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VLBI MEASUREMENTS FOR TIME AND FREQUENCY TRANSFER

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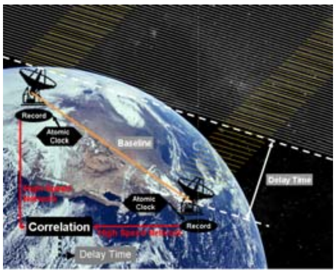
INTRODUCTION

TAI is computed by the BIPM from a set of atomic clocks distributed over the world. The time transfer between these remote clocks is mostly performed by **GPS** and **TWSTFT**.
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 TWSTFT 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.



VLBI measures the arrival time delays between multiple stations utilizing radio signals from distant celestial radio sources like quasars and pulsars.
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.

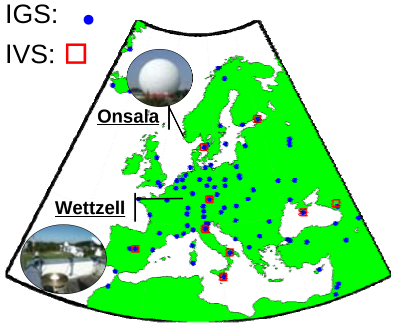
The averaged formal error (1 sigma) of the clock offsets is typically about **20ps** when analyzing geodetic VLBI experiments which are regularly conducted by the IVS.

In this study :
We compare frequency transfer precision between VLBI and GPS carrier phase in order to confirm the potential of VLBI time and frequency transfer.

COMPARISON BETWEEN VLBI AND GPS USING IVS AND IGS DATA

First, we checked the ability of time transfer of VLBI and GPS carrier phase using IVS and IGS data.

We selected the two stations (Onsala, Wettzell) which belong to IVS and IGS network. These two stations have in common that at each site VLBI and GPS are sharing the hydrogen maser.



DOY	IVS		IGS
(2007)	Session	Station	Station
092	R1270	ONSALA60, WETTZELL	onsa, wtzr
100	R1271		
113	R1273		
122	R1274		

Data Analysis

VLBI
- CALC/SOLVE
- multi baseline
- S/X ionosphere-free linear combination
- reference to Wettzell

estimate
- station coordinates
- atmospheric delay /1h
- **clock offset** /1h

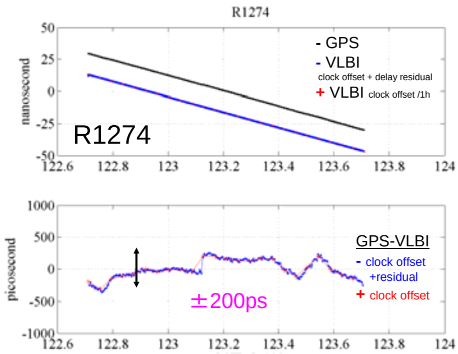
GPS
- GIPSY-OASIS II
- Precise Point Positioning

estimate
- station coordinates
- atmospheric delay /5min
- **clock offset** /5min

Time Difference
clock offset A – clock offset B

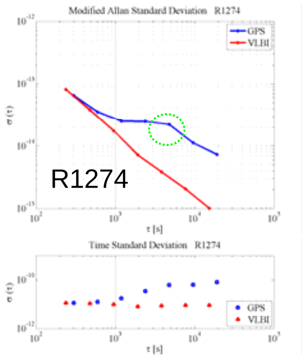
Time series of the Clock Differences

The time series of the clock difference between Onsala and Wettzell (session R1274) calculated from GPS and VLBI respectively. The lower part is the difference between GPS and VLBI clock offsets showing a good agreement within **+/-200ps**.

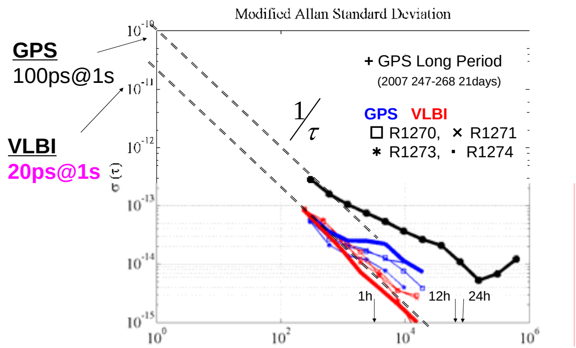


Day-Boundary DOY : 91-123 : 94 ps

Stability

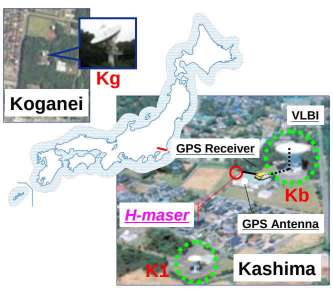


The frequency stability of clock difference as obtained from VLBI (red) and GPS (blue). The short term stability of by GPS carrier phase seems to be slightly better than those from VLBI for averaging periods up to 10^3s. However, VLBI is more stable at averaging periods longer than 10^3s in any sessions.



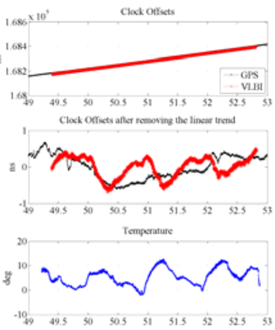
In general, the VLBI frequency transfer stability follows a 1/tau law very close when averaging up to 10^4s. And that shows the stability have reached about **2×10^{-11} (20ps) @1s**.

COMPARISON BETWEEN VLBI AND GPS USING KASHIMA – KOGANEI BASELINE



Kashima and Koganei station has 3 radio telescopes (34-m, 11-m: Kashima, 11-m: Koganei) and 3 permanent GPS receivers which are sharing the H-maser with VLBI.
These systems are usually set-up for geodetic purposes.
At first, we carried out a test experiment in the unchanged systems. After removing a linear trend, the clock offsets of VLBI reveal a diurnal variation which can not be seen in the GPS results.

The cable length between the point where the reference signal from the H-maser is injected and the observing system itself is different for VLBI and GPS. The bottom plot reveals that the clock offsets of VLBI are strongly affected by the outside temperature (correlation coefficient : **-0.72**, lag : 2hours).
These results suggest that it is necessary to calibrate the instrumental delay of the VLBI system. In the next step, we are planning to measure the instrumental delay of the VLBI system by the zero baseline interferometry (ZBI) method, and we also want to replace the transmission cable by optical fiber.

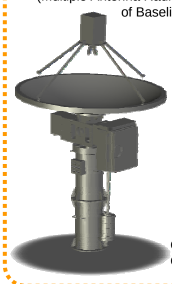


SUMMARY

To compare the results of VLBI and GPS (carrier phase) frequency transfer, we have analyzed IVS and IGS data. The results of the VLBI frequency transfer show that the stability follows a 1/tau law very close (phase noise dominant). And that shows the stability have reached about 2×10^{-11} (20ps) at 1 sec. In this study, the results show that VLBI frequency transfer is more stable than GPS on the same baseline and same period.
And also, we started the instrumental setting that used Kashima-Koganei baseline by time and frequency transfer for our compact VLBI system.

Development of a compact VLBI system

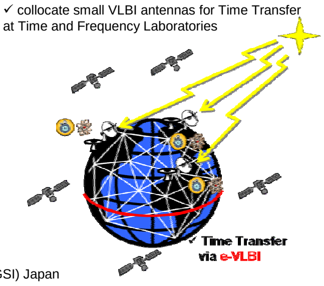
MARBLE SYSTEM
(Multiple Antenna Radio-interferometry of Baseline Length Evaluation)



- Diameter **1.6m**
- Receiving Frequency
  - **S/X-band**
- Front-fed paraboloidal reflector
- Az-El mounting
  - Max speed AzEl **5** deg/sec
- **Transportable** by human

Collaborating with Geographical Survey Institute (GSI) Japan

Future Image
✓ collocate small VLBI antennas for Time Transfer at Time and Frequency Laboratories



NiCT Kashima Space Research Center