VLBI MEASUREMENTS FOR TIME AND FREQUENCY TRANSFER

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Abstract

Modern cold-atom-based frequency standards have already archived the uncertainty of 10^{-15}at a few days. Moreover cold-atom-based optical clocks have the potential to realize the uncertainty of from 10^{-16} to 10^{-17} level after a few hours. On the other hand, time transfer precision of two-way satellite time and frequency transfer and GPS carrier phase experiments have reached the 10^{-10}@1sec (10^{-15}@1day) level. In order to compare such modern standards by these time transfer techniques, it is necessary to average over long periods. Since these techniques are not sufficient to compare next standards improvements of high precision time transfer techniques are strongly desired. Space geodetic techniques like Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR) and Global Positioning System (GPS) are based on precise time measurement using very stable reference signals. VLBI measures the arrival time delays between multiple stations utilizing radio signals from distant celestial radio sources like quasars and pulsars. By using VLBI, it is possible to measure subtle variation of rotation and Earth orientation parameters (EOP). In the usual geodetic VLBI analysis, clock offsets and their rates of change at each station are estimated with respect to a selected reference station. The averaged formal error (1 sigma) of the clock offsets is typically about 20 picoseconds when analyzing geodetic VLBI experiments which are regularly conducted by the International VLBI Service for Geodesy and Astrometry (IVS). This precision is nearly one order better than other techniques like GPS or two-way satellite time transfer. It is feasible to use geodetic VLBI for comparison of primary frequency standards when radio telescopes are deployed at time and frequency laboratories. For this purpose, we have started to develop a compact and transportable VLBI system (see details Ishii et al., 2007).

In this study we compare time transfer precision between VLBI and GPS carrier phase using the 109 km baseline between Kashima (having an 11m and a 34m antenna) and Koganei (11m antenna) in Japan in order to confirm the potential of VLBI time and frequency transfer. VLBI experiments were performed four times (two 24 hour sessions, one 3 days session and one 7 days session) and GPS observations were carried out at the same time sharing common reference signals. The averaged formal error (1 sigma) of the hourly estimated clock offsets as obtained from VLBI analysis was 29 picoseconds. The difference between VLBI and GPS was about +/-500 picoseconds what is considered to be caused by the uncertainty of the GPS time transfer. The results show that VLBI time transfer is more stable than GPS time transfer on the same baseline, but is not as stable as GPS time transfer using International GNSS Service (IGS) stations (ONSA and WTZR), which is considered to be caused by the management of our masers. In general, the VLBI time transfer stability follows 1/tau very close in the time range from 100 to 4000 seconds. Based on these findings, we will discuss about the possible improvements of time and frequency transfer using the compact VLBI system.

Ishii et al., Development of a compact VLBI system for a length examination of a reference baseline, IVS NICT-TDC News, No.28, 2-5, 2007.