Analysis of Two-Way Satellite Time and Frequency Transfer with C-Band

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***Abstract*—Two-Way Satellite Time and Frequency Transfer (TWSTFT) with C-band is influenced more seriously by ionosphere delay than that with Ku-band. The TWSTFT link between Xi'an and Urumchi with C-band has been established and it works via SINOSAT-1 geostationary satellite at 110.5° E with the uplink frequency 6.3 GHz and downlink frequency 4.1 GHz. To study and evaluate the instability introduced by ionosphere delay in the TWSTFT link with C-band, we calculated the influence of ionosphere delay based on global TEC map in 2006 provided by the International GNSS Services (IGS). First, we build a sphere harmonious model based on IGS TEC data file, so that we can easily obtain the TEC at any penetration point on the sphere 450 km above the earth surface at any time. Then, we calculate the two penetration point positions with the coordinates of two stations and the nominal coordinate of the satellite. After that, the uplink and downlink ionosphere delay of each station are calculated, and the influence to TWSTFT is also obtained. The result shows that the non-reciprocity introduced by ionosphere delay in the TWSTFT link with C-band varies day by day, and the maximum amplitude of the daily variation is 0.38 ns in 2006.**

I. INTRODUCTION

Now Two-Way Satellite Time and Frequency Transfer (TWSTFT) with Ku-band is a regular method for calculating TAT and UTC [1,2]. C-band and Ku-band are the main communication frequency bands in satellite communication for civil application. Study of TWSTFT with C-band may extend the application range of the method.

For Ku-band the uplink is normally at 14 GHz and the downlink is at 11 GHz, the influence from ionosphere delay in Ku-band TWSTFT has been analyzed in the reference [2,3]. For C-band the uplink is normally at 6 GHz and the downlink is at 4 GHz. The ionosphere delay is inversely proportional to the square of frequency. Therefore, TWSTFT with C-band may be influenced more seriously by the ionosphere delay. To study the instability introduced by the ionosphere delay in TWSTFT with C-band, we calculated the ionosphere delay in the TWSTFT experiment between National Time Service Center (NTSC) and Urumchi Observation (UO) with C-band transponder in SINOSAT-1 satellite in 2006, and calculated the influence from ionosphere delay. The global TEC map provided by IGS is used in our calculation [4].

II. CALCULATION METHOD

The TEC map is contained in the daily IONosphere map EXchange format (IONEX) file. In the IONEX files, the TEC values are reported at a 2 hour epoch with a 2.5 degree latitude by 5 degree longitude grid on a sphere 450 km above the earth's surface. We can get TEC values at 5184 (72*72) gridding points every two hours. Such data is not convenient to use when we analyze the influence of ionosphere delay in TWSTFT with C-band. We fit all the TEC values at global girding points at a certain time with the sphere harmonious function model expressed as

$$TEC(\alpha,\beta)=\sum_{n=0}^{max\_n}\sum_{m=0}^{n}P_{nm}(\alpha)\cdot(a_{nm}\cos(m\beta)+b_{nm}\sin(m\beta)) \quad (1)$$

where TEC(α, β) is the TEC at point with α degree latitude and β longitude in ionosphere spherical shell mentioned above, and it's in the normal direction of the sphere. max_n is the maximum fit degree, $P_{nm}(\alpha)$ is normalized Legendre polynomial, a_{nm} and b_{nm} are the sphere harmonious coefficient which is obtained by fitting 72*72 TEC values at a certain time.

Based on the coordinate of the TWSTFT station and the longitude of sub-satellite points of geostationary satellite, we can calculate the coordinate of the penetration point on the sphere 450 km above the earth's surface. With sphere harmonious function model, we can obtain the TEC value in the normal direction at the penetration point at the given time. Furthermore, we can calculate the TEC in the direction from the station to satellite. A group of IGS TEC value is given every 2 hours and we can get the TEC at any time with linear interpolating method.

The ionosphere delay in the direction from station to the satellite may be calculated with the expression given by

$$\tau_{ion} = TEC_l(\alpha,\beta) \cdot 40.28 / f^2 \qquad (2)$$

where τ_{ion} is the ionosphere delay, $TEC_l(\alpha, \beta)$ is the TEC in the direction from station to satellite and the penetration point is α degree latitude and β longitude, f is the signal radial frequency.

The influence from ionosphere delay in TWSTFT is expressed by

$$\Delta = (A_u - A_d)/2 - (B_u - B_d)/2 \qquad (3)$$

where Δ denotes the influence from ionosphere delay in TWSTFT between station A and station B, A_u is the ionosphere delay in the uplink in station A, A_d is that in the downlink in station A, B_u is that in the uplink in station B, B_d is that in the downlink in station B.

III. RESULT

For the TWSTFT experiment link between NTSC and UO with C-band transponder of SINOSAT-1, the influence from ionosphere delay is calculated with all IGS TEC value in 2006 and the sphere harmonious function model mentioned above. SINOSAT-1 satellite is in the 110.5 deg. E, and the distance from NTSC to UO is about 2000 km. The uplink frequency is 6.3 GHz and the downlink frequency is 4.1 GHz. We first give the result in May, June and July, which are shown in Fig. 1, Fig. 2 and Fig. 3.

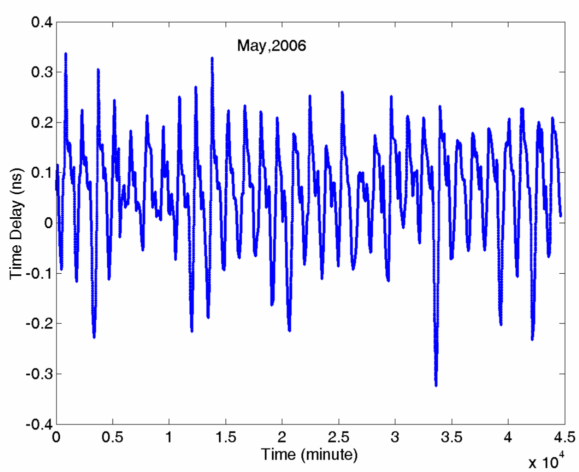

Figure 1. The influence from ionosphere delay in the TWSTFT link in May, 2006.

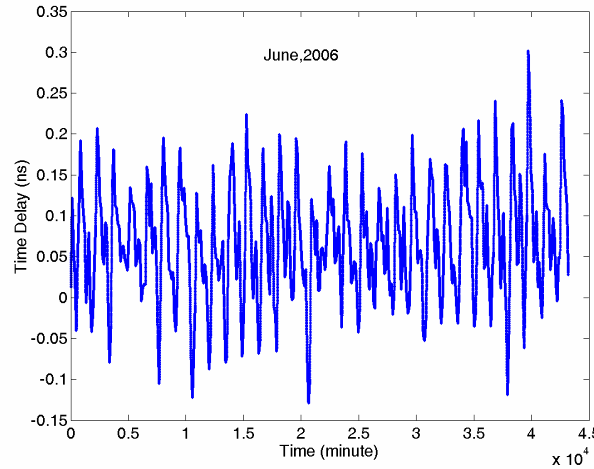

Figure 2. The influence from ionosphere delay in the TWSTFT link in June, 2006.

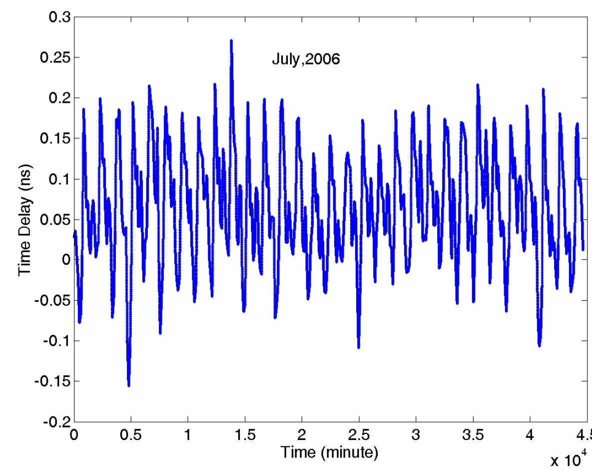

Figure 3. The influence from ionosphere delay in the TWSTFT link in July, 2006.

The ionosphere delay is large in summer and small in winter. The influence from ionosphere delay in TWSTFT with C-band is calculated in November, December and January in 2006, and the results are shown in Fig. 4, Fig. 5 and Fig. 6.

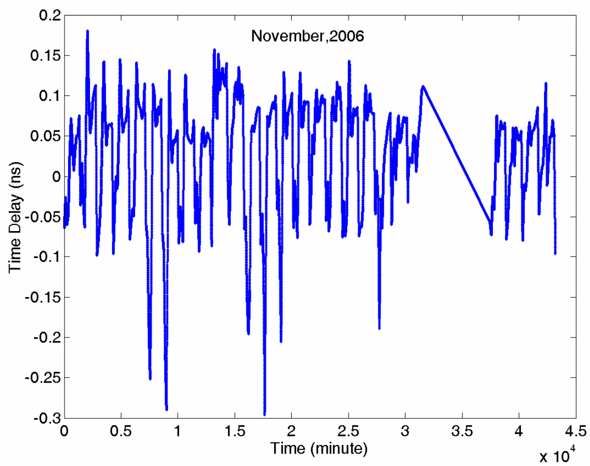

Figure 4. The influence from ionosphere delay in the TWSTFT link in November, 2006.

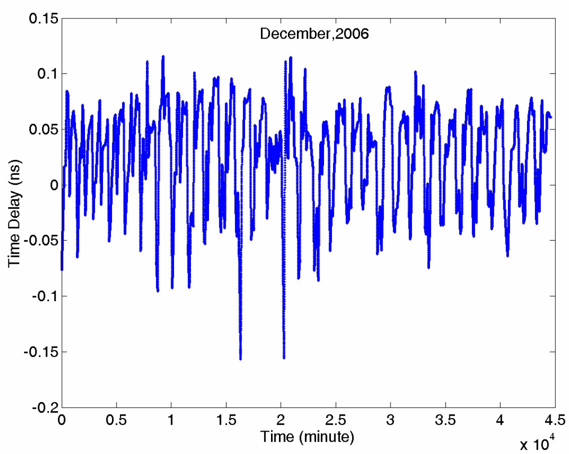

Figure 5. The influence from ionosphere delay in the TWSTFT link in December, 2006.

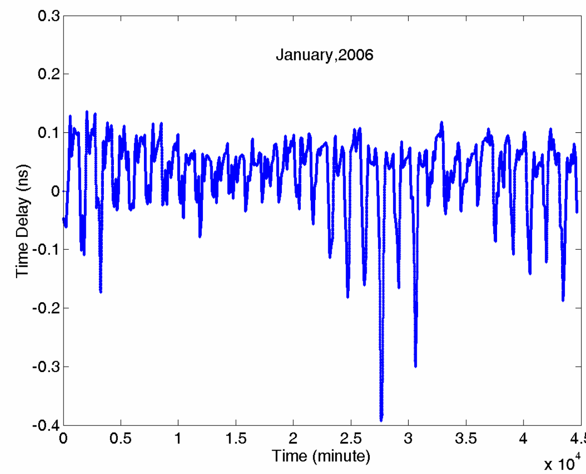

Figure 6. The influence from ionosphere delay in the TWSTFT link in January, 2006.

IV. ANALYSIS AND DISCUSSION

The calculating result shows that the non-reciprocity introduced by ionosphere delay in the NTSC-UO TWSTFT link with C-band varies day by day, and the maximum amplitude of the daily variation is 0.38 ns in 2006.

The elevation are 50.5 degree at NTSC and 34.5 degree at UO, the two elevations are not low. In addition, the ionosphere delay is small in 2006. Therefore, our calculating result is only a reference.

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REFERENCES

[1] Michito Imae, “Review of Two-Way Satellite Time and Frequency Transfer”, Journal of Metrology Society of India,Vol.21, No.4, pp.243-248, 2006.

[2] “The operational use of two-way satellite time and frequency transfer employing PN codes”. Rec. ITU-R TF.1153-2, 2003.

[3] T.E. Parker and V. Zhang , “Sources of Instabilities in Two-Way Satellite Time Transfer”,2005 Joint IEEE International Frequency Control Symposium and Precise Time & Time Interval (PTTI) System and Applications Meeting, pp.745-751, 2005.

[4] International GNSS service, ftp://cddis.gsfc.nasa.gov/gps/products/ionex/