Heterodyne Frequency Measurement Method Based on Virtual Instrument

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***Abstract*—The heterodyne method is one of main methods in high precision frequency measurement. In the traditional heterodyne method, the counter is used to measure the square wave of beat signal. This method is inconvenient to the multi-channel measurement and real-time display of measurement results. In this paper, based on the technique of virtual instruments, the traditional heterodyne method is improved. The Analog Digital Converter and computer are used to replace counter. The sine wave of beat signal is converted into digital signal with ADC. The digital signal will be analyze by computer, its frequency calculated by the digital signal processing. This method is convenient for the multi-channel measurement and the real-time display of measure results. This method compared with the traditional heterodyne method, it is better than the traditional method in accuracy.**

***Key Words:* frequency, measurement, virtual instrument**

I. INTRODUCTION

Time and frequency metrology play important roles in many areas of science and technology, it is important domain of electric measurement too. The time and frequency of high stability and precision in metrology are driven by modern quanta frequency standard and electric technology. Its performance is more excellent than any other levels of metrology, so the time and frequency metrology keep ahead of all other metrological standards[1,2].

Virtual Instrument is a kind of new measure instrument, its hardware architecture is simple, and each kind of function mainly realized by software , So, it is applied more convenient and more wide with its stronger function[3].

Measurement that devices of time and frequency metrology combine with technology of virtual instrument will be more flexibility and currency, and the cost can be cut back too.

II. HETERODYNE FREQUENCY MEASUREMENT METHOD

Heterodyne frequency measurement method is one of means of high precise measure[4]. The principle is shown in figure 1. The signal from frequency under test（fx） and reference frequency source with appending frequency difference（fref） are fed into the mixer and processed as illustrated in figure 1. The difference frequency or the beat frequency is obtained as the output of a low pass filter which follows the mixer. The beat frequency is the value that frequency under test subtracts from referenced frequency. The signal is then amplified and shaped into square wave, which measured by a counter. This system has excellent precision even lower accuracy is measured in counter. The measured accuracy heightens the times of difference beat factor (beat frequency divide by frequency under test). Illustrated is what might process the beat frequency 1Hz out of the frequency under test 10MHz and referenced frequency 9.999999MHz, the beat frequency factor is 10MHz/1Hz = 10^7. The system described in this section has demonstrated a precision of 10^{-13}, such precision refer a counter of resolution 10^{-6}.

In general, the design of difference beat is using counter to measure frequency. The severe limitation to performance due to real-time data are showed and processed. Usually, computer is introduced to solve these problems, but it is waste[5,6].

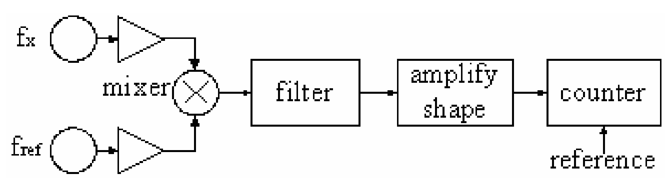

Figure 1. Heterodyne frequency measurement method

III. ANALYSIS THE FREQUENCY MEASUREMENT METHOD

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The traditional method is measure the beated square wave. This method is based on the detected the up-crossing point of signal. Its theory is shown in figure 2. The up-crossing point of signal is measured. The frequency offset is calculated by the time difference between two adjacent up-crossing point:

$$\frac{\Delta f}{f} = \frac{T(1) - T(2)}{P_0}$$

where, the $\Delta f / f$ is fractional frequency offset, the T(1) and T(2) are up-crossing points, P_0 is the nominal period.

The precision of this method is depend on the detection of up-crossing point. The error of up-crossing point is reflected to the error of frequency measurement. In order to improve the precision of measurement, high exact equipment for detect zeros up-crossing point is needed, it is expensive.

A new method to measure frequency is given, it is shown in figure 3. If the frequency under test is sine wave, it is sampled, its frequency is estimated by the sampled points. If 10000 points is sampled, the error of sample in one point is decreased to 1/100. This method can improve the measure precision.

Because the limited sample rate, this method is apply to low frequency measurement. In high frequency, it can be transformed to low frequency by heterodyne. So, this is low in cost and high in precision, it can be used in many situations.

The method we given is based on this.

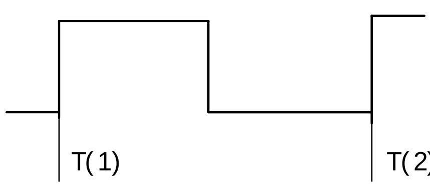

Figure 2. Measure frequency by time difference

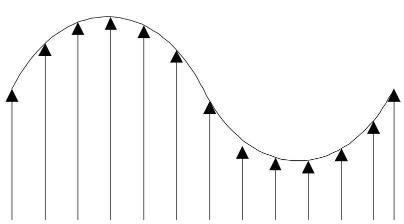

Figure 3. Measure frequency by ADC

IV. Proposed Heterodyne Frequency Measurement Method

In order to enhance the ability of processing data and increase flexibility, the heterodyne frequency measurement method is changed based on the theory of virtual instrument. We name it virtual heterodyne frequency measurement method. The proposed device is illustrated in figure 4.

In figure 4, Analog Digital Converter (DAC) and computer are used to substitute the counter. The signal from mixer is fed into A/D converter. The digital signal of sampling will be transmitted into computer. The PC will undergo signal analysis and calculation. Frequency and phase of digital signal will be solved, and then the input signal could be deduced.

The system is more flexible after improving. It is easy to extend to multichannel signals too. This system can be also applied to measure phase and show data, as well as very good at reprocessing the measured data.

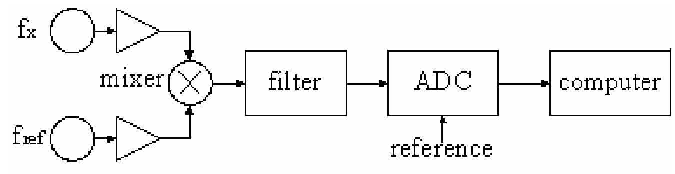

Figure 4. Virtual heterodyne frequency measurement method

V. Measurement Result Comparison

When comparing differences between the traditional method and virtual method, a system in figure 5 is designed to implement this aim. High stability quartz frequency standard （FTS1050） output 10MHz frequency. The frequency is divided into two ways. One way signal is fed into the frequency offset generator （HROG1050） to get the sine wave of 10MHz -1Hz as referenced frequency, then it will be send to one of interface of the system; The other way signal will be fed into the other port directly. The two frequencies are mixed and generate difference frequency 1Hz. In fact, one can set up an interesting structure of kinds of measurement systems: 1) those can measure frequency used for counter (traditional method); 2) those can measure frequency with virtual instrument (virtual method). Comparing the measurement precision between the traditional method and virtual method. The results are given by figure 6 and figure 7. Measure precision is more high and the result more near to zero, because under test frequency and referenced frequency come from the same source.

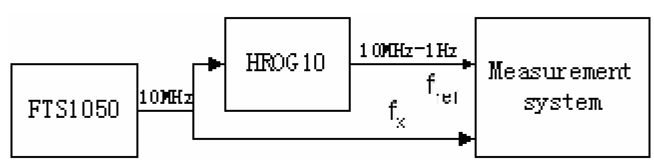

Figure 5. Test platform of measure system

Figure 6 shows the result of measure 1Hz using traditional mehod. The mean value of measurement relative error 1.31e-12 averaged over 1800 times. The Allan deviation is –4.25e-12/2s. Figure 7 shows result of the virtual method. The mean value of measurement relative error 7.30e-15 averaged over 4000 times. The Allan deviation is 1.01e-14/5s, it is no more than 5e-14/2s. These data show that the virtual method better than the traditional method in precision.

VI. RESULT

Aiming at the improvement of flexible data aftertreatment and the limitation of high cost, the virtual method of DAC instead of counter is put forward. The virtual method has many advantages besides the high precision. Result of measurement gets real-time display and easy to save as common format.

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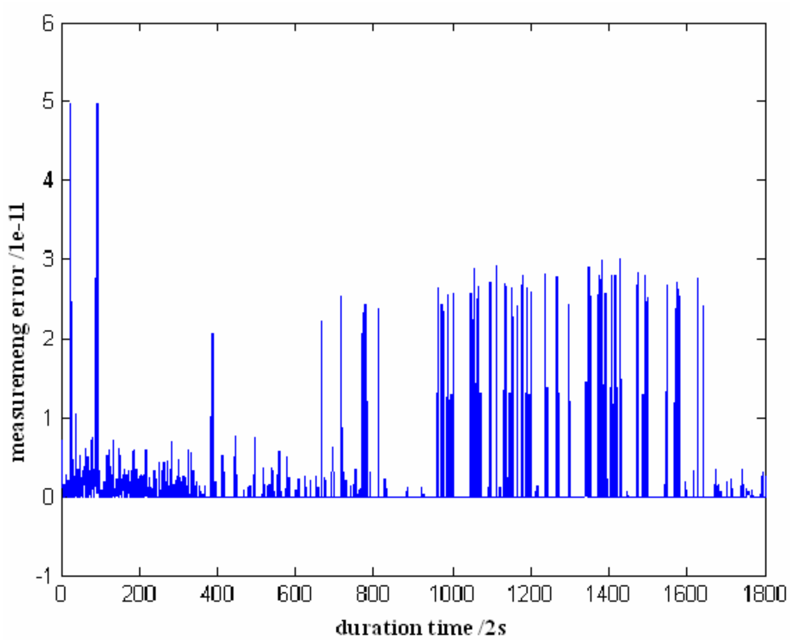

Figure 6. Results from traditional method

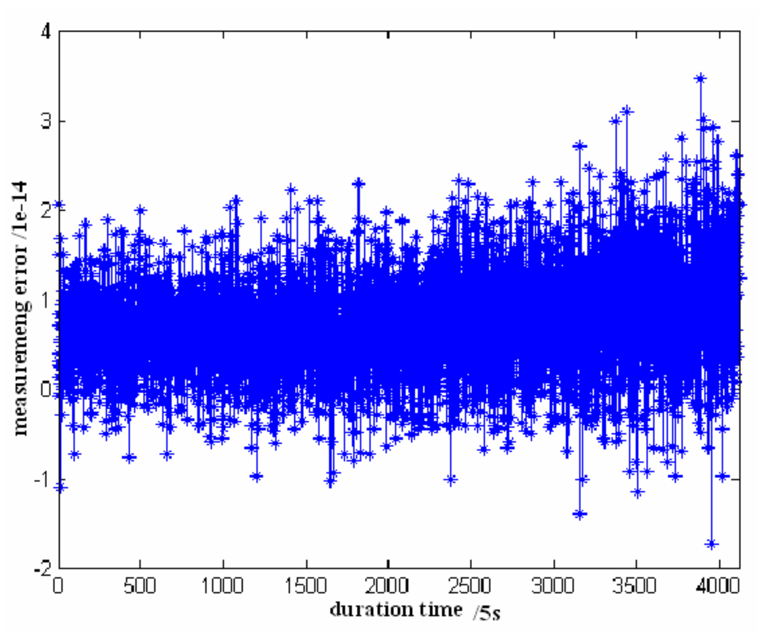

Figure 7. Results from virtual method