Development of Wideband VLBI System with Transportable Small Telescope for Distant Frequency Transfer

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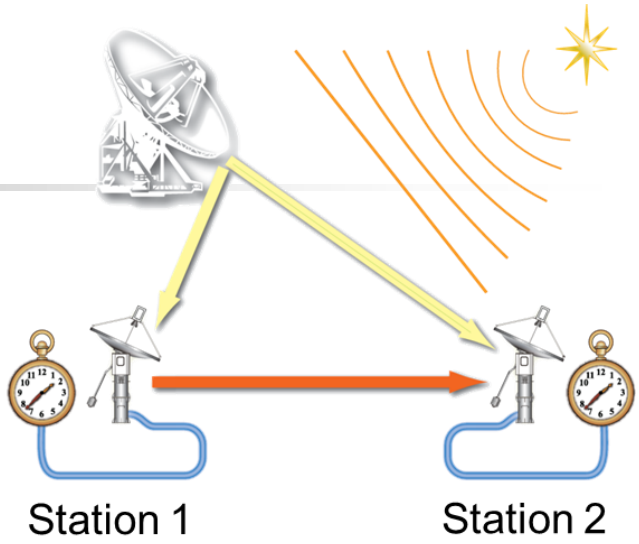
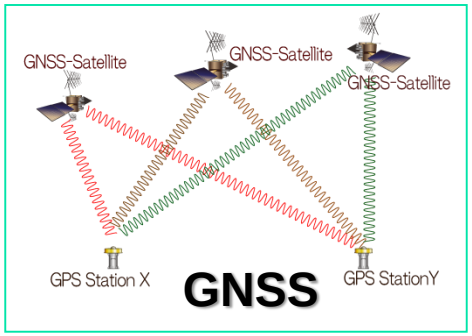
T. Kondo,T. Hobiger, S.Hasegawa, R. Ichikawa,
and Y. Koyama

Contents of presentation

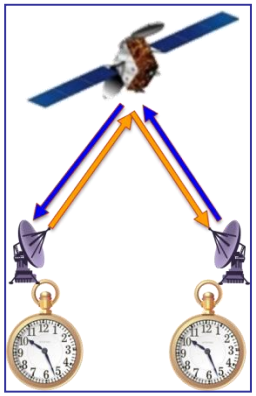


1. Frequency transfer via VLBI
2. Gala-V system Development
   - Broadband observation(3-15GHz)
   - VLBI Observations with transportable small antenna(M1,M2) pairs and Large antenna.
   - Compliant with VGOS (Next generation Global VLBI system)
3. Installation to NMIJ(Tsukuba) and NICT(Koganei)
   - Geodetic observation after installation
   - Time Comparison analysis with VLBI data

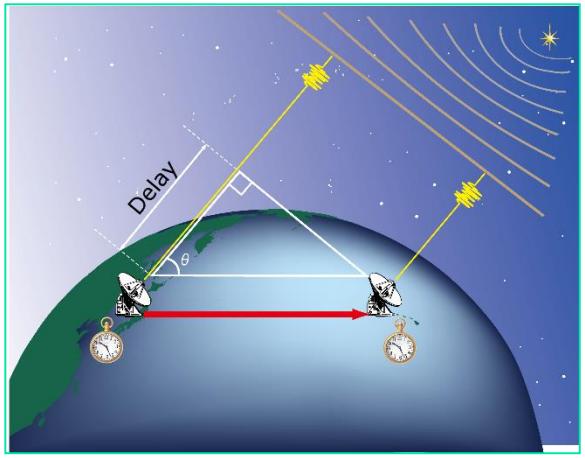
Frequency Transfer over intercontinental distances



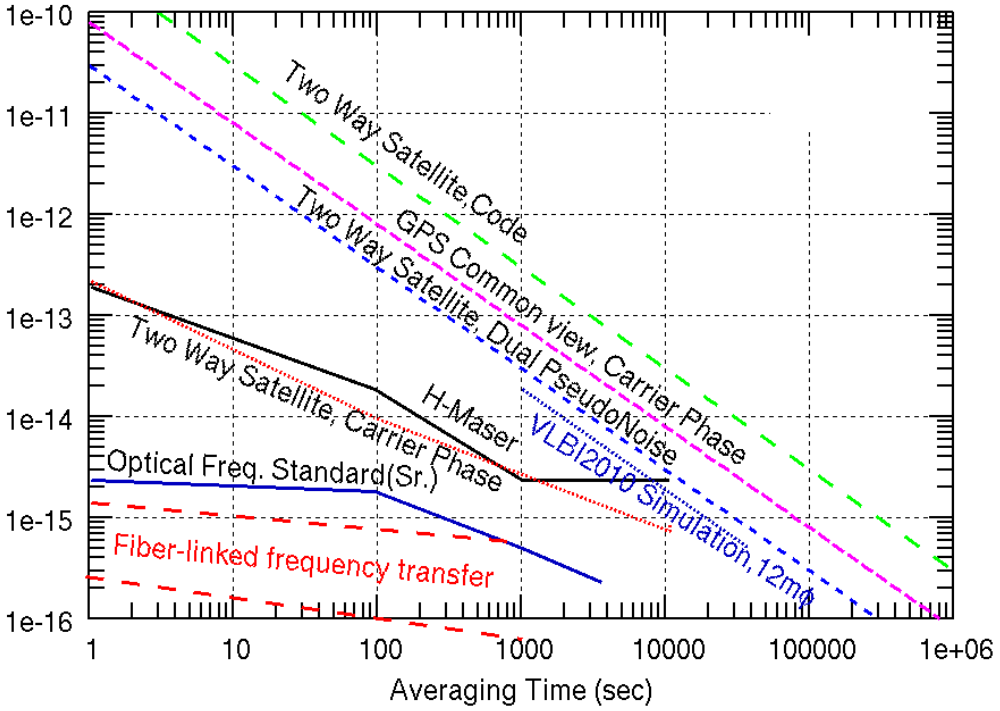
- **Space Technologies for Distant Frequency Comparison**
  - GNSS(Common view, PPP)
  - Two way Satellite Time and Frequency Transfer(TWSTFT)
  - **VLBI**



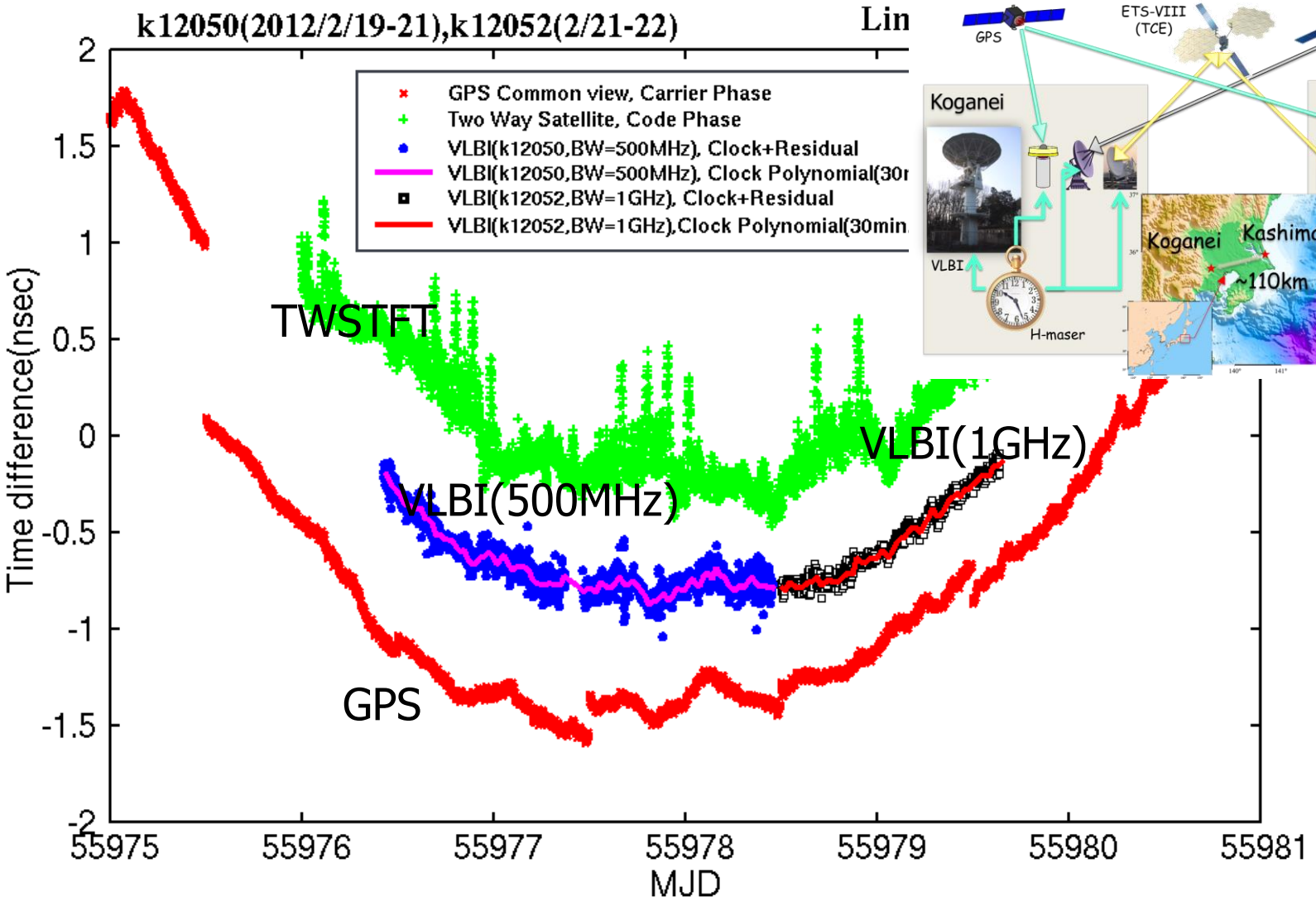
TWSTFT



VLBI

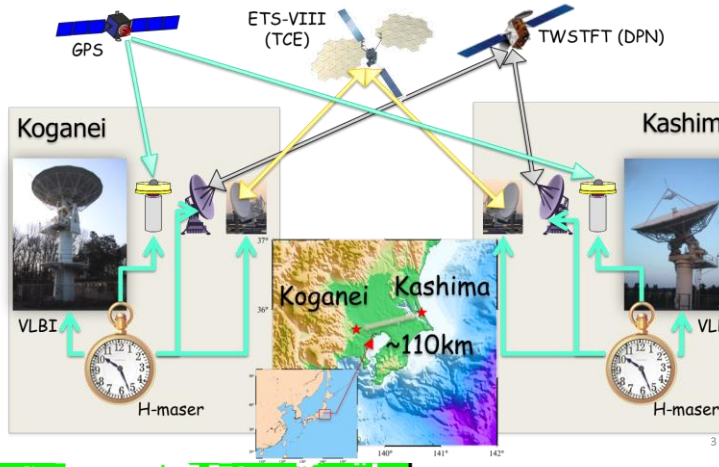


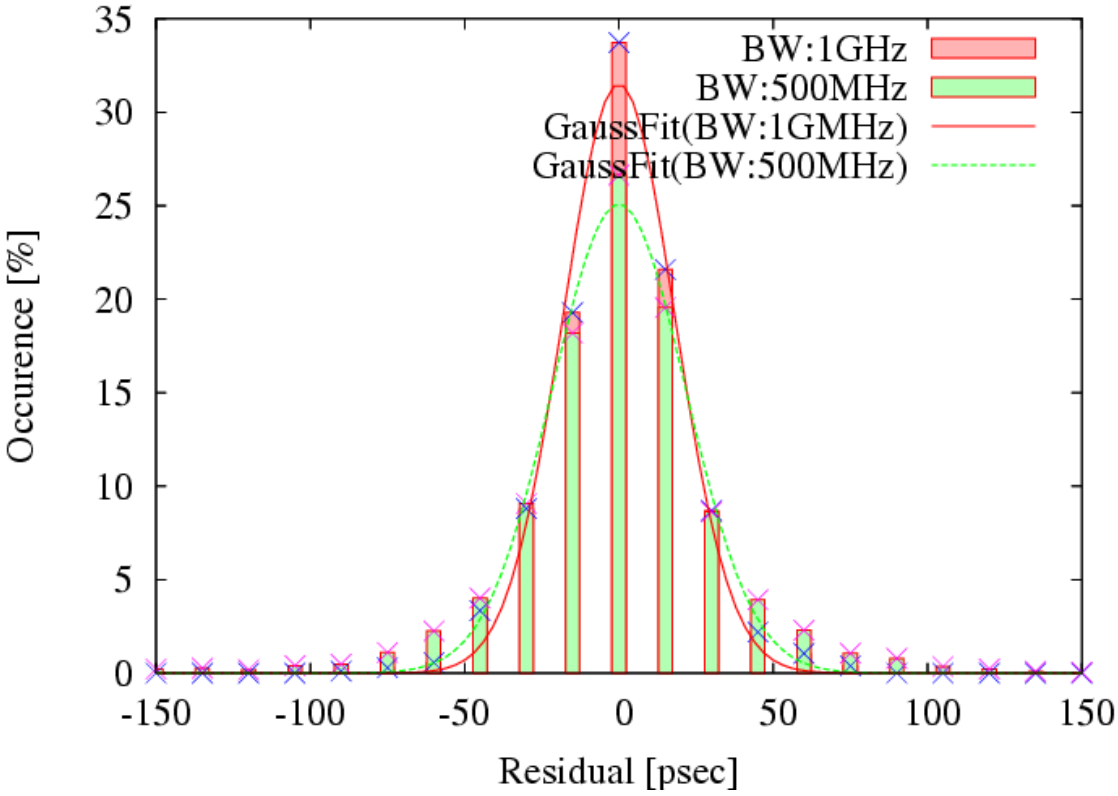
Comparison of TWSTFT,GPS,VLBI Exp. on 19-22 Feb. 2012



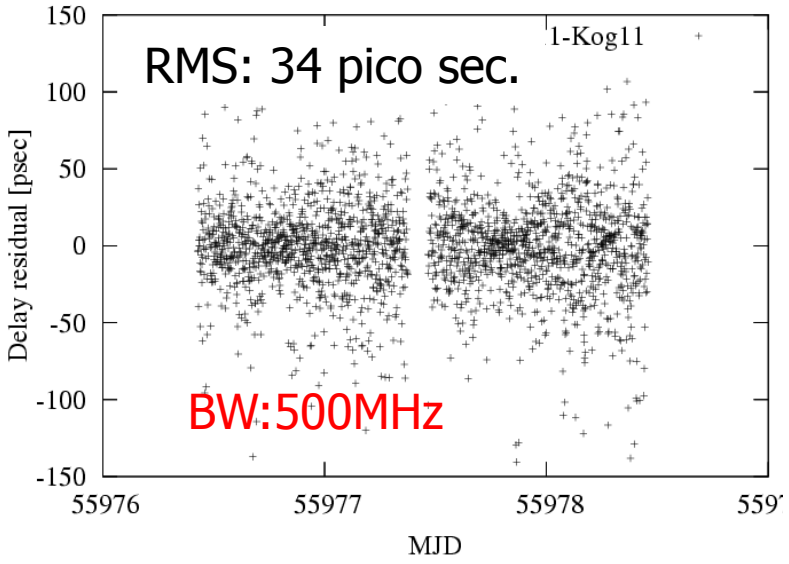
Comparison of Frequency Transfer Techniques
Experiment on 100 km baseline

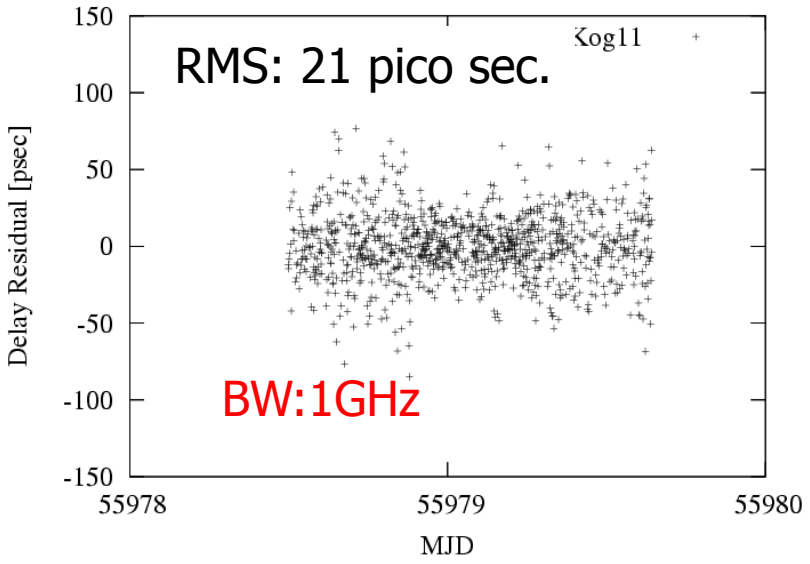
Comparison of TWSTFT,GPS,VLBI Exp. on 19-22 Feb. 2012





VLBI Delay residual is improved by expanding observation frequency band.





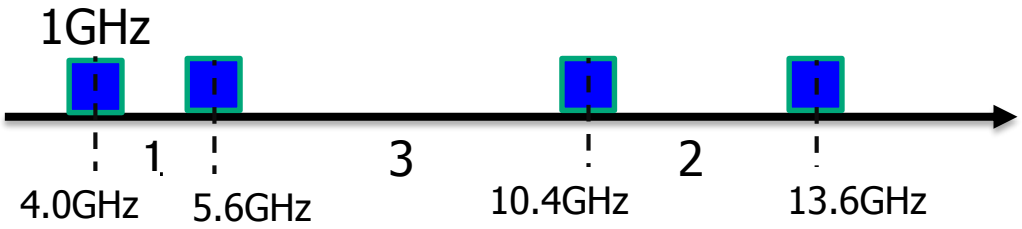
Gala-V project Overview

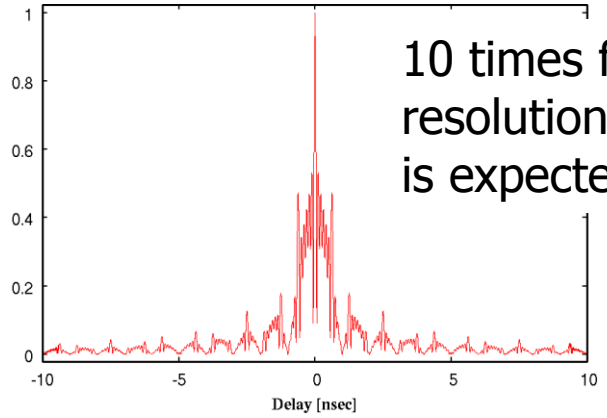
VLBI Sensitivity$=\propto D_1 D_2 \sqrt{BT}$

B: 16MHz → 1024MHz (64 times)

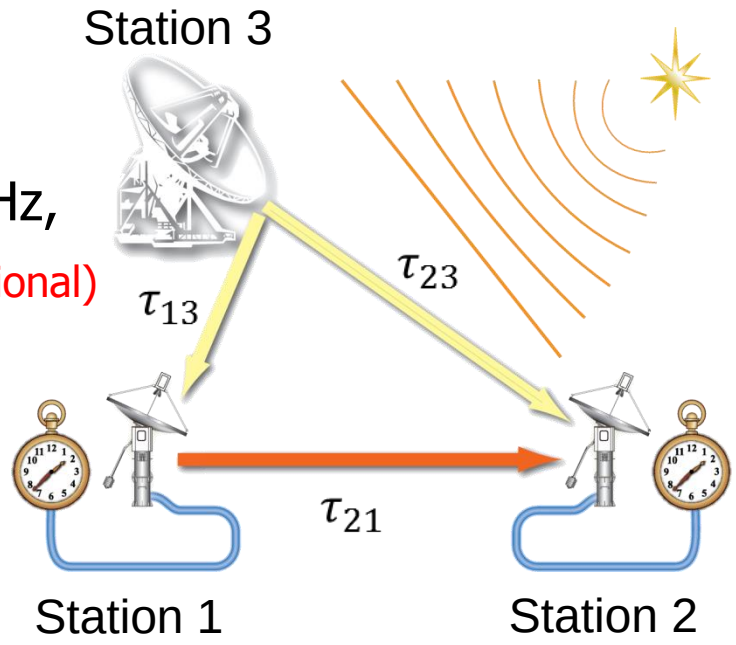
Combination of Small and Large Diameter antennas

- Obs. Freq. : 3-14GHz Freq. Range
- Observation: 4 band (1024MHz)
  - Fc = 4.0GHz, 5.6GHz, 10.4GHz, 13.6GHz,
  - Effective BW: 3.8GHz (10 times of conventional)





10 times finer delay resolution function is expected.



$$\tau_{21} = \tau_{13} - \tau_{23} + O_{(1)}$$

New Technologies for the Gala-V system

Target Precision: 30 ps -> 7 ps

Broadband observation

Broadband Feed Design

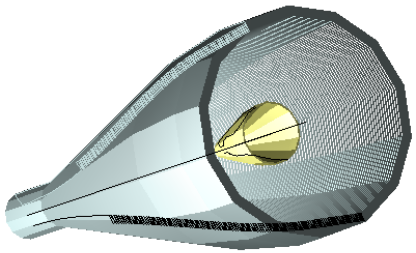


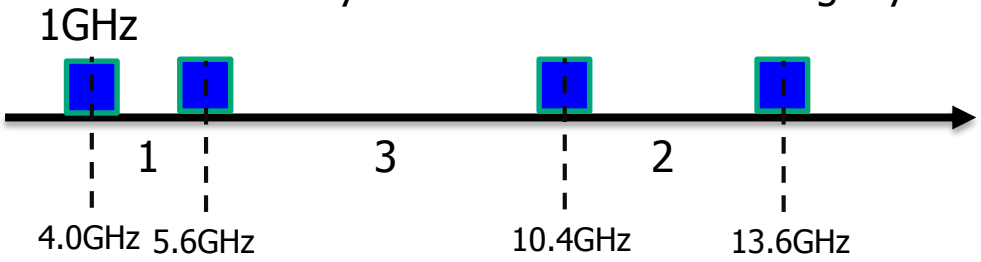
Image of `Iguana' feed

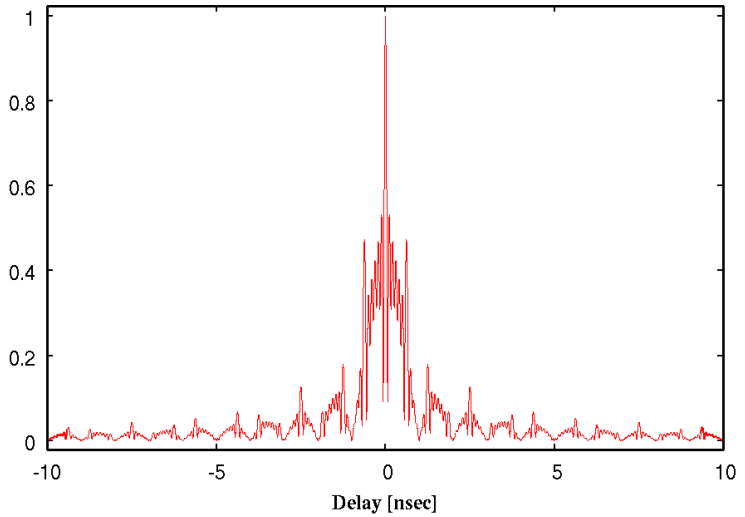
Direct RF Sampling

High speed sampler (16GHz) GALAS

Bandwidth Synthesis for 10 times wider frequency range

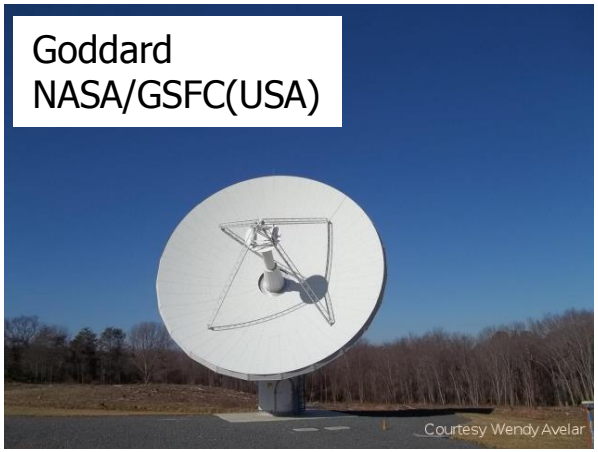
- Zero redundancy Array for 4 channels.
- Fine Delay resolution without ambiguity.

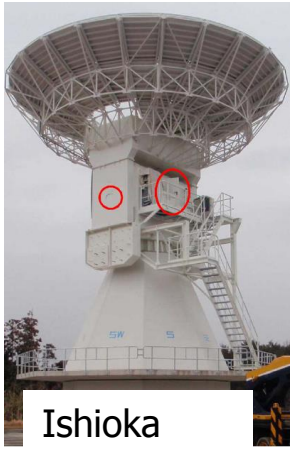




VLBI2010 Global Observing System VGOS(Next generation Geodetic VLBI)

- Radio Frequency:　2-14GHz
- Antenna Slew Speed:（>3deg/sec)
- Target Accuracy:　1mm



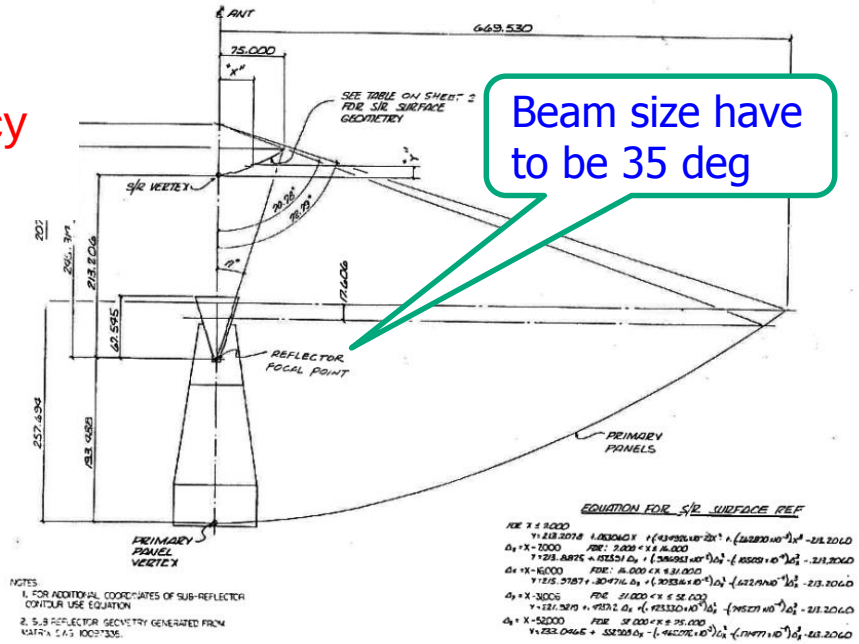


Broadband Feed Development

Requirement:

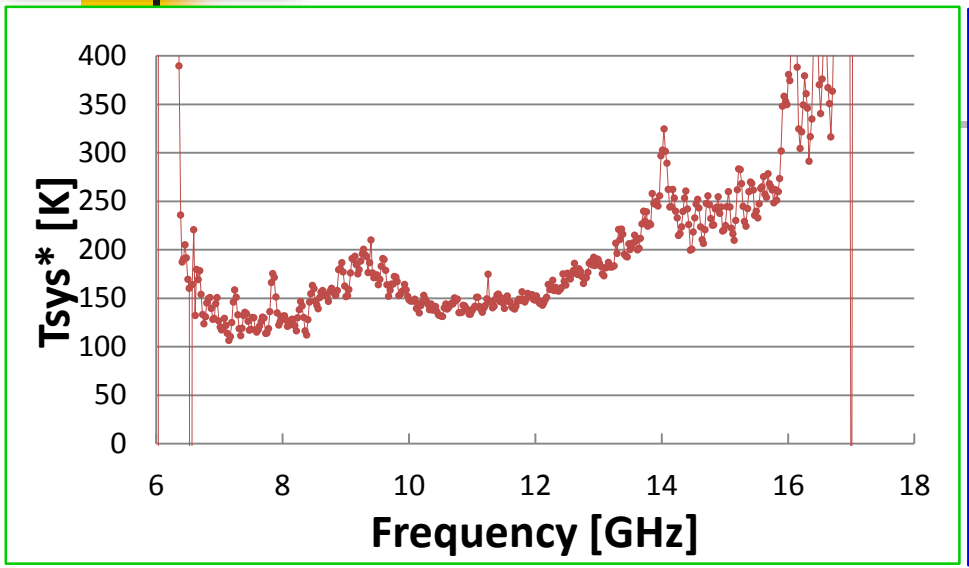
- 35 deg. Beam width over the wide frequency range.

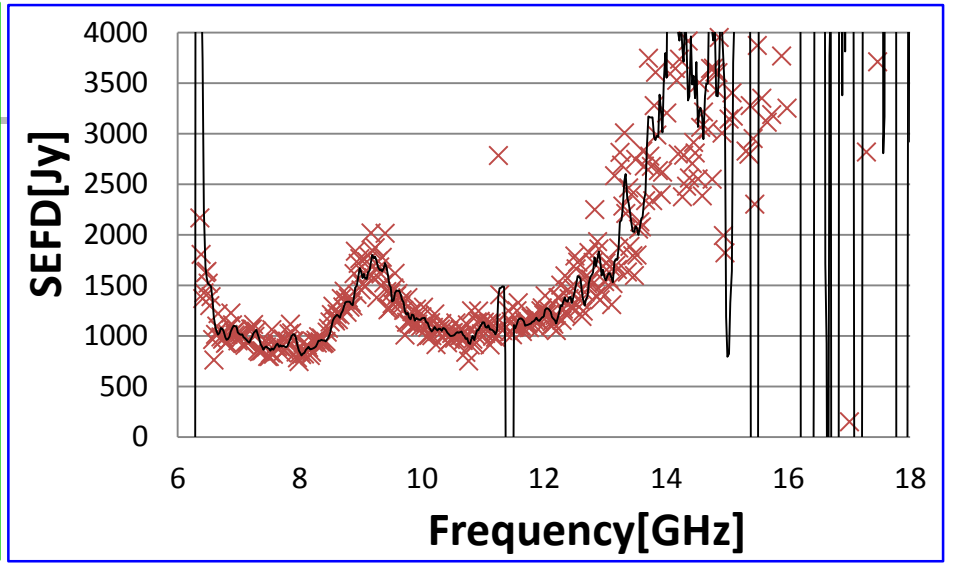
Dr. Ujihara designing broadband prototype feed and it has been installed to Kashima 34m at the end of 2013.

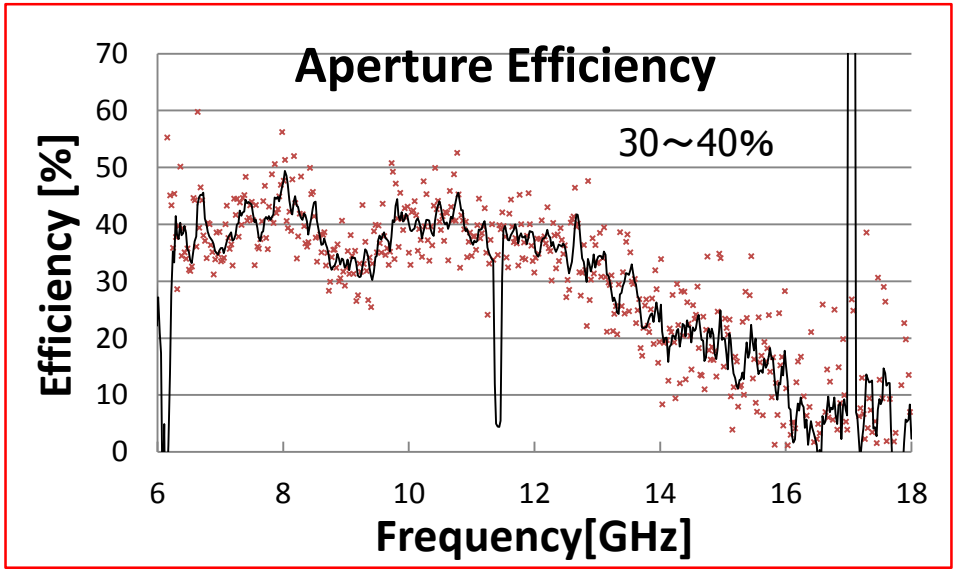


This prototype feed has sensitivity at 6.4-14GHz range.
Next design of will have 2.2-18GHz Freq. range.

Performance of the Prototype broadband Feed

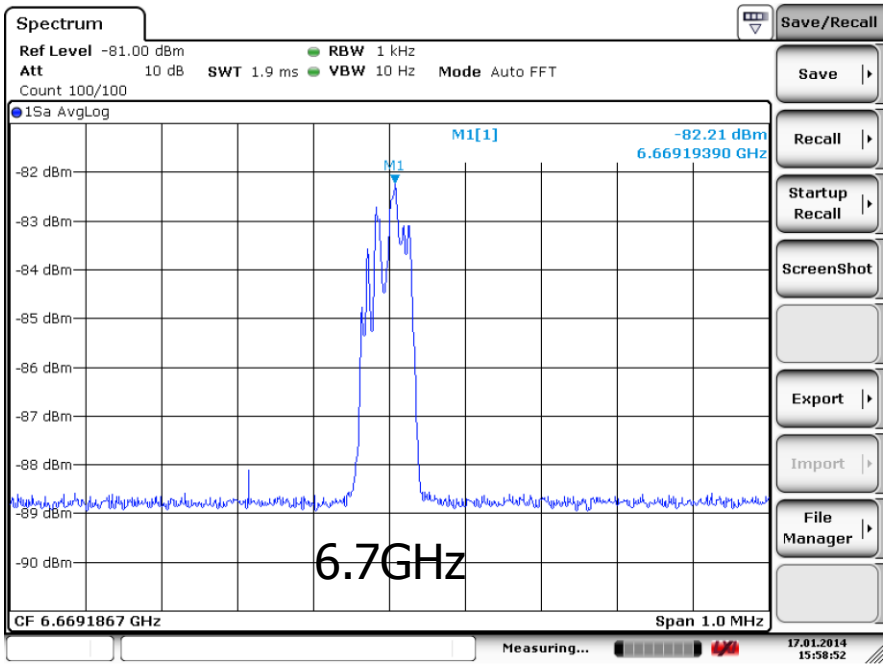




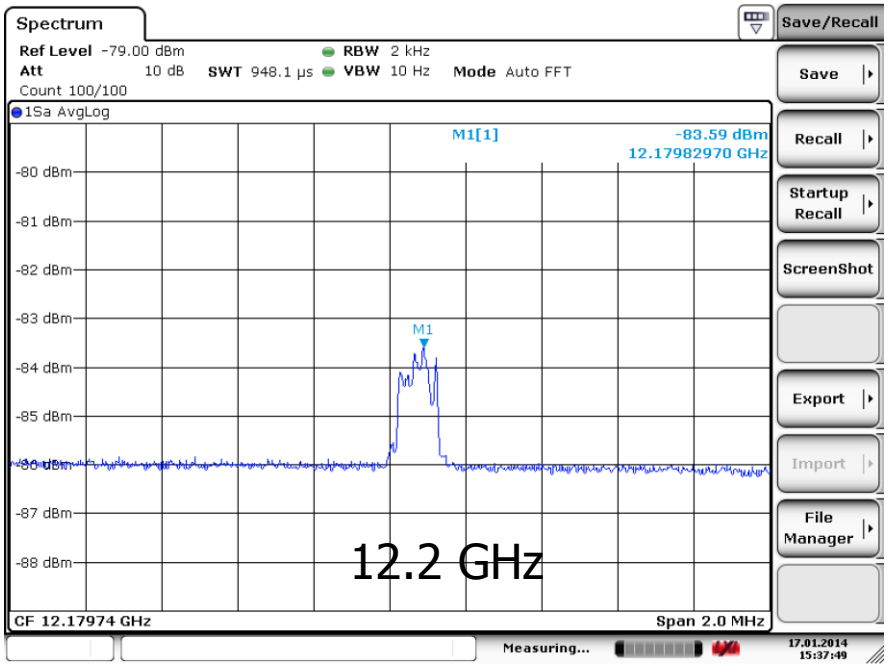


Methanol Maser

- Simultaneous Observation of Methanol Maser line at 6.7GHz and 12.2GHz on W3OH for test observation (first light) on 16 Jan.2014.

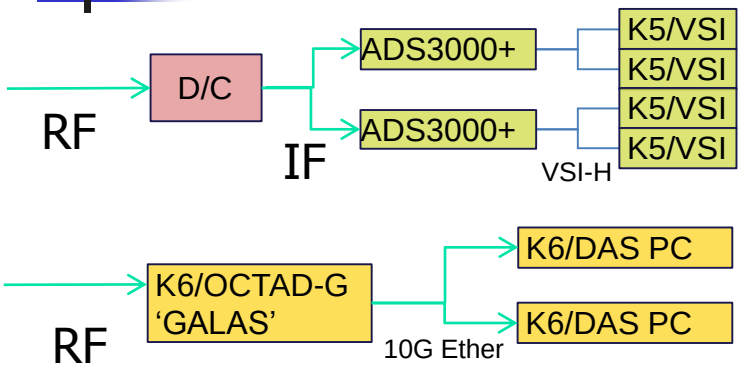


Date: 17.JAN.2014 15:58:51



Date: 17.JAN.2014 15:37:49

Data Acquisition: 1GHz x 4 Ch



Two Approaches

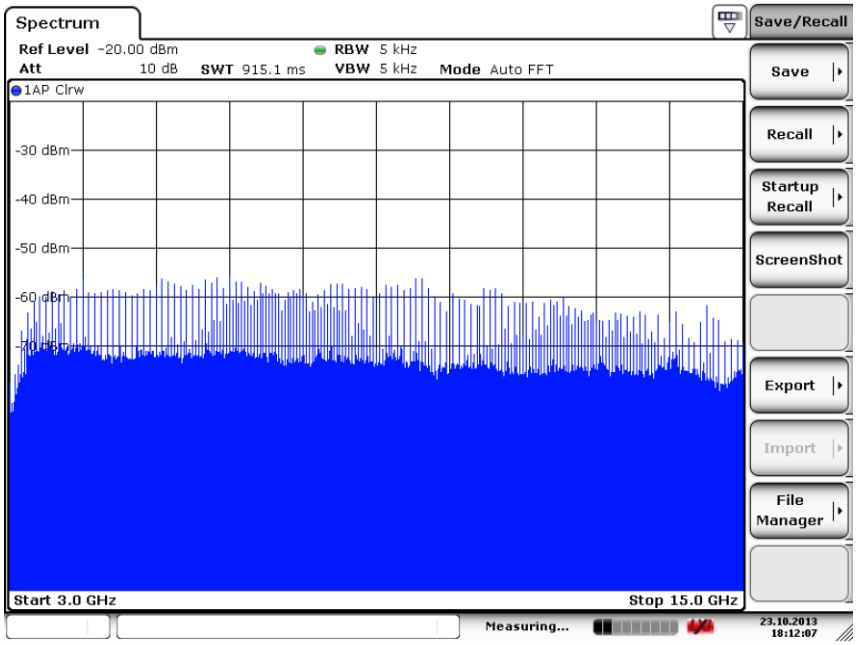
1. Analog Down Converter + "ADS3000+"
   - Digital BBC function for legacy mode observation.
2. Direct Sampler "GALAS"
   - Digital Down Conversion function for any frequency by 1MHz step.

ADS3000+ Sampler
DBBC or 2 Gsps

Sampling Rate	**16384MHz**
Output data rate	**4096 or 2048Msps**
Sampling Quantization	**3 bit**
Output Interface	**10GBASE-SR**
Number of analog input	**2**

RF-Box of MARBLE small antenna

Monitoring at Observation Room (3-15GHz). RBW=5kHz



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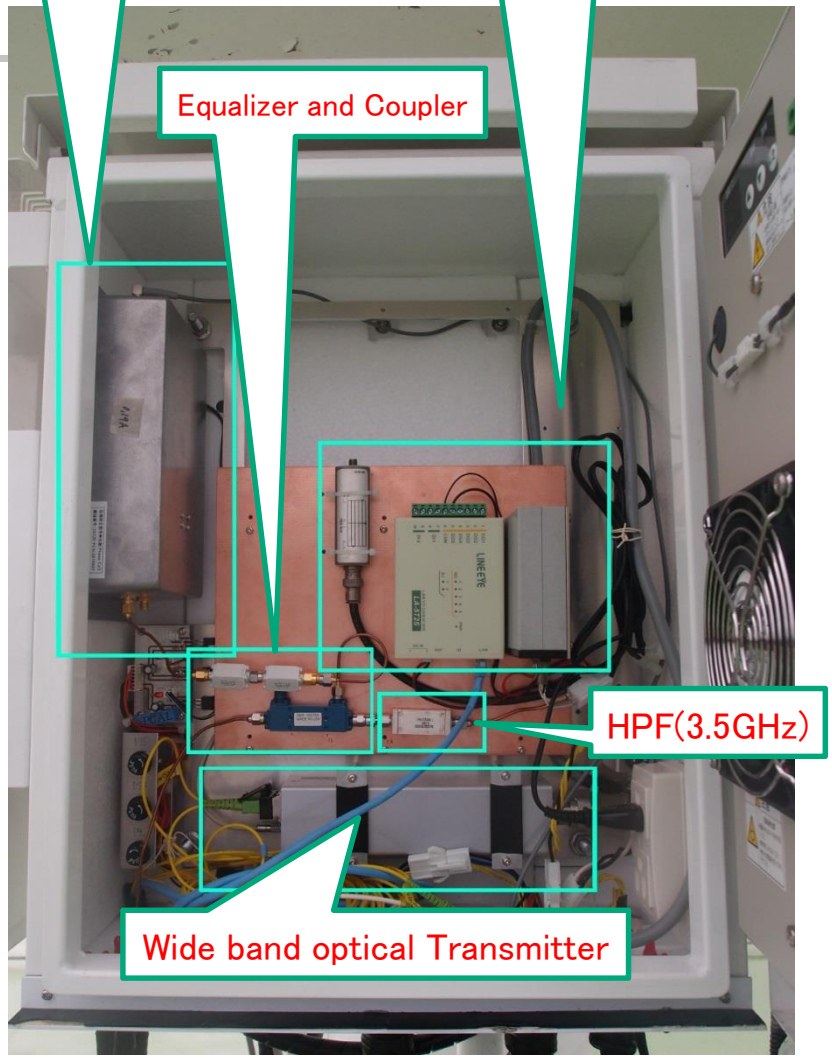
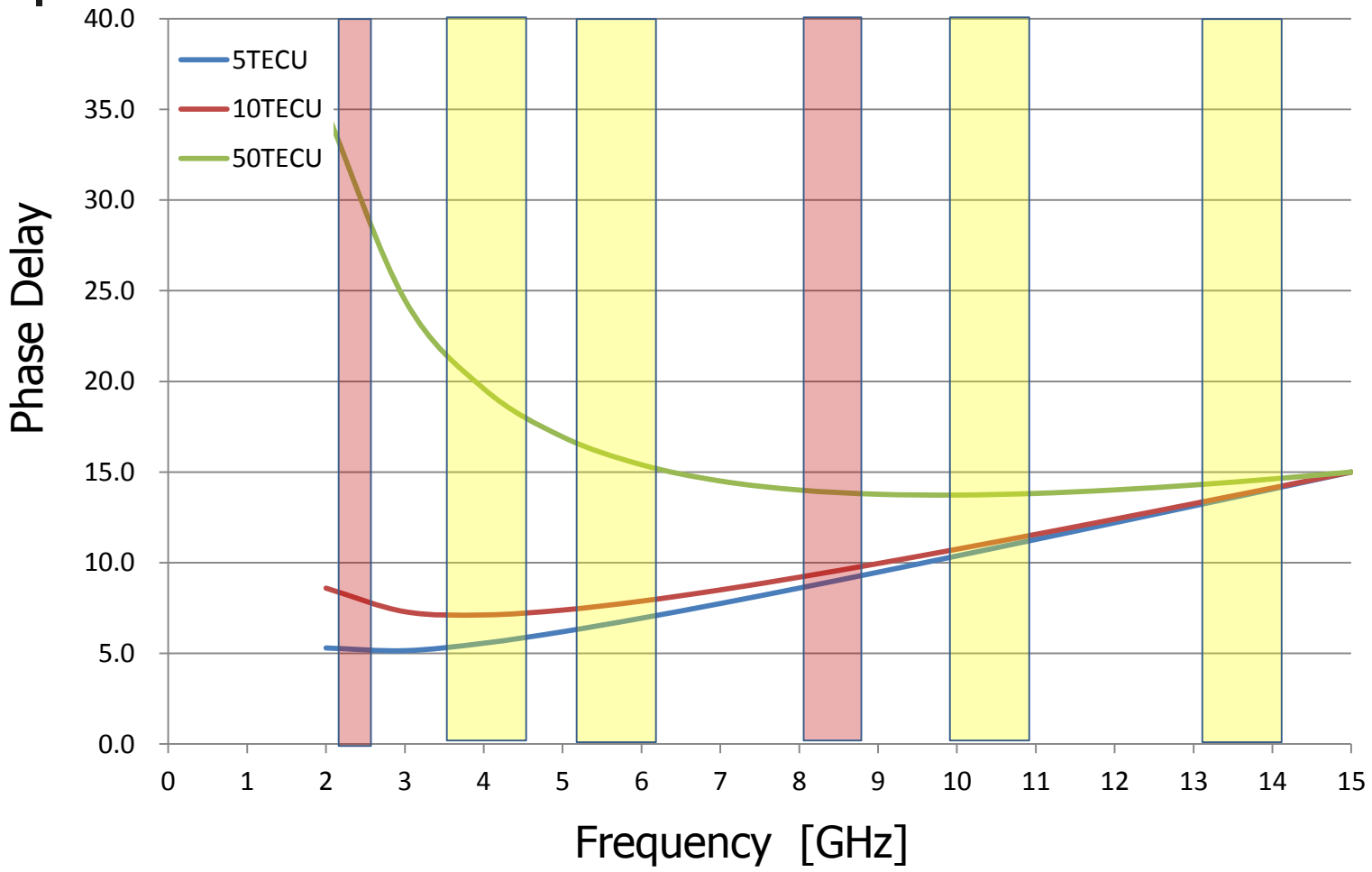
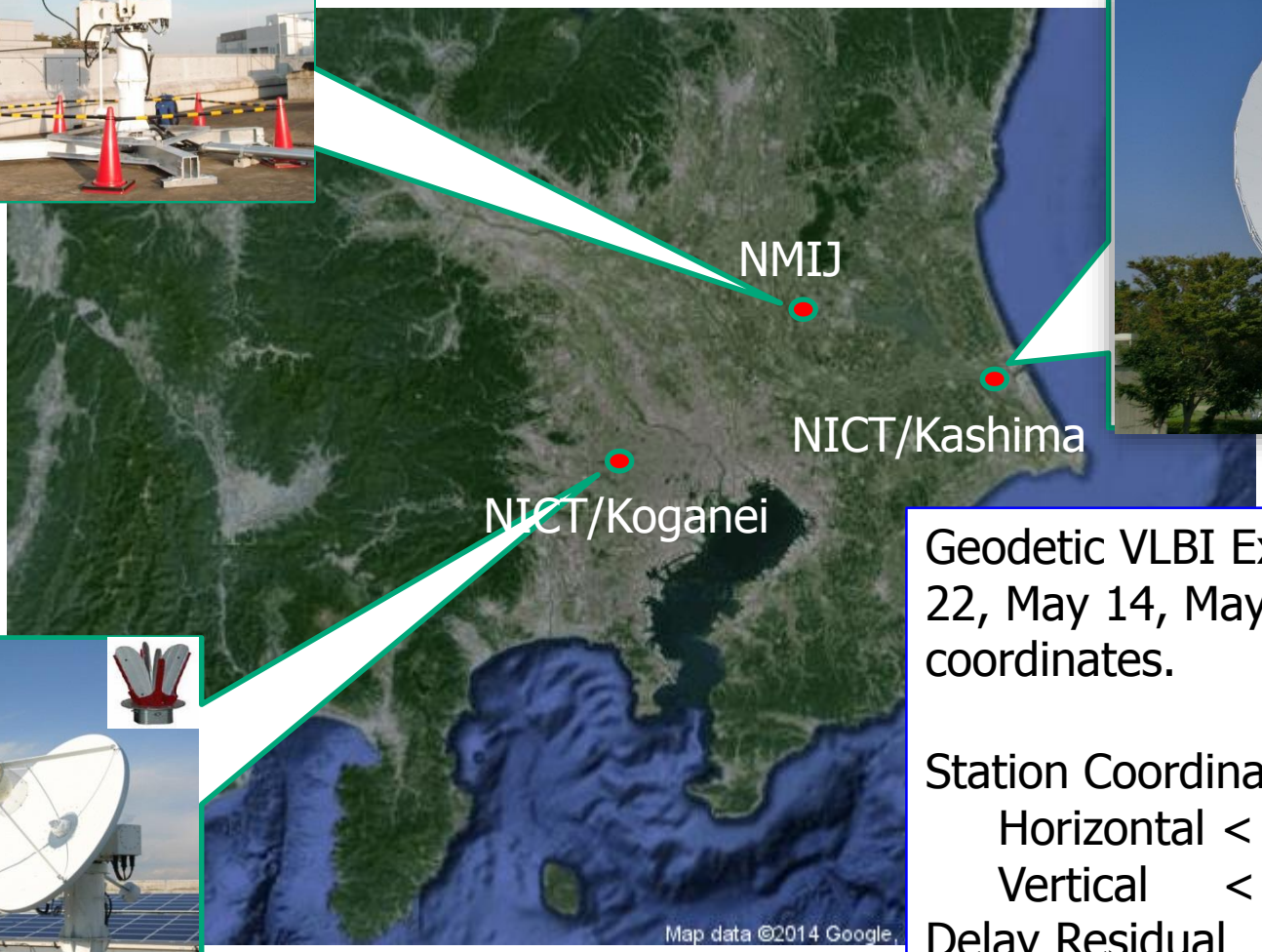


Observation Frequency Band & Ionosphere Delay Contribution



1.6m/1.5m and 34m VLBI antennas have been installed for T&F.



Geodetic VLBI Experiments on Apr. 22, May 14, May30 to fix station coordinates.

Station Coordinates Repeatability:
- Horizontal < 6mm
- Vertical < 15mm

Delay Residual
- WRMS is about 35 psec@30sec.

Ready for Observation

KASHIMA 34m

34m Antenna NICT Kashima

MARBLE2

1.5mAntenna NICT Koganei

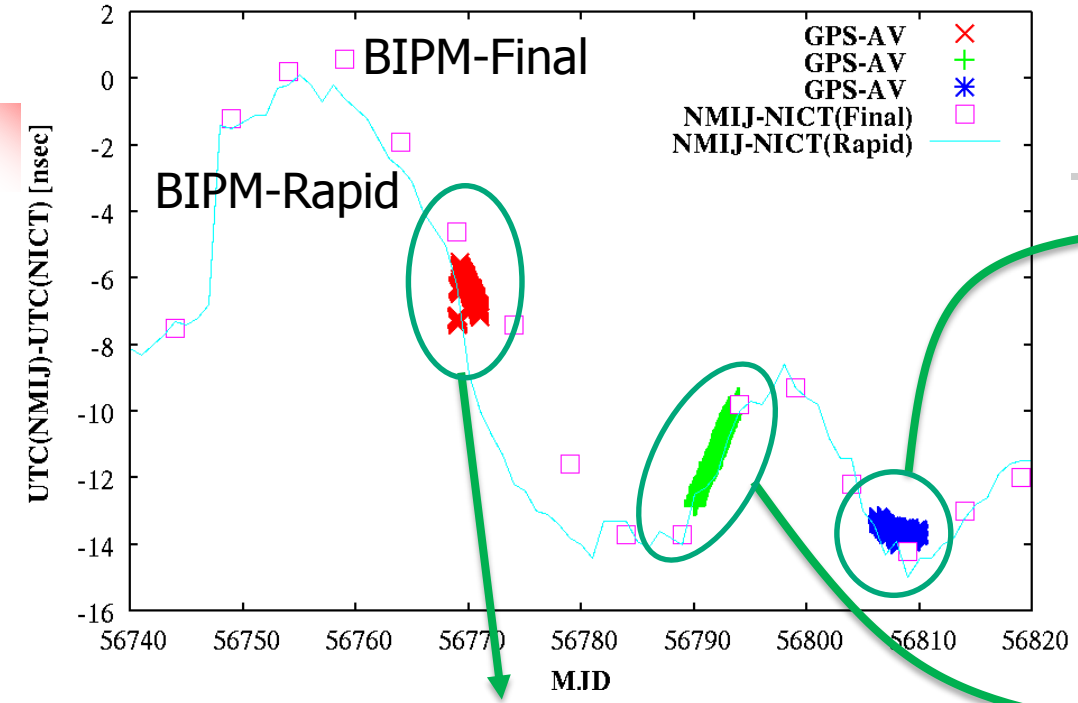
MARBLE1

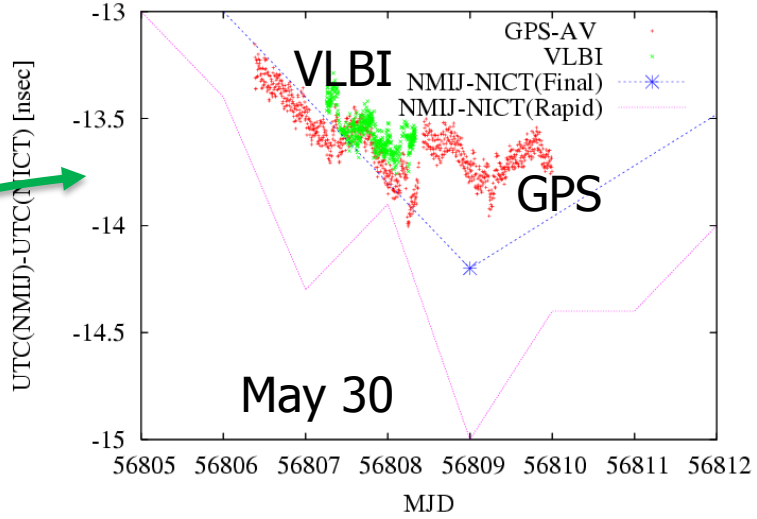
1.6m Antenna NMIJ Tsukuba

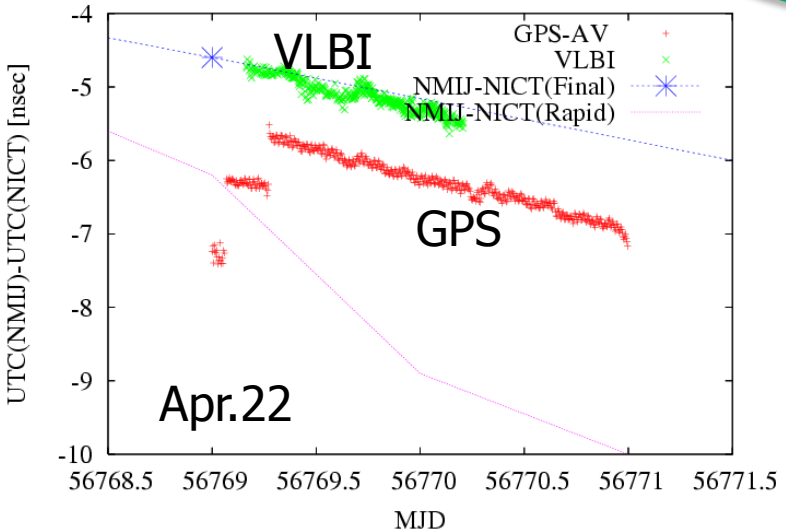
Clock Estimation

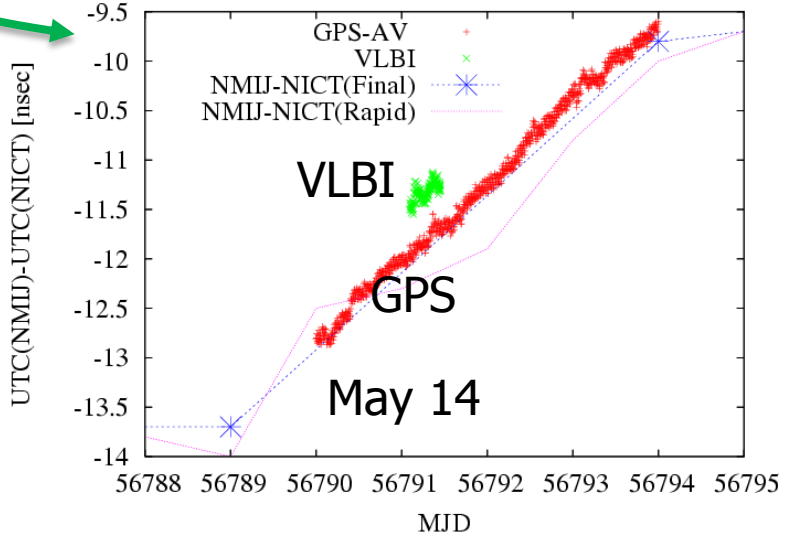
- Stations:
  - Kashima(34m),Tsukuba(1.6m),Koganei(1.5m)
- Experiments:
  - Gx14112: 2014. Apr. 22-23 24 hours.
  - Gx14134: 2014. May 14-15 24 hours.
  - GX14150: 2014. May 30-31 24 hours.
  - Geodetic solution:
    - Horizontal <5mm, Vertical <3cm
- Analysis:
  - OA,OB->AB baseline data conversion
  - $\tau_{21} = \tau_{31} - \tau_{32} - \dot{\tau}_{21} \times \tau_{32}$

Time comparison NMIJ-NICT (GPS,VLBI)

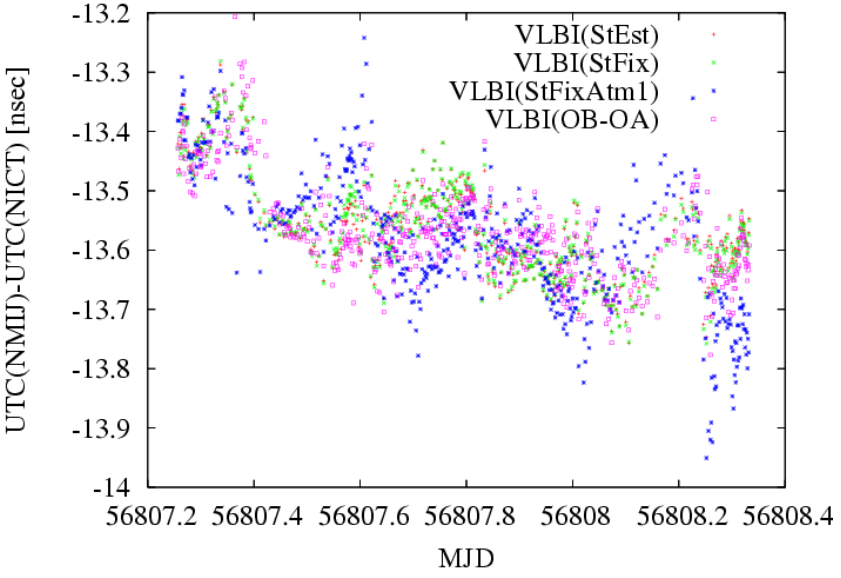


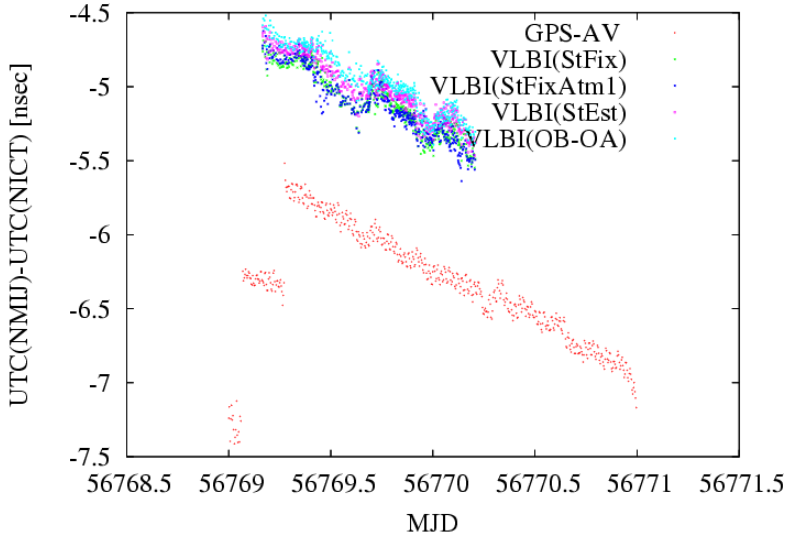






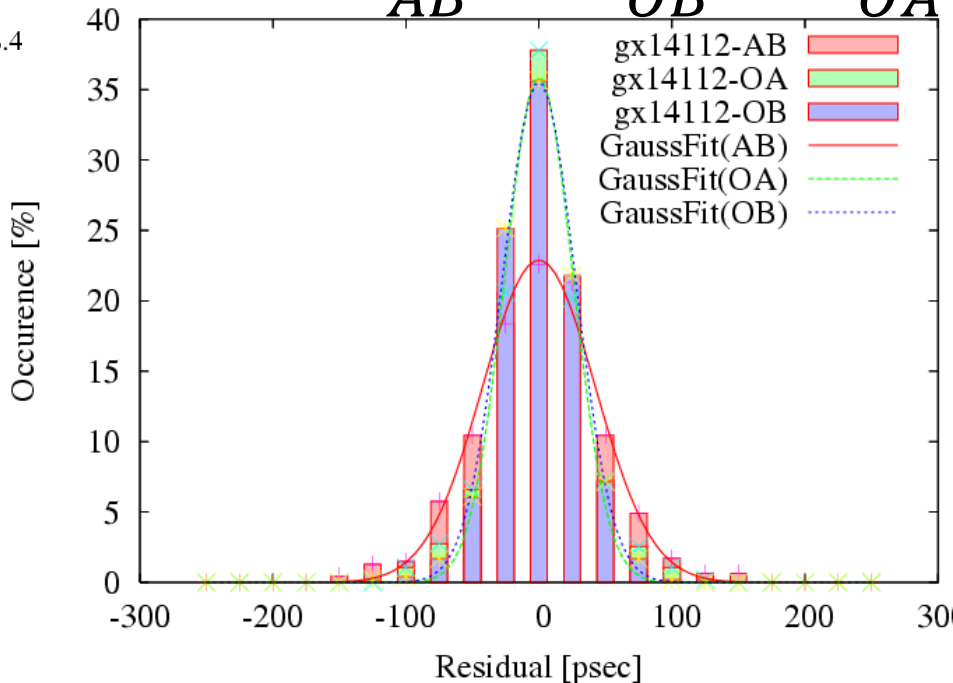
Clock Estimation from VLBI data





- Clock parameters seems is stable against changes of analysis conditions.
- Error of AB baseline data composed from OA,OB data increased by sqrt(2) as expected.

$$\tau_{AB} = \tau_{OB} - \tau_{OA}$$



Nest steps to be done

- Long span VLBI observations for frequency comparison
- Broadband Observations
  - Target Precision : (X-abnd)45ps ->7 ps
  - Domestic: Kashima34,Marble1,Marble2
    - Geodetic, Time transfer experiments
  - International: We are planning to perform intercontinental broadband observation with MIT/Haystack.

Acknowledgements

- Broadband Feed Development is supported by NAOJ-fund(Prof. Fujisawa et al.)
- Gala-V Experiments is supported by
  - NMIJ:(Dr.Watabe, Dr.Amemiya, Dr.Suzuyama)
- GPS-AV(PPP) analysis was done by Dr. H.Takiguchi

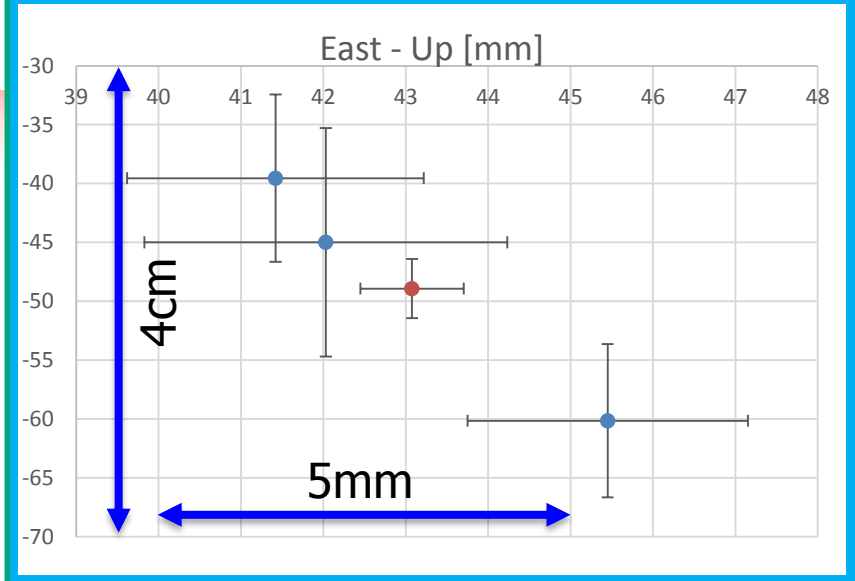
Thank you for Attention!

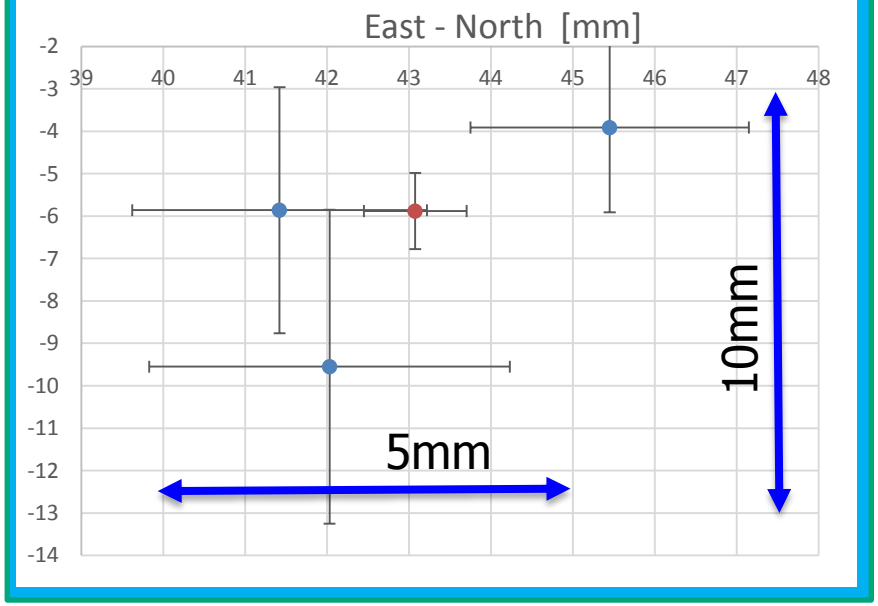
Geodetic VLBI Observation

- Stations:
  - Kashima(34m),Tsukuba(1.6m),Koganei(1.5m)
- Radio Frequency:
  - X-band: 8080-9080MHz, Bandwidth: 1GHz
- Experiments:
  - Gx14112: 2014. Apr. 22-23 24 hours.
  - Gx14134: 2014. May 14-15 24 hours.
  - GX14150: 2014. May 30-31 24 hours.

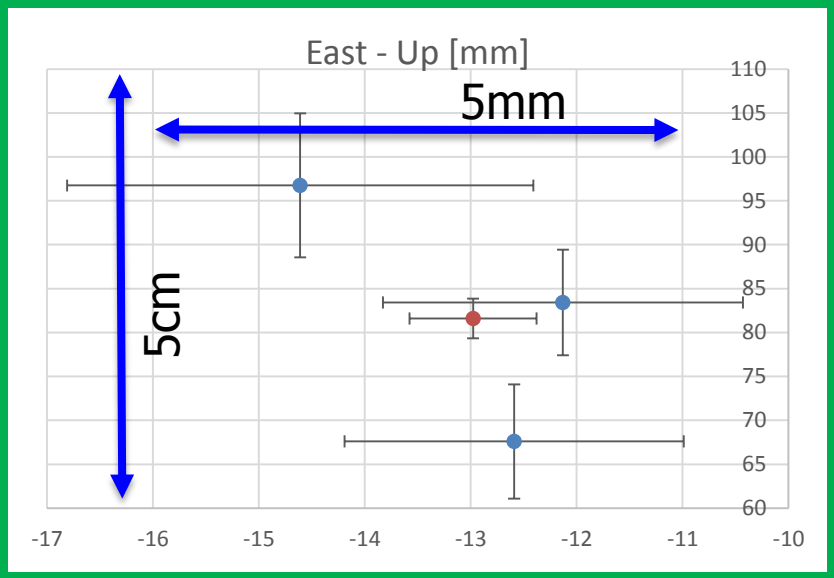
Geodetic Observation in April-May

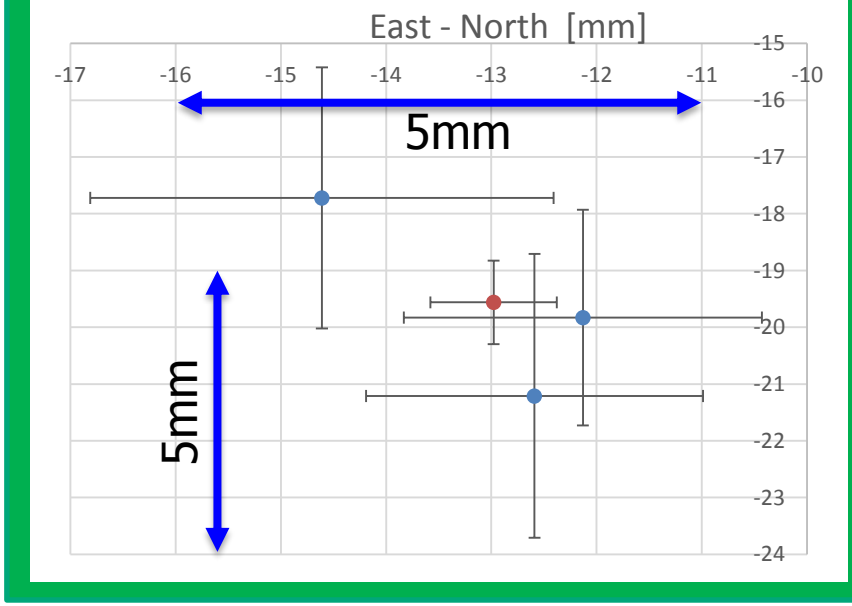
MARBLE1(NMIJ,Tsukuba)



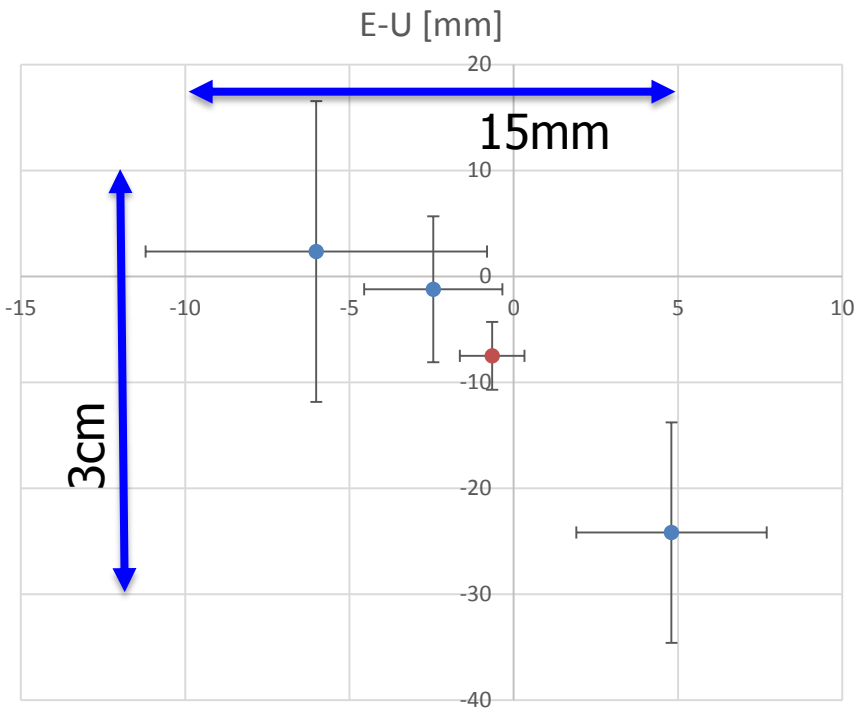


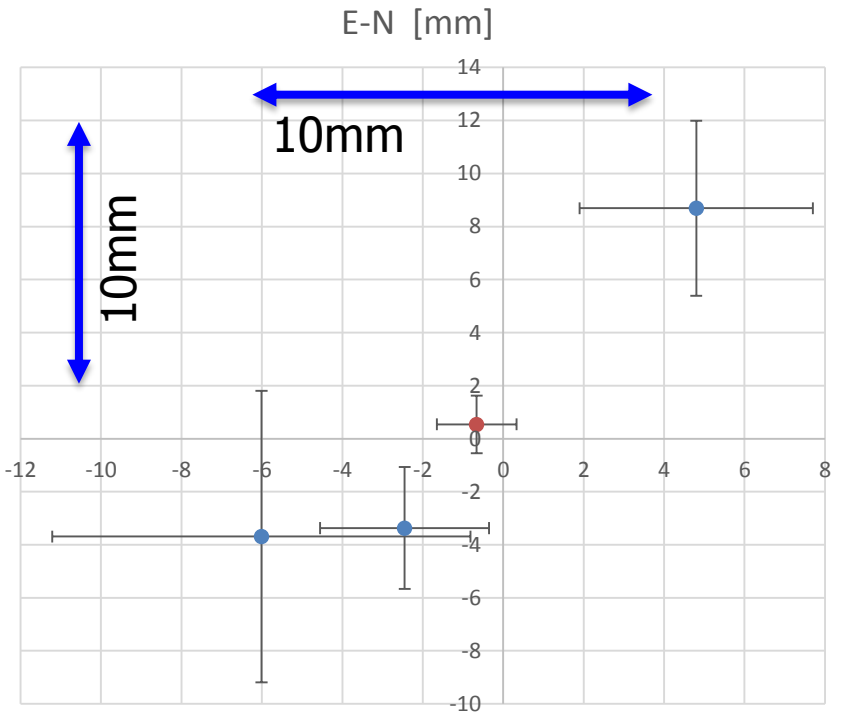
MARBLE2(NICT,Koganei)





AB Baseline Data





Frequency Transfer Test with NICT and AIST/National Metrology Institute of Japan(NMIJ) and NICT

At the roof (3rd floor) of AIST/NMIJ building, 1.6m antenna was settled.

Webcam Monitor for Remote Operation

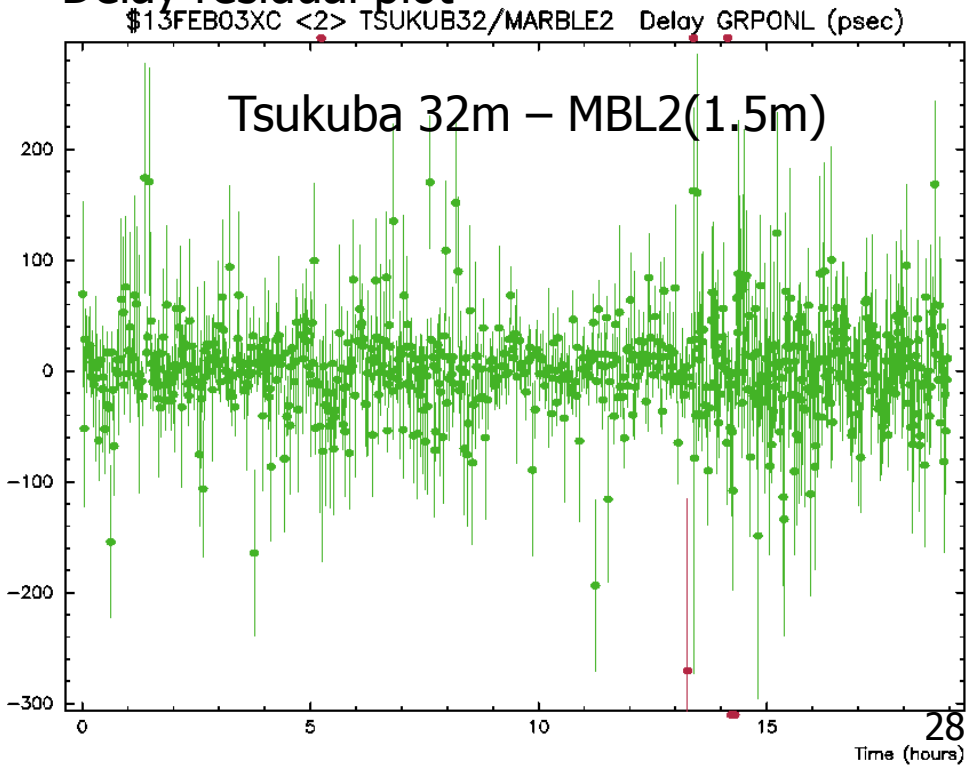
Precision of VLBI

Tsukuba 32m

MBL2(1.5m)
Koganei

Antenna Diameter	RMS residual
11m-11m	~ 30 psec.
32m-11m	~ 20 psec.
32m-1.5m	~ 30 psec.

Example of VLBI analysis
Delay residual plot

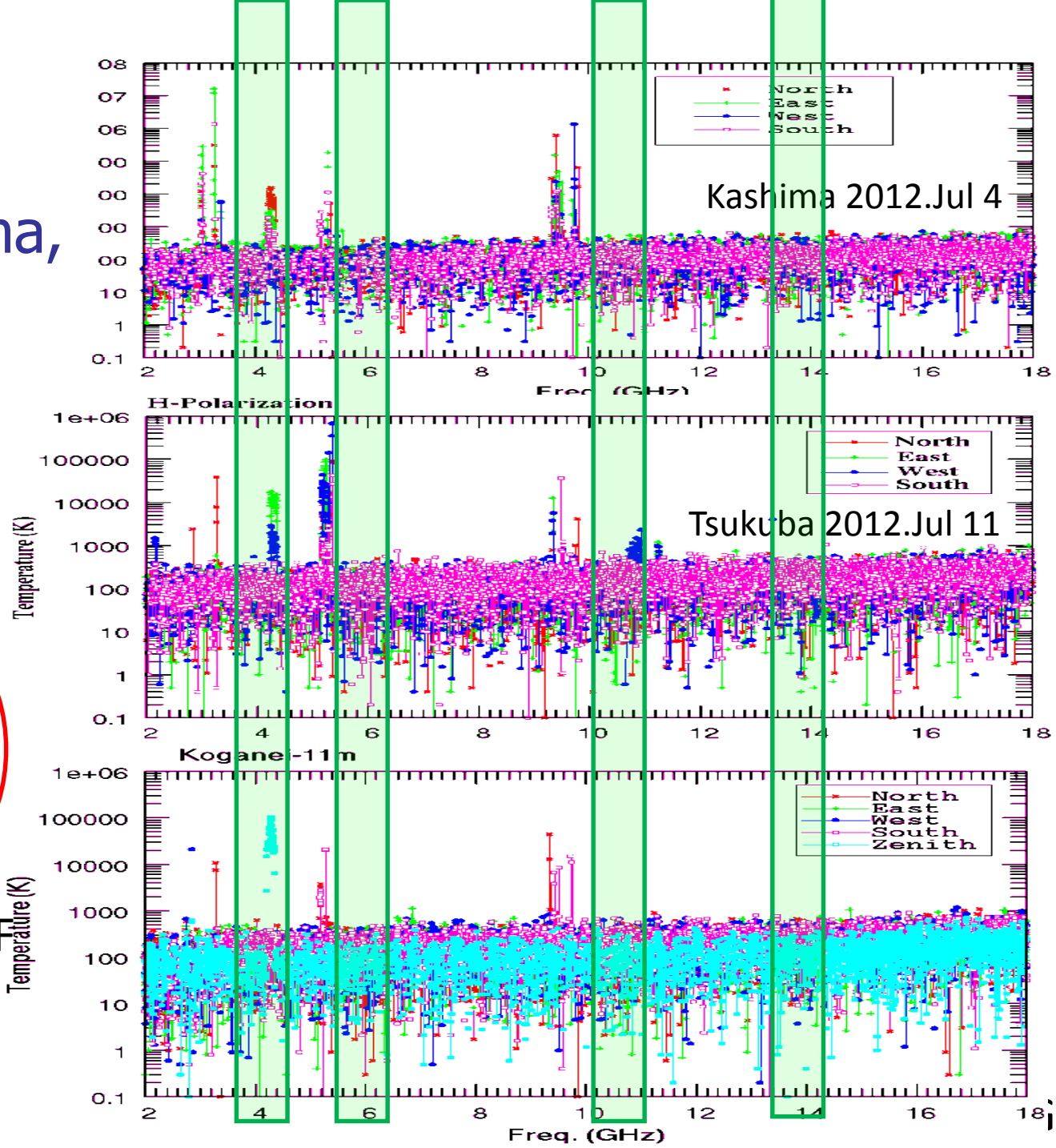


Major error sources

1. Error of atmospheric delay estimat
2. Thermal noise ∝ 1/(SNR x BW)

RFI 調査
2-18GHz at Tokyo,Kashima, and Tsukuba

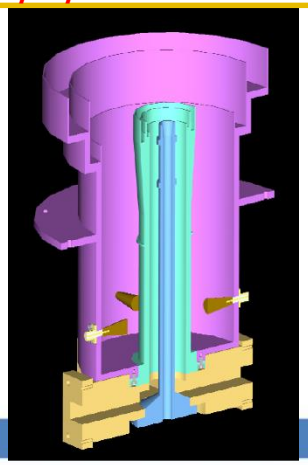
With 3.5GHz HPF before LNA



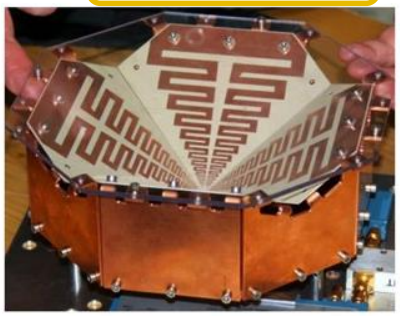

Ny Ålesund
Yellowknife
Onsala
Medicina
Matera
Nanshan
Kashima 11
Koganei
Kokee Park
Mauna Kea
Brewster
Algonquin
Hancock
Westford
Fortaleza
Concepción
Katherine
Yarragadee
Tidbinbilla
Warkworth
O'Higgins
Syowa
More stations needed below 15°N latitude
IVS Site
Cooperating VLBI Site
Former IVS Site
Forthcoming IVS Site
Locations not decided
Twin telescope
Planned or proposal in preparation
Proposal submitted
Funded
Under construction
Operational

Analog Technologies – Feeds

S/X/Ka Triband

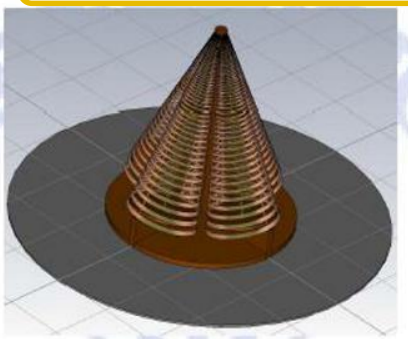


開発が遅延



JPL開発、MIT,NASA

スペイン独自開発中



	Eleven	QRFH	Yebes-Feed
Frequency range (GHz)	1.2-14	2.2-14	2.2-14
Polarization	Dual-Linear	Dual-Linear	Dual-Circular
Port Configuration	Differential	Single-Ended	Differential
LNAs per			
LNAs			
Calibration Signal Injection	post-LNA	pre-LNA, or post-LNA	-
Aperture Efficiency	See Next Slide		65% - 13.2m Telescope
Size	Diameter 210mm height 65 mm	diameter 160mm height 150mm	height 169 mm
Cost (USD)	33K (TBC)	15K	TBD

現在観測可能なアンテナはMITとNASAのアンテナのみ。
NICTの34mアンテナと　長基線の広帯域VLBI観測を実施したい。