

# OVERVIEW OF 5G COMMUNICATION INSTRUMENT CALIBRATION AND TESTING TECHNOLOGY

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**Abstract:** 5G adopts a new network architecture, network slicing, large-scale antenna arrays and ultra-dense networking technologies, with large bandwidth, high reliability and low-latency features, is the direction of future communication development. 5G test instruments are the foundation and guarantee for the widespread application of 5G technology, is its value accurate? Indeed, it directly affects the research and development of the 5G industry, production and quality costs, as well as process control and quality levels of produced finished products. From 5G communication instruments Calibration test perspective explains 5G terminal, 5G bearer network test instruments and 5G large-scale array antenna calibration test technology status and problems faced.

**Keywords:** 5G ; Instrument calibration test; 5G terminal; 5G bearer network test instrument

## 1 INTRODUCTION

Mobile communication from 20th Century 1980s birthday Since birth, go through More than 30 years of explosive growth, has become the basis for connecting human society basic information network, will promote a high degree of integration of various industries and develop. Driven by the development of 5G technology, Manufacturing and R&D of 5G phase A large number of new technologies have been introduced into related products, New Technology, infrastructure Even new iteration, enterprises' needs for calibration services of 5G communication test instruments Seek something much greater than what you already have 2G, 3G and 4G technology, due to 5G pass Information technology uses new frequency bands, ultra-wideband technology and large Large-scale antenna array, 5G communication test instruments adopt new frequency bands, new standards and new protocol, At present, 5G communication instruments lack corresponding calibration specifications., prone to problems, So right 5G terminal, 5G bearer network test Instrumentation and calibration testing of 5G massive array antennas presents new challenge. This article will start from 5G terminal, 5G Bearer network test instruments and Calibration parameters of 5G large-scale array antenna, current situation and problems faced Several aspects to discuss the calibration and testing technology of 5G communication instruments.

## 2 5G COMMUNICATION DEVELOPMENT STATUS

In recent years, 5G communication technology has developed rapidly. international technology Technical cooperation and competition are also intensifying, the high level of 5G communication technology To a certain extent, low reflects the country's future development momentum and potential. The development history of domestic communication technology is shown in the figure 1 shown. 1G era mining Transmitted using analog signals, Poor communication security, susceptible to interference, adopted by various countries 1G communication standard is not one To. Enter 2G hour generation, Achieved the leap from analog to digital modulation, The mobile phone has Got it Internet function, The transmission rate reaches 10~15 kb/s. Year 2009 January, Ministry of Industry and Information Technology for China Mobile, China Telecom and China Unicom issue 3G licenses, middle China enters the 3G era, the information transmission rate increases by an amount class. year 2013 December, the Ministry of Industry and Information Technology issues TD to the three major operators - LTE Card According to, 2015 Year 2 month, electricity letter, couplet Pass get hair FDD- LTE license, China turns on 4G In this era, 4G has further improved the speed of 3G step up, High-quality images can be transferred quickly, audio and See frequency wait. 2015 Year 10 month, country international electricity link batch Right push Into the 5G research process resolution, 5G column Enter the country Home " ten three five " planning, Got the country Project 863, nation Science and technology are important special support, Key technology verification has been completed in 2018, Technical solutions Validation and system validation 3 level Section's technology research and development test, 2019 Year start Launched 5G enhancement and millimeter wave technology research and development tests, Terminal Testing and Interoperability Testing, 2019 Year open beginning Pre- negotiation use net establish, 2020 Year just Mode Commercial. Internationally, 5G Has become the strategic commanding heights of information technology development in various countries, China IMT-2020 (5G) Promotion group, European Union 5G PPP, Japan 5GMF, Korea 5G Forum and Americas 5G Americas and other organizations first Established later, Promote the 5G needs of various countries and regions, technology and spectrum research work, 5G- related organizations have been established in various countries and regions., Promoted the rapid

development of the 5G industry. at the same time, Central Europe Expand 5G Project cooperation, IEEE It has also begun to work on 5G research [1-2].

5G era, Massive chain catch, extra large belt wide, super Low hour extend, Its speed is improved in all aspects compared with 4G, The rate of the downstream peak can be reach 20 Gb/s, superior OK peak worth it speed Rate Can able overtake Pass 10 Gbps. 5G ultra-low latency for the Internet of Vehicles, industrial control and smart grid, etc. Straight industry offers safer, reliable internet connection. at the same time, It enables autonomous driving, telemedicine and other application fields Scenery comes to light Real, 5G The network's millions of connections per square kilometer make everything interconnected connection possible [3].

With June 2019 moon Issuance of 5G commercial licenses and 5G net Large-scale rollout of network construction, 5G is accelerating into our lives Come. As of 2019 Year 7 moon, Nationwide each Province city hair cloth 5G 35 relevant policy documents, Accelerate 5G In the industrial Internet, pay Innovative applications in multiple industries such as Tonghe Medical, the 5G era has arrived Come. In terms of industrial development, upstream equipment manufacturers in the 5G industry chain have begun develop And production 5G equipment, Operator dense set establish set up 5G net network, Leading terminal factory Businesses publish one after another 5G mobile phone. cut to 2019 7 moon, 38,000 5G base stations have been built nationwide. In terms of standards, In June 2018, the first version of the 5G standard completed the enhanced mobile band wide scene, the second version of the 5G standard in 2020 will achieve low latency and high Reliable scenario. Chinese manufacturers are formulating 5G standards, Made a heavy important contribution [1].

### 3 5G COMMUNICATION TEST INSTRUMENT

Communication tester as a communication Industrial chain development key in link, from The early stages of development of the 1G communications industry, accompanied by communication The maturity of industrial development, Comprehensive coverage of base station testing, terminal test try, field testing, certification/ pre-certification testing and laboratory testing, etc. The entire life cycle of products in the mobile industry chain, Completed Good pass Letter testing technology system and product system [3].

5G test instruments are mainly divided into 5G terminal base station test instruments, Field environment simulation and monitoring instruments, device component testing instruments and 5G bearer network test instrument, as shown in picture 2. in, terminal Base station test instruments mainly include Sub 6G and millimeter wave terminal/ base station tester, Large-scale matrix antenna tester, terminal emulator with base Station RF one Consistency tester, etc.; Field environment simulation and Monitoring master There must be 5G Air interface monitor, Network optimization test instruments, etc.; Device Component testers mainly have vector signal sources, signal analyzer and no Line comprehensive tester, etc.

### 4 COMMUNICATION TEST EQUIPMENT CALIBRATION TECHNOLOGY

5G communication equipment has high frequency bands, large bandwidth and low latency new features, so that the design of the device, process and testing equipment The calibration of the For example: Devices in design, Requires bandwidth exceeding 800 M ; in manufacturing, the manufacturing process will enable use 7 nm work art Full foot 5G high speed Rate and Low achievement consumed need beg ; In terms of test equipment calibration, 5G pass signal band, Sub -6 GHzFR1 frequency segment frequency range for 450 MHz ~ 6 GHz, millimeter rice Wave FR2 frequency The range of the segment is 24.25 ~ 71 GHz, the bandwidth range is 100 ~ 800 MHz, Far greater than 4G era 20 MHz bandwidth; After using the millimeter wave band, To improve spectrum efficiency and transmission performance, to achieve multi-carrier aggregation, The antenna size also becomes millimeter Meter level, communication The base station uses a large-scale array antenna; At the same time, 5G uses 5G NR format and eCPRI protocol, The transmission rate of the backbone network is increased from 40 Gbps Lift to 100 Gbps, none Wire Association discuss of pass lose speed rate by 600 Mbps~10 Gbps, promoted to 10~25 Gbps. based on 5G The above changes in test equipment, Research set up for terminal testing Test equipment (vector signal source, analyzer), large-scale array antenna and Measurement for bearer network test equipment (100G, OTN, eCPRI) testing standard equipment, Research and compile relevant metrological verification procedures and calibration gauge fan, improve the existing communication measurement standard system, is imminent.

#### 4.1 5G TERMINAL Test Instrument Calibration Technology

5G terminal test instruments mainly include: vector signal source, Signal Analyzer, wireless comprehensive tester and network analyzer, etc. school allow Mainly divided into transmitter parameter testing, receiver parameter test, like surface 1 Place Show. hair shoot machine school allow ginseng number host want have frequency Rate allow correct Spend, Output level, spectral purity, single sideband phase noise, Modulation signal modulation quality, Occupied bandwidth, spectrum emission template, adjacent road Leakage power ratio and EVM Equalizer spectrum flatness etc. catch The receiver calibration parameters mainly include reference sensitivity level, maximum loss input level, adjacent

channel selectivity, blocking characteristics, modulation quality parameters Digital analysis and RF input port voltage standing wave ratio, etc.

For vector signal sources, wireless comprehensive test instrument launch Machine parts, etc., the common calibration parameters of this type of instrument such as output frequency Rate, Output Power, spectrum characteristics and modulation quality, Calibration party The method is the same as the 4G terminal test instrument. Use frequency meter, achievement rate meter, spectrum analyzer, comprehensive tester and other equipment for calibration allow; And for 5G NR Vector modulation parameters, currently not available There are publicly published calibration specifications, standard vector signals can be used Analyzer calibrated, and adopts broadband calibration technology to vector Calibrate the amplitude and phase characteristics of the analyzer, ensuring the calibration of broadband modulated signals. For vector signal analyzers, wireless comprehensive test Tester receiving part, etc., Common calibration parameters for this type of test instrument If you enter frequency, input power and frequency characteristics, Calibration method and The 4G test equipment is the same, Using vector signal source, frequency meter and measurement Measurement receivers and other equipment are used to calibrate parameters such as frequency and power; And for 5G NR Demodulation parameters, currently not publicly released calibration method, Standard vector signal generator can be developed, Pick Use pre Distortion technology produces high- quality 5G NR Modulated signal, Use standards Calibrate modulation parameters using vector signal analyzer comparison. To sum up, the frequency of the 5G terminal test instrument, Power parameter traceability to frequency meters and measuring receivers, 5G NR Vector modulation/ demodulation parameters Data traceable to standard vector analyzers, Ultimately traced to National measurement standard device. As shown in Table 1.

**Table 1** 5G Terminal test instrument calibration parameters

Calibration content	specific parameters
Transmitter parameters	frequency accuracy, output level, spectral purity, single sideband phase noise, Modulation signal modulation quality, Occupied bandwidth, Spectral emission mask and adjacent channel leakage power ratio, and EVM Equalizer spectrum flatness and other parameters
Receiver parameters	Reference sensitivity level, maximum input level, adjacent channel selection sex, blocking characteristics and modulation quality parameter analysis, And cum Frequency input port voltage standing wave ratio and other parameters

In 5G terminal test instruments, Greatly improved frequency and bandwidth at the same time, Adopted new 5G NR standard, SUB -6G and 5G in millimeter wave bands NR Modulation functions have changed. at present, There are many studies on ultra-wideband technology based on narrow pulses at home and abroad. And base Research on ultra-wideband technology based on bandpass carrier modulation method less, Only Solve the problem of in-band amplitude and phase characteristic parameter calibration of ultra-wideband signal analyzers allow, In order to ensure the amplitude flatness and phase flatness within the ultra-wideband Tan Spend, The current calibration method only refers to the vector signal analyzer school quasi-normative, However, the modulation performance parameters of ultra-wideband have not been obtained. To school allow, now have school allow square Method host want technology technique according to according to for JJF 1277 - 2011 《 none Wire bureau domain network Measurement try instrument school allow regulation Fan", JJF 1443 - 2014 LTE "Comprehensive Test of Digital Mobile Communications" Test instrument calibration gauge Fan", JJF 1396 -2013 "Spectrum Analyzer Calibration Specifications" and JJF 1174-2007 "Calibration Specifications for Digital Signal Generators " etc., For 5G terminal testing calibration of instruments, need 5G NR school allow regulation fan, It is necessary to improve the ultra-wideband modulation parameter calibration method.

**4.2 5G Large-Scale Array Antenna Testing Technology**

Before 5G, the test of radio frequency indicators of base station antenna is to use By conduction method, The terminal antenna only radiates power omnidirectionally (TRP) and omnidirectional radiation sensitivity (TIS) use OTA test. 5G mining large scale antenna array, has the following characteristics.

**4.2.1 Highly integrated antenna and RF channel**

In 5G millimeter wave large-scale arrays, In order to reduce the transmission and connection loss, Convenient for a large number of antenna units and transmitters frequency channel integrated, The antenna unit will be directly connected to the radio frequency channel Way.

**4.2.2 Large number of antennas and RF channels**

5G millimeter wave base stations adopt large-scale MIMO form, common The number of antennas and RF channels is 64, 128 and 256 wait.

**4.2.3 Large system bandwidth 5G millimeter wave system bandwidth Width**

Pass road bring Width Will reach arrive 400 MHz, even bigger.

#### 4.2.4 RF front-end size reduction

Millimeter wave has short wavelength, 5G millimeter wave massive MIMO Array Compared with arrays of the same size in the low frequency band, its size is significantly reduced.

#### 4.2.5 Using beam forming technology

Millimeter wave space The transmission loss is large, Beamforming shape technology Can improve the gain of the antenna, thereby increasing the equivalent emission Power and connection Receiving signal to noise ratio. Other on the one hand, The introduction of multi-beam technology Deposit can be withdrawn High system capacity, improve system performance.

For 5G Large-Scale Antenna Array RF Testing, Both need to be transmitted guided test (Basic antenna performance, That is, the passive parameters of the antenna) and need Need air OTA test (Antenna system performance, That is, the antenna active parameter number). Conducted testing uses radio frequency cables to directly connect the instrument and the measured things connected to one rise, Avoid interfering signals from space radiation for testing Impact. OTA The test is radiated directly through the antenna. Depend on Measuring antenna reception, Then pass the signal into the test instrument square Law, To avoid spatial interference signals and multipath, Need to be in Absorbing dark Conducted in the room. The main calibration parameters of the 5G antenna are shown in Table 2. none Source parameter test parameters mainly include power, standing wave ratio, antenna side Towards picture, beam width and gain, etc., Calibration methods and 4G test instruments same, Using vector network analyzer plus spread spectrum device, accomplish 100 GHz spectrum coverage, test types include plane, cylinder and Spherical measurement try. sky Wire have source Measurement try ginseng number host want have Wave valve, TPR and TIS, Since the beamforming function requires the coordination of the radio frequency module Only under the same conditions can we work, Millimeter wave 5G base station antennas can only pass through the air mouth test, 3GPP The consistency of low and high frequencies has been clarified test, like EVM, ACLR and OBUE All will Pick use OTA method [5-6].

**Table 2** 5G large-scale antenna array test parameters

Calibration content	specific parameters
Passive antenna parameters	Antenna coefficient, antenna gain, direction diagram, standing wave ratio, axle rear ratio sum 3 dB Lobe width, etc.
Active antenna parameters	equivalent isotropic radiated power, adjacent channel leakage power ratio, Equivalent omnidirectional sensitivity and adjacent channel selectivity, etc.

5G Large-scale antenna arrays have antenna elements and radio frequency channels number public many, sky Wire one Yuan and shoot frequency Pass road high Spend set Made special point, Its 5G active antenna parameters and calibration test methods in the 4G era are different. same, the calibration method of conductive testing, that is, passive parameters, is the same as that of the 4G era. same, Main technical basis: GJB/J 5410-2005 "electricity Magnetically compatible Antenna coefficient calibration specifications for measuring antennas", ANSI C 63.5-2017 "Electromagnetic Compatibility- Electromagnetic Interference (EMI) Controlled radiation measurement days linear calibration (9 kHz ~40 GHz)» and JJF 1706 -2018 " 9 kHz ~ 30MHz Whip Antenna Calibration Specifications» wait. For the calibration of active parameters, several methods have been proposed. like Rotate vector Law, Utilizing mutual coupling between antenna units and independent calibration channel system [7], We urgently need the number of channels in the channel, baseband processing, test time and cost Find a reasonable balance between, Propose a low-cost, High-efficiency 5G large-scale antenna array calibration test device.

### 4.3 5G Bearer Network Test Instrument Calibration Technology

5G bearer network test equipment has optical modules, Network performance score Analyzer,Light Transfer Comprehensive Score analyze instrument (OTN) and Association discuss point analyze Instrument (CPRI/ eCPRI) wait. Calibration is divided into basic parameters, Optical transmission parameters and optical network parameter testing. Basic optical communication parameters master There must be light power, light wavelength, optical return loss and light polarization, etc. Calibration party Fa Tong 4G bearer network test instruments are the same, using optical power meter,light source, Spectrum analyzer, optical return loss meter and other equipment to carry out relevant parameters the school quasi-test; Optical transmission parameters have signal output waveforms,reflection attenuation and spirit sensitive Spend Waiting for electricity interface ginseng number and letter Number flat all hair deliver Light achievement Rate, Jitter, Eye, spectral characteristics, receiving sensitivity and jitter characteristic and other optical interface parameters, Using optical transmission analyzer, Eye chart,error Calibration of relevant parameters of equipment such as coders and femtosecond laser sources accurate measurement try, For jitter parameters, there are currently no calibration specifications. Feasibility study system The high-precision jitter source generates a continuously adjustable jitter optical signal; Optical network Network parameters have delays, packet loss rate and

CPRI/ eCPRI Agreement, etc. There are currently no calibration specifications. Network damage instrument can be used, frame header touch hair Perform calibration tests on relevant parameters of equipment such as instruments. As shown in Table 3.

**Table 3** Optical communication test instrument calibration parameters

Calibration content	specific parameters
Basic optical communication parameters	Optical power, light wavelength, optical return loss, light polarization, decline reduce, Extinction Ratio, insertion loss and stability
Optical transmission parameters	Electrical interface parameters: Signal output waveform, Reflection attenuation reduce, sensitivity; optical interface parameters: average signal Sending light power, jitter, Eye, spectral characteristics, catch Receiver sensitivity and jitter characteristics
Optical network parameters	Delay, packet loss rate and CPRI/ eCPRI Protocol testing

5G optical communication adopts eCPRI protocols and new technologies, trunk net pass lose speed rate by 40 Gbps carry Lift to 100 Gbps, none Wire Association discuss pass Transmission speed rate by 600Mbps ~10 Gbps, increase to 10 ~ 25 Gbps, 5G spread quickly, large information flow, operating efficiency high, now some school allow square Law host want ginseng According to JJF 1237-2017 SDH/ PDH "Transmission Analyzer Calibration Specifications", JJG 813-2013 "Fiber optical power meter", JJG 963-201 "Optical Wavelength Meter for Communications" Verification Regulations", JJG 1035-2008 "Spectral analyzer inspection for communications "Established regulations", JJG 958-2000 "Calibration Regulations for Stable Light Sources for Optical Transmission ", JJF 1325-2011 "For communication Optical return loss instrument school Standards and JJF (electronics) 30905-2007 "Fiber Optic and Optical Devices" Parts Polarization Characteristics Calibration Specifications » Wait, there is currently no target OTN and eCPRI Publish calibration specifications, Standard transmission analyzers and protocols can be used It is recommended that different types of alarm signals occur on the analyzer for verification. like jitter, noise, delay and other parameters for calibration, It's 5G light New topics in communication measurement calibration, Domestic needs OTN and CPRI/ eCPRI calibration specifications.

**5 CONCLUSION**

Vector signaling generator, vector points Analyzer, wireless comprehensive Combined test Test instrument and CPRI/ eCPRI wait 5G communication main test instrument, Its accurate value is the foundation and guarantee for 5G technology research and development and industrialization. 5G, as a major player in the world today, strategic system High Point, and beauty, South Korea and Japan are both in the first echelon of China, We have been accelerating the commercialization of 5G Cut down, As 5G commercialization continues to deepen,, Test instruments use higher frequencies,new standard 5G NR, new agreement eCPRI and mm The calibration problem of large bandwidth faced by wave has not been effectively solved ; If it is not resolved, Will become a shortcoming in the development of the industry. on the one hand, Measurement and calibration institutions are required to propose new calibration methods and develop Certain correlation standard; on the other hand, Enterprises should also take the lead in the industry, Actively seek cooperation, Work with universities/ research institutions/ measurement institutes and other parties to road, Promote the implementation of methods, To ensure that the measurement values of the testing instruments are accurate, Support 5G product quality, accelerating 5G industrialization.

**COMPETING INTERESTS**

The authors have no relevant financial or non-financial interests to disclose.

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