to compute the fitting parameters [4, 5].

Figure 6 has shown the Huawei P9 pseudorange noise of each satellite. In general, the value decreases when the CNR gets higher. Most of the pseudorange noise values of each satellite were within 8–12 m and no higher than 20 m. The mean noise value of all is 10.10 m, close to the theoretical pseudorange noise while that of Novatel receiver was only 0.023 m, as shown in Fig. 7.

3.3 Carrier Phase Measurements

3.3.1 Carrier Phase Noise

As mentioned already, the tracking noise of carrier phase measurements is the main factor of carrier phase range noise. The principles were shown as follows.

$$\sigma^2_{coherent} = \frac{K_3}{C_s/N_0} \tag{3.5}$$

$$\sigma^2_{cost} = \sigma^2_{coherent}\left[1 + \frac{K_4}{C_s/N_0}\right] \tag{3.6}$$

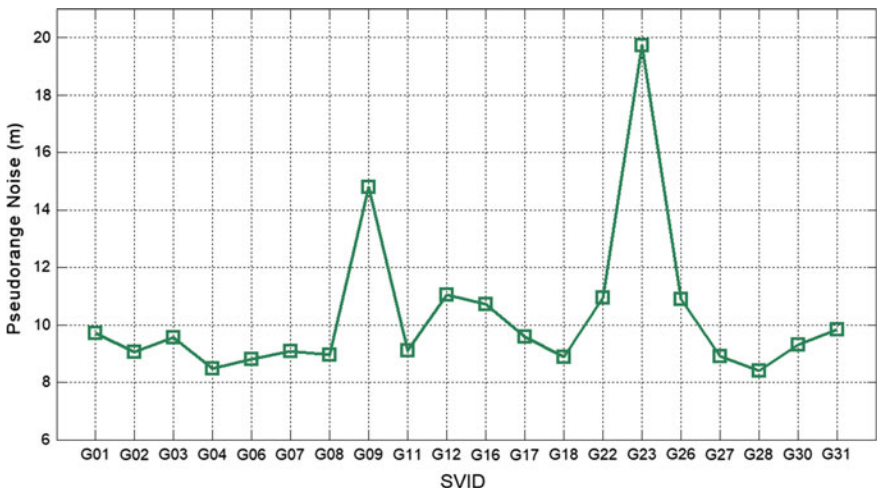

Fig. 6 Pseudorange noise of Huawei P9

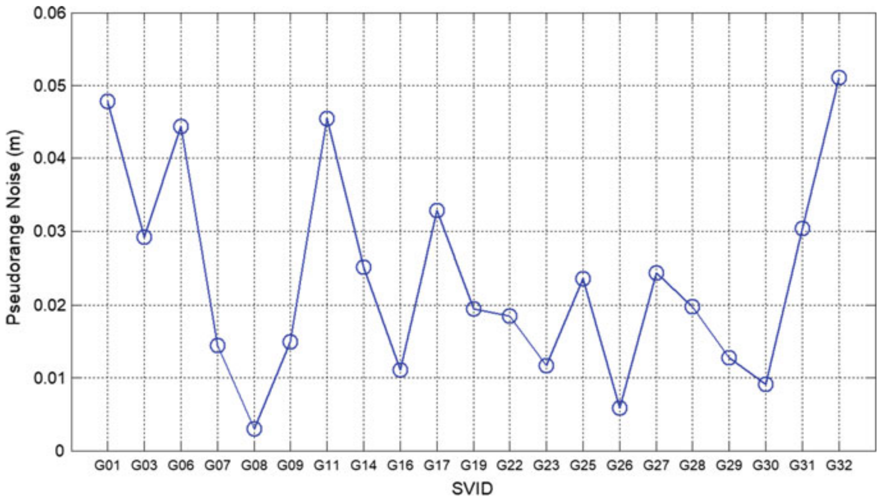

Fig. 7 Pseudorange noise of NovAtel receiver

$$K_3 = \frac{B_\theta(1 - 0.5B_\theta T)}{\int_{-\beta/2}^{\beta_r/2} G_s(f)df} \tag{3.7}$$

$$K_4 = \frac{1}{2T\int_{-\beta_r/2}^{\beta_r/2} G_s(f)df} \tag{3.8}$$

$\sigma^2_{coherent}$ is the coherent delay-locked loop tracking error; σ^2_{cost} is the noncoherent delay-locked loop tracking error; B_θ is loop bandwidth [5]. And also the tracking precision decreases as the CNR gets lower [3].

As is shown in Figs. 8 and 9, when cycle slip occurred, the carrier phase range noise overflows and without cycle slip, the noises mainly distributes within 0.001–0.006 m, reducing as the C/N0 gets higher.

3.3.2 Cycle Slip Detection

Cubic epoch differential method was adopted to detect cycle slip with carrier phase measurement.

$$\Delta\rho(t_i) = \rho(t_i) - \rho(t_{i-1}) \tag{3.9}$$

$$\nabla\Delta\rho(t_i) = \Delta\rho(t_i) - \Delta\rho(t_{i-1}) \tag{3.10}$$

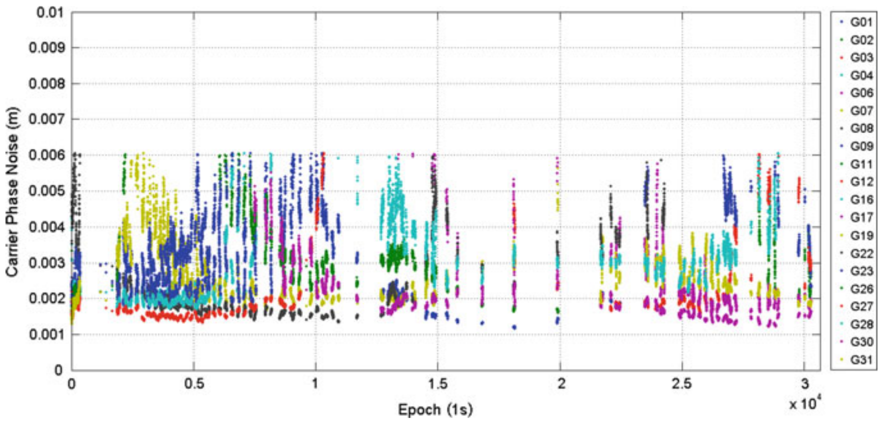

Fig. 8 Distribution of carrier phase noise

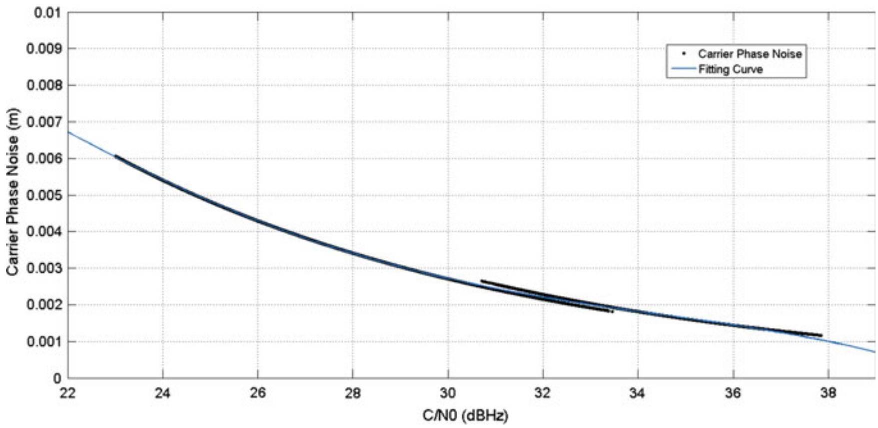

Fig. 9 Fitting curve: carrier phase noise and C/N0

Table 2 Principle of cycle slip detection

Epoch	Phase	Single difference	Double difference	Triple difference
1	0	0	0	0
2	0	0	0	0
3	ε	ε	ε	ε
4	ε	0	−ε	−2ε
5	ε	0	0	ε
6	ε	0	0	0
7	ε	0	0	0

Table 3 Cycle slip of Huawei P9

SVID	Cycle slip	Cycle slip ratio (%)
G01	8053	51.16
G02	1037	38.85
G03	6627	56.85
G04	2942	32.13
G06	5039	58.82
G07	11,060	66.66
G08	9929	58.29
G09	5514	43.71
G11	11,194	66.53
G12	728	43.31
G16	4505	43.97
G17	11,774	69.03
G18	7640	62.00
G22	8678	72.09
G23	3268	33.12
G26	1935	45.81
G27	4657	40.32
G28	12,585	65.69
G30	8710	57.82
G31	1480	39.30

Table 4 Cycle slip of Nexus 9

SVID	Cycle slip	Cycle slip ratio (%)
G03	3	0.84
G07	41	1.27
G08	34	0.88
G09	40	1.03
G11	29	0.98
G16	37	0.95
G23	36	0.93
G26	14	0.58
G27	38	0.98
G30	27	3.09
G31	11	0.44

$$\Delta\nabla\Delta\rho(t_i) = \nabla\Delta\rho(t_i) - \nabla\Delta\rho(t_{i-1}) \tag{3.11}$$

By means of differential method, the cycle slip of carrier phase can be amplified to be more detectable [6].

It was found after analysis that the cycle slip ratio of carrier phase measurements received from Huawei P9 smartphone is overtop. According to statistics, there are 120, 759 measurements with cycle slips in 227,831 carrier phase measurements (Table 2). Compared with Huawei P9, that of NovAtel is much lower with only 28 measurements containing cycle slip. However, not all the Android smart devices (Table 3) have this fault. In similar conditions, using the Nexus 9 tablet with better performance collecting 31,791 measurements during 22:32:21–23:36:59, Aug. 7th, 2017 (GPST), there was only 326 cycle slips detected (Table 4).

4 Conclusion

The report briefly introduced GNSS libraries and raw measurements of Android system. Moreover, it assessed the Huawei P9 GNSS measurements and compared it with that of NovAtel receivers. It was demonstrated that in the same observing environment, the quality of Huawei P9 GNSS measurements still need to be improved.

(1) The mean value of signals CNR from NovAtel GNSS receivers is 44.63 dBHz, much higher than that from Huawei P9, 28.88 dBHz.
(2) The mean pseudorange noise of NovAtel receiver is only 0.023 m, while that of Huawei P9 smartphone reaches above 8 m. Moreover, the cycle slip of carrier phase measurements occurs much too frequent on Huawei P9.
(3) Though the GNSS raw measurements are now available in the output of Android Nougat, the GNSS module inside smartphone still needs to be optimized.

References

1. Guo L (2016) The first line of code, 2nd edn. Post and Telecom Press, Beijing, China, pp 01–04
2. Simon B, Van Frank D (2016) Innovation: precise positioning using raw GPS measurements from Android smartphones. GPS World J 27:43–48
3. Chen W, Li X (2015) Accuracy assessment for carrier phase and code measurements of BDS B1/B3 frequency observation. Aerospace Shanghai J 32:62–66
4. Guan M, Jiao W, Jia X (2017) Accuracy analysis of BDS pseudorange observation. Geom Sci Eng J 37:21–25
5. Zhang X, Wang F (2011) Research and analysis on pseudo-range noise modeling method. Aerospace Controland Appl J 37:44–48
6. Zhao L (2012) The Application of Triple-frequency Data Combination in Cycle Slip Detection and Repairing. Liaoning Technical University