Broadcasting System Time Scales Offsets in Navigation Messages. Assessment of Feasibility

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GNSS System Time Synchronization

Operational and emerging Global Navigation Satellite Systems GPS, GLONASS, Galileo, BeiDou and others provide high-accuracy determination of position, velocity and time for land, marine, air and other kinds of users.

To achieve this the time scales of all space vehicles are synchronized to System Time and the System Time is synchronized to the Reference Time.

That's why GNSS System Time synchronization is necessary for interoperability of different GNSS to provide users with positioning and timing services by signals from space vehicles of different GNSS.

GNSS-GNSS System Time Scales offsets

Users can get the information on GNSS-GNSS System Time offset (GGTO) on the base of:

- processing navigational signals themselves from Space Vehicles (SV) of different GNSS;
- corrections for GNSS-GNSS System Time offset broadcast in navigation messages.

GGTO Calculate in User's Equipment

Users calculate GNSS-GNSS System Time offset in accordance with the following formula:

$$\Delta T_{STi-STj}(t) = \Delta T_{STi-User}(t) - \Delta T_{STj-User}(t)$$

where:

$\Delta T_{STi-STj}(t)$ - the offset between i^{th} и j^{th} GNSS System Time;

$\Delta T_{STi-User}(t)$ - the offset of the user's time relative to i^{th} GNSS System Time;

$\Delta T_{STj-User}(t)$ - the offset of the user's time relative to j^{th} GNSS System Time.

GGTO Calculate in User's Equipment

The offset of the user's time relative to each GNSS System Time is calculated in accordance with the following formula:

$$\Delta T = S - (D/c - \tau_{rel} - \tau_{ion} - \tau_{trop} - \tau_{\text{L1-L2}} - \tau_{SV} - \tau_{user}) + \Delta T_{SV}$$

where:

S - measured pseudorange between SV and user;

D - geometrical range between SV and user;

c - speed of light;

$\tau_{rel}, \tau_{ion}, \tau_{trop}$ - corrections for Earth rotation, for ionospheric and tropospheric effects;

$\tau_{\text{L1-L2}}$ - correction for the frequency difference in L1 and L2 bands;

τ_{SV} - signal delay in onboard SV equipment;

τ_{user} - signal delay in user's receiving equipment;

ΔT_{SV} - the correction for the SV's time offset relative to GNSS system time, transmitted in navigation message.

GGTO Calculate in User's Equipment

As a consequence, the accuracy of the calculated offset between user's time and GNSS System Time depends on the following:

- the error of one-way range measurements;

- the error of the calculated range including the error of ephemeris and user's current position coordinates;

- the error of processing one-way measurements including the error of all calculated corrections in above formula;

- the error of the correction for the offset of SV's time relative to GNSS System Time.

GGTO Calculate in User's Equipment

To use the above method in general situation it is necessary for the user to have no less than 4 visible SVs from one of GNSS. It makes impossible using signals from different GNSS in challenging environment where only 3 or even less SVs from different GNSS can be visible.

Possible solution is to store the calculated values of GNSS-GNSS System Time offset and to use the stored values.

However this approach brings additional error because of the growing error of the stored values.

Using Broadcast GGTO's

Using corrections for GNSS-GNSS System Time offset broadcast in navigation messages users can get navigation solution and determine their position in any environment.

Corrections for GNSS-GNSS System Time offset are generated on the base of processing measurements of SV signals of different GNSS by ground measuring facilities in accordance with above formula.

However, the accuracy of GNSS –GNSS Time offset is considerably higher because of reducing the errors of several components, mostly the error of measuring facility coordinates.

Using Broadcast ST-UTC(k) Corrections

Corrections for System Time (ST) offset relative to the reference time are also broadcast in navigation messages of all GNSS.

As a rule, national realization of universal time coordinated UTC(k) is used as the reference time.

All UTC(k) are kept close to UTC with predetermined accuracy and, as a result GNSS-GNSS time offset can be calculated.

Using Broadcast ST-UTC(k) Corrections

GNSS-GNSS time offset can be calculated with using these corrections in accordance with the following formula:

$$\Delta T_{STi-STj}(t) = \Delta T_{STi-UTC}(t) - \Delta T_{STj-UTC}(t)$$

где:

$\Delta T_{STi-STj}(t)$ - the offset between i^{th} и j^{th} GNSS System Time;

$\Delta T_{STi-UTC}(t)$ - the offset between i^{th} GNSS System Time relative to UTC;

$\Delta T_{STj-UTC}(t)$ - the offset between j^{th} GNSS System Time relative to UTC.

However, the accuracy of GNSS-GNSS time offset calculated by this method depends only on the UTC(k) synchronization to UTC accuracy, and isn't influenced by GNSS characteristics and now is lower as compared with the two methods mentioned above.

Conclusion

Nowadays the method of using GNSS-GNSS corrections broadcast in navigation messages provides the most accurate navigation solution with using signals from SVs of different GNSS.

Thank you for your attention!