ITA-JPN Broadband VLBI Experiment for Optical Clock Comparison

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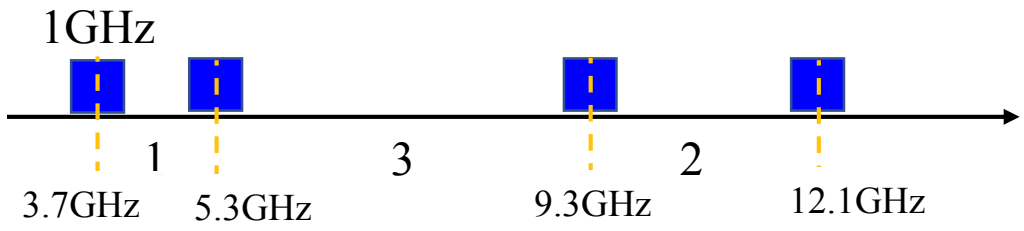
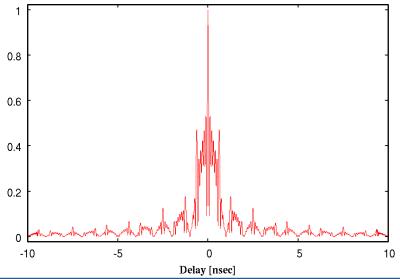
EVGA2019

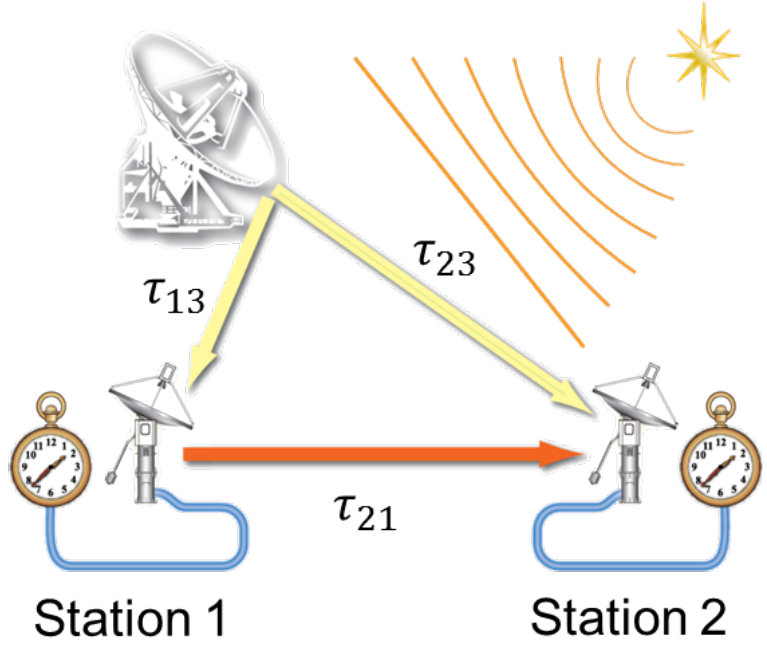
GALA-V Project Overview

Frequency comparison by using transportable broadband telescopes.

- Radio Frequency： 3.2-14 GHz
- Data Acquisition： 4 band (1024MHz width/band)
  - Nominal Freq. Array : Fc=3.7GHz, 5.3GHz, 9.3GHz, 12.1GHz
  - Effective Bandwidth：3.3GHz (10 times wider than conventional system)





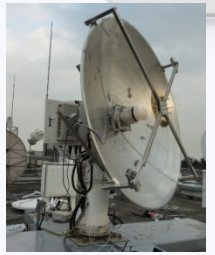


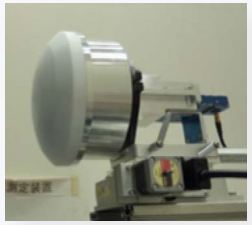
$$\tau_{21} = \tau_{13} - \tau_{23}$$

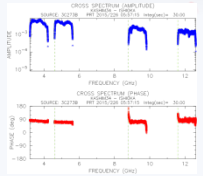
Closure delay is computed for small antenna pairs.

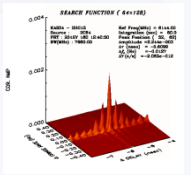
Broadband Feed for Cassegrain → RF-Direct Sampler → VDIF Stream → Recording → Correlation GICO3 → Broadband Synthesis → Mk3DB → Calc/Solve

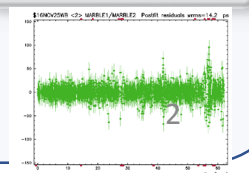
Compatible with Mk6, Flexbuf (jive5ab)









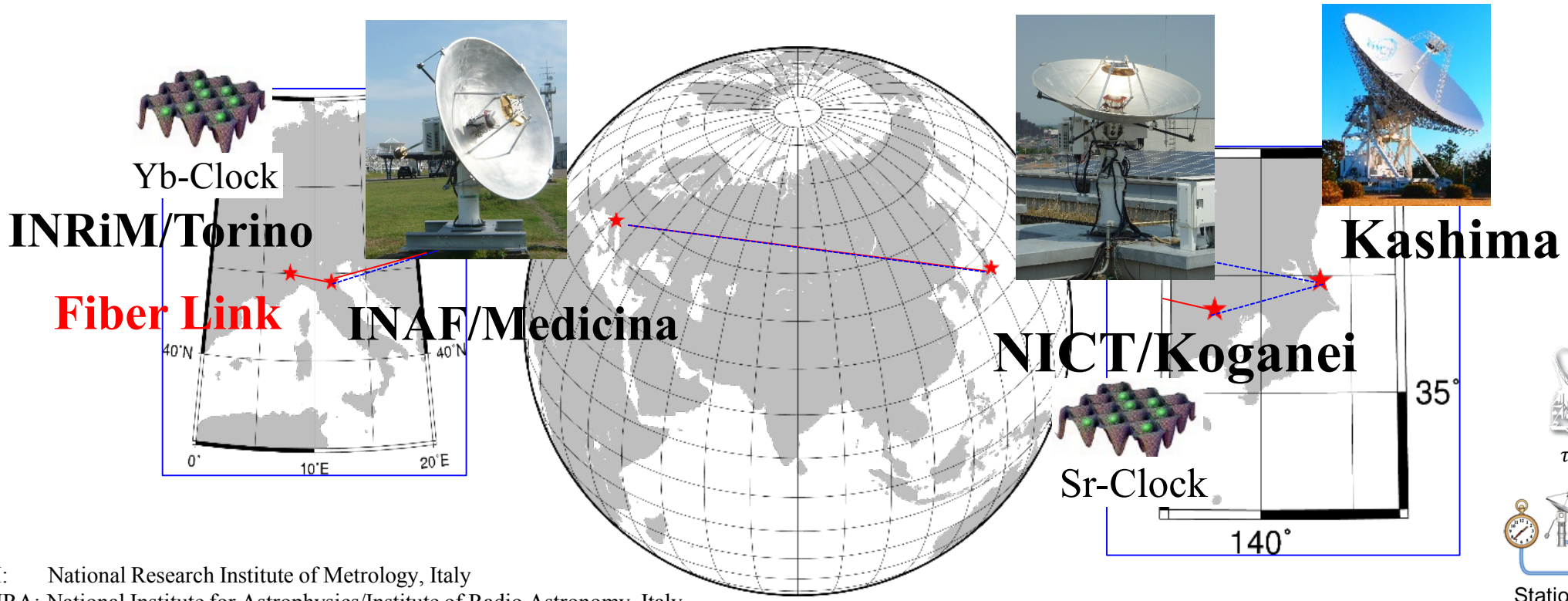


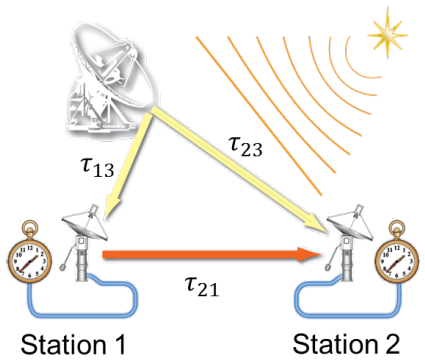
Broadband VLBI Experiments

Frequency Link Experiment : INRiM-INAF-NICT

Target: Intercontinental Frequency Link of Optical Frequency Standard. In addition to existing techniques: TWSTFT, GPS(PPP, IPPP)

Aug. 2018 :2.4m Antenna installed at INAF/Medicina



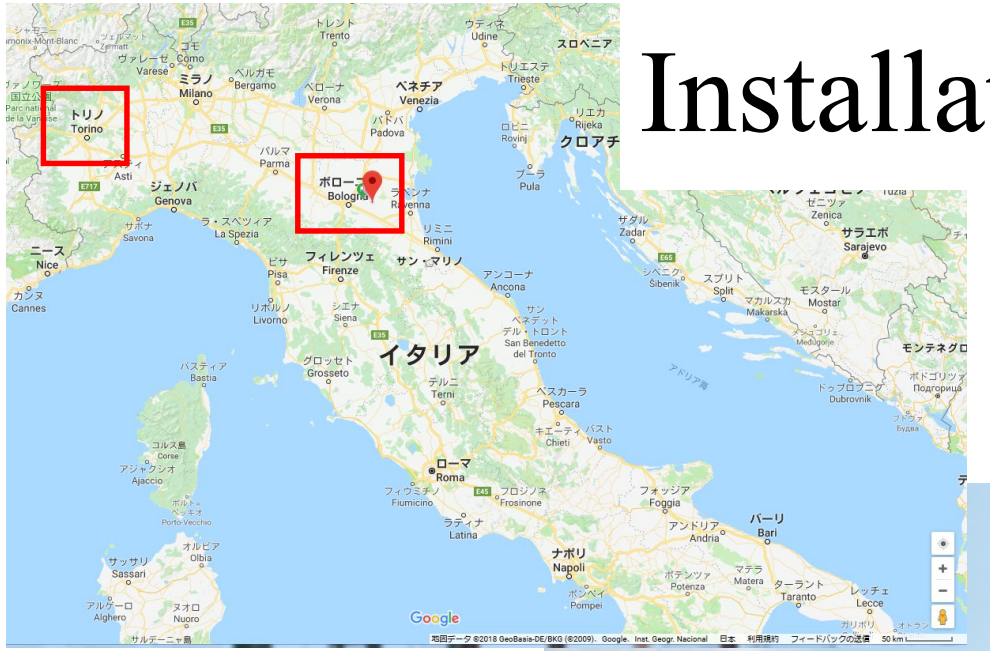


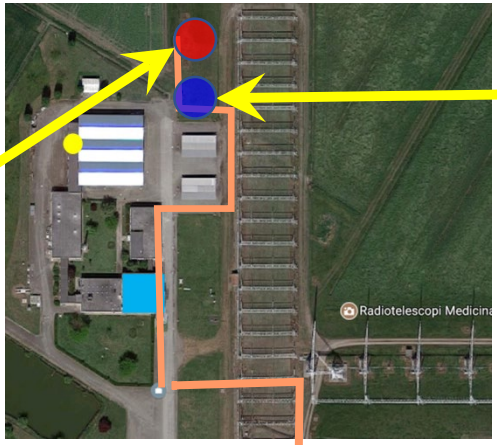
INRiM: National Research Institute of Metrology, Italy
INAF/IRA: National Institute for Astrophysics/Institute of Radio Astronomy, Italy
NICT: National Institute of Information and Communications Technology, Japan

Transporting Small VLBI Station set
Jul. 2018

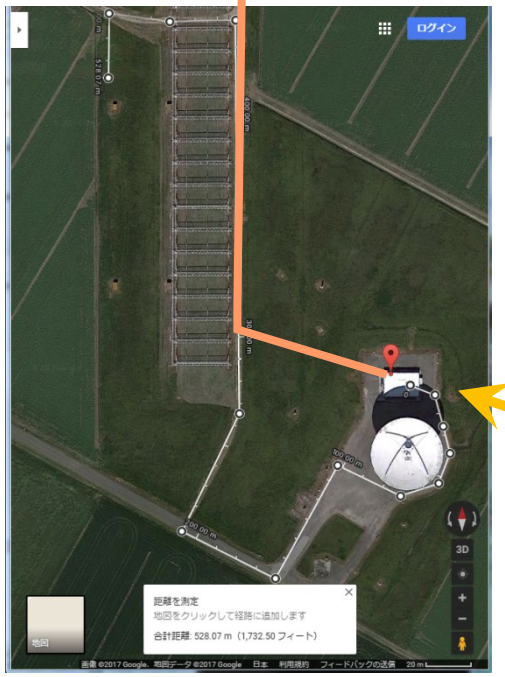
Antenna, DAS, FS-PC, Container are transported from Japan to Medicina for two year term contract. Local trench, optical fiber installation are prepared by INAF and INRiM

Installation at Medicina





Container for Antenna Control



Data Acquisition PC, 10G-net, **Clock Fiber Link from INRiM**

- Visiting in 21 Jul- 3rd Aug. (for 10 days)
- Unpacking 1.5d, Antenna Assemble 2.5d, Network set up, Antenna Testing 1.5d, Pointing 2d, VLBI Fringe test 2d, Meeting 0.5day.

Peoples of INAF/Medicina and INRiM. Meeting after installation

INAF: F.Perini,
M.Negsini, R.Ricci,
G.Maccaferri
INRIM: D.Calonico,
C. Clivati, A. Tampellini

1st Aug. Meeting for maintenance of Antenna, Reference signal, and power supply.

INAF: Federico Perini, Claudio Bortoloni,
Mauro Roma, Paolo Zacciroli,
Fuiseppe Maccaferri.

VLBI Observations

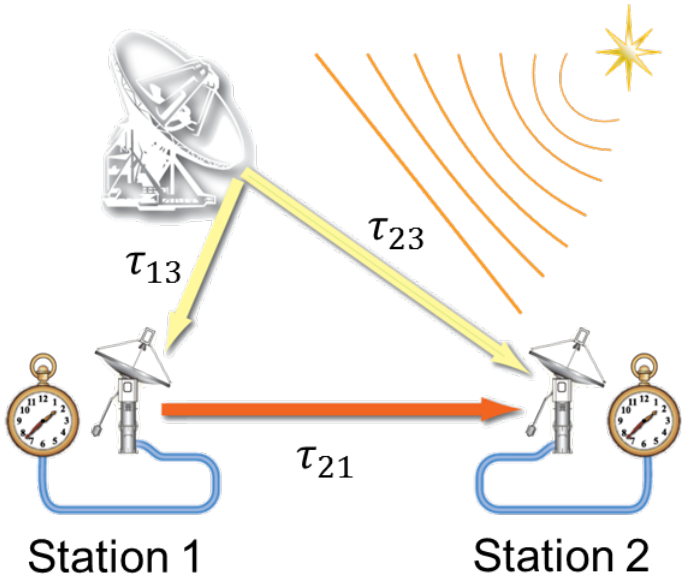
- Stations: MBL1(2.4m)@Medicina, MLB2(2.4m)@Koganei,
  Kashima34m@Kashima
- Observing Frequency: (6.0, 8.5, 10.4, 13.3 GHz), BW:1GHz, 1bit
- Polarization: V-pol (2.4m), V+H-pol (34m)
- Session: No less than 28 hours (Disk Capacity 70TB limited). > 400 scans
- Sessions: Oct.: 3 sessions, Nov.: 3 sessions, Dec.:3 sessions,
  2019 Jan.: 2 sessions, Feb.: 2 sessions; Total 13 Sessions.
- Sources: selected from larger flux sources from ICRF3

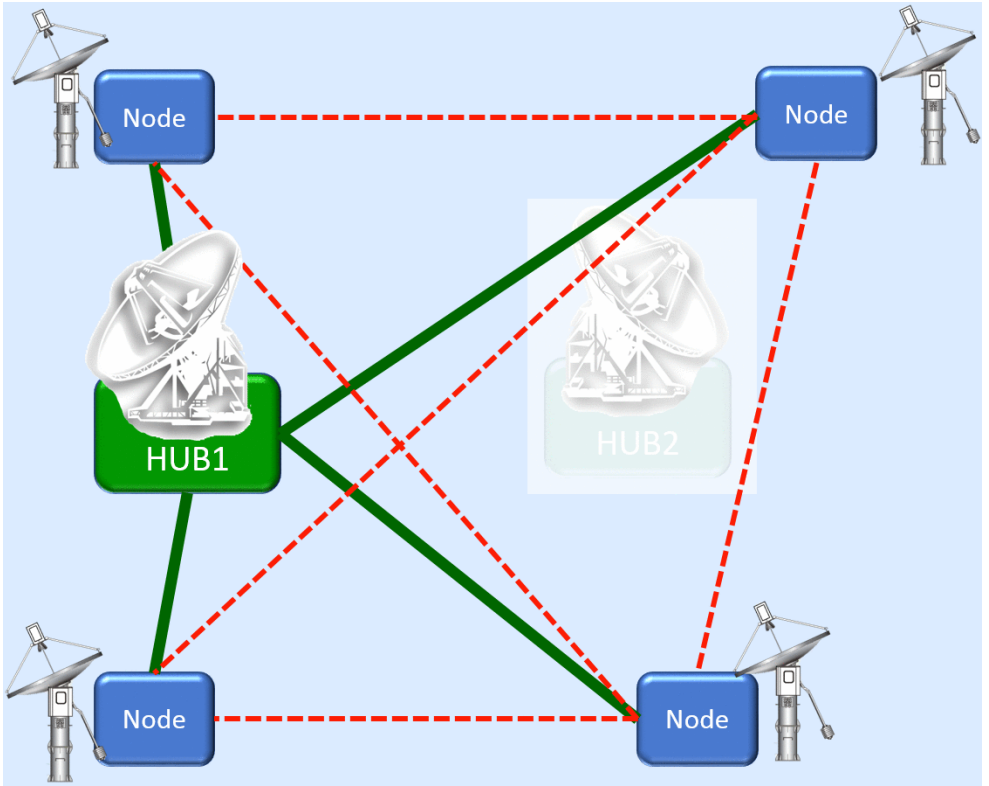
‘Node-Hub’ style VLBI

- Closure delay relation used to derive delay between ‘small-small’ baseline.

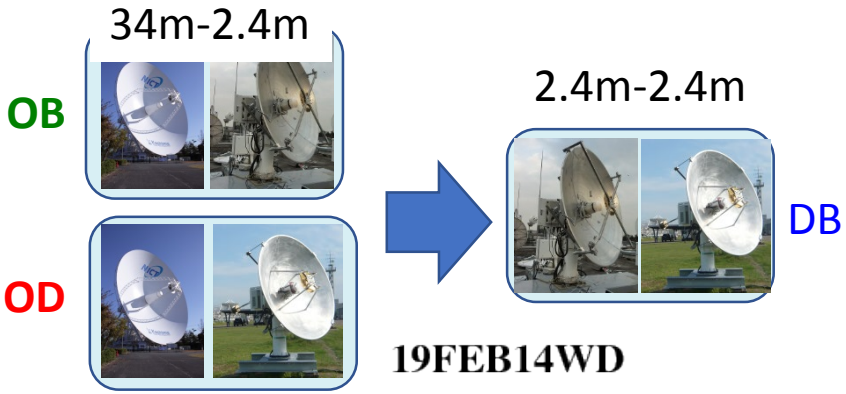
$$\tau_{21}(t_1) = \tau_{23}(t_1) - \tau_{13}(t_1) + \tau_{13}(t_1)\dot{\tau}_{21}(t_1)$$

- Advantages of using small antennas :
  - Quick slew and small distortion.
  - Large antenna’s effects are canceled out.
  - Lower cost.
- Disadvantage:
  - Lower sensitivity, ←boosting SNR with large diameter telescope
  - Source structure effects to closure delay.





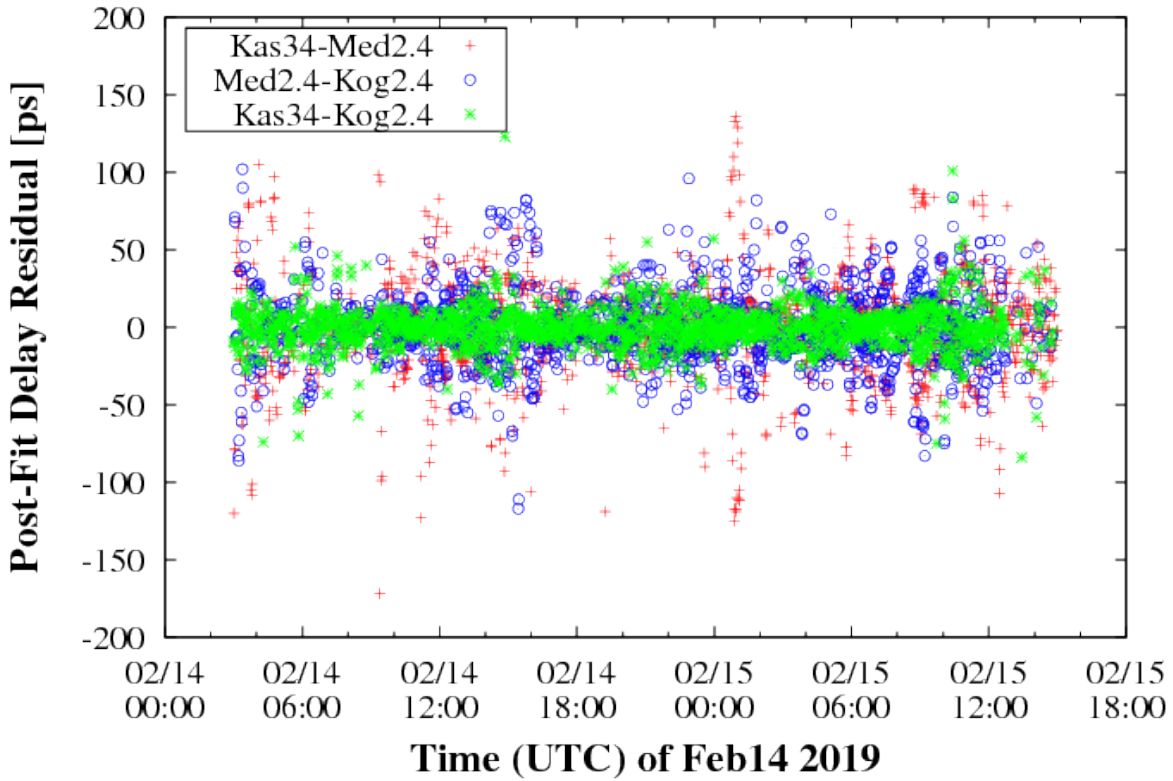
Delay residuals of 'Node-Hub' style VLBI

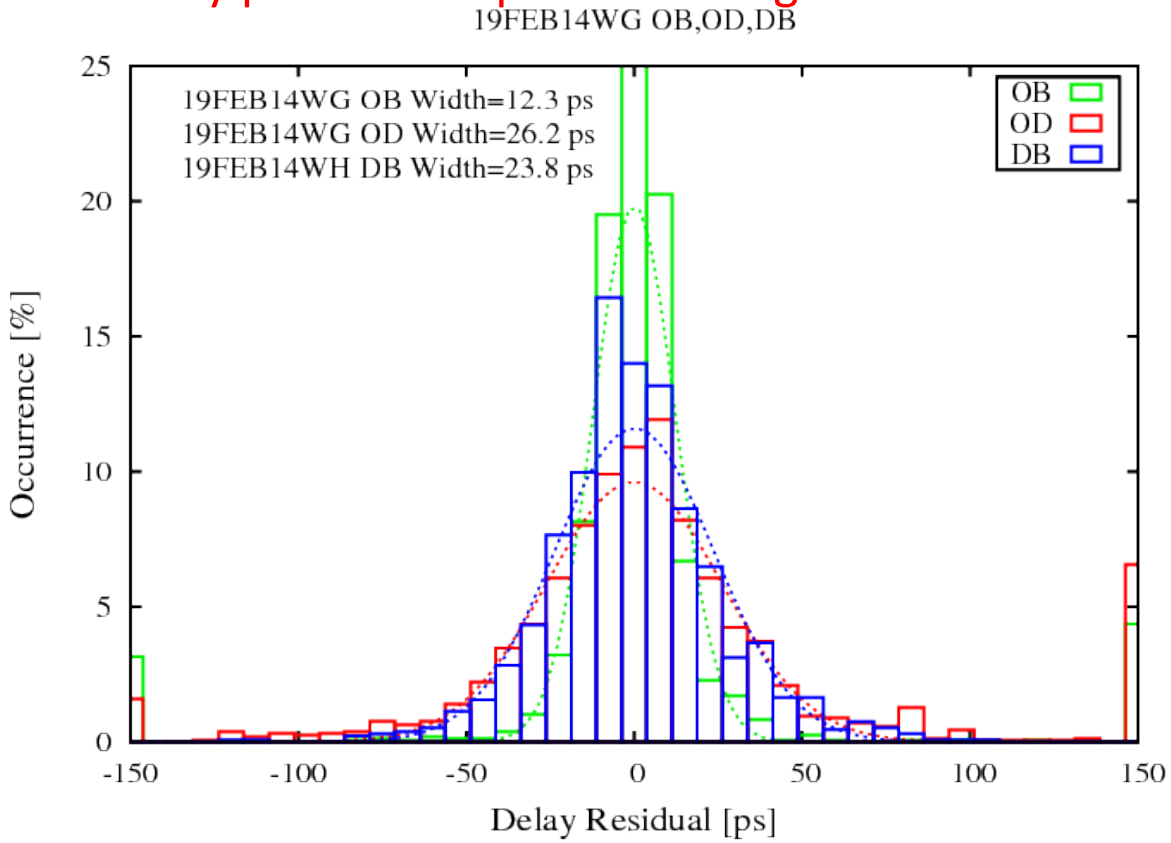


NH-VLBI delay residual is no larger than standard.

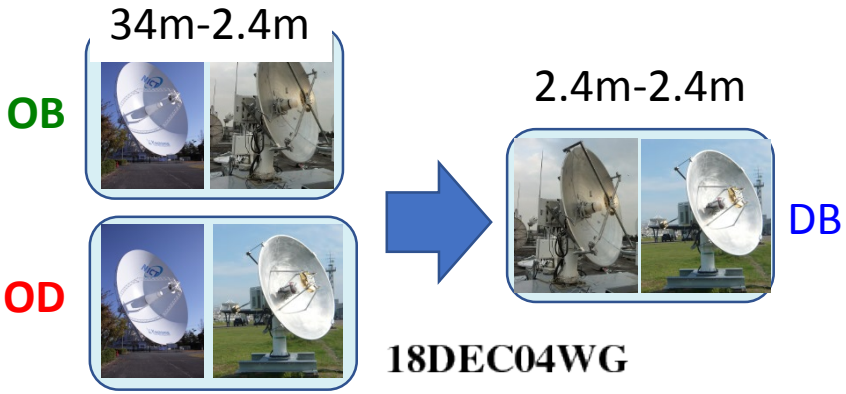
- OB(100km) baseline residual ~ 13ps
- OD and DB (8700km) baseline ~ 26 ps

Broadband VLBI delay precision is precise enough to use NH-VLBI

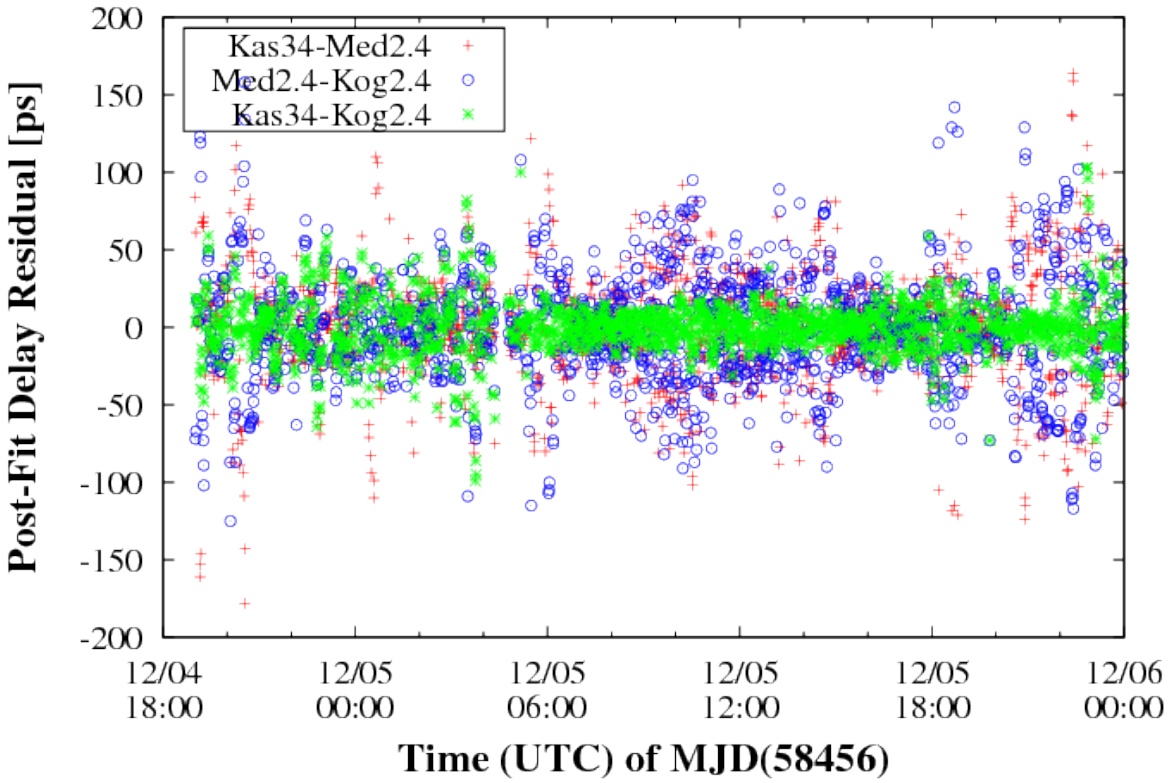


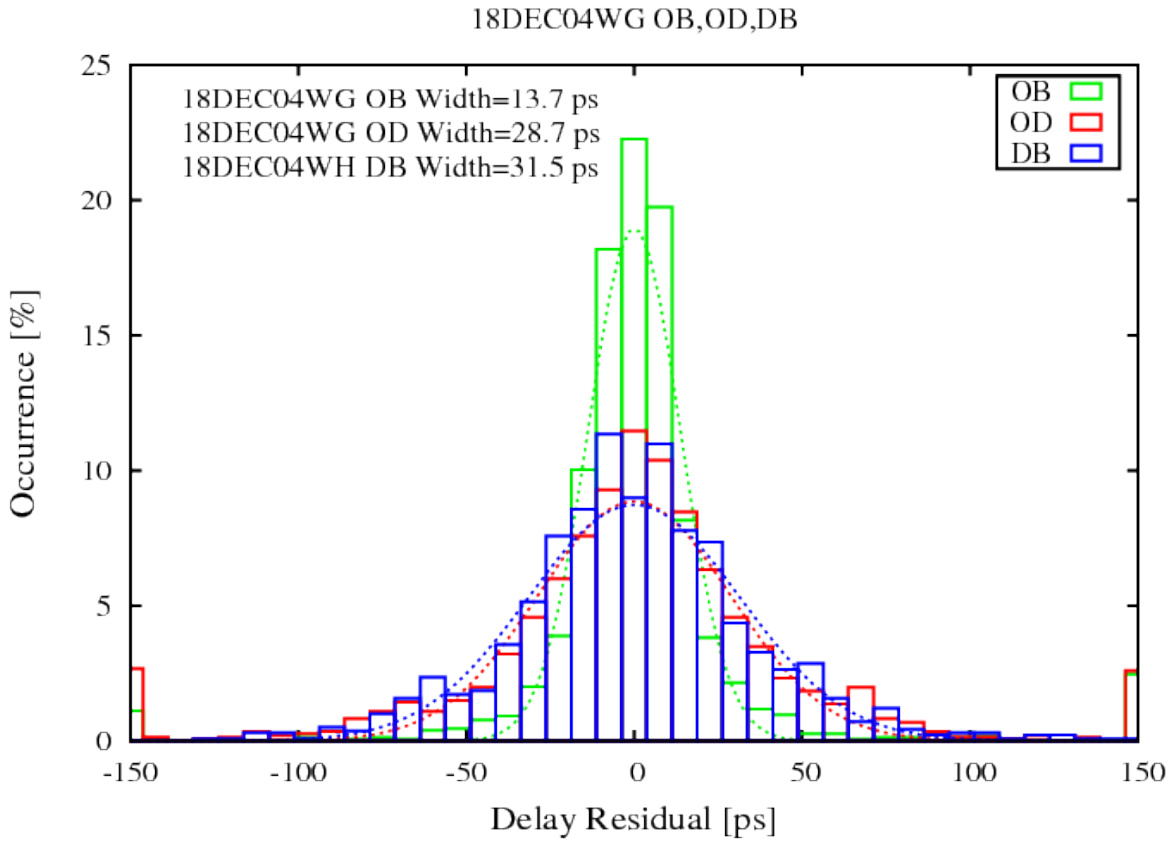


Delay residuals of 'Node-Hub' style VLBI

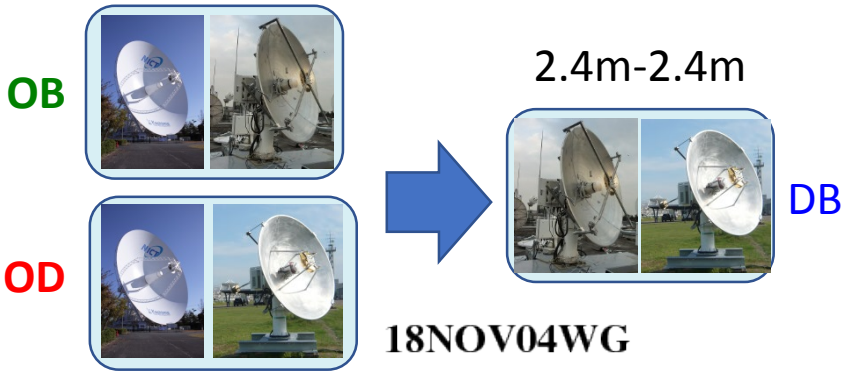


- OB(100km) baseline residual ~ 14ps
- OD and DB (8700km) baseline ~ 30 ps

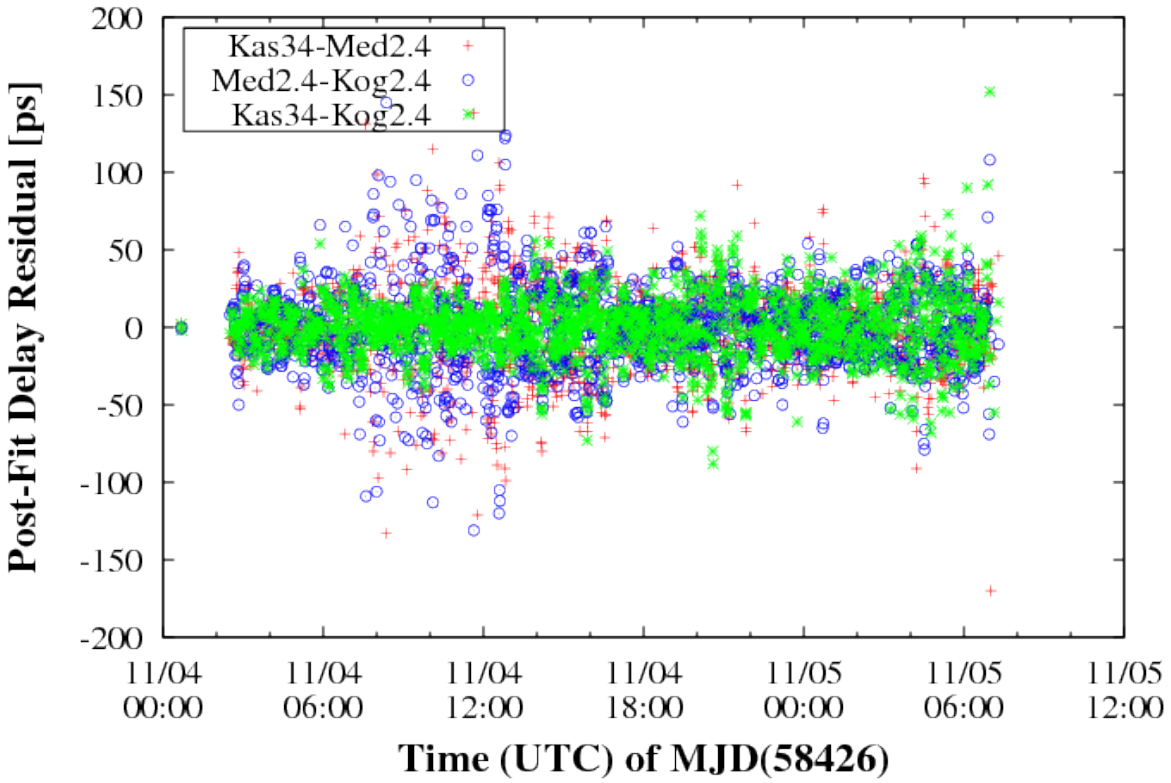


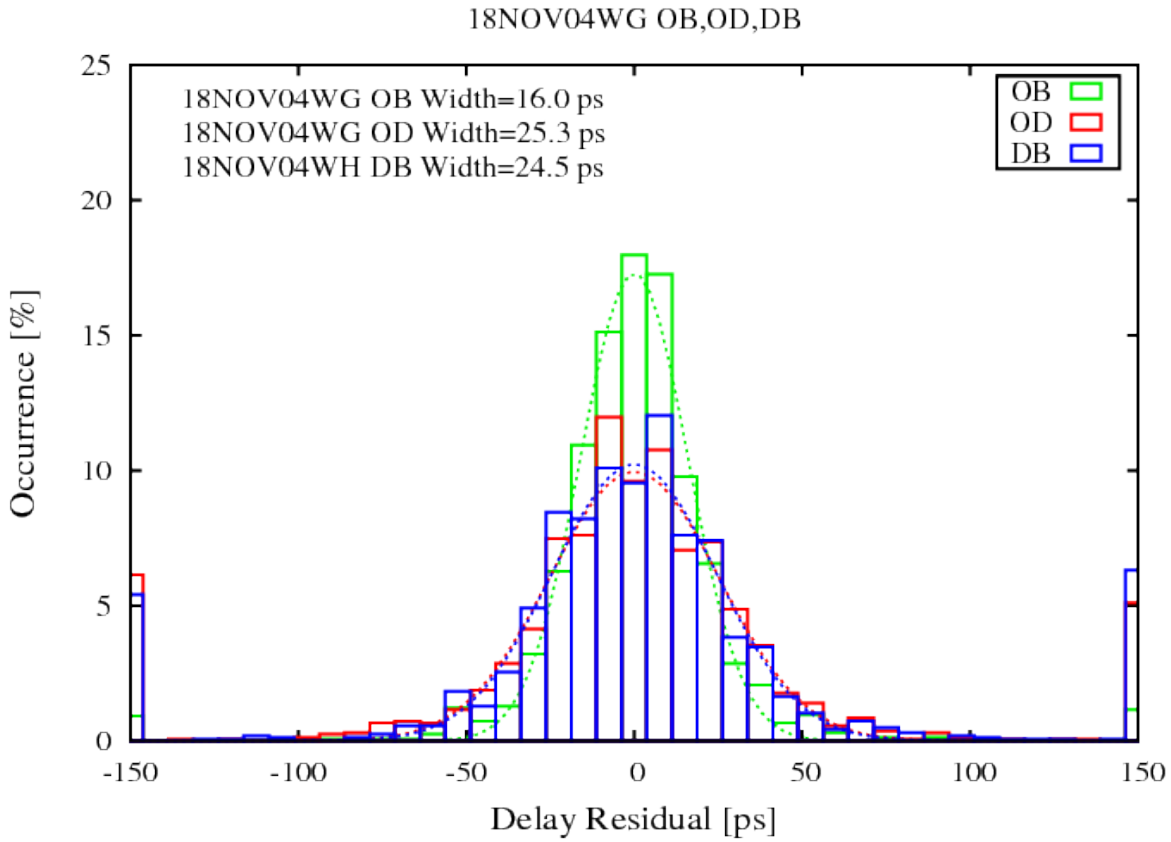


Delay residuals of 'Node-Hub' style VLBI

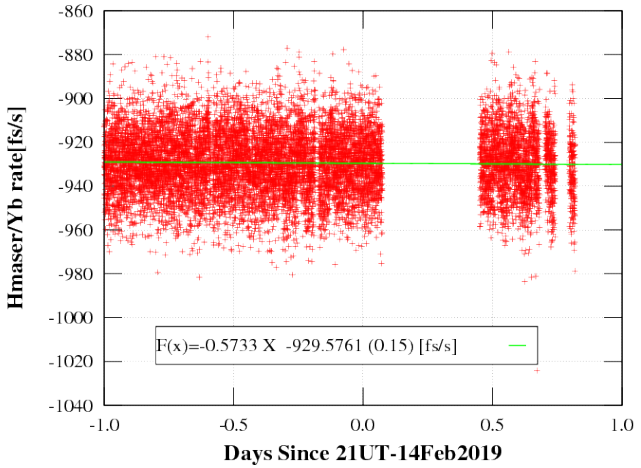


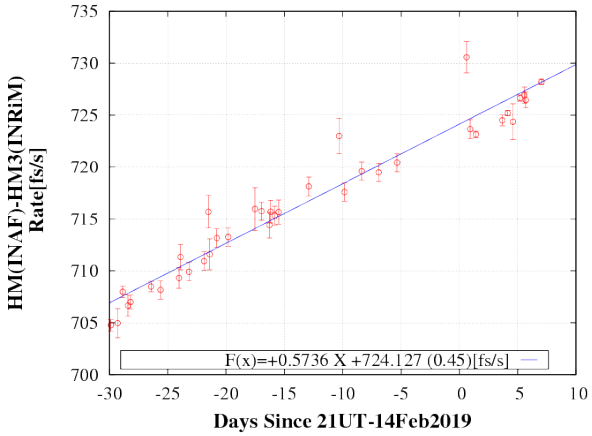
- OB(100km) baseline residual ~ 16ps
- OD and DB (8700km) baseline ~ 25 ps

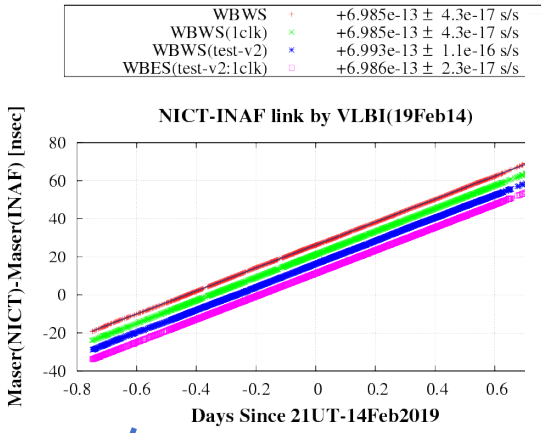


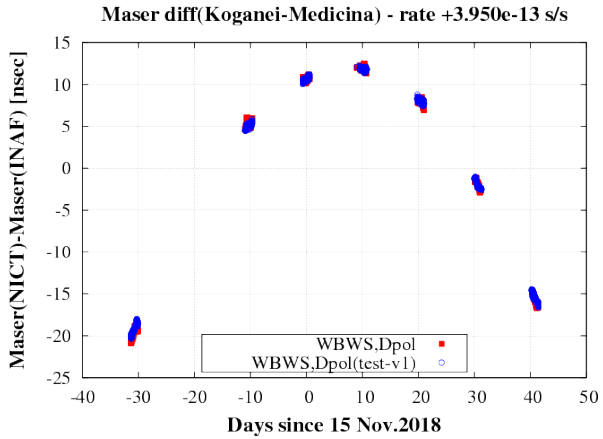


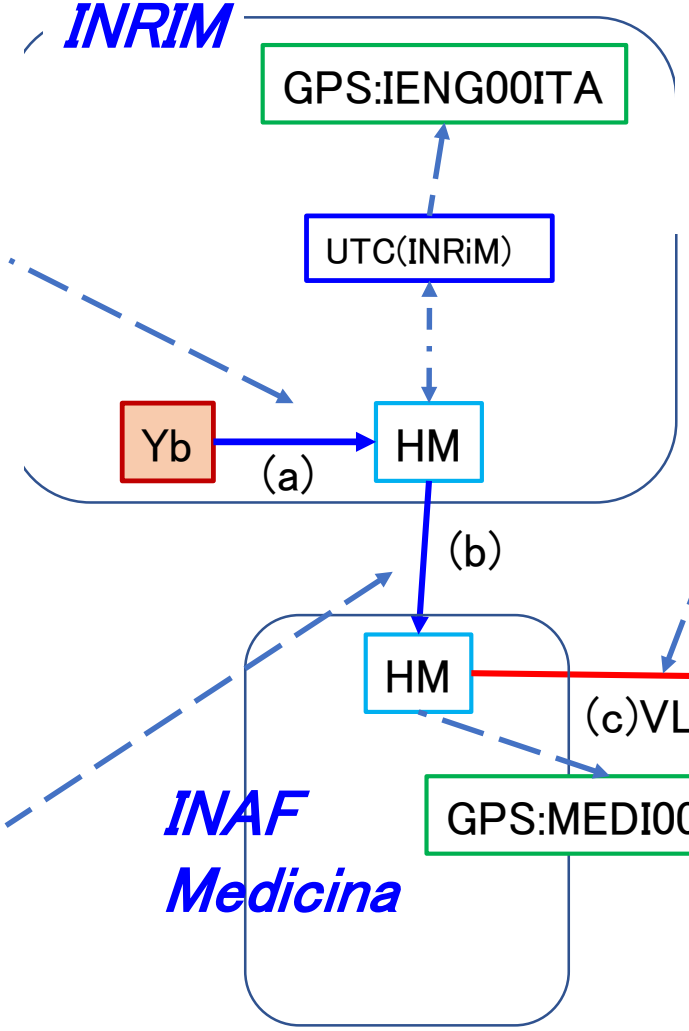
Freq. Link Block Diagram

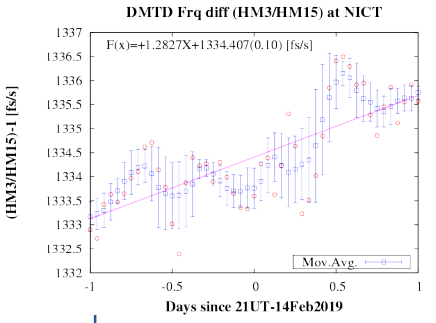


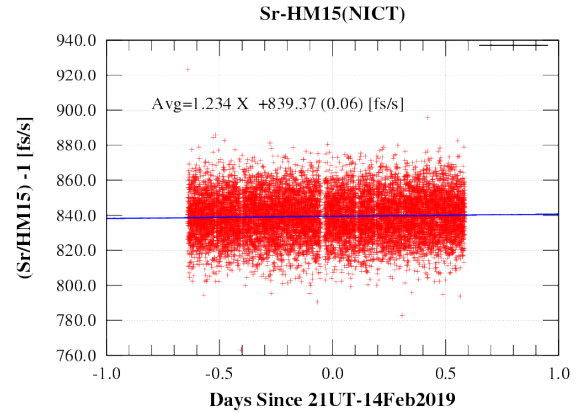












Preliminary summary of Sr/Yb Freq. Link by single session in the experiments for Dec. 2018- Feb.2019

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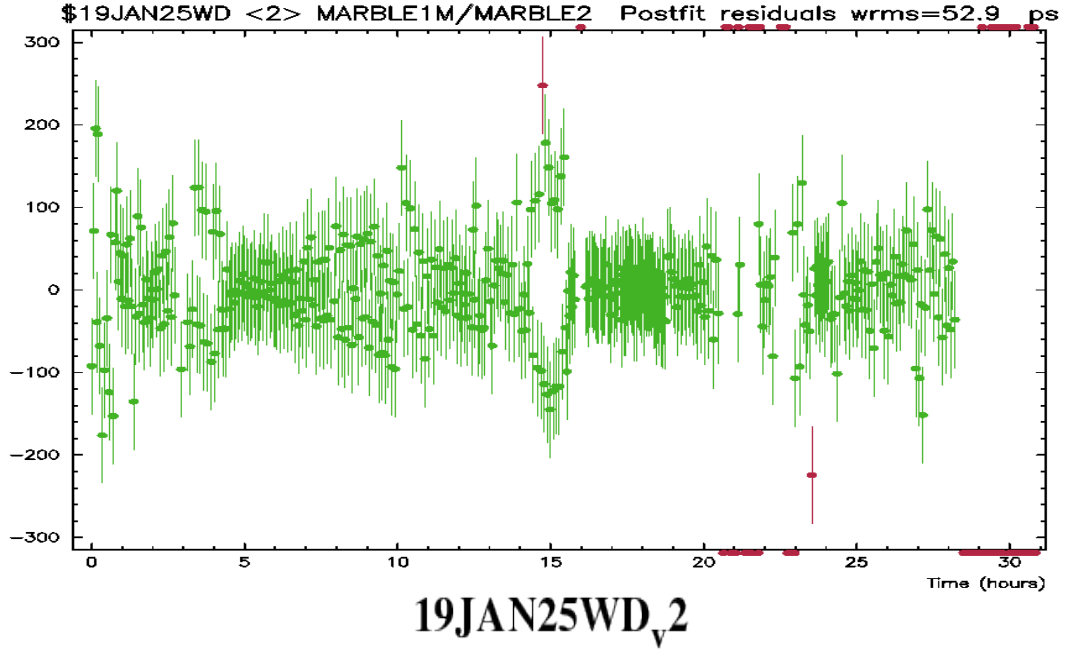
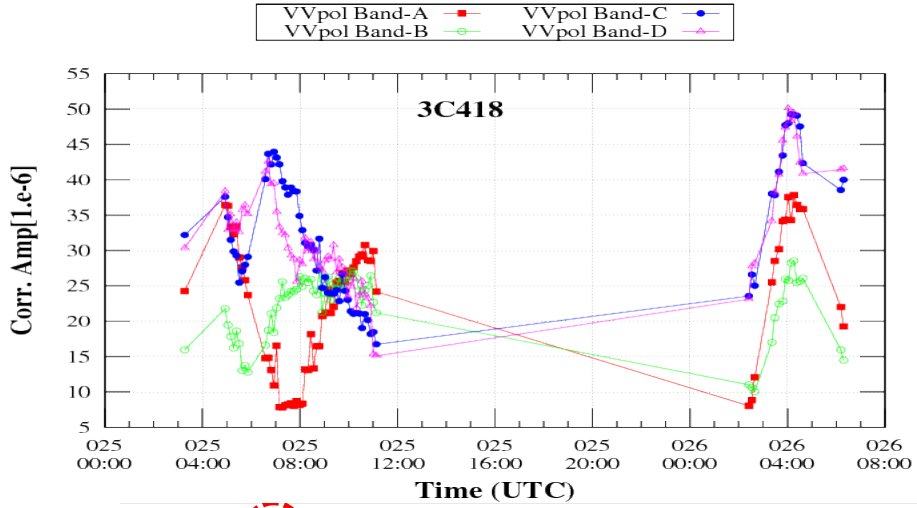
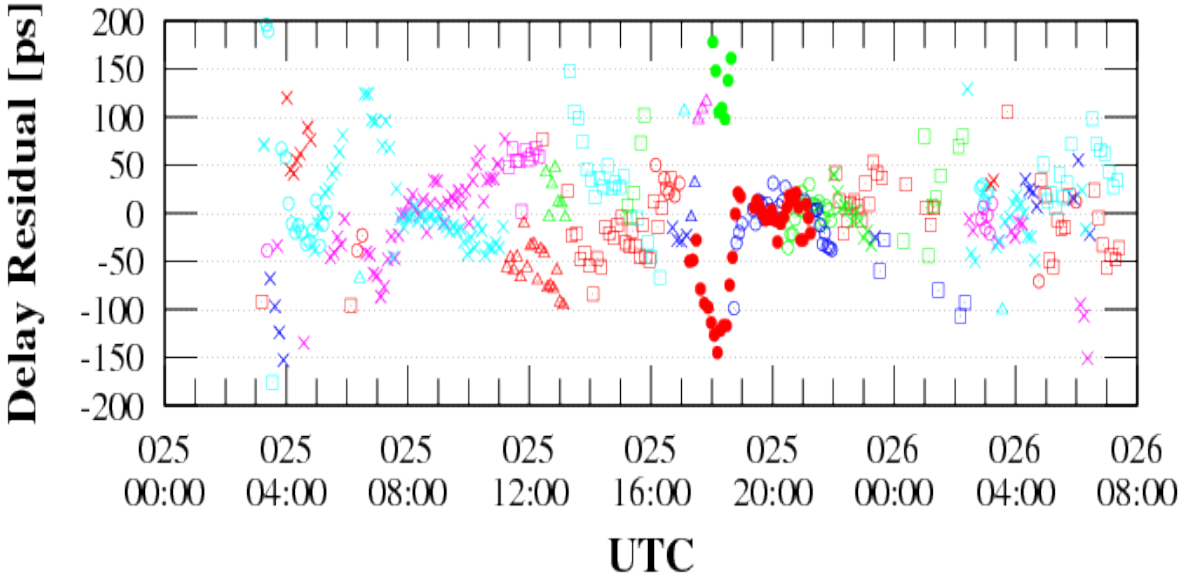
One of the Error Sources: Splitting of Residual







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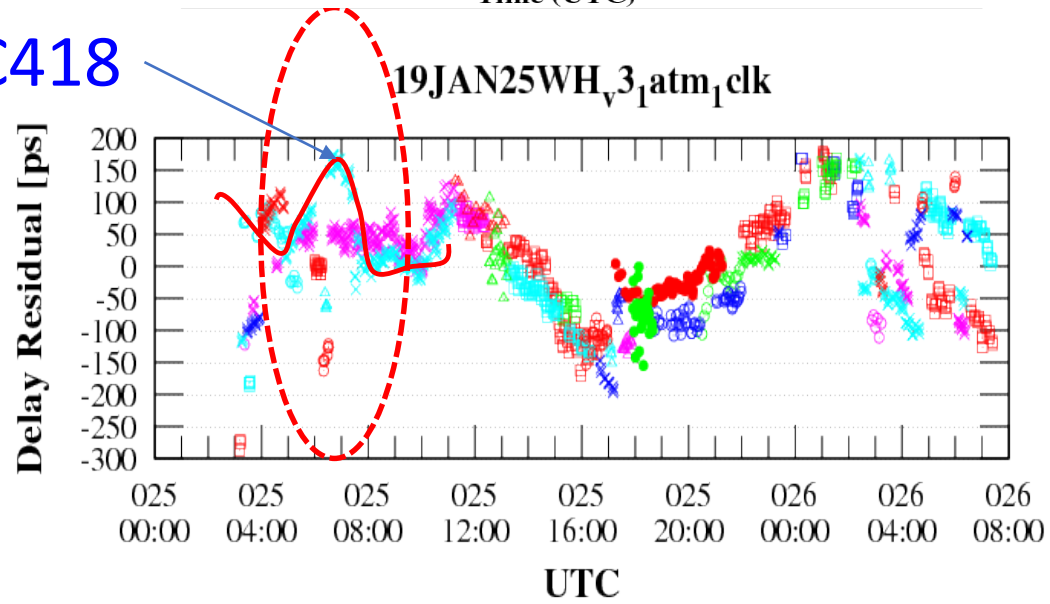
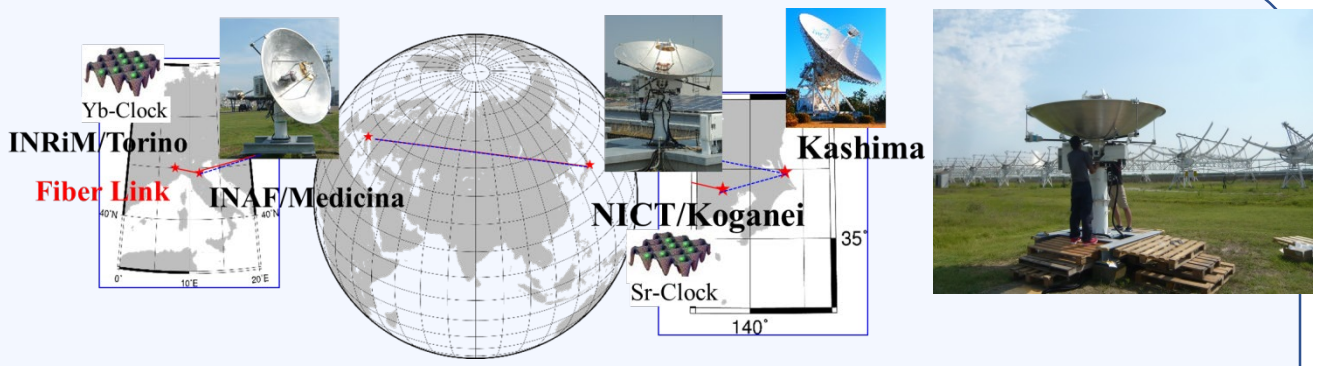
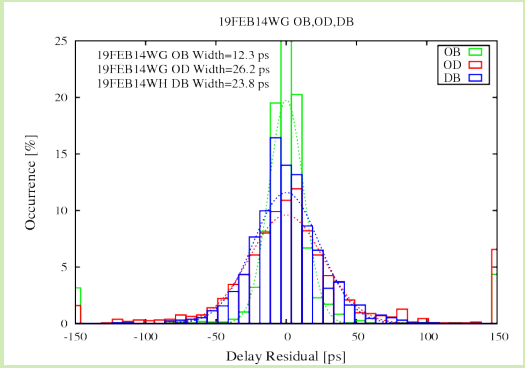
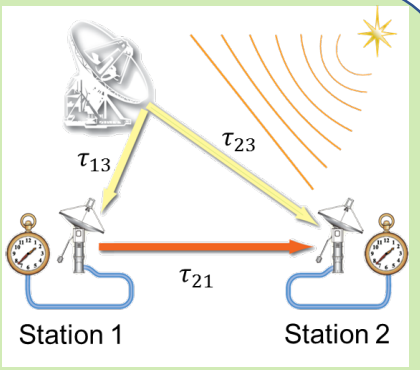


Summary



Installation of broadband 2.4m Antenna to Medicina for Optical Clock link.





Node-Hub style VLBI works with Broadband 2.4m antenna

1. **Broadband 2.4m diameter GALA-V** system was installed at INAF/Medicina. We started frequency link experiments from Oct. 2018. We are targeting frequency link in order of -16.
2. **Node-Hub style VLBI scheme** in our experiments works properly with small(2.4m) Broadband VLBI station. This might be an future option of VLBI observation with low cost terminal.
3. Significant source dependent delay residual need to be investigated.

Thank you for your Attention

Acknowledgements

- IPPP results were computed by J. Leute and G. Petit of BIPM using the CNES GINS software.
- Highs speed research network environment is supported by JGN,GARR, GEANT, Internet2, and TransPAC. High speed data transfer(~5Gbps) of VLBI data is enabled by JIVE5ab developed by H.Verkouter.
- Our project is supported by VLBI Analysis software Calc/Solve, Antenna Control Field System9, scheduling software Sked are developed by NASA/GSFC.