The Clock Model of Tracking and Measuring the GNSS Orbit About Motion Observation Station

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Abstract. The clock model is analysed much in this paper which is key to GNSS orbit determination. First it is introduced how to calculate sampling distance. That is necessary and mostly to rebuild the clock model of incept equipment from both GNSS single data of especial PRN codes point positioning and passive ranging system. Then the formula is gived about both clock error model of GNSS and the change from G PST to time of absolute positioning. And the express about telegraphese navigation to GPST is taken apart particularly. Last both the process of GNSS amending clock model with telegraphese navigation code and of calculating sampling distance and experience of shorting positioning distance first are given.

Keywords: Clock model of GNSS telegraphese navigation code sampling distance TTC.

1. Introduction
GNSS refers to the GPS / GLONASS combined positioning system, which has been widely used in the outer ballistic measurement of missiles, launch vehicles and other highly dynamic targets. It has two working modes: single-point positioning and differential positioning. It is moving and cannot provide a reference point for reference. Therefore, shipborne GNSS cannot perform differential positioning. It can only perform single-point positioning. Single-point positioning is divided into three positioning methods: single GPS, single GLONASS and GPS / GLONASS combination. The satellite's working state is not stable enough, and the positioning accuracy is low. At the same time, because the target's flight trajectory is less affected by the earth's occlusion, a sufficient number of satellites can be guaranteed. Therefore, the actual external ballistic measurement usually uses a single GPS positioning. The mechanism of GNSS single-point positioning is that the dynamic carrier collects and compiles downlink telemetry channels after acquiring the original measurement data. The surveying ship receives the demodulated telemetry signals and sends the telemetry original code to the GNSS outer processing terminal. Produce and compile original GNSS measurement data, and simultaneously receive GNSS satellite navigation messages obtained by the target receiver or local reference receiver to complete the dynamic target positioning solution. Because both the target receiver and the reference receiver only obtain the raw data and do not perform the processing, the receiver can be significantly simplified and very suitable for high dynamic targets. This is a significant advantage of GNSS positioning, but it also increases the processing of terrestrial GNSS terminals. Complexity because GNSS terminals not only obtain the pseudo range of the target receiver during positioning, but also the absolute time of the target receiver sampling each discrete pseudo range value.
The absolute time is based on the target receiver clock, so the clock model of the target receiver needs to be reconstructed.

2. Two-time references for GNSS positioning

From the pseudo-range positioning observation equation, the coordinate value of the GNSS satellite at the time of C/A code transmission must be known beforehand during the positioning solution. This coordinate value must be obtained through the broadcast ephemeris in the satellite navigation message subframe, but the broadcast star the calendar does not directly provide the coordinate values of the GNSS satellites at each launch time, only the orbital number of the satellite at a certain ephemeris reference time. Need to know the absolute time of each pseudo-range transmission time, GNSS receiver can only obtain the absolute time of C/A code receiving sampling time. Because the positioning solution does not obtain the observation pseudorange and time directly at the GNSS terminal, the clock model of the target receiver must be reconstructed to achieve the correspondence between the observation pseudorange and observation time of each point. The clock model refers to the time calculation and conversion model of the GNSS receiver. Since the GNSS positioning is based on the passive ranging principle, the pseudo range is obtained by measuring the relevant shift chip of the receiver's local copy of the C/A code signal and the received code signal. The time delay between the sampling time and the transmitting time of the receiver is obtained indirectly. Therefore, there are two kinds of time reference-GNSS satellite clock and receiver clock time. In fact, even if the two are strictly synchronized, due to the different clock start time of the two places, it still cannot be unified with a time base, which is determined by the passive ranging system and cannot be changed. The two-time references must be characterized by their own clock parameters: that is, there are their own clock differences, clock speeds, and clock drifts. In other words, these two different clock hours must be represented by their respective clock models. Because the original observation data constantly changes with time, the modeling of temporal information is very necessary to interpret the positioning results.

3. GNSS clock difference calculation model

The GNSS receiver clock oscillator uses a highly stable crystal, and its oscillation frequency can be described by the following formula:

$$f(t) = f_0 + \Delta f + f'(t-t_0) + \delta f(t)$$  \hspace{1cm} (1)

The left term of the equal sign of formula (1) is the actual frequency, and the right terms are the nominal frequency, frequency difference, frequency drift, and random error terms.

The clock hour reading can be expressed as:

$$T(t) - T(t_0) = \int_{t_0}^{t} \frac{f(t)}{f_0} dt = t - t_0 + \frac{\Delta f}{f_0} (t - t_0) + \frac{f'}{f_0} (t - t_0)^2 + \int_{t_0}^{t} \frac{\delta f(t)}{f_0} dt$$  \hspace{1cm} (2)

From formula (2):

$$T(t) - t = [T(t_0) - t_0] + \frac{\Delta f}{f_0} (t - t_0) + \frac{f'}{f_0} (t - t_0)^2 + \int_{t_0}^{t} \frac{\delta f(t)}{f_0} dt$$  \hspace{1cm} (3)

A new coincidence is introduced, and the calculation model of the receiver clock error is:

$$\Delta T(t) = a_0 + a_1 (t - t_0) + \frac{a_2}{2} (t - t_0)^2 + \int_{t_0}^{t} y(t) dt$$  \hspace{1cm} (4)
The measurement of high dynamic target pseudorange mainly needs to consider the effect of long stability. Especially when using a high stability crystal, the effect of short stability on the pseudorange error can be ignored. Therefore, the calculation and modification of the GNSS clock model is mainly to calculate the long-term stability term in the second-order polynomial for the clock difference.

4. GPST to UTC conversion model

The GNSS receiver uses GPS to calculate the positioning time during external ballistic positioning processing. GPST cannot directly provide the absolute time of positioning. It is a relative time. It must be converted to obtain the absolute time. Specifically, it is based on 1980. The time origin of calculating the absolute time at UTC at 0 o'clock on the day of June 6 is also called the epoch, that is, at this moment, the two are strictly synchronized and aligned. Time is the cumulative value of time relative to the epoch. In this way, the absolute time of any time can be obtained only by the addition operation, which is very suitable for computer processing. GPST is further divided into GPS week and GPS second. They are expressed as GPS time system time parameters in the navigation message corresponding to GPS satellites. GPS week refers to the whole week number of relative epochs at any time in GPS time series. WN is used in Chinese. GPS seconds refer to the remaining part after deducting the whole number of weeks relative to the epoch at any time, that is, the number of whole seconds in the week. It is expressed in TOW in the message. Because GPST is different from the calendar time we use every day, it is not intuitive enough, so the display of GNSS positioning time still uses intuitive calendar time. Therefore, the clock model also includes the GPST to UTC conversion model.

But the time conversion from relative time to absolute time is not a simple addition operation. It needs to consider the difference between GPS time and UTC time, the ambiguity of WN in the navigation message, the difference between the number of days in the month and year, and the GPS time. Many links such as the conversion to GMT, not only the GPS week and GPS seconds, but also the Z count, toe and other parameters. The following shows the GPST time expression in the navigation message and the detailed process and calculation of the above time conversion formula. The complete representation of GPS time by GPS satellites uses a counting method, a total of 29 bits, and the time in the navigation message actually broadcast to the user is 27 bits, where the first 10 bits of the 3rd word of the first subframe is used to indicate WN, and The first 17 bits of the HOW code in each sub-frame represent TOW, and some literatures call it the truncated Z count or 6Z count, because the GPS satellite's local Z count is 19 bits, and the Z count is the P code broadcast to the GPS satellite. The cycle count of the X1 subcode is zeroed once a week, so the maximum value that the local Z count needs to represent, that is, the longest time in the week: total seconds in the week / 1.5 = 7 × 24 × 3600 / 1.5 = 403200, This requires at least 19 bits of binary bits. In fact, it is truncated to the first 17 bits of the HOW word code. The reason is that the HOW word code is located in the second word code of each sub-frame, and the sub-frame period of the navigation message is 6 seconds. With 17bit, the week count of the 6-second sub-frame period can be completely expressed, and the expression of TOW can also be satisfied. Its timing relationship is shown in Figure 1.

![Figure 1. Timing relationship diagram of GPS satellite local Z count (TOW) and message truncated Z count](image-url)
It can be seen from Figure 1 that the TOW and 6Z counts are aligned with the start time of each week, so the start time of each subframe in the navigation message can be completely expressed by the 6Z count. If combined with WN, it can be converted by the formula can get the absolute time of the start time of any subframe of the message. The specific conversion formula is:

\[
WN = \frac{d_1}{7} - 1024 \\
d_1 = (y - 1980) \times 365 + \text{doym} \times 1 + d + D_1 - 6 \\
D_1 = \left(\frac{y - 1980}{4} + 1\right)
\]

If \((y - 1980) \mod 4 = 0\) or \(m \leq 2\), then \(D_1 = 1\)

\[
TOW = \left(d_1 \mod 7\right) \times 86400 + (\text{hh} - \text{Timezone}) \times 3600 + m \times 60 + s + 13
\]

If \(TOW \leq 0\), then \(WN - 1\), and \(TOW = TOW + 604800\)

\[
Z\text{Count} = \text{INT}(TOW/6) + 1
\]

As mentioned earlier, WN is only represented by 10 bits, ranging from 0 to 1023. Therefore, there is ambiguity in WN. The time after the first 1024 weeks from the epoch is the time 0 on the night of August 22, 1999, and the second time the time after 1024 weeks is at 0 o'clock on the day of April 7, 2019. The current time is between the two, so when switching from GPS to UTC, add 1024 to WN.

Due to the leap seconds at UTC, so far, the time difference between UTC and GPS is 13 seconds, so the week number expressed by 10bit can only be displayed until 23:59:47 on August 21, 1999.

5. Reconstruction process of target receiver clock model by ground GNSS processing terminal

From the above analysis, during the GNSS positioning process, the GNSS raw measurement data needs to be selected from the telemetry channels. Among them, the pseudo-range and receiver sampling time are used to establish the observation equations for the positioning solution. However, the current target GNSS receiving Taking into account the channel capacity factor, the original measurement data transmitted by the telemetry channel did not directly transmit an accurate sampling time, but only transmitted a time count value. The ground processing terminal will perform time recovery based on the count value and the GNSS satellite navigation message at that time, that is, the process of reconstructing and correcting the clock model of the target receiver is completed. Therefore, the ground processing software cannot locate immediately after receiving the original measurement data of the target GNSS receiver. Instead, it needs a time recovery process, which takes at least 6 seconds and no more than 30 seconds.

The receiver sampling time is expressed in TIC counts. TIC is a signal generated by the channel processing module of the receiver every certain period. The receiver simultaneously measures the signals of all satellites at each TIC interval to obtain the pseudo range, Doppler and carrier of each satellite at the TIC time. Raw measurement data such as phase. TIC is generated as soon as the receiver is turned on, and its value has been accumulated since then. Its unit or cycle can be set or changed externally. Therefore, as long as you know the magnitude of the TIC value, you can know the receiver's working time, Receiver Time, from the time it is turned on.

\[
\text{Receiver Time} = \text{TIC} \times \text{TIC\_PERIO}
\]

If the accurate GPS time \(T_{gps}\) of the receiver at the TIC0 time point is known, the clock of the receiver can be corrected accordingly. If the clock drift rate of the receiver is known, the GPS time of the receiver at the TIC can be estimated more accurately.

The whole process of the receiver's GPS clock model correction is:

(a). When the receiver is turned on, TIC = 0, and the GPS time stored in RAM is used as the initial value of the GPS clock model.

(b). If the receiver does not receive the satellite signal after working for a period of time, if at this time the external sends a time initialization command through the serial port to set the time for the receiver, then use the value of the current TIC and the set GPS cycle and seconds to the GPS clock model The parameter is assigned an initial value.

(c). If the receiver receives data from the first sub-frame of the navigation message of the GPS satellite for the first time, the clock model is roughly calibrated, and the GPS clock model is corrected.
with the Z count value in the message and the day of the week in the message. The result of the correction makes the receiver's time accuracy on the order of 100 milliseconds.

(d). If the receiver has received coarse calibration of step (3), and then receives the satellite code phase and Doppler measurement information, it can be used to further fine-tune the clock model of the receiver. The correction also needs to consider the clock error of the GPS satellite. The final accuracy of the clock also depends on the initial position accuracy of the receiver. If its accuracy is guaranteed to be within 100 milliseconds, the accuracy of the calibration can be guaranteed to be 1 millisecond.

(e). If the receiver is already located, after each positioning, the newly calculated receiver clock difference, clock speed and clock drift must be used to recalculate the clock model parameters. The corrected accuracy is within 1 microsecond.

The modification of the clock model for GLONASS positioning is exactly the same as the above-mentioned modification for GPS, but the specific parameters are not the same.

The receiver's time calibration and precise positioning are performed synchronously, and the two complement each other to improve accuracy. If the accuracy of one party is low, the accuracy of the other party will be affected. The initial positioning result has a large deviation, so the positioning result during the first positioning has no practical significance. You need to wait for about 10 seconds.

6. Conclusions
The GNSS clock model plays a vital role in the positioning solution. During use, it is found that if the clock model is not initialized effectively and the positioning time is displayed incorrectly, GNSS cannot give the positioning result at all. In addition, according to experience, in order to shorten the first positioning time and accelerate positioning, the clock model of the target receiver must be established as soon as possible. At this time, the local reference receiver for differential positioning needs to be turned on in advance and cooperate with receiving the navigation message of the GNSS star to determine WN in advance. In this way, when the GNSS terminal receives the pseudorange, it only needs to receive any one frame of the message sub-frame to complete the first positioning. This method can shorten the first positioning time from 30 seconds to 6 seconds.

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