Navigation RF front-end group delay fluctuation measurement method

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ABSTRACT

Group delay is an important parameter of navigation receiverability. When the navigation signal passes through the RF front-end, it will generate signal delay, which affects the positioning accuracy. The receiver RF front-end has the function of converting RF signals into IF signals, which makes the measurement of its group delay characteristics difficult. This paper firstly introduces the definition and concept of group delay, and from the test mechanism, based on the comb wave generator, it carries out the research on the group delay measurement method of navigation RF front-end, and carries out the experimental verification. The results show that the group delay measurement method based on the comb wave generator has a reliable calibration method and can stably measure the group delay characteristics of the navigation RF front-end.

Keywords: Group delay, navigation, phase, modulation

1. INTRODUCTION

Group delay is the rate of change of the phase (phase shift) of a system relative to a frequency at a given frequency[1]. For navigation signals, when the navigation signal passes through the antenna and enters the RF channel, each spectral component has a different phase speed, and each frequency component produces different phase shifts or delays, which can result in a disturbed phase relationship of the navigation signal[2].

The delay difference between a group of frequency components can reflect the degree of phase distortion, called group delay[3]. Navigation RF front-end is one of the basic components of the navigation receiver link, is the core component of the navigation receiver, and its group delay index expresses the delay size of the navigation signal transmission in the RF front-end, reflecting the degree of linear distortion of the receiver network. The measurement of group delay needs to be carried out using a vector network analyzer[4]. The navigation RF front-end needs to convert the received navigation RF signal into an IF signal, and the difference between the input frequency and the output frequency also leads to the impossibility of calibrating the navigation RF front-end using the traditional network analyzer calibration, and a mixer is needed to mix the signal to the same frequency as the input frequency in order to perform the test. The extra delay caused by the external mixer can be removed by means of system calibration[5].

This paper discusses the methodology of calibrating the RF front-end input and output based on a comb-wave generator and performing delay measurements using the Group Delay mode of a network analyzer[6,7].

2. DEFINITION OF GROUP DELAY

Navigating the RF front-end network as shown in Figure 1, with inputs and outputs shown in terms of *V*in and *V*out, respectively, there is an RF front-end network with phase-frequency characteristics[8]:

$$\mathrm{H}(j\omega) = \mathrm{A}(\omega)\mathrm{e}^{-\mathrm{j}\varphi(\omega)}$$

$\mathrm{H}(j\omega)$ is the navigation RF front-end network transfer function, $\mathrm{A}(\omega)$ is the amplitude response function, which reflects the RF front-end network amplitude-frequency characteristics, and $\varphi(\omega)$ is the phase frequency characteristic function,

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reflecting the phase frequency characteristics of the network[9,10].

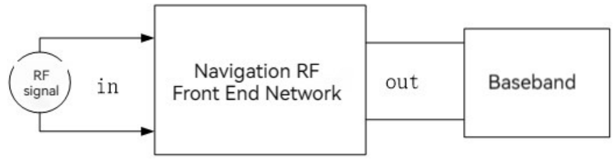

Figure 1. Schematic diagram of the navigation RF front-end network.

The group delay is the rate of change of the phase frequency of the system with respect to the corner frequency: $\tau(w) = -\mathrm{d}u(w)/\mathrm{d}(w)$, where $u(w)$ is the phase frequency characteristic, and w is the angular frequency, and $\tau(w)$ is the group delay[11]. When the signal has been modulated, with a specific bandwidth, through the network, the combination of different frequency signals will produce envelope distortion, that is, the group delay[12]. The modulation frequency is β. The carrier frequency is w_c, the upper side frequency is $w_c + \beta$ and the lower side frequency w_c-β The three frequencies are generated through the network as $r(w_c)$, $r(w_c + \beta)$, $r(w_c - \beta)$, and the group delay is $\frac{r(w_c+\beta)-r(w_c-\beta)}{2a}$.

3. GROUP DELAY MEASUREMENT TECHNIQUES FOR NAVIGATION RF FRONT-ENDS

3.1 Measurement procedure

The test includes the following parts, as shown in Figure 2:

Step 1 We determine the frequency (with RF input, IF output, and local oscillator);

Step 2 We set the network analyzer center frequency and bandwidth;

Step 3 Calibration (straight-through calibration, inverter calibration);

Step 4 Synchronization of the test instrument with the DUT clock;

Step 5 We set the network analyzer to Group Delay mode;

Step 6 We setting the test instrument center frequency.

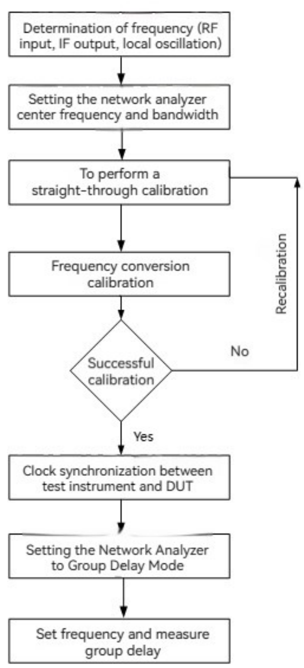

Figure 2. Block diagram of test steps.

3.2 Test methods

The main test flow is as follows:

1) Calibration

Before starting the test, it is necessary to perform the network analyzer RF calibration and frequency calibration, which are shown in the Figure 3:

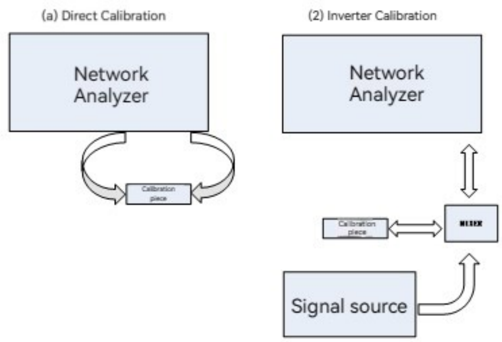

Figure 3. Schematic diagram of calibration.

The calibration and testing procedure was carried out as follows.

Step 1: We perform frequency confirmation. The frequency to be confirmed includes the RF input frequency, IF output frequency and the local oscillation frequency of the corresponding channel of the navigation RF front-end.

Step 2: We set the network analyzer parameters. We set the center frequency of the network analyzer as the channel frequency of the navigation RF front-end, set the sweep width as the corresponding channel operating bandwidth of the navigation RF front-end, and calibrate the group delay through according to the left figure of the calibration schematic.

Step 3: Group time-delay frequency conversion calibration. We set the signal source frequency as the IF output frequency, and perform the group time-delay frequency conversion calibration according to the right figure of the calibration schematic.

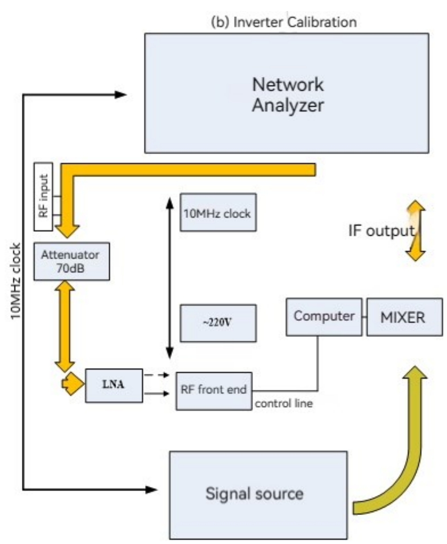

Figure 4. Schematic diagram of the test.

Once calibration is complete, make the test system connections according to Figure 4 and then follow the steps below.

Step 1: Clock synchronization. Signal source, network analyzer and the navigation RF front-end under test need to have a unified clock signal, all test instruments and units under test in the test system need to be synchronized, and the reference source comes from the 10MHz output clock of the signal source.

Step 2: After the setup is complete, we adjust the network analyzer to the RF input band and the network analyzer is set to GroundDelay.

Step 3: We record the maximum and minimum RF front-end group delay values over the bandwidth range. The difference between them is the group delay fluctuation.

4. EXPERIMENTAL RESULTS AND ANALYSIS

Experiments were conducted using a vector network analyzer N5247B from YesterTech, the object under test was a navigation RF front-end, which was tested using the Group delay module. The results of the power-on phase jitter test are shown in Figure 5, and the results of the group delay test are shown in Figures 6 and 7.

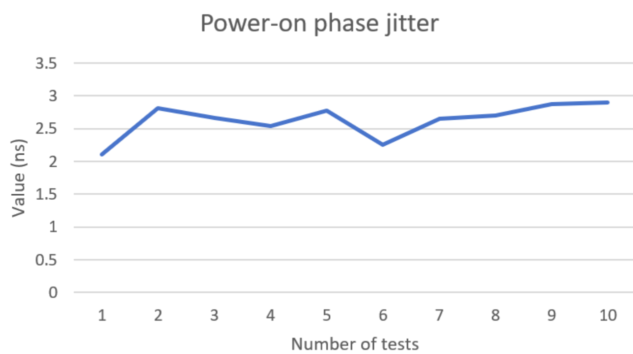

Figure 5. Power-on phase jitter.

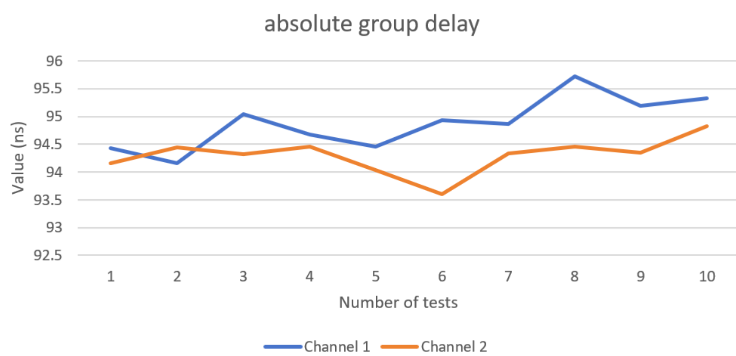

Figure 6. Absolute group delay at frequency 1.

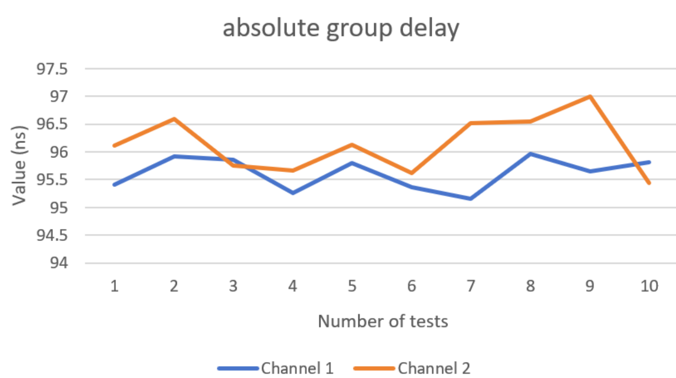

Figure 7. Absolute group delay at frequency 2.

From the test results, it can be seen that the group delay test method with comb wave generator can measure the delay amount of the navigation RF front-end stably. As can be seen from Figure 5, the measured deviation value of power-on phase jitter is within 1ns, and as can be seen from Figures 6 and 7, the measured deviation value is within 2ns, and the test results have a good consistency. This article focuses on the measurement method of group delay in the RF part of navigation receivers, but the impact of group delay on positioning accuracy has not been studied yet. This is the content that needs to be considered in future research work.

5. CONCLUSION

In this paper, a measurement technique based on navigation receiver RF front-end for group delay characteristics is proposed and experimentally verified. The navigation RF front-end has variable frequency characteristics, so a vector network analyzer should be used. In the group delay measurement of navigation RF front-end, the network analyzer needs to be calibrated first. For the calibration of the inverter device, a comb wave generator can be used; for the measurement of the time delay, the Group delay function of the vector network analyzer can be used. The results of several experiments show that the test method adopted in this paper has good measurement consistency, and the results of several measurements have small deviation, which is good for the measurement of the group delay of the navigation RF front-end.

It should be noted that for devices with variable channel gains, the group delay should be set to a fixed value when measuring it. The experimental results show that the accuracy of the group delay of the navigation RF front-end measured by this measurement method reaches the nanosecond level, which meets the group delay test requirements of the current mainstream satellite navigation equipment.

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