Measuring Method for Carrier Phase Based on Phase Difference Group Processing

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Abstract—**Accurate navigation orientation technique can be realized not only by the measurement of time delay in the transmission, but also by the analysis of periodicity phenomenon and phase relations between signals. This paper proposes a method of accurate navigation orientation technique which is based on dual-frequency signals group phase difference disposal technique by analyzing the carrier wave phase measurement. This method uses the inherent regularity of the carrier wave signal itself, the stability of the carrier wave signal and its device. On the basis of practical applications the method is put forward. The phase comparison between two frequency signals can be conducted on the same frequency even on the different frequencies. It can distinguish the minute changes like, some fractions of the signal period, of the phase difference. Because of the additional frequency difference between two compared carrier signals, and the regularity and periodicity of the phase difference change, the regularity of signal transmission change can be caught and processed. This method does not need additional information and other aid, but makes full use of the characteristics of the object itself, and combining with the practical application, a high reliability and high resolution solution with simplicity and effectiveness can be obtained. On basis of the analysis and experimental verification this method can provide a basis and reference for further in-depth research.**

I. INTRODUCTION

Accurate navigation orientation technique can be realized not only by the measurement of time delay in the transmission, but also by the analysis of periodicity phenomenon and phase relations between signals. There exists phase difference regularity between any two frequency signals, and phase comparison can be conducted on the same frequency signals even on the different frequencies. The period of phase difference regularity shift between the two periodical signals is their Least Common Multiple Period through research. The phase coincidence point always appears during the every Least Common Multiple Period, it changes with the relation of the two different frequencies [1]. When the frequency relation is accurate between the two signals, its phase relation also is accurate. There are a certain number of compared signal periods between the two or several phase coincidence points. They are quietly close to integral multiple periods. Measurement of the Least Common Multiple Period is much easier because of it is much longer than the periods of the two compared signals respectively. It is an effective method to use this theory in the carrier phase measurement, especially in integer ambiguity resolution. This method can be implemented for the problem of determine ambiguity in the carrier phase measurement.

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II. THEORY OF PHASE DIFFERENCE GROUPS BETWEEN COMPARISON SIGNALS

It is always difficult to discover the regularity of phase difference between the carrier signals in continuous period. If the Least Common Multiple Period $\boldsymbol{T}_{\min \boldsymbol{c}}$ is seen as one period, all the same phase differences are not existed in one group which is defined as all phase differences in one $\boldsymbol{T}_{\min \boldsymbol{c}}$ [2]. The phase difference is ranked in diverse order as a arithmetic progression and the common difference is Quantized Phase Variation Resolution $\Delta \boldsymbol{T}$. Corresponding phase differences and permutation is completely identical in each $\boldsymbol{T}_{\min \boldsymbol{c}}$ interval when the relationship of the two frequency is accuracy and they have not farther change, strictly corresponding relation is existed in all phase differences in interval of the $\boldsymbol{T}_{\min \boldsymbol{c}}$ which is shown in figure1. The compared time of two random phase differences state of two compared signal in this phase differences groups can be obtained on the basis of their phase relationship. The set of the phase difference in the every $\boldsymbol{T}_{\min \boldsymbol{c}}$ is determined a phase difference group. There are shifts in the time between phase difference groups when two frequency signals has some minute phase differences except their accuracy frequency relationship. Corresponding phase difference will be changed in the next $T_{\min c}$ though initial phase difference is zero in the first $\boldsymbol{T}_{\min \boldsymbol{c}}$ caused by frequency difference. Additional relative frequency difference and the change of phase difference can be reflected with the time by the phase difference groups which are seeming disorderly .The array of phase differences is different, but corresponding change tendency have the same regularly. However, the change range of the phase difference is limited. Every phase coincidence is also become boundary between the maximum and minimum phase difference. Continuity change of phase difference in random frequency signals exists in phase difference groups between every $\boldsymbol{T}_{\min \boldsymbol{c}}$ rather than in each $\boldsymbol{T}_{\min \boldsymbol{c}}$.

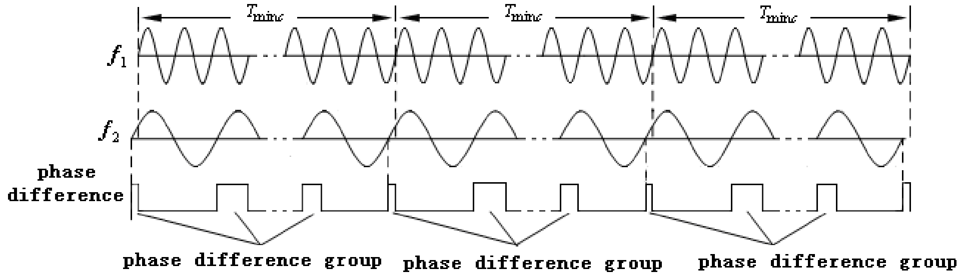

Figure 1. Waveform of the phase difference groups between two frequencies which have certain relationship

III. MEASURING METHOD FOR CARRIER PHASE BASED ON PHASE DIFFERENCE GROUPS PROCESSING

Carrier phase process technique is used to realize the measurement of signal propagation distance or time delay by which is based on the phase shift measurement between the satellite and receiver. This method don't need information of the satellite transmit code. If S-satellite transmits carrier wave with phase φ^{s} in the t moment, the signal phase is φ_k. When it propagates to K-receiver and corresponding phase shift equation is as follows[3]:

$$\Delta\varphi_{k}^{s} = \varphi_{k}(t+\Delta t_{k}) - \varphi^{s}(t+\Delta t_{k}) + N_{k}^{s} + d_{k}^{s} \quad (1)$$

$$\Delta\varphi_{k}^{s} = \Delta\varphi + N_{k}^{s} + d_{k}^{s} \quad (2)$$

Where, $\varphi^{s}(t+\Delta t_{s})$ is the reference phase of the S-satellites, $\varphi_{k}(t+\Delta t_{k})$ is the received phase by K-receiver, Δt_{k} is the clock bias, N_{k}^{s} the number of the carrier frequency period. d_{k}^{s} is the phase error because of the other reason such as ionosphere, troposphere, and so on . $\Delta\varphi$ is the fall short of one period.

It is the phase shift of $\Delta\varphi + N_{k}^{s}$ from the satellite to receiver that we mainly research. Single carrier phase measurement is based on difference value between reference phase and received phase. The difference represents the instantaneous distance between receiving and transmitting. But in fact, phase precision measurements only can accomplish in decimal part, the integer period has problem of integer ambiguities. Determination of integer ambiguities takes many troubles to data processing and measurement. Dual-frequency signals can take more information than the single frequency does. Phase difference groups principle between dual-frequency can provide a new way in integer ambiguity resolution.

The two carrier frequency of GPS in L band is sourced from the same frequency standard in the satellite. The other signal components such as pseudo random code, satellite ephemeris, adjustable coefficient of ionosphere, and so on, are all modulated in the two frequencies. The relationship of the two frequencies and frequency standard are as follows[4]:

$$f_{L1} = 154 f_{0} = 1575.42 MHz \quad (3)$$

$$f_{L2} = 120 f_{0} = 1227.60 MHz \quad (4)$$

Where f_0 is the frequency of the frequency standard, f_{L1} is the frequency of the carrier wave L_1, f_{L2} is the frequency of the carrier wave L2 .

Obviously, the Greatest Common Factor Frequency of the two frequencies is $2f_0$ and the Least Common Multiple Period is $T_{\max} = 1/2f_{0}$, the Quantized Phase Variation Resolution is $\Delta T = \frac{2f_{0}}{f_{L1} \cdot f_{L2}} = 10.58 ps$.

The phase relation of the two frequencies L1 and L2 has regular change characteristics in one $T_{\max}$. The phase difference variation begins with original phase difference and successively adding by ΔT , change to the end phase difference which is the same as original phase difference in the one $T_{\max}$. There exists another available the period that is $T_{\max}$ except the respective periods of the two frequencies in the carrier phase measurement. Carrier frequencies have high-stability, and $T_{\max}$ have high-stability certainly inevitably. The regular phase difference variation between two signals can implement high precision time transfer for it actually takes the instant information.

The carrier waves come from the same signal source. The two signals have the same paths and almost the same influence in the transmission process. The influence can be canceled. So the carrier waves can be consider as remaining unchanged and they have the constant frequency difference Δf . Even there is small relative frequency shift, which only arouses the limited variation of the phase difference that can not influence measurement precision. And in the case, the integer ambiguity resolution can be realize by phase difference groups measurement.

There exists the Greatest Common Factor Frequency of the two carrier frequency. The phase difference of two signals can change periodically. There has one phase coincidence in the determined $T_{\max}$. The number of the carrier frequencies period can be measured by the measurement of their Least Common Multiple Period and relative phase relation between two signals. The decimal part measurement of corresponding carrier phase can be conversed into phase difference variation measurement. $\boldsymbol{T}_{\max}$ is much longer than the periods of the two carrier frequencies. The methods can greatly reduce integer ambiguity in carrier phase measurement. Waveform of two carrier frequency measurement is shown in figure 2.

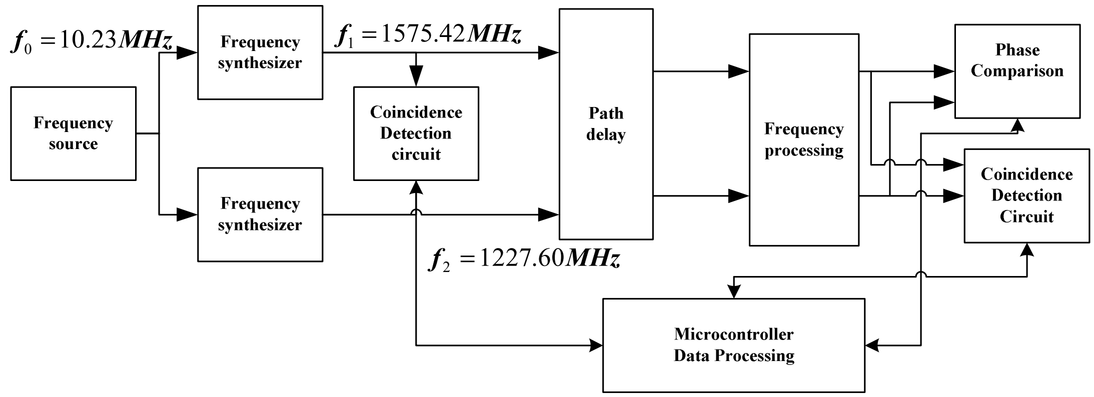

Figure 2. Block diagram of two carrier frequency measurement system

The phase relation of carrier frequencies is established by phase coincidence detection at Satellite's Sending Time. The phase relationship can be gained by phase comparison. The location of phase difference is defined in the whole phase difference group by phase comparison. The phase $\Delta\phi_0$ that is the phase from the compared moment to the next phase coincidence moment can be obtained. The $\Delta\phi_0$ can be obtain, and we also can get the number of carrier frequency integral periods in the phase $\Delta\phi_0$. The numbers of $\boldsymbol{T}_{\max}$ measurement is easier than carrier frequency periods between two phase coincidences. The corresponding equations are as follows. Equations are as follows.

$$\Delta\varphi + \mathrm{N}_k^s = \mathrm{N}_0 \mathrm{T}_{\max} - \Delta\phi_0 \tag{5}$$

$$\mathrm{N}_k^s = \mathrm{N}_0 \frac{77}{\mathrm{f}_{L1}} - \boldsymbol{n_m} \tag{6}$$

Where N_0 is the number of the $\boldsymbol{T}_{\max}$, $\Delta\varphi_0$ is the fall short of one $\boldsymbol{T}_{\max}$, $\boldsymbol{n_m}$ is the number of carrier frequency integral periods in the $\Delta\phi_0$.

The method only needs to increase phase detection in the measurement system. The phase variation can be obtained by calculating the phase difference. Integer ambiguity resolution of carrier frequency is converted to integer ambiguity resolution of $\boldsymbol{T}_{\max}$.

If integer ambiguity resolution is determined by comparison of the two carrier frequency, the main influence factors are the precision of the phase coincidence detection. The phase coincidence detection between the two carrier frequency signals should be better than their Quantized Phase Variation Resolution $\Delta\boldsymbol{T}$, or measurement precision can be affect very much. For the restriction of apparatus, it is different to detect phase coincidence and phase comparison. The carrier frequency received in GHz should be reduced and the detection and comparison should be done in the intermediate frequency. The phase relations of the two signals do not change after reducing frequency, but they process easily.

IV. CONCLUSION

Additional frequency difference between the two carrier frequencies forms the characteristics of regular and cyclical changing of the phase difference, so we can use the phase relationship between them to capture and process regular changes in the signal transmission. Because the $\boldsymbol{T}_{\max}$ is 77 times and 60 times by two carrier signal cycles respectively, the integer ambiguity can be reduced to 1/77 and 1/60 of the original after converted which will greatly reduce the calculation than the method of using complex search algorithms to determine ambiguity. And the method will be great helpful to improve accuracy of the integer ambiguity resolution and the research efficiency. The improvement measure is accomplished by strict and definite relationship of phase difference group sequence and inherent characteristics of the two carrier signal.

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