Satellite-Ground Two-Way Measuring Method and Performance Evaluation of BDS-3 Inter-Satellite Link System

YAN BAI1,2, YANMING GUO1,2, XIN WANG1,2,3, AND XIAOCHUN LU1,2

1National Time Service Center, Chinese Academy of Sciences, Xi’an 710600, China
2University of Chinese Academy of Sciences, Beijing 100049, China
3Fengkai Low-Frequency Time-Code Time Service Station, Zhaoqing 526500, China

Corresponding author: Yanming Guo (gym2480@163.com)

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ABSTRACT From November 2017 to December 2018, Beidou navigation satellite system (BDS) completed the basic system construction of Beidou-3 system (BDS-3) and opened the initial service, BDS-3 satellites are equipped with Ka-band inter-satellite link (ISL) payloads, satellite autonomous orbit determination (OD) and time synchronization (TS) can be realized through ISL technology. At present, 18 BDS-3 medium earth orbit (MEO) satellites have been formally networked, and a series of ground-satellite link (GSL) test and connection test of Ka-band ISL signals are carried out, through the test, the working state and functional performance of the ISL payloads can be evaluated. This article focuses on the GSL measurements and performance evaluation of the ISL signals of BDS-3, the basic architecture of the GSL test platform is given, the principle of Ka-band GSL measurement and basic data processing methods and performance evaluation methods are introduced. Obtained the GSL observation data of 18 BDS-3 MEO satellites using the Ka-band ground station of the National Time Service Center (NTSC), and evaluate the performance of the GSL ranging and time synchronization. The result shows that GSL ranging accuracy of 18 MEO satellites is better than 0.02m and GSL time synchronization accuracy is better than 0.2ns. Thus, this meets the requirements of ISL system. The assessment methods and analysis results presented in this article can provide the reference of the function and performance verification for inter-satellite link system, and provide technical and data accumulation for the time synchronization extension application based on ISL signals.

INDEX TERMS BDS-3, inter-satellite link, satellite-ground measurement, time synchronization, performance evaluation.

I. INTRODUCTION

Beidou system (BDS) formed regional active positioning service capability around 2000, and the regional passive positioning service capability was formed in 2012, and about 30 BeiDou-3 system (BDS-3) satellites launch to network will be completed by 2020, building a global satellite navigation system, providing services to worldwide users. BDS-3 satellites have carried out a series of technical upgrades. The Ka-band inter satellite link (ISL) payloads carried by BDS-3 satellites can realize high-precision ranging and communication between satellites. The inter-satellite link (ISL) technology uses the inter-satellite ranging function to realize the orbit determination (OD) and time synchronization (TS) of the global arc of the satellite, and uses the inter-satellite communication function to update the message and control the on-board payloads in real-time. It helps to solve the problems of full-arc precision OD, navigation message update and real-time control of on-board payloads, and it can greatly improve the system’s autonomous operation capability without the support of ground stations. At present, the ISL technology is regarded as the key technology of future navigation satellite, and the Global Navigation Satellite System (GNSS) have all deployed or designed different ISL systems.

From March 2015 to February 2016, China has launched five new-generation BeiDou test satellites, including three medium earth orbit (MEO) satellites and two Inclined Geosynchronous Orbit (IGSO) satellites, and the
comprehensive verification test of ISL is carried out, the results show that the two-way ranging data is used in OD, the root mean squares (RMS) of residual is less than 10 cm, the mean of result is better than 1 cm, the stability of zero value is better than 0.2 ns. After adding the data of ISL, the clock error prediction for BD satellite can quickly converge, and its accuracy increased improving 1 ns from 2-4 ns [12]; the TS accuracy of the ground-satellite link (GSL) based on one hour is 0.15 ns [13]. The OD performance of the experimental satellite is analyzed, the results show that, R direction error using ISL data is less than 0.5 m, and the R direction error combined ISL with L-band data is less than 0.3 m [14].

Since November 2017, the BDS-3 navigation satellites entered the launch phase of high-density networking. By the end of 2018, 18 BDS-3 MEO satellites were in orbit and in operation, BDS-3 can make comprehensive use with ground monitoring station and ISL observation data to realize the OD and TS of all satellites in the whole constellation. Among the 135 inter-satellite links (ISLs) formed by the 18 MEO satellites of BDS-3, root mean square (RMS) of clock error fitting residuals are between 0.04 and 0.23 ns, with an average value of 0.1 ns [15]. The measurement noise of the ISL of the BDS-3 satellite is 2.9 cm, and the ranging accuracy is about 4.4 cm. The position accuracy of the 24-hour orbit forecast after adding the ISL data has been improved to 20.3 cm from 114.1 cm [16], [17].

The current literature on the performance analysis and evaluation of the BDS-3 satellites are mostly based on inter-satellite observations or autonomous OD performance or navigation signal evaluation. The analysis of GSL measurement data based on the ground station can not only test or navigation signal evaluation. The analysis of GSL measurement data based on the ground station can not only test or navigation signal evaluation. The analysis of GSL measurement data based on the ground station can not only test or navigation signal evaluation. The analysis of GSL measurement data based on the ground station can not only test or navigation signal evaluation.

II. SATELLITE-GROUND TWO-WAY MEASUREMENT

A. THE PRINCIPLE OF TWO-WAY MEASUREMENT

The ground-satellite link (GSL) of the Ka-band adopts a two-way mode to achieve ranging and time synchronization (TS), two-way measurement is a dual one-way measurement, and is the best mode for time difference and relative distance measurement, this can eliminate most of the systematic errors and correlation errors of GSL ranging [18], [19]. The principle of satellite-ground two-way measurement is shown in Figure 1. In a measurement process of two-way measurement, both sides of the satellite and the ground station send signals to each other for measurement, and then exchange measurement data, to perform calculations, to obtain a relative measurement. For the satellite and ground station, it is difficult to realize that the signals are sent the same time. It is a combination of dual one-way measurements referring to a certain time sequence. Thus, it is impossible to obtain the pseudo-range of the dual one-way measurement of the GSL at the same observation time, pseudo-ranges in up-link and down-link vary greatly in dual one-way measurement, that need to use a priori ephemeris or other observation data to convert pseudo-ranges at different times into pseudo-ranges of a unified reference epoch. Using the pseudo-range corrected through measurement error correction and epoch conversion correction, a pair of GSL measurement equations can be formed, and figure out the satellite-ground distance and clock errors.

In Figure 1, the satellite and ground device respectively transmit ranging signals to each other at the rising edge of the local second pulse, where Δt is the satellite-ground clock difference between the satellite and the ground equipment, τ1 and τ2 are the transmitting equipment delay of satellite and ground station, τR1 and τR2 are the receiving equipment delay of satellite and ground station, τ21 is space delay from the ground to satellite, τ12 is space delay from satellite to ground.

In addition, the additional space propagation delays τrel−21 and τrel−12 due to relativistic effects and troposphere, ionosphere, etc. should be considered in the actual measurement environment, δ1 and δ2 are the measurement noise of satellite and ground equipment, then the observation pseudo-ranges T1 and T2 obtained by satellite and ground equipment are expressed as:

\[
T_1 = \tau_{f} + \tau_{21} + \tau_{R1} + \Delta t + \tau_{rel-21} + \delta_1 \quad (1)
\]

\[
T_2 = \tau_{f} + \tau_{12} + \tau_{R2} - \Delta t + \tau_{rel-12} + \delta_2 \quad (2)
\]

Adding equations (1) and (2) can eliminate the time difference Δt and get the expression of the distance between satellite and ground station:

\[
\frac{1}{2}(\tau_{12} + \tau_{21}) = \frac{1}{2}(T_1 + T_2) - \frac{1}{2}(\tau_{f} + \tau_{R1}) - \frac{1}{2}(\tau_{f} + \tau_{R2}) + \frac{1}{2}(\tau_{rel-12} + \tau_{rel-21}) + \frac{1}{2}(\delta_1 + \delta_2) \quad (3)
\]

The equipment delay parameter for each satellite is the sum of transmitting equipment delay and receiving equipment delay which cannot be estimated separately. Thus, where τf + τR1 is the equipment delay of the satellite, τ2 + τR2 is the equipment delay of the ground station. These two delays can be obtained by closed-loop self-calibration, that is, satellites or ground equipment can regularly transmit test sequences signals, and the signals return to baseband signal processing through their own transmitters and receivers,
forming a closed-loop test, then all delays are measured. That is, the delays $\tau_{T1} + \tau_{R1}$ and $\tau_{T2} + \tau_{R2}$ of the receiving and transmitting channels of the satellite and the ground system are measured through the closed-loop method. The relativistic effect and additional space propagation delay can be corrected by the corresponding model, and finally the equation (3) can be used to solve the propagation delay of satellite-ground.

Subtracting equations (1) and (2) can get the expression of the satellite-ground clock difference:

$$\Delta t = \frac{1}{2}(T_1 - T_2) + \frac{1}{2}[(\tau_{T1} + \tau_{R2}) - (\tau_{T2} + \tau_{R1})]$$

$$+ \frac{1}{2}(\tau_{T2} - \tau_{T1}) + \frac{1}{2}(\tau_{rel-12} - \tau_{rel-21}) + \frac{1}{2}(\delta_2 - \delta_1)$$

(4)

where \((\tau_{T1} + \tau_{R2}) - (\tau_{T2} + \tau_{R1})\) reflects the time difference between the signal from the satellite to the ground station without considering the path, which is the difference in the circuit delay between the dual one-way measurement, which is related to the zero value of the device. For two identical devices, this value will be a certain small amount, which can be reduced or eliminated by calibration [20], [21].

$\tau_{T1}$ and $\tau_{T2}$ contain the information of dual one-way delay, so when the dual one-way propagation path is consistent, $\tau_{T1} = \tau_{T2}$ is zero, the effect of the propagation path delay is offset, and the TS accuracy is further improved. But for the Ka-band GSL with the navigation ISL system, “dual one-way” measurements between satellite and ground station are not performed simultaneously, and there is a certain relative movement between satellite and ground station, so $\tau_{T2} \neq \tau_{T1}$, these two vector differences vary with time, and need to be compensated according to the relative velocity and time [22]. The main compensation method is to perform epoch conversion on the up-link and down-link observation pseudo-ranges in the measurement equation to obtain the up-link and down-link ranging values at the same time, which can be achieved by a direct epoch conversion algorithm or a polynomial fitting method. The two methods have their own advantages and disadvantages. The former generally needs to be based on a complex dynamic model, which requires a large amount of calculation; the latter requires a certain amount of data accumulation, and there are real-time problems. On this basis, according to equation (4), the final solution of the satellite-ground clock errors $\Delta t$ are obtained.

For BDS, the GSL share the same communication and measurement system with the ISL. Thus, the processing method mentioned above is suitable for ISL measurements as well [23].

B. THE OUTLIER PROCESS (RANGING DATA PROCESSING)

Generally, after extracting the original measurement data of the satellite-ground, the first thing to do is to process the outliers, and then to calculate the distance and clock error based on the principle of two-way measurement. In fact, the processing of the outliers is to identify and eliminate the gross errors of ranging, the main purpose is to eliminate the observation abnormality caused by the measurement equipment or the abnormal data caused by the satellite platform. Outliers may have a serious impact on the measurement accuracy and data processing results, which must be corrected or eliminated to ensure measurement accuracy. There are many methods to remove outliers from satellite-ground ranging data, among which threshold discrimination is a common one.

Define a rule to check outliers, the rules of the threshold discrimination method are expressed as:

$$h_{min} \leq h(t_i) \leq h_{max}$$

(5)

where the pseudo-range value observed at time $t_i$ is $h(t_i)$, $h_{min}$ and $h_{max}$ are the minimum and maximum measured parameter values allowed for a given satellite-ground observation.
FIGURE 2. Basic framework of satellite-ground test platform.

Then

\[ h_{\text{min}} = \rho(k) - n\delta - \varepsilon \]  
\[ h_{\text{max}} = \rho(k) + n\delta + \varepsilon \]  

where the satellite-ground distance \( \rho(k) \) is obtained by the integration processor at time \( t_k \), the integrator error is \( \Delta \delta \), and the random measurement error is \( \varepsilon \).

In addition, testing the modulus of the difference between two adjacent observations can also be used as a supplementary method to determine outliers, express as:

\[ h(t_{i+1}) - h(t_i) \leq f(t_{i+1} - t_i) \]  

where \( f \) is the maximum change value at two adjacent moments of the given observations, and satisfy the equation as follow:

\[ f = |\rho(k + 1) - \rho(k)| \]  

III. SATELLITE-GROUND TEST PLATFORM

Based on the above dual one-way measurement principle, building a satellite-ground test platform for Ka-band ISL or GSL signals, considering its flexible expansion interface and configuration capabilities, enables adaptation to different test scales and scopes. The entire platform can be composed of several modules such as phased array antenna, frequency conversion channel, integrated baseband, time-frequency, signal acquisition and analysis, the basic composition architecture is shown in Figure 2. The functions of each module are introduced as follows:

The antenna is an active phased array antenna, which uses the highly flexible pointing characteristics of the phased array antenna to allocate the corresponding time gap and establish the satellite-ground measurement and communication link.

The frequency conversion channel module realizes the frequency spectrum shift of signal transmitting-up conversion and receiving-down conversion, and has the functions of RF frequency control, transceiver gain control, channel cold backup, multi-channel switching, etc.

The integrated baseband module includes multi-functional digital baseband and upper computer, it is an important unit of ISL or GSL measurement and communication, the core of the whole system. It can realize bidirectional ranging by pseudo-code, receive instructions from the upper computer, control the working mode and parameters of active phased array antenna, generate control instructions for frequency conversion channel and frequency synthesis module, and report the measurement data and communication information frame generated by baseband to the upper computer.

The signal acquisition and analysis module is mainly composed of acquisition and playback equipment and spectrum analyzer, it is mainly for real-time monitoring of input signals and online fine processing, so that users can find problems and analyze and solve problems in time during testing and experiment.

The time-frequency module consists of frequency synthesis and distribution equipment, reference time input and time difference monitoring equipment.

The test platform completes the measurement between the ground equipment and the satellites based on the two-way measurement system. The so-called two-way measurement is actually a combination of dual one-way measurements according to a certain time sequence, assuming the time of one-way measurement is 1.5s, within 3s of a measurement cycle, the satellite first sends 1.5s ranging signal to the ground station, and write the phase information of the signal into the measurement frame. The ground station receives the ranging signal at this time, completes the sampling and extracts the satellite’s sampling information from the measurement frame, thereby completing the 1.5s down-link unidirectional measurement. Later 1.5s, the two parties exchange roles to complete the up-link unidirectional measurement. In such
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FIGURE 3. Self-calibration delay result of the fixed station (more than 40 hours).

a measurement cycle, two-way pseudo-range measurement and data exchange are realized between the satellite and the ground station. The satellite and the ground can use the sampling information of both sides to solve the distance between the satellite and the ground station and the clock error. Then continue the next 3s measurement cycle.

Under the ISL system, to achieve a satellite-to-ground transmission and reception chain, the initial time of satellites and ground equipment must be kept within a certain synchronization range, only the clock difference between the satellite and the ground equipment (the time deviation between the satellite or ground equipment and the Bei Dou Time (BDT)) can be obtained to ensure the final resolution accuracy of the two-way measurement. The clock difference of satellites can generally be obtained through satellite forecast almanacs or precision ephemeris, and the clock difference of ground equipment can also be obtained in certain ways, for example, by accessing the standard system time, namely the Coordinated Universal Time UTC (NTSC) system of the National Time Service Center. At present, the UTC (NTSC) performance maintained by the national time service center is in the forefront of the world, and the time deviation from the BDT is kept within 150 ns. As shown in Figure 2, the implementation method of obtaining ground equipment clock difference forecast by UTC (NTSC) is given. When the UTC (NTSC) 1PPS and 10MHz signals output from the main station of the national time service center are sent to the ka ground station test platform as the time-frequency source reference, and the time deviation between the test platform and UTC can be obtained through the prediction model of UTC (NTSC) and BDT provided by the time difference monitoring system of the time center. The forecast model is through the special equipment to keep the national time service center for timing of UTC (NTSC) with BDT time deviation monitoring, after the time error between the original monitoring data, combined with BDT evaluation data and the IGS precise orbit, clock, ionosphere, troposphere data, etc., to modify the real-time monitoring data, and then will correct data and the existing monitoring data for future short-term and long-term system combining forecast the output of the jet lag. The time deviation forecast of UTC (NTSC) and BDT given by this system is better than 3ns (1) for 1 day. In addition to the uncertainty of the delay calibration of the cables and other equipment connected to the ground system, the accuracy of the system time prediction of the ground test platform relative to the BDT can generally reach 5ns.

The experiment uses the ground test platform to carry out the self-transmission and self-reception of Ka-band signal, the time slot is 3s, and the time exceeds 40 hours, the obtained closed-loop self-calibration delay result can be seen in Figure 3, and the result shows that the delay standard deviation (STD) obtained is better than 0.2s, thus the ground equipment can run stably for a long term.

IV. PERFORMANCE EVALUATION METHOD OF INTER-SATELLITE LINK SIGNAL

The performance evaluation of inter-satellite link signals based on the above ground test platform has the following aspects:

A. LINK PAYLOAD PERFORMANCE EVALUATION

For the test of related performance indexes of satellite ISL payloads phased array antenna, the ground test platform can receive and collect the satellite transmitting signals,
calculate the parameters such as the signal-to-noise ratio \((C/N_0)\), and then verify and evaluate the key indexes such as the satellite equivalent isotropically radiated power (EIRP) and pointing accuracy. EIRP appraisal concrete method is in a spread spectrum test mode, receive the downlink signal from the satellite ground station, using digital baseband receiving carrier to noise ratio, with the corresponding calibration of the ground ahead of the entry level values, and then use the ground entry level value, and cooperate with the satellite precision orbit, station coordinates, ground station performance index \((G/T)\ value, and the relevant parameters such as atmospheric loss and equipment to loss, backstepping EIRP satellite launch. In addition, by statistics of the antenna beam coverage area when the satellite antenna and each ground station are set up for the ground-to-ground beam, the map of the ground-to-ground beam coverage area and its power intensity under different pointing can be obtained, and the pointing accuracy characteristics under different pointing can be calculated.

**B. SIGNAL QUALITY ANALYSIS AND EVALUATION**

For the test of the relevant indicators of the quality of the signal transmitted by the satellite ISL, a spectrum analyzer or vector signal analyzer can be used to observe and analyze the out-of-band characteristics of the signal transmitted by the payload, such as real-time analysis of the frequency and time domain characteristics of the signal to obtain the signal power Carrier frequency, carrier signal stability, spectrum, signal bandwidth, abnormal code or carrier waveform, in-band harmonics, out-of-band harmonics, signal loss of lock, carrier-to-noise ratio and other parameters. However, it should be noted that this test must ensure that the ground receiving system has sufficient receive gain to receive the Radio Frequency (RF) signal. In addition, Ka-band link signals can also be collected using high-speed acquisition equipment, and the post-processing method of the software receiver can be used to further analyzed the modulation domain characteristics of the transmitted signal, including IQ orthogonality, code carrier consistency, IQ power ratio, and signal-related characteristics, etc.

**C. EVALUATION OF INTER-SATELLITE LINK SYSTEM AND NETWORKING PERFORMANCE**

The ground test platform is used as a satellite node to join the inter-satellite link network. After a certain link-building plan, the ground station and satellite are networked in a steady state according to the ISL system workflow and achieve normal transmission, ranging and communication. Monitoring the status data received by the ground test platform and whether the equipment is operating normally can
Determine the connectivity status of the satellite-ground link and verify the feasibility of the ISL system. By monitoring the ground test platform as a node, the status data of each node in the process of adding or withdrawing from the network is determined to determine whether each node is operating in accordance with the new chain-building plan to verify the flexible networking capability of inter-satellite links. You can also determine the correctness of the upload of the operation control / measurement and control information through the status of the ground receiving signals. By comparing the test data between the forwarding nodes on the satellite and the ground transmission data, you can determine the correctness of the satellite forwarding data.

D. RANGE AND TIME SYNCHRONIZATION PERFORMANCE EVALUATION

The measurement data based on satellite-ground link can be used to evaluate the measurement performance, including ranging performance and time synchronization performance. First, ensuring that the satellite-ground link continuous and stable test environment, by extracting satellite-ground measurement data, using a certain amount of time synchronization algorithm and data processing method, and use the relevant ephemeris can decoding and output parameters such as distance and star clock bad results, finally through a certain evaluation method for distance and time synchronization performance are analyzed. The commonly used evaluation method is the fitting residual method, that is, the fitting...
residual without system difference is obtained by fitting the distance or clock difference results with higher-order polynomials, and then the standard variance is calculated by statistical analysis of the fitting residual. In addition, comparison methods can also be used for evaluation. That is, the measurement results of L-band satellite-ground measurement or other means such as laser can be used as the true value to compare with the satellite-ground measurement results of Ka-band link. Finally, the standard variance of the comparison difference between the two can be calculated.

When the ISL measurement data of BDS network-forming satellites are obtained by other means, the satellite’s autonomous OD and autonomous TS can be further evaluated by combining the GSL and ISL measurements.

V. ASSESSMENT AND ANALYSIS RESULTS

The national time service center (NTSC) of the Chinese academy of sciences (CAS) has built a large-scale comprehensive test site in Xi’an space base, in which Ka-band ground station can support the test operation and test
verification of Beidou ISL system. Based on the ground station, satellite-ground measurement data of 18 BDS-3 networking satellites on January 7, 2019 were selected to evaluate and analyze the satellite and ground measurement performance of Ka-band ISL signals of each satellite. This article mainly gives the evaluation and analysis results for several key indicators, such as carrier-to-noise ratio ($C/N$), signal pseudo-distance mass, ranging performance and time synchronization performance.

### A. CARRIER-TO-NOISE RATIO ANALYSIS

Extracting the up-link and down-link $C/N$ data of the Ka-band ground station and 18 MEO satellites in a continuous chain arc. As shown in Figures 3, it can be seen that the down-link carrier-to-noise ratio of one satellite is generally greater than the up-link, and the up-link carrier-to-noise ratio of each satellite is in the range of $54 \sim 66$ dB-Hz, and the down-link carrier-to-noise ratio is in the range of $59 \sim 67$ dB-Hz. Within this range, each satellite and ground station can work normally.

As shown in Figure 5 that the change of the downlink carrier-to-noise ratio with the off-axis angle. It can be seen that the downlink carrier noise of the M5 and M17 satellites during the overhead period is slightly higher than that of other satellites.

### B. INITIAL PSEUDO-RANGE DATA QUALITY ANALYSIS

The mass of the up-link and down-link initial pseudo-range of 18 MEO satellites was analyzed, and the fitting residual RMS of the original pseudo-distance was given, as shown in Figure 6. It can be seen that the quality of up-link and down-link pseudo-range of the 18 network-forming satellites is better than 0.05m, which can provide reliable source data for the next step, to solve two-way distance and clock error calculation.

### C. PERFORMANCE EVALUATION OF DUAL TWO-WAY RANGING

The satellite-ground two-way ranging performance of 18 MEO netted satellites was evaluated. Using the
down-link one-way initial measurement data, based on the satellite-ground dual one-way ranging principle, and through time conversion and delay correction processing algorithms. Thus, satellite-ground distance can be calculated, and then to get the distance of polynomial fitting, fitting residual RMS value, as shown in figure 7,8 and 9 respectively from the fitting of (one hour and one week) data residual error curve, and residual RMS value of statistics for one hour and one week. It can be seen that the satellite-ground bidirectional ranging performance of 18 MEO satellites has been greatly improved compared with that of unidirectional ones, and the two-way ranging performance within one hour is better than 0.014m, while the two-way ranging accuracy within one week is better than 0.018m. For the 18 MEO satellites, there are a few visible arcs in one week observations, and the accuracy of every arc of one satellite is approximative. Therefore, this reveals the ranging accuracy can remain relatively stable for a long term.

D. TIME SYNCHRONIZATION PERFORMANCE EVALUATION
The satellite-ground time synchronization performance of 18 netted satellites was evaluated. Using down-link one-way initial measurement data, based on the satellite-ground two-way ranging principle, and through certain time conversion and delay correction processing algorithms, thus, the satellite clock difference can be calculated, and then to get the satellite clock differential polynomial fitting, fitting residual RMS value, as shown in figure 10 and 11 respectively satellite clock difference fitting residual error curve and residual RMS value of statistics. It can be seen that the RMS value of the clock-difference fitting residual of the 18 satellites ranges from 0.03 to 0.14ns, and the fluctuation of the clock-difference fitting residual of the M5 satellite is slightly larger than that of other satellites, whose RMS value is 0.14ns. The clock-difference fitting residual of the other satellites is better than 0.07ns. The performance of ranging and time synchronization between ground station and M5 satellite is analyzed synthetically, it can be seen that the two-way ranging and one-way ranging performance are comparable to other satellites, the two-way time synchronization accuracy is 0.14 ns, although this also belongs to the normal accuracy range, but slightly worse than other satellites.

VI. CONCLUSION
The measurement model of two-way measurements at Ka-band is introduced. Detailed introduction to the composition of the Ka-band satellite-ground test platform in NTSC. With the real measurements of the next-generation BDS MEO satellites, multiple evaluation indexes that affect the accuracy of time synchronization and ranging performance are presented and analyzed.

1. The ground test platform can maintain stable operation for a certain period of time, and the delay standard deviation (STD) is better than 0.2s.
2. It can be seen from the analysis of the carrier-to-noise ratio(C/N) of satellites, all 18 MEO can work normally, and the M5 and M17 satellites during the overhead period is slightly higher than that of other satellites.
3. The quality of up-link and down-link pseudo-range of the 18 network-forming satellites is better than 0.05m.
4. Satellite-ground bidirectional ranging performance of 18 MEO satellites has been greatly improved compared with that of unidirectional ones, and the two-way ranging accuracy of the 18 MEO are better than 0.02m( one hour and one week).
5. With the GSL between 18 MEO satellites and ground station, the clock-difference fitting residual of M5 is 0.14s, and the other satellites is better than 0.07.

This research is suitable for evaluating and analyzing the relative performance of ISL system, not only for the evaluation of measurement data between satellites and the ground stations, but also for the analysis of measurement data between satellites. The method in this article can also provide certain technical accumulation for the expansion and application of time synchronization based on Ka-band links. The shortcoming of this article is the lack of satellite-satellite data to verify the various evaluation indicators.
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