VLBI MEASUREMENTS FOR FREQUENCY TRANSFER

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Introduction

✔ Development of frequency standard

- Atomic fountains

  2 × 10^{-15} @ a few days

- Optical clocks

  10^{-16} to 10^{-17} @ a few hours

Background

✔ Time and frequency transfer technique

- GPS Carrier Phase
  2 × 10^{-15} @ 1 day

- TWSTFT
  2-4 × 10^{-15} @ 1 day

- Long averaging period
- Insufficient accuracy

- Improvements of highly precise time and frequency transfer techniques are strongly desired

VLBI

NICT-CsF1
..... developing

NICT
optical clocks
..... developing

VLBI

NiCT
Kashima Space Research Center
Activities at NICT

1. Developing a compact VLBI system
   » MARBLE SYSTEM
     Multiple Antenna Radio-interferometry of Baseline Length Evaluation

   - Diameter 1.65m
   - S/X-band
   - Front-fed paraboloidal reflector
   - Az-El mounting
     - Max speed AzEl 5 deg/sec
   - Transportable
     by few person
   Collaborating with GSI

2. Verifying the ability of VLBI frequency transfer
   » to show the capability of the current VLBI system
     ▪ Intercomparison between VLBI and other techniques

This study
Previous study

Intercomparison: VLBI vs. GPS

1. Wettzell-Onsala
   - VLBI vs. GPS CP
   - IVS and IGS data

IGS: ○
IVS: □

GPS long period
(2007 91-105 15days, 106-124 19days)

 VLBI stability: follows a 1/τ law very closely

VLBI is more stable than GPS
surpassing the stability of atomic fountain at 10^3s

The geodetic VLBI technique has the potential for precise frequency transfer
Intercomparison: VLBI vs. other techniques

Kashima34m – Kashima11m 239m
Kashima11m – Koganei11m 109km

Kashima
Kashima Space
Research Center

Koganei/Tokyo
Headquarters

Koganei

VLBI
GPS

VLBI
GPS

TWSTFT
TEC (ETS-8)

VLBI
Kashima11m

VLBI
Kashima34m

GPS: kgni

GPS: ksmv

GPS: ks34

H-maser, DMTD

Please see the poser: JD06-p:21
Hosokawa et al., “Recent activities at NICT Space-Time Standards Group”
Can the VLBI measure the right time difference?

✔ **Kashima34m – Kashima11m**

» Artificial time difference change
  ▪ using **Line Stretcher**

» Intercomparison between VLBI, GPS and DMTD

**DMTD**

6x10^{-12}@1s (6ps)
Differences with the normal observation

✅ Normal Geodetic VLBI

» Observation
  - multiple sources
  - antenna slew time
  - different scan time
  - 24 hours

» Data Analysis
  - estimate
e clock parameter
atmospheric delay
station coordinates

✅ This study

» Observation
  - one source: 3C84
  - no antenna slew time
  - same scan time
  - a few hours

» Data Analysis
  - estimate only
clock parameter
atmospheric delay:
short baseline, one source
station coordinates:
fixed to a-priori coordinates
Data analysis

✓ VLBI
  » CALC/SOLVE
  » single baseline
  » S/X ionosphere-free linear combination
    ▪ clock offset / 10sec

vs. DMTD  Time Difference / 1sec

✓ GPS
  » NR Canada’s PPP
    ▪ IGS Rapid Orbit & Clock
  » Precise Point Positioning
    ▪ satellite clock interpolation
    ▪ clock offset / 30sec

» Time Defference
  clock offset A – clock offset B / 30sec
GPS vs. DMTD

large difference opposite sense

Line Stretcher
A B

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after removing offsets
VLBI vs. GPS and DMTD

After removing offsets, there is a good agreement between the measurements.
Artificial change

- VLBI vs. DMTD: good agreement (<10ps)
- GPS vs. DMTD: sometimes, opposite sense

Other parts

- VLBI vs. DMTD: good agreement (<50ps) for short time range
  larger difference for longer time range due to the effect of atmospheric variation
- GPS vs. DMTD: good agreement

Can the VLBI measure the right time difference?

YES
Conclusions

✓ Can the VLBI measure right time difference?

» VLBI vs. GPS CP and DMTD

» Artificial change
  - VLBI vs. DMTD: good agreement (<10ps)
  - GPS vs. DMTD: sometimes, opposite sense

» The geodetic VLBI technique can measure the right time difference.
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