A Research on Errors in Two-way Satellite Time and Frequency Transfer

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The two-way satellite time and frequency transfer (TWSTFT) is one of the most accurate means for remote clock comparison with an uncertainty in time of less than 1 ns and a relative uncertainty in frequency of about $10^{-14}$ d$^{-1}$. The transmission paths of signals between two stations are almost symmetrical in the TWSTFT. In principal, most of signals of path delays are canceled out, which guarantees the high accuracy of TWSTFT. However, the development of TWSTFT and the increase in the frequency of observations, it is important to study the diurnal variation of systematic errors. The TWSTFT is more and more widely applied in many fields, and its in-depth study has important practical significances.

The atmospheric effect. This includes ionospheric and tropospheric effects. The effects are very small, and they can be ignored. The ionospheric error can be corrected by using the IGS ionosphere product. The variations of ionospheric effect are about 0.05 ns and 0.7 ns at Ku band and C band, respectively, and have the same variation characteristics.

The equipment time delay. The equipment delay is closely related with temperature, presenting a linear relation at the normal temperature. Its outdoor part indicates the characteristics of the diurnal variation with the environment temperature. The various the effects related with the modem are studied. Some resolutions are proposed.

The satellite transponder effect. This effect is studied by using the data of international TWSTFT links. It is analyzed that different satellite transponders can highly increase the amplitudes of the diurnal variation in one TWSTFT link. This is the major reason of the systematic errors in the TWSTFT. The function fitting method is used to basically solve this problem.

The satellite motion effect. The geostationary satellites have the diurnal motion of uplink and downlink paths. The Sagnac effect in the satellite motion situation is analyzed in detail. Satellite motion can cause the uplink geometric paths unequal to the downlink geometric paths. The geometric path error caused by satellite motion depends on the sum of the geometric velocity in the sight direction and the time difference between the signals from two radio sources arriving at the satellite. The diurnal variations are about 0.1 ns and 0.05 ns for the geometric path delay, respectively.

The GNSS has become the major time transfer technology since 1980's. The short-term stability of GNSS is better than that of TWSTFT, but the long-term stability of TWSTFT is better than GNSS's. The amplitude of the diurnal variation can be decreased with the number of combination of GNSS time transfer and TWSTFT, and by using the Vondrak-Demmel algorithm. The TWSTFT is more and more widely applied in many fields, and its in-depth study has important practical significances.