Antenna Performance Evaluation Method for 5G AGPS Wireless Devices

Na Wang¹, Lei Chen¹, Xianhui Liu¹, Panpan liang¹, Qinjuan Zhang¹*

¹China Telecommunication Technology Labs (CTTL) of China Academy of Information and Communications Technology (CAICT). Beijing, 100191, China

Email of all the authors: wangna@caict.ac.cn; chenlei5@caict.ac.cn; liuxinahui@caict.ac.cn; liangpanpan@caict.ac.cn; zhangqinjuan@caict.ac.cn

* Corresponding Author’s e-mail: zhangqinjuan@caict.ac.cn

Abstract: The 5G AGPS positioning technology has been widely used in wireless devices. The principle, test method and test system of the 5G AGPS positioning technology are presented in this paper. This method can evaluate positioning antenna performance in simulated environment that is close to real use. The test results show that the system can reflect the positioning antenna performance of EUT very well and provide the test guarantee for user experience.

1. Introduction

GPS Global Positioning System is a high-precision radio navigation and positioning system based on artificial Earth satellites. It provides accurate geographical location, vehicle speed and accurate time information anywhere in the world and in near-Earth space. AGPS Assisted Global Positioning System in conjunction with traditional satellite positioning systems and network resources, by downloading available satellite information from the cellular network for the current region (including information on the satellite frequency band, azimuth, elevation available in the region), it can avoid searching with all frequency and wide range, So that the speed of the first search greatly increased and the time is reduced from a few minutes to a few seconds. The cellular network from 2G, 3G, 4G to 5G, all can assist positioning. AGPS positioning methods are divided into MSA (MS-Assisted) and MSB (MS-Based). The difference between the two positioning methods lies in the different calculation methods of the final positioning results. For MSB method, The system downloads the auxiliary data to the terminals and the terminals completes the location calculation by itself, then upload the results to the location server; For MSA method, after the system downloads the auxiliary data to the terminals, terminals start to observe visible satellites, then upload the observations to the location server, Finally, the terminal position is calculated by the location server and the calculation results are downloaded to the terminals [1].

The harmonics of cellular antenna can easily interfere GPS antenna in AGPS system. Good antenna performance can ensure the quality of navigation and positioning service and the final user experience. Therefore, it is very important to evaluate the positioning GPS antenna performance of AGPS terminal in cellular assistance scenario.
AGPS OTA tests are performed in simulated real usage scenarios to evaluate the receiving performance TIS (Total isotropic sensitivity) for the positioning antenna of wireless terminals. The North American PTCRB certification organization has required testing of 2/3G AGPS OTA performance since 2011 and 4G AGPS OTA performance test began in 2013. North American operators including T-Mobile/AT&T/VZW also have test requirements for AGPS OTA.

With the continuous popularization of 5G technology, 5G AGPS OTA performance testing becomes crucial. This paper introduces the test method and system for 5G AGPS OTA in EN-DC mode in order to guide the actual test work.

2. 5G AGPS Antenna Performance Evaluation Method

So far there are no official international and domestic 5G AGPS OTA test standards, CTIA standard organization has some discussion in this field in contribution CATF200207_R3[3]. North American operators T-Mobile have put forward 5G AGPS OTA limit requirements, enterprises and operators urgently need the corresponding test system to complete 5G AGPS OTA testing. 5G AGPS OTA test principle refer to principle of LTE AGPS OTA in CTIA standard with 3.9.1 version [2]. The testing process is divided into three steps:

(1) 3D Pattern Measurement

This step is to obtain the spherical pattern of the positioning antenna of the EUT, to make the basis for the subsequent TIS calculation, and to find the best azimuth point and polarization direction in the upper hemisphere.

The pattern data shall be determined by averaging Carrier-to-Noise (C/N0) measurement of all visible GPS satellites for each measurement at each point on the sphere. The GPS satellite simulator shall provide the number of satellites specified herein and each satellite vehicle shall be at the same power. All C/N0 measurements shall be done with the GPS engine in a tracking mode or by using individual UE-assisted measurements. Orthogonal linear polarizations will be measured. The device is not located in this step.

(2) Linearization test

In this step, the EUT and measurement antenna are adjusted to obtain the best azimuth and polarization direction in 3D pattern measurement. After the completion of this step, the carrier to noise ratio obtained in the first step and power value will form a one-to-one corresponding relationship. Linearization is the most critical step in the whole test, non-linearity is not allowed, if it occurs, it must be retested. At the end of a normal linearization test, either the power is reduced to the set value, or the power is not reduced to the set value, but the carrier to noise ratio is about 20dB, both of which are considered normal;

(3) Power Reduction Test

In this step, the EUT and measurement antenna are adjusted to obtain the best azimuth and polarization direction in 3D pattern measurement. At this time, by adjusting the transmission power of the satellite simulator, the power of the satellite signal reaching the EUT is reduced until the positioning accuracy of the EUT reaches the critical point of 95%. The maximum A-GNSS sensitivity search step size shall be no more than 0.5 dB when the satellite vehicle power level is near the A-GPS sensitivity level. The test parameters are as follows:

| Satellite Number | 8 |
|------------------|---|
| HDOP range       | 1.1 to 1.6 |
| Propagation Condition | AWGN |
| GPS L1 time assistance | Coarse positioning plus or minus 2 seconds |
| EU response time | LPP 20 seconds, RRLP 16 seconds |
| Acceptable response time to network | 20.3 seconds |
3. 5G AGPS OTA test system and result analysis

The antenna performance test of 5G AGPS equipment is required to be carried out in a full anechoic chamber. The composition of the test system is shown in Figure 1.

As the core equipment of the test system, the main function of the satellite signal simulator is to transmit the simulated satellite signal to the EUT and test the receiving sensitivity of EUT. 4G base station simulator and 5G base station simulator are used to transmit simulated EN-DC cellular signal and establish cellular communication connection with EUT. The switch controller is used to switch between different RF links to realize the automation of test. The turntable controller is used to control the rotation of the turntable in the chamber so as to realize the positioning of EUT in three-dimensional space. The PC installed with system control software is the control center of the whole system. The control software controls the whole system. During automatic test, the relevant test parameters are set in the control software. The control software will send the test parameters to the corresponding instrument in the form of command, so as to realize cooperative operation, complete the test automatically and generate the test result diagram.

The laboratory built the test system with reference to figure 1, and the instrument models used are shown in Table 2. The test chamber is ETS AMS8800. Two test conditions were selected. One is free space and the other one is besides head and hand phantom showed in figure 2.

The uncertainty of the system was evaluated which includes the following contributions:

(1) Mismatch

| Success rate | 95 successful fixes with the necessary accuracy out of 100 attempts (95%) |
|--------------|--------------------------------------------------------------------------|
| Positioning accuracy | 101.3 meters |
(2) Cable Factor
(3) Satellite Simulator Absolute Output Level uncertainty and Output Level Stability
(4) Sensitivity Search Step Size
(5) Offset of phase center of EUT from axes of rotation
(6) Blocking Effect of EUT on Measurement Antenna: VSWR variation
(7) Blocking Effect of EUT on Meas. Antenna: Chamber Standing Wave
(8) Phase Curvature Across the EUT
(9) Temperature Influence
(10) Head and hand Phantom Uncertainty
(11) Head and hand Phantom Fixture Uncertainty
(12) EUT Positioning Uncertainty
(13) EUT Re-Positioning Uncertainty
(14) Coarse Sampling Grid Contribution
(15) Miscellaneous Uncertainty
(16) Range Reference Measurement uncertainty
(17) Satellite Simulator Relative Output Level Linearity
(18) Linearization of conducted/ radiated RSS measurement
(19) Uncertainty of RSS data from EUT
(20) Quantization of EUT reporting mechanism for RSS data

After analysis, the system measurement uncertainty of AGPS OTA in free space is 2.02db, and the measurement uncertainty in head and right hand phantom is 2.49db, which meets the uncertainty limit requirements of CTIA standard.

![Figure 2. Test Conditions](image1.jpg)
(a) Free Space Condition
(b) Head and hand phantom

The laboratory uses the test system to test three mobile terminals supporting 5G AGPS. Before the test, EUT is set according to the chip type. This test selects 5G typical low frequency DC_2A_n71A and typical high frequency DC_66A_n41A. The test mode includes MS assisted and MS based, the test condition includes free space and head and right hand phantom. The test data is shown in Figure 3.

By analyzing the data, it can be found that the TIS results of the three mobile phones are quite different, especially in the low frequency band the deviation is up to 3dB. In the high frequency band, the deviation of free space data among the three mobile phones is small, while the deviation is up to 2dB besides the head and hand phantom. These phenomena are related to the antenna design of mobile phone, and also reflect the real positioning performance of EUT.
Figure 3. 5G Mobile Phones AGPS OTA Test Results

4. Conclusion
The 5G AGPS OTA test method introduced in this paper is suitable for the EUT supporting EN-DC assisted GPS positioning.

5G AGPS OTA system is more complex than the 4G system, especially in EN-DC mode, the system needs to realize the dual connection of 4G and 5G cellular signals, which puts forward higher requirements for system construction.
This system described in this paper has the advantages of high test accuracy, simple operation, high degree of automation and low uncertainty. It can accurately reflect the antenna performance of the EUT and provide test guarantee for ensuring user experience.

References
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