Development Status of Broadband VLBI System (Gala-V) -(II)

M.Sekido[1], K.Takefuji[1], H.Ujihara[1], M.Tsutsumi[1], Y.Miyauchi[1], S.Hasegawa[1], T.Kondo[1], E.Kawai[1], R.Ichikawa[1], H.Takiguchi[1], T.Goto[1], K.Watabe[2], T.Suzuyama[2], Y.Koyama[1]

1) National Institute of Information and Communications Technology

2) National Metrology Institute of Japan

Contents of presentation

- Frequency transfer via VLBI
- Gala-V system Development
  - Broadband observation
    - Marble1,2 (1.5m,1.6m) : 3-15GHz
    - Kashima34m : 6-14GHz
  - Compliant with VGOS (Next generation Global VLBI system)
- Installation to NMIJ(Tsukuba) and NICT(Koganei)
  - First Geodetic observation after installation
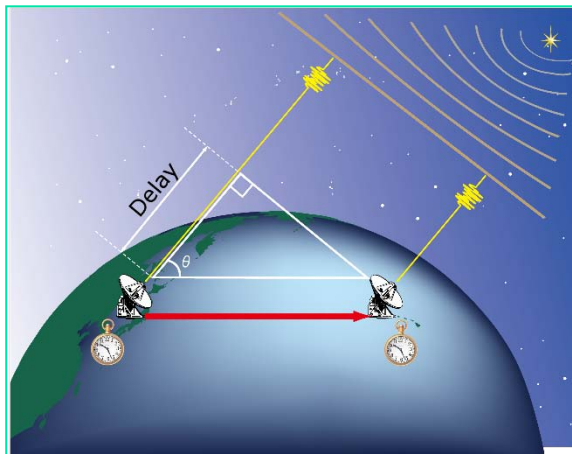 - Principle proving
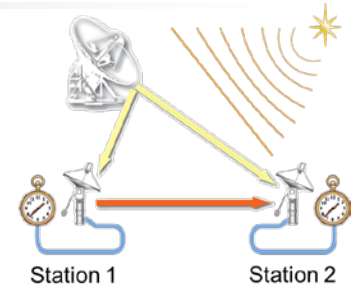
Precise Frequency Transfer over intercontinental distances

GNSS

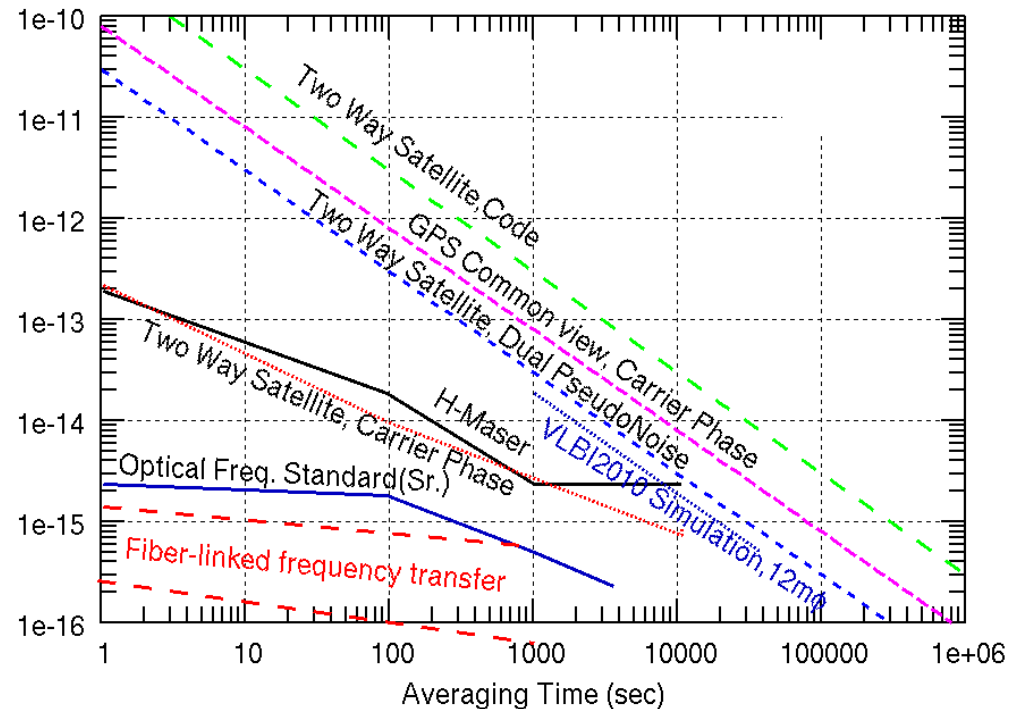## Space Technologies for Distant Frequency Comparison

- GNSS(Common view, PPP)

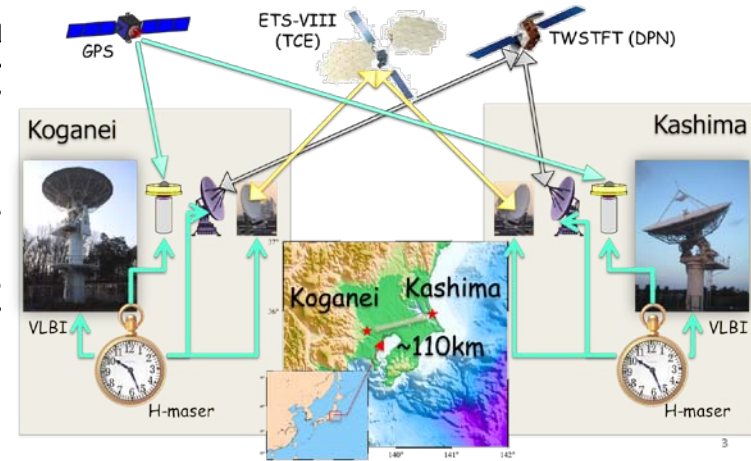- Two way Satellite Time and Frequency Transfer(TWSTFT)
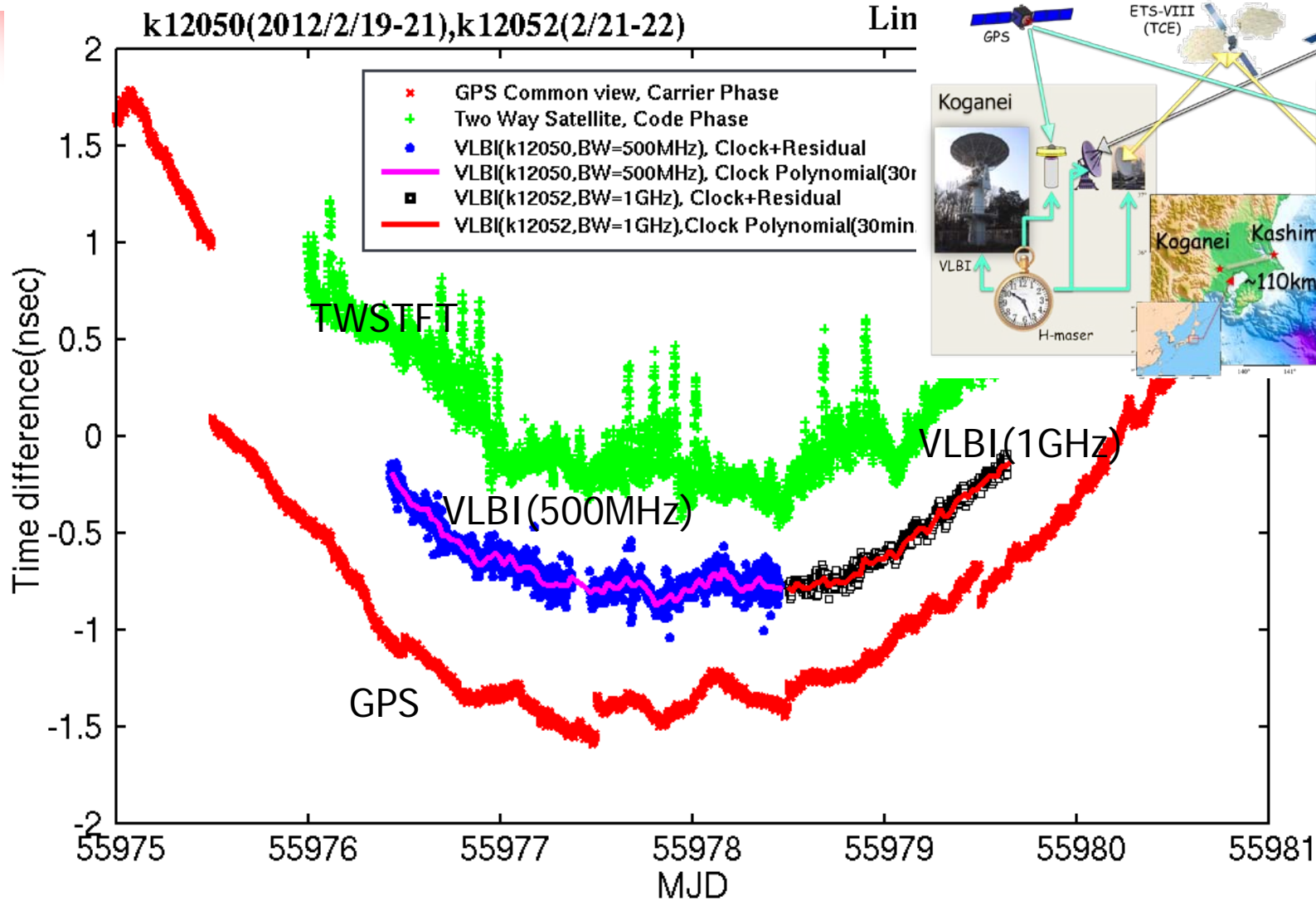
- **VLBI**
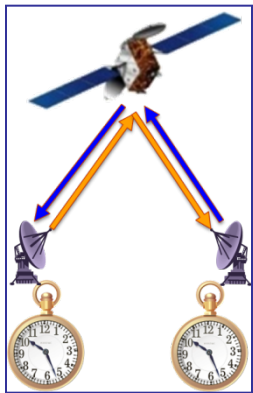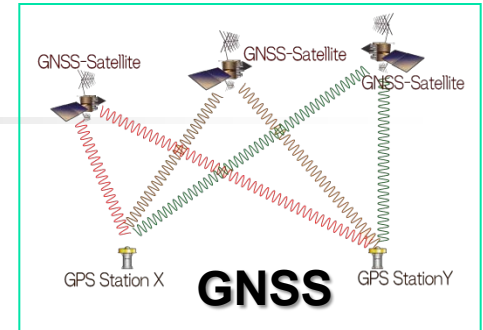
TWSTFT

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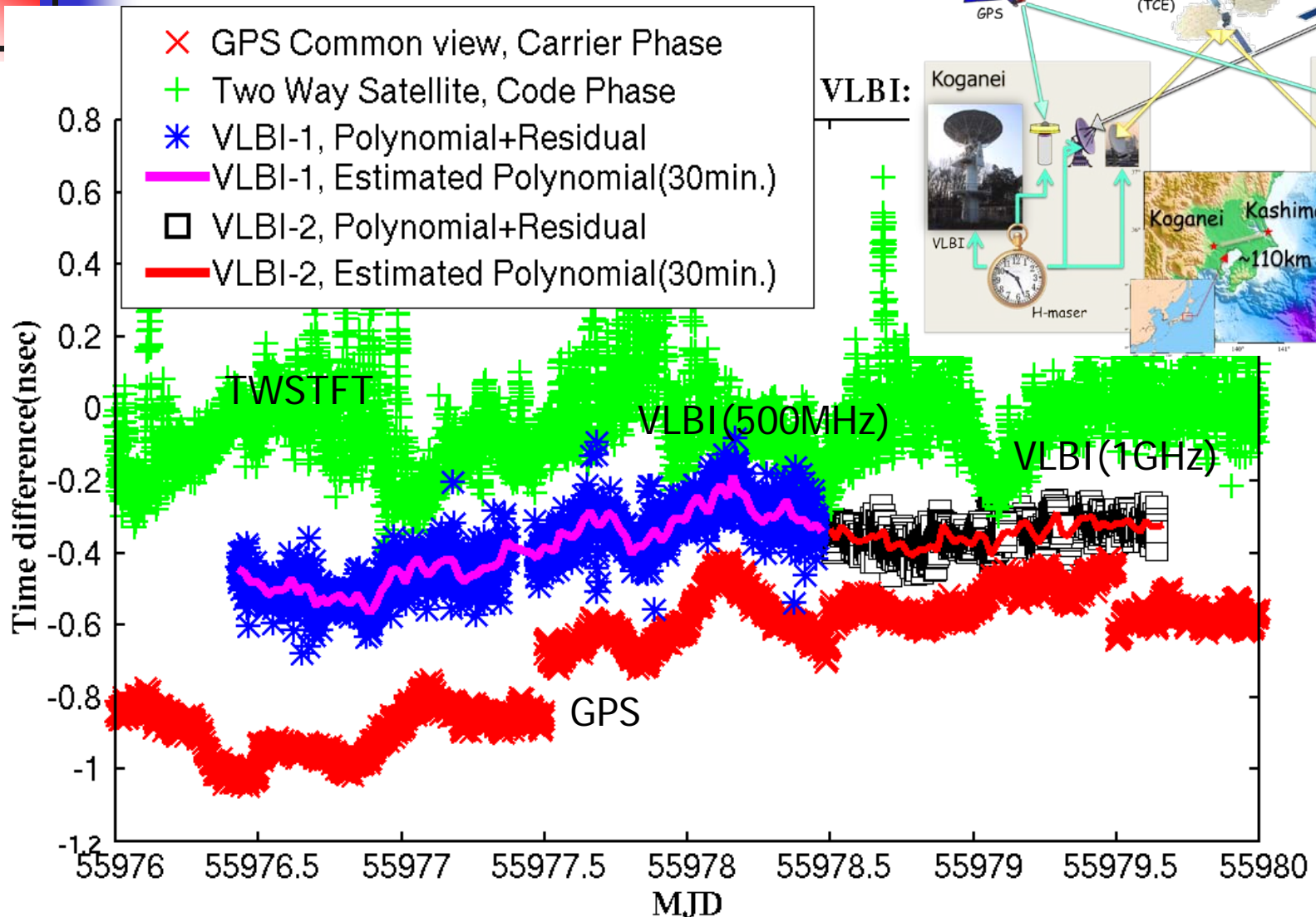
Comparison of TWSTFT,GPS,VLBI Exp. on 19-22 Feb. 2012

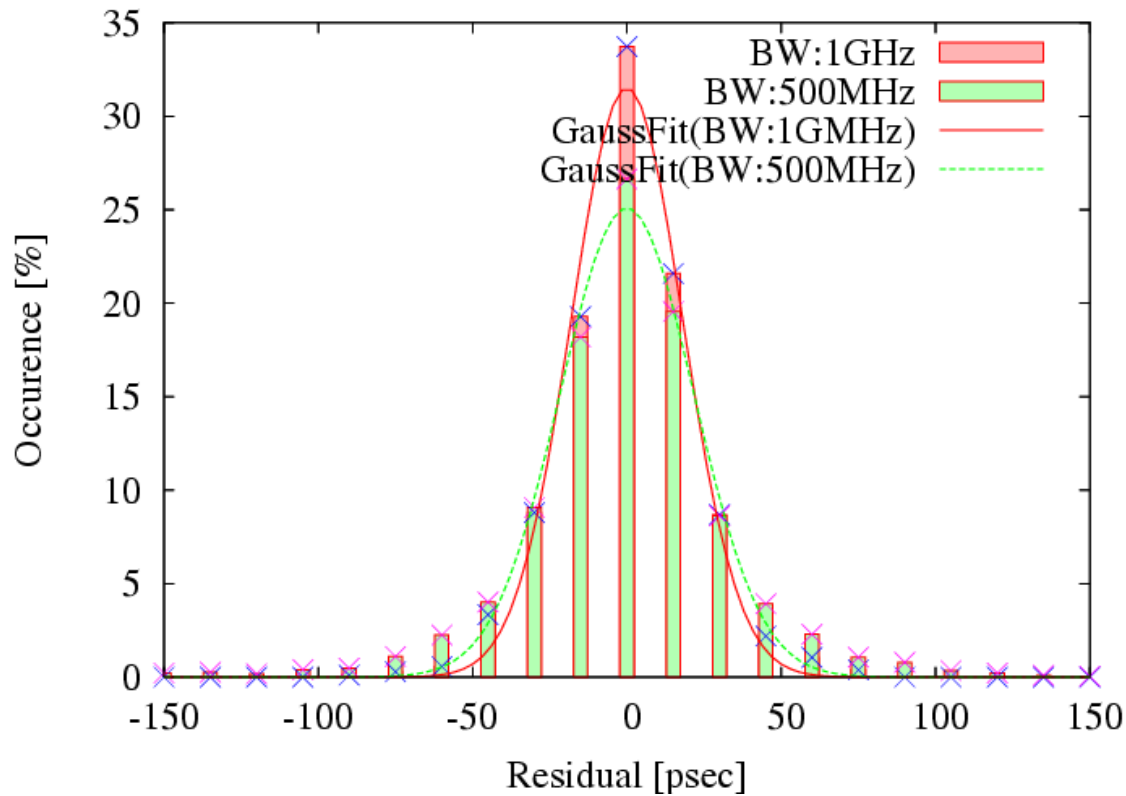Comparison of Frequency Transfer Techniques
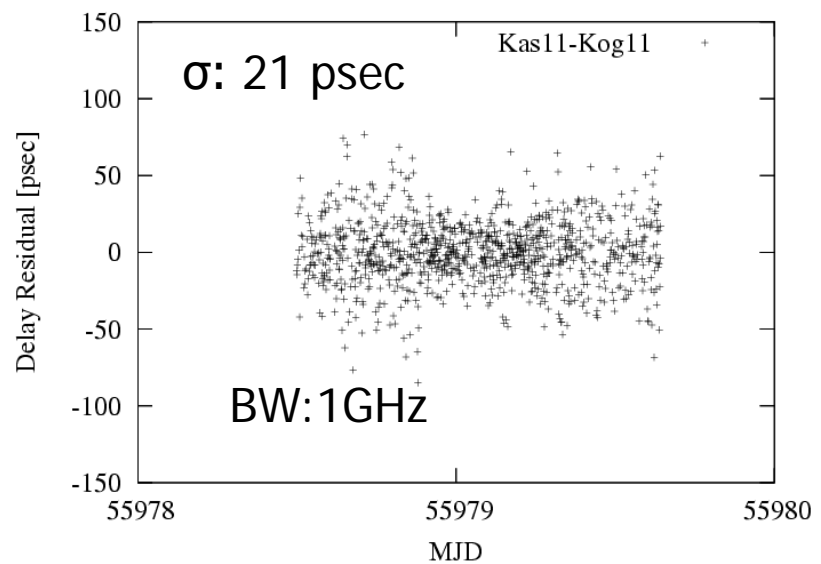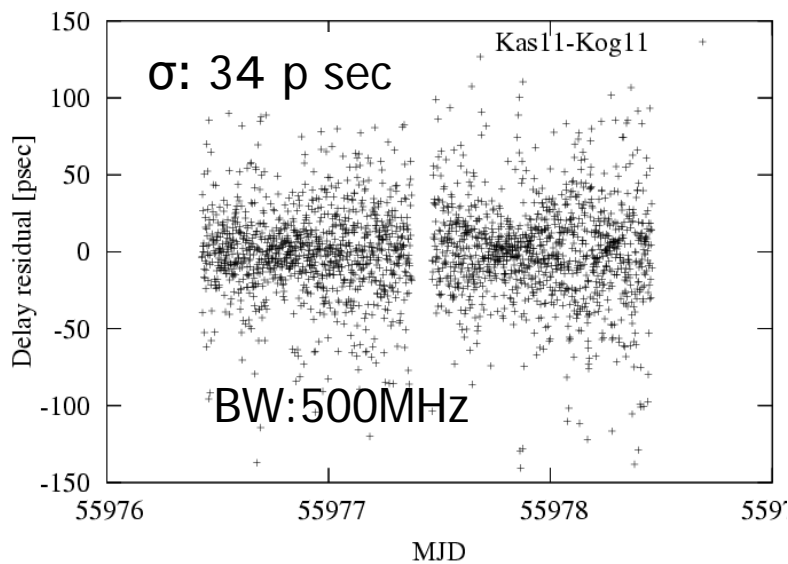Experiment on 100 km baseline

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

Comparison of Frequency Transfer Technique Experiment on 100 km baseline

VLBI Delay residual is improved by expanding observation frequency band.

σ: 34 p sec

BW:500MHz

σ: 21 psec

BW:1GHz

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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.

Major error sources
1. Error of atmospheric delay estimat
2. Thermal noise $\propto$ 1/(SNR x BW)

Example of VLBI analysis
Delay residual plot

$13FEB03XC <2> TSUKUB32/MARBLE2 Delay GRPONL (psec)

Tsukuba 32m – MBL2(1.5m)

Time (hours)

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)

1GHz

| 1 | 3 | 2 |
4.0GHz 5.6GHz   10.4GHz   13.6GHz

10 times fine delay resolution function is expected.

Station 3

τ_{13} τ_{23}

τ_{21}

Station 1   Station 2
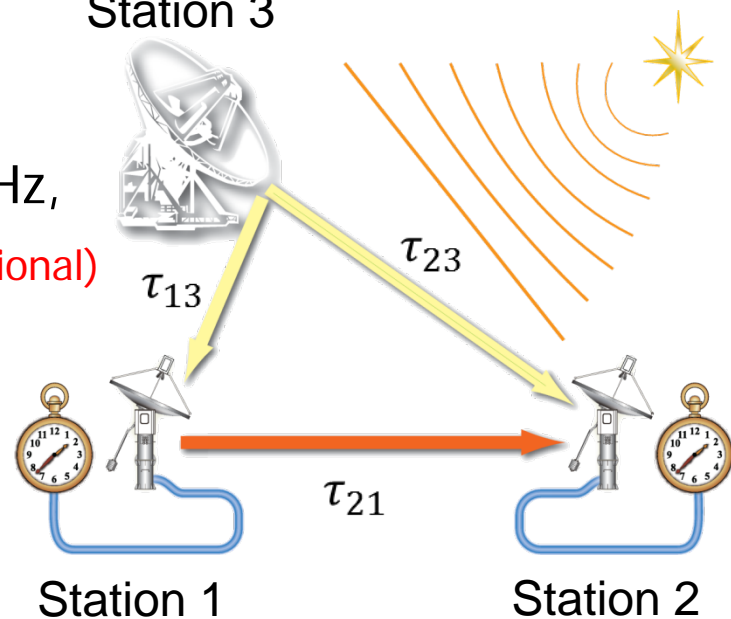
$$\tau_{21} = \tau_{13} - \tau_{23}$$

Delay observable of Baseline 1-2 is obtained from 1-3 and 2-3 baseline data.
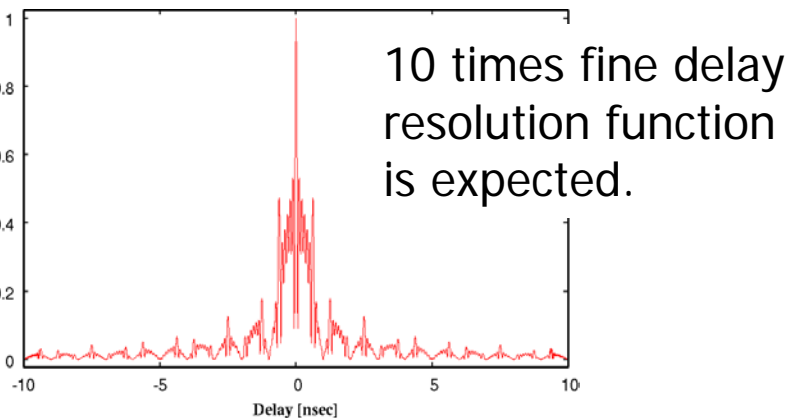
Developments of New Technologies for the Gala-V system

Target Precision: 30 ps -> 7 ps

Broadband observation
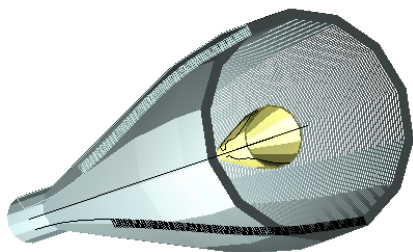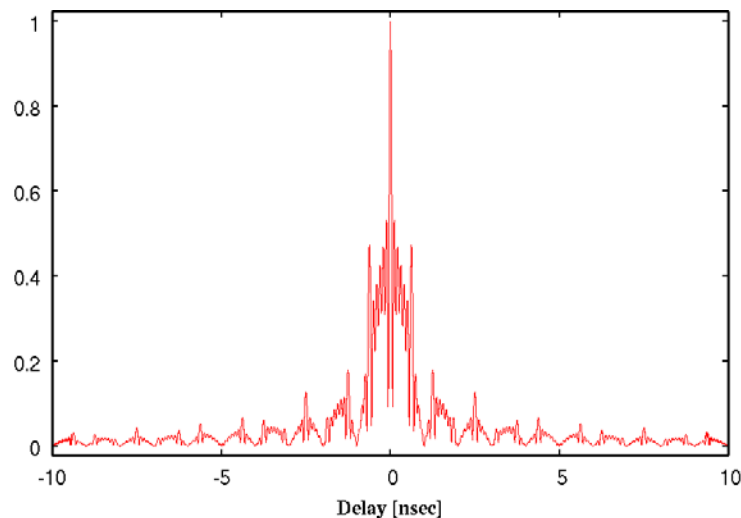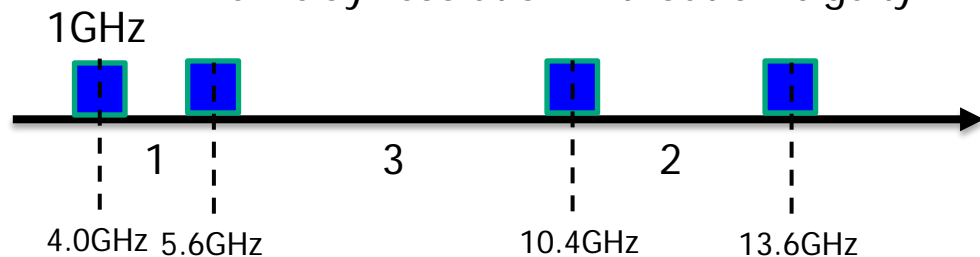
Broadband Feed Design

Image of `Iguana' feed

Direct RF Sampling

High speed sampler (16GHz) GALAS
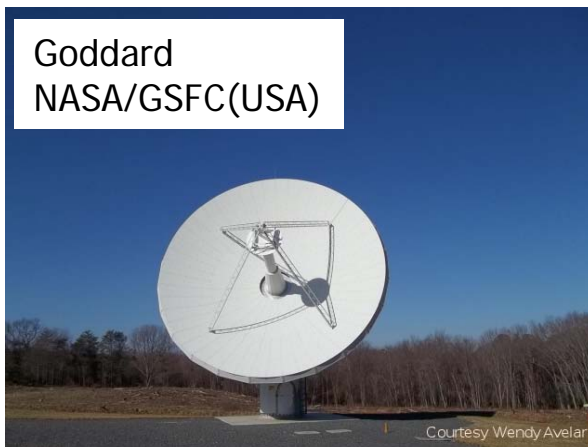
Bandwidth Synthesis for 10 times wider frequency range

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

1GHz

1   3   2

4.0GHz 5.6GHz   10.4GHz   13.6GHz

VLBI2010 Global Observing System VGOS(Next generation Geodetic VLBI)

Roadmap to the First VLBI session ("Jorge Juan"):

a) Installation of the triband receiver:
February 2014

b) Remote control commissioning:
March-April 2014

c) *First VLBI session:*
May **2014**

The antenna will take part in first VGOS tests.

Spain

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

Goddard NASA/GSFC(USA)

Ishioka GSI（Japan)

Wettzell BKG(Germany)

Badary IAA(Russia)

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

With 3.5GHz HPF before LNA

Kashima 2012.Jul 4

Tsukuba 2012.Jul 11

iHz

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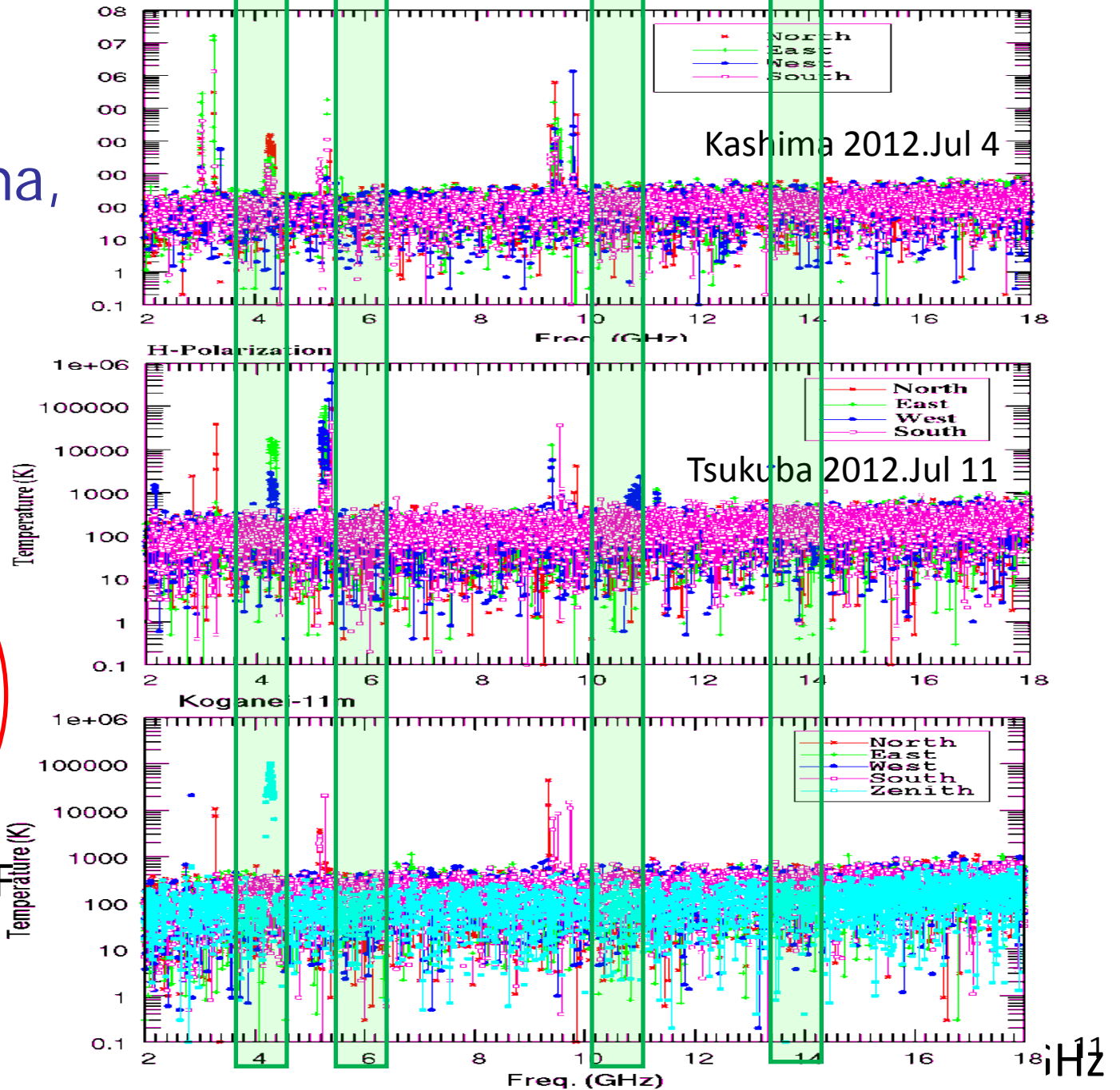
1.6/1.5m and 34m VLBI antenna

1.5m compact antenna

Kashima 34m antenna

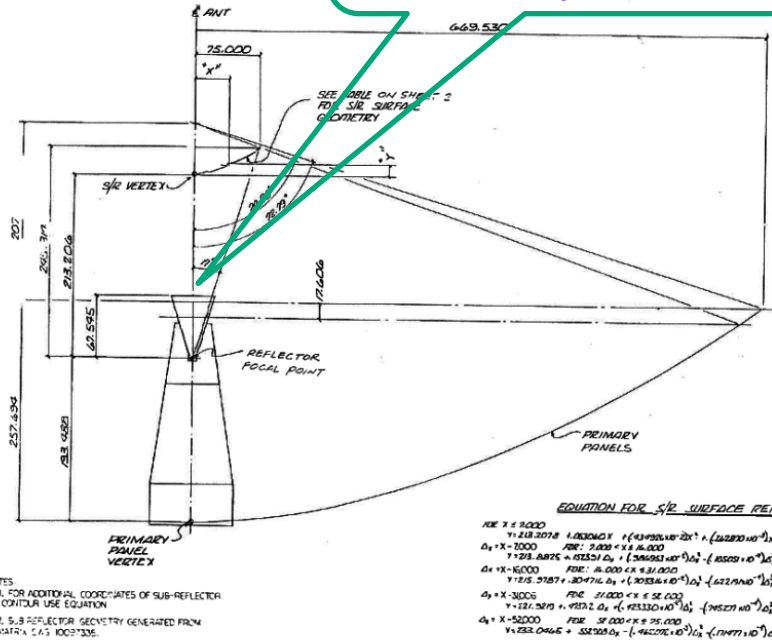- VLBI2010 仕様に 部分準拠
  - 1 GHz x 4 band   3-15GHz Frequency Range

"Iguana" Feed

Apparent diameter of subref. is 35 deg. from focal point.

Requirement:

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

Wideband prototype feed designed by Dr. Ujihara has been installed to Kashima 34m with room temp. LNA at the end of 2013.

This feed has sensitivity at 6.4-14GHz range at present. Upgraded feed with 2.2-18GHz Freq. range is intended.
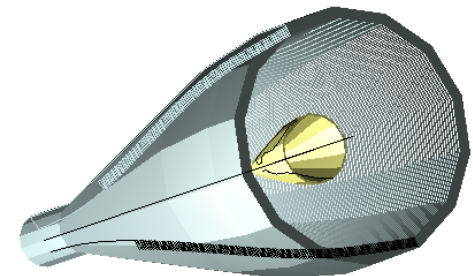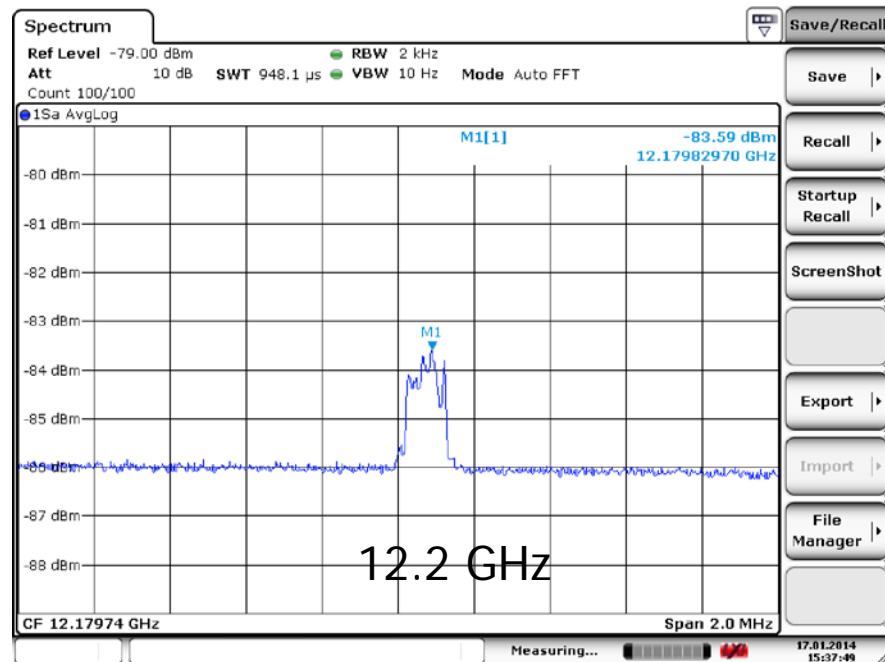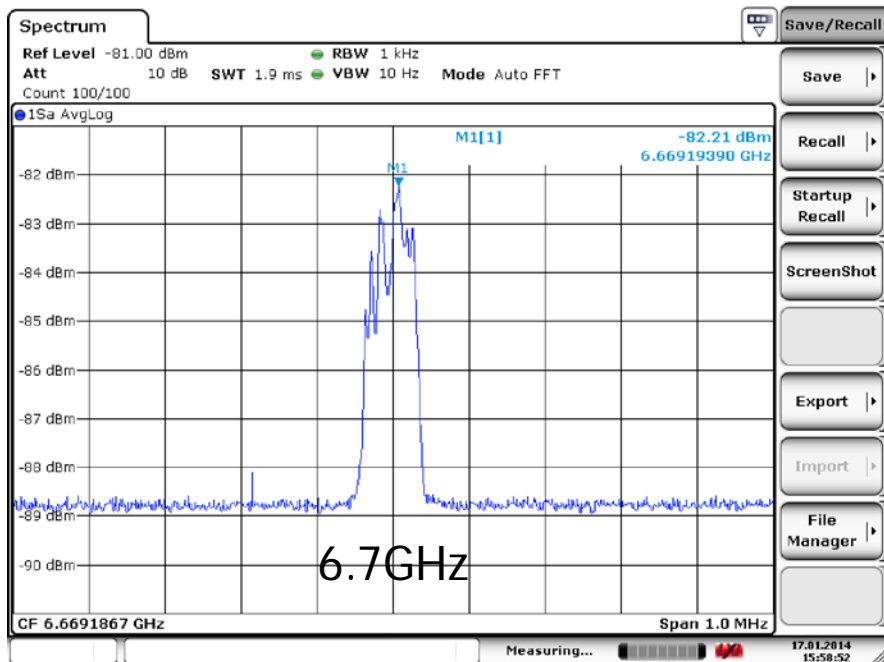

Image of `Iguana' wideband feed
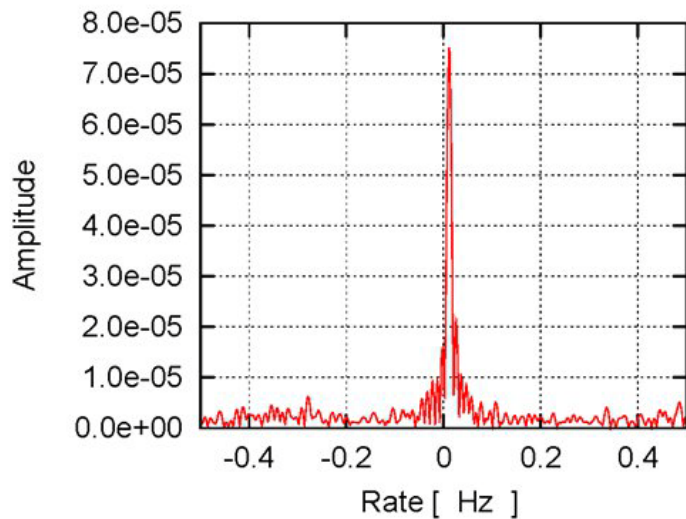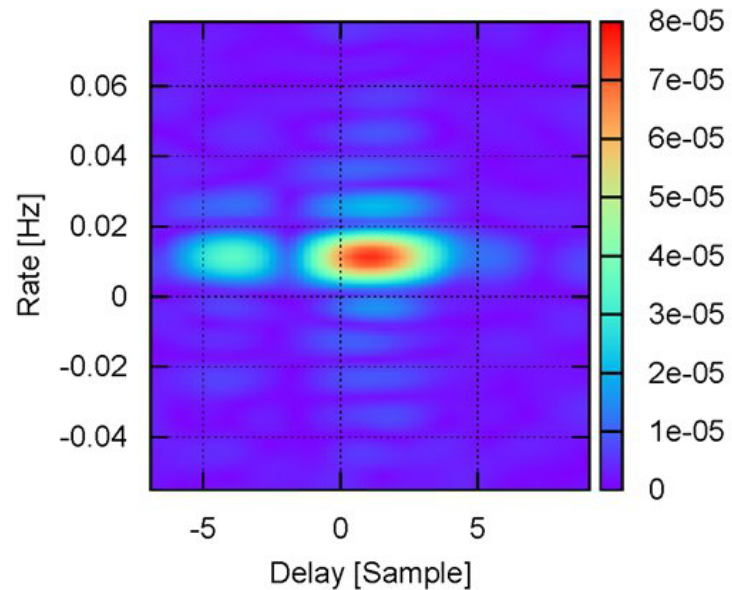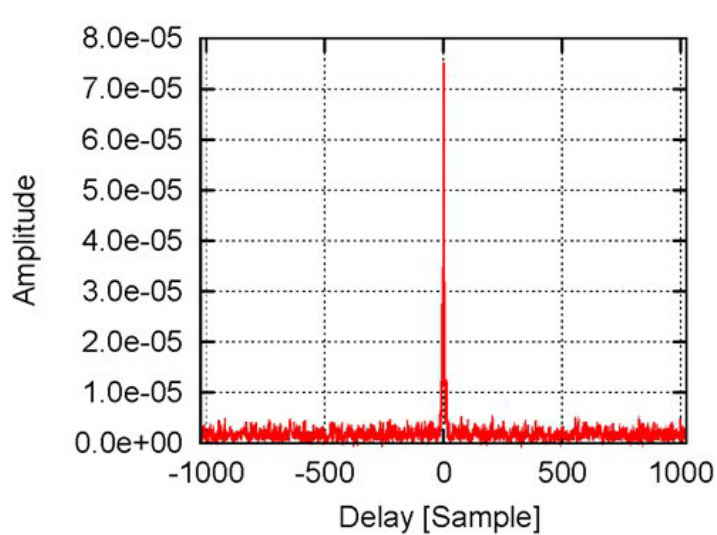
<#>

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.

6.7GHz

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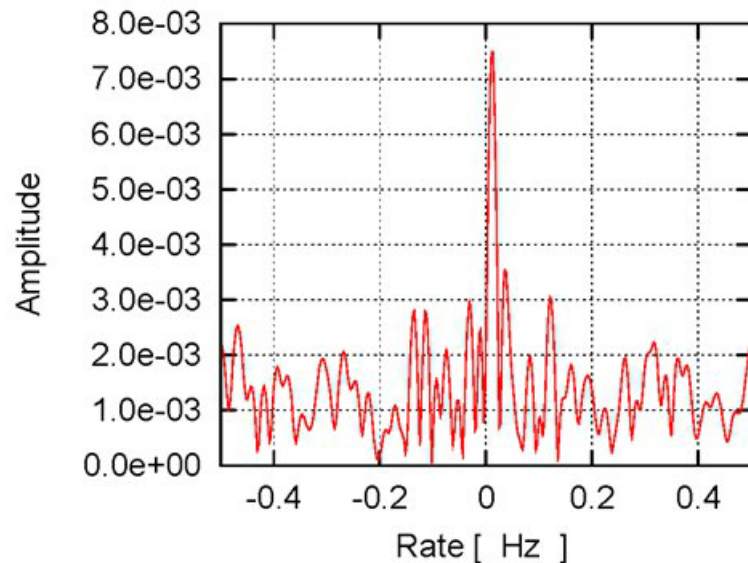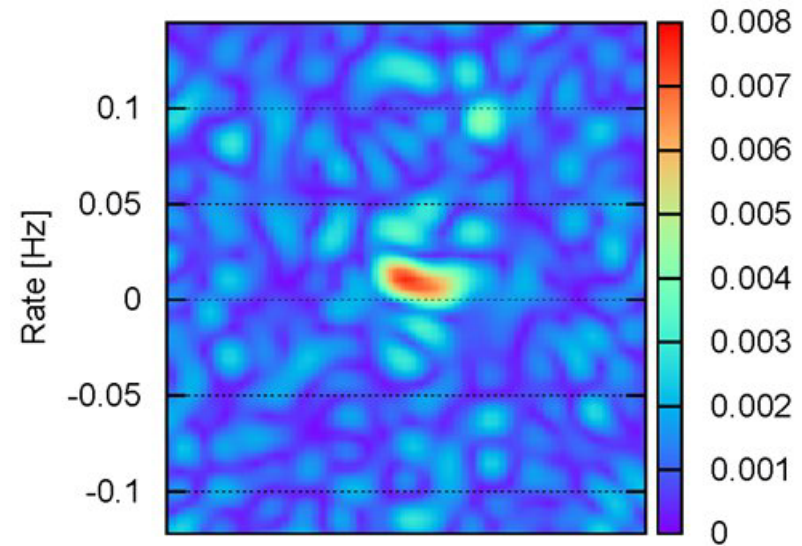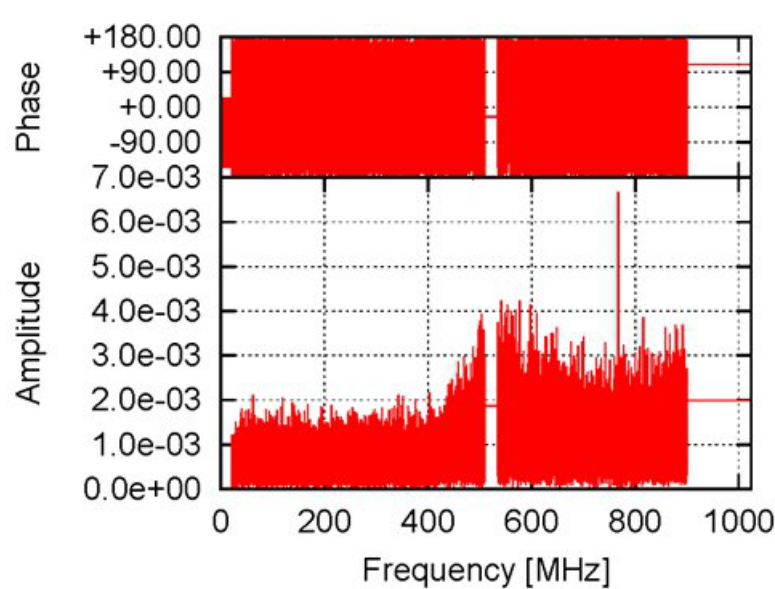
Date: 17.JAN.2014 15:58:51

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

Kas34-MbI1 (12GHz:512MHz) 3C273B

Epoch   : 2014/281 06:10:00
Station-1:   kas34
Station-2:   mbl1
Source   :   3C273B
Length   :   120.000000[sec]
Sampling :   2048000000[sps]
Frequency:+11414.000000[MHz]
Peak Amp :   0.007527[%]
Peak Phs :   47.832690[deg]
Delay   :   +1.085587[spl]
Rate   :   +11.651866[mHz]
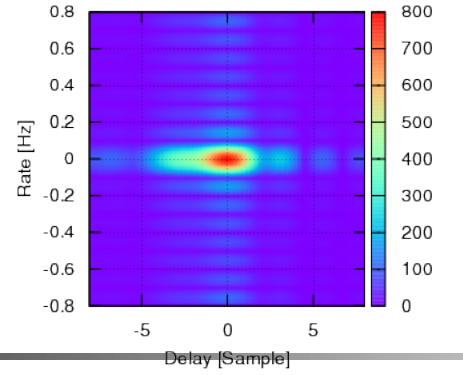SNR   :   42.662682
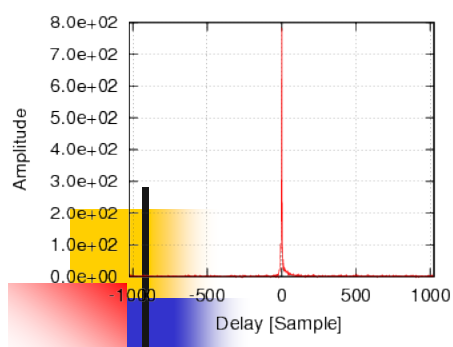
16

Kas34-Mbl1 W3OH（12.181GHz）

Epoch   : 2014/281 06:23:00
Station-1:   kas34
Station-2:   mbl1
Source   :   w3oh
Length   :   60.000000 [sec]
Sampling :   2048000000 [sps]
Frequency:+11414.000000 [MHz]
Peak Amp :   0.755263 [%]
Peak Phs :   96.430956 [deg]
Peak Freq: +767.138633 [MHz]
Rate   :   +11.454010 [mHz]
SNR   :   16.599317

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First Fringes
with VERA (6.7GHz)

Observation on
1ˢᵗ-2ⁿᵈ Oct. 2014

Epoch   : 2014/274 12:50:00
Station-1:   KASHIM34
Station-2:   ISHIGAKI
Source   :   3C84
Length   :   10.000000[sec]
Sampling : 1024000000[sps]
Frequency: +6408.000000[MHz]
Peak Amp : 78367.191596[%]
Peak Phs :   61.470817[deg]
Delay   :   -0.025192[spl]
Rate   :   +0.160217[mHz]
SNR   :   429.267698
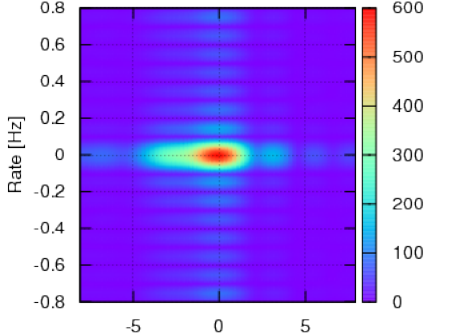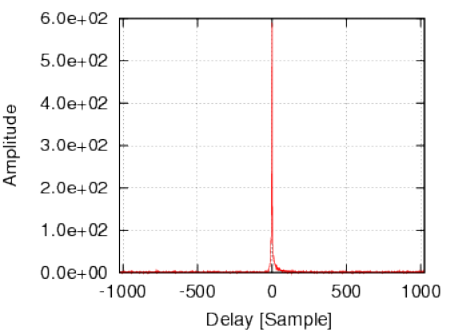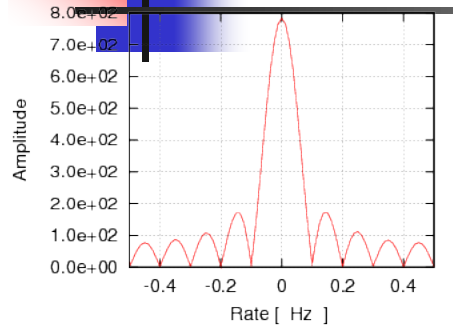
Epoch   : 2014/274 12:50:00
Station-1:   KASHIM34
Station-2:   OGASA20
Source   :   3C84
Length   :   10.000000[sec]
Sampling : 1024000000[sps]
Frequency: +6408.000000[MHz]
Peak Amp : 59136.762216[%]
Peak Phs :   48.150952[deg]
Delay   :   -0.084427[spl]
Rate   :   -0.064087[mHz]
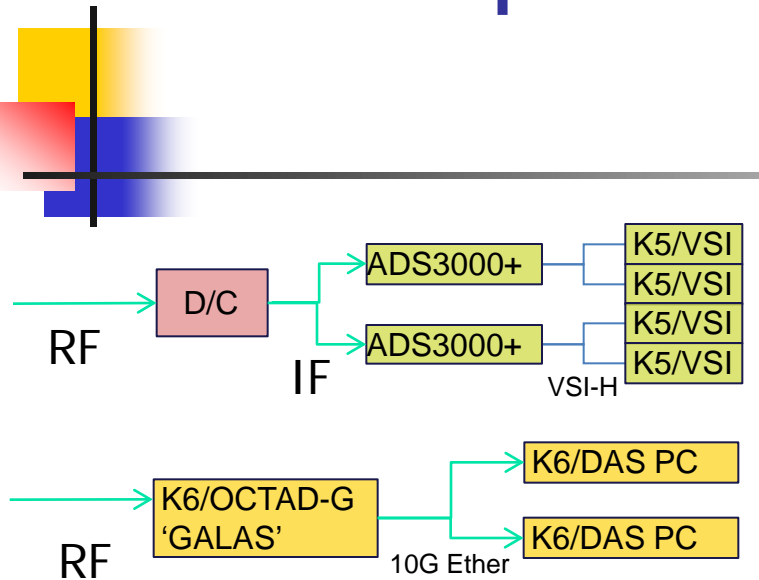SNR   :   344.224222
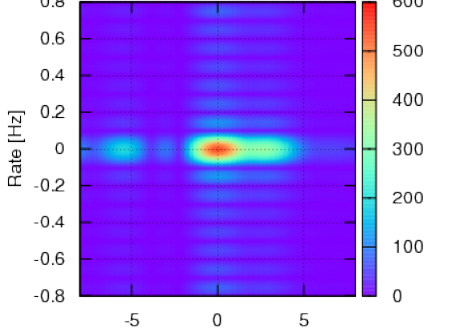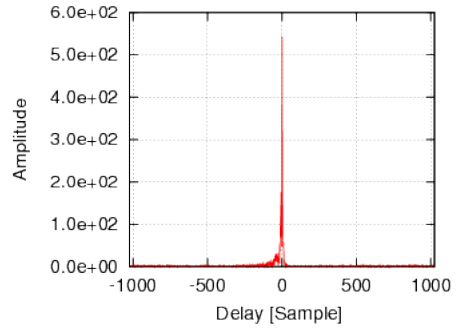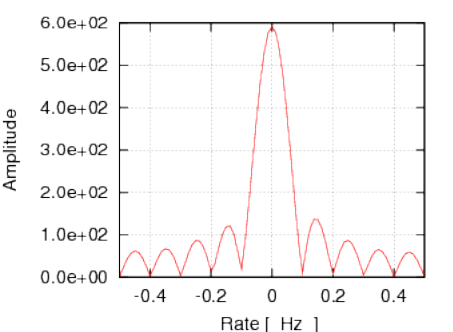
Epoch   : 2014/274 12:50:00
Station-1:   MIZNAO20
Station-2:   KASHIM34
Source   :   3C84
Length   :   10.000000[sec]
Sampling : 1024000000[sps]
Frequency: +6408.000000[MHz]
Peak Amp : 54394.542049[%]
Peak Phs : -170.898469[deg]
Delay   :   +0.000397[spl]
Rate   :   +0.001526[mHz]
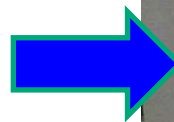SNR   :   313.880318
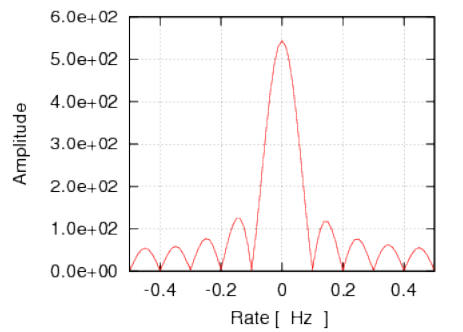
Data Acquisition: 1GHz x 4 Ch
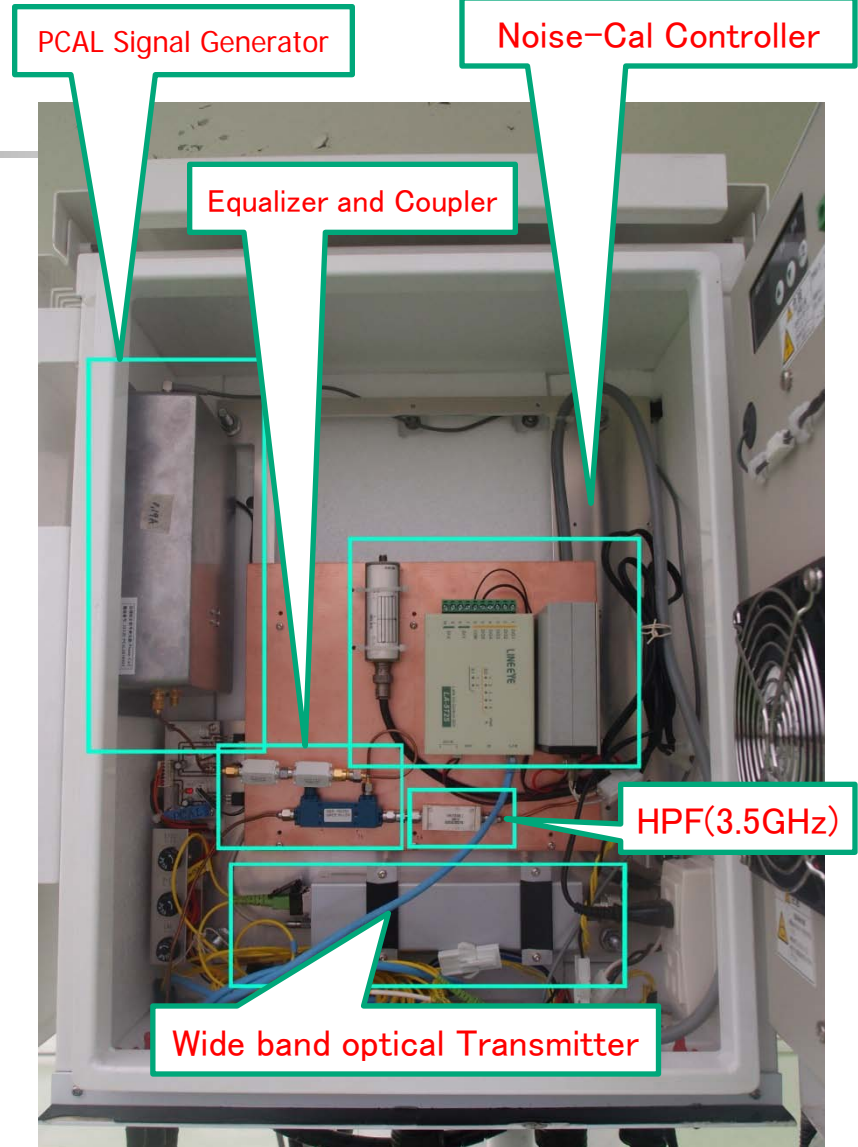
Two Approaches

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.

RF → D/C → IF → ADS3000+ → K5/VSI, K5/VSI
ADS3000+ → K5/VSI, K5/VSI
VSI-H

RF → K6/OCTAD-G 'GALAS' → 10G Ether → K6/DAS PC, K6/DAS PC

ADS3000+ Sampler
DBBC or 1-2 Gsps

Direct Sampler
K6/OCTAD-G
code name="GALAS"
DBBC(BW=1024MHz)

RF-Box of MARBLE small antenna

Peltier Cooler

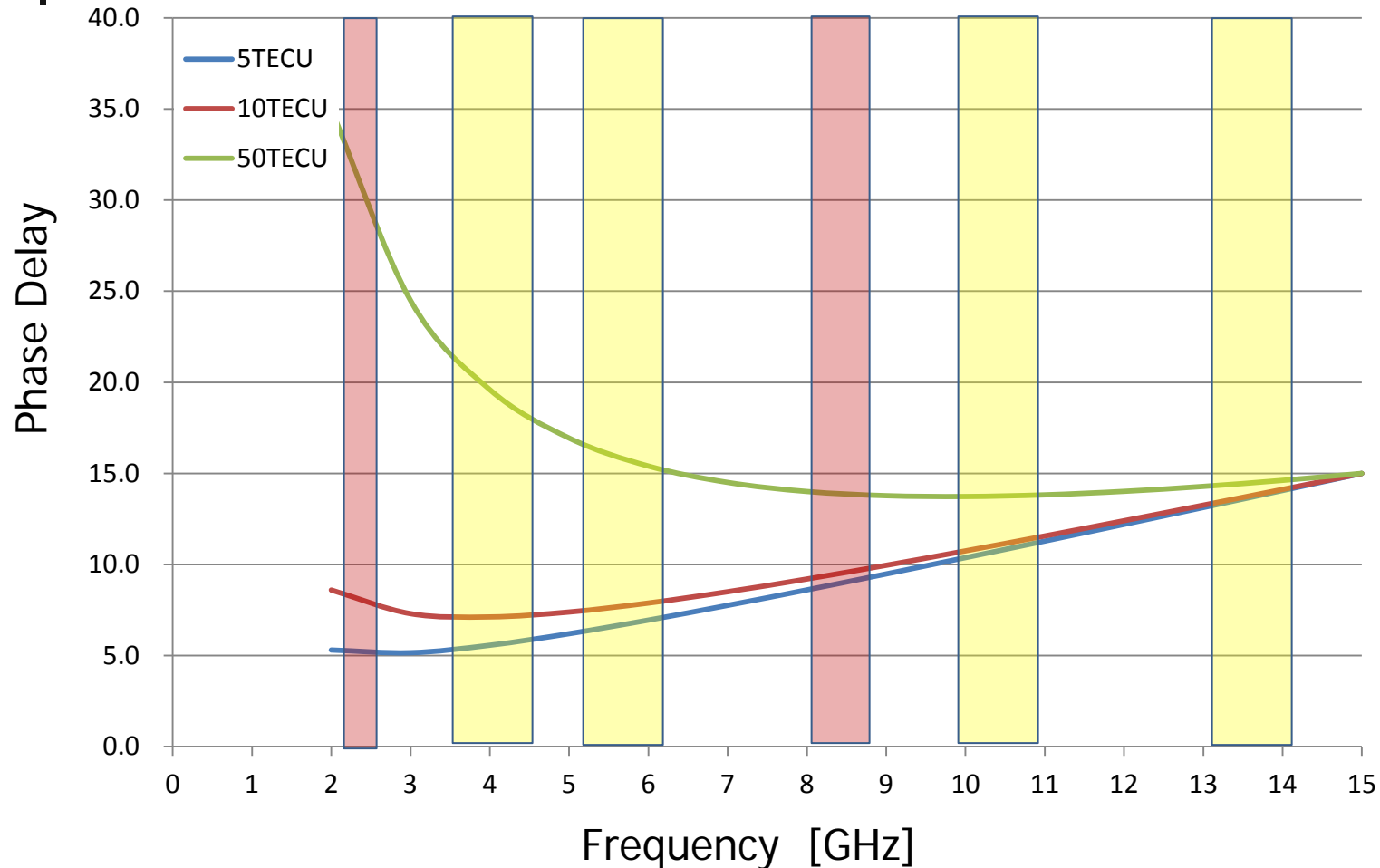PCAL Signal Generator

Noise-Cal Controller

Equalizer and Coupler

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

HPF(3.5GHz)

Wide band optical Transmitter

Spectrum | Save/Recall

Ref Level -20.00 dBm   ● RBW 5 kHz
Att   10 dB   SWT 915.1 ms   VBW 5 kHz   Mode Auto FFT
● 1AP Clrw

-30 dBm
-40 dBm
-50 dBm
-60 dBm

Save
Recall
Startup Recall
ScreenShot
Export
Import
File Manager

Start 3.0 GHz   Stop 15.0 GHz

Measuring...   23.10.2013 18:12:07

Date: 23.OCT.2013 18:12:07
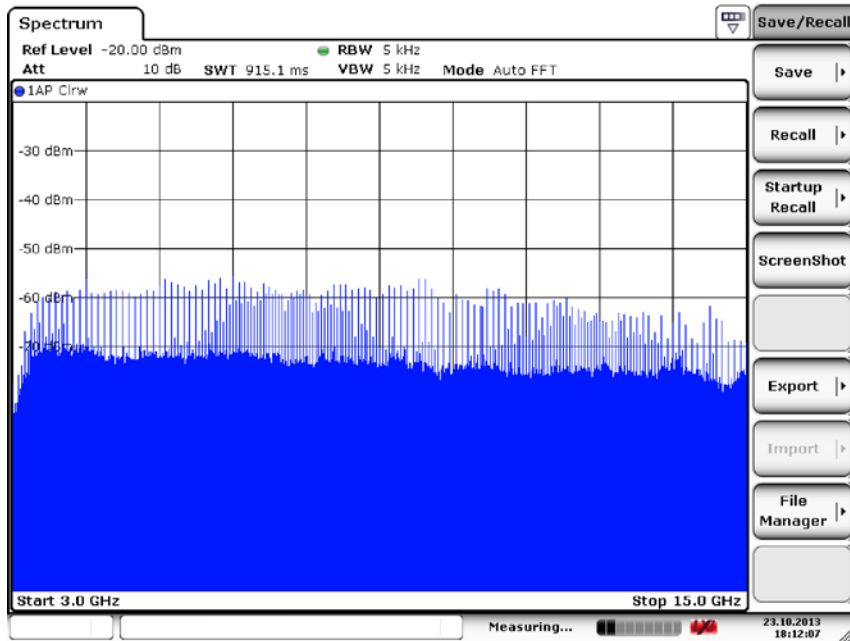
Observation Frequency Band & Ionosphere Delay Contribution

Ready for Observation

KASHIMA 34m

MARBLE2

MARBLE1

34m Antenna   NICT Kashima

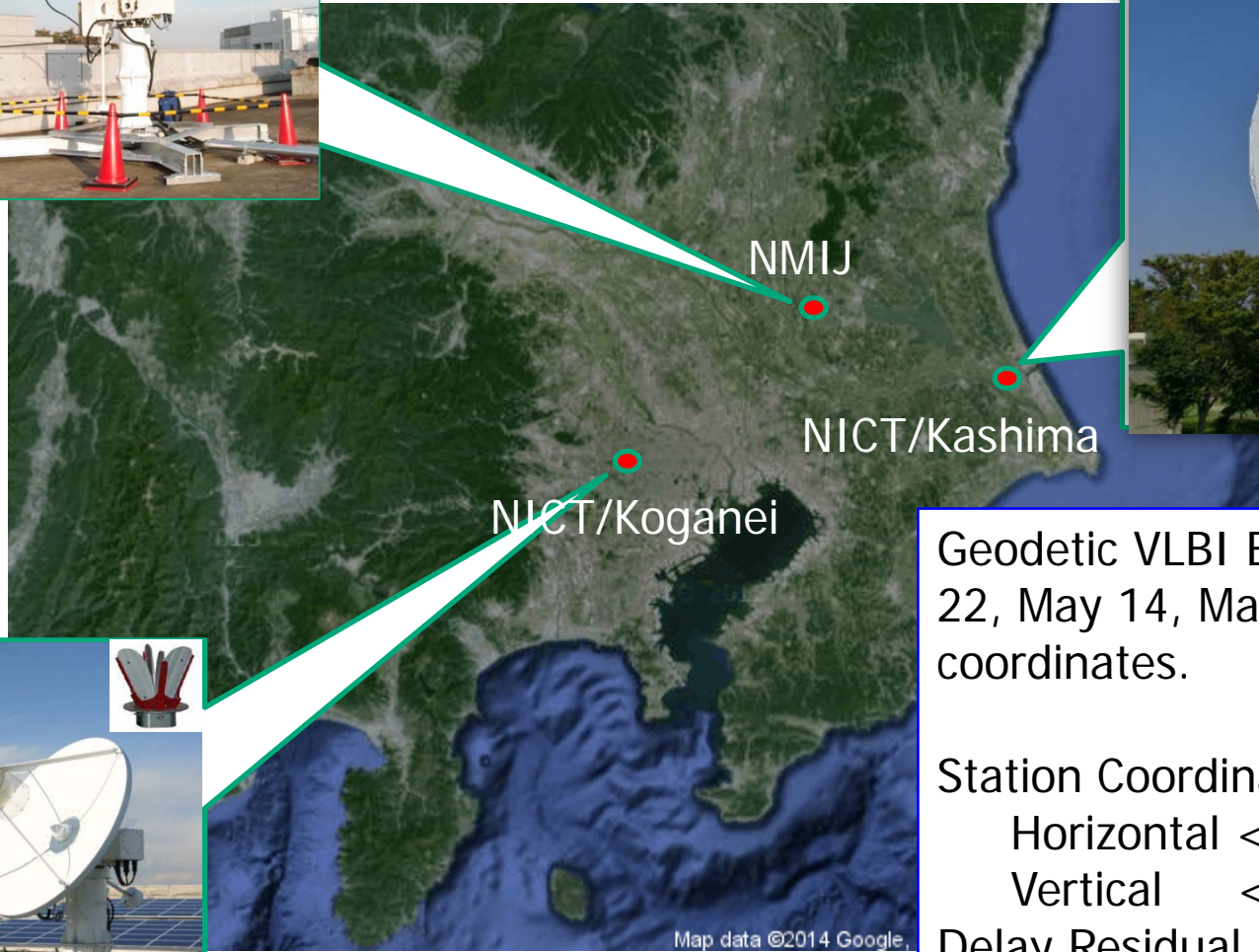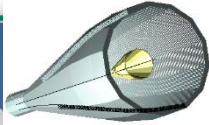
1.5mAntenna NICT Koganei

1.6m Antenna NMIJ Tsukuba

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

NMIJ

NICT/Kashima

NICT/Koganei

Map data ©2014 Google

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

Station Coordinates Repeatability:
  Horizontal < 6mm
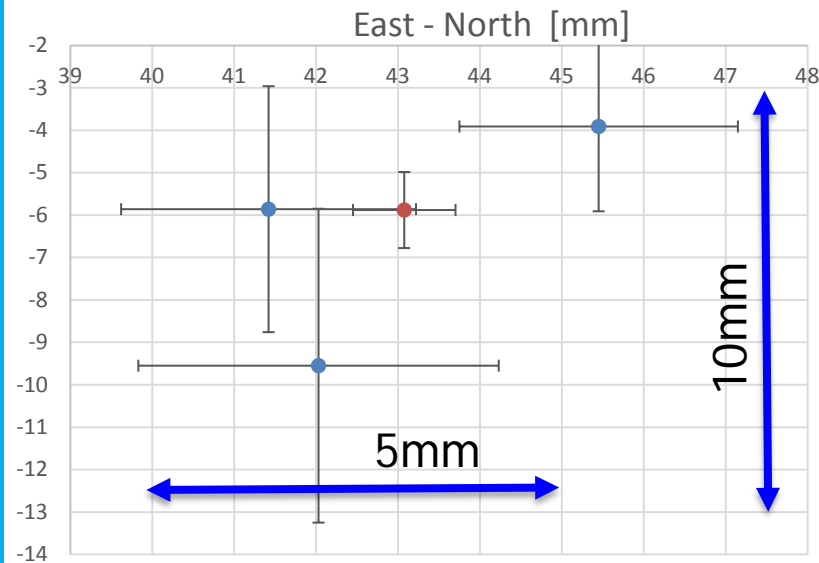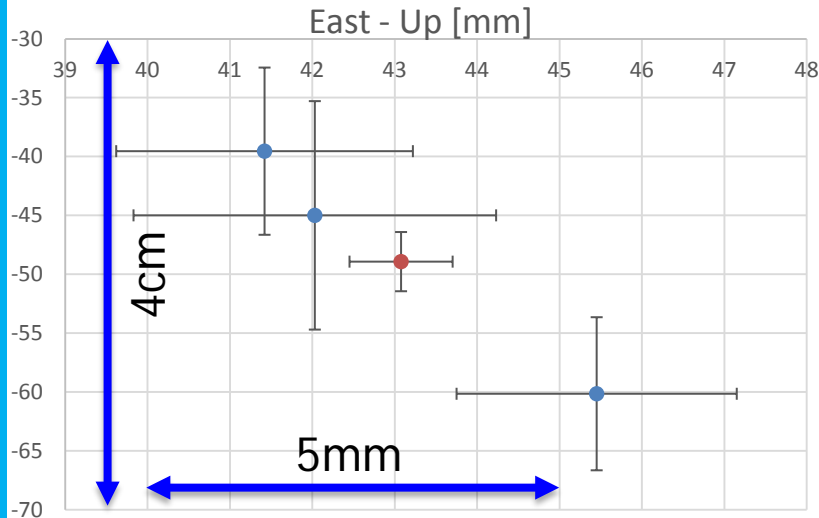 Vertical   < 15mm
Delay Residual
  WRMS is about 35 psec@30sec.
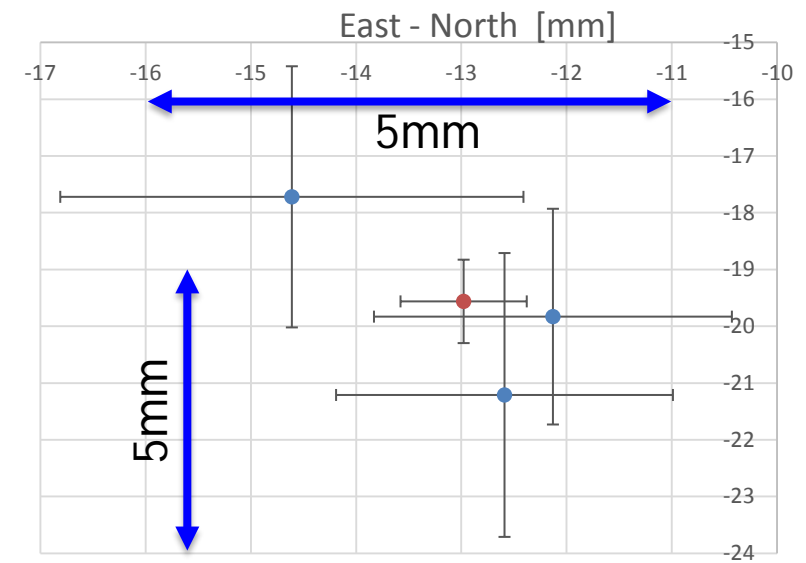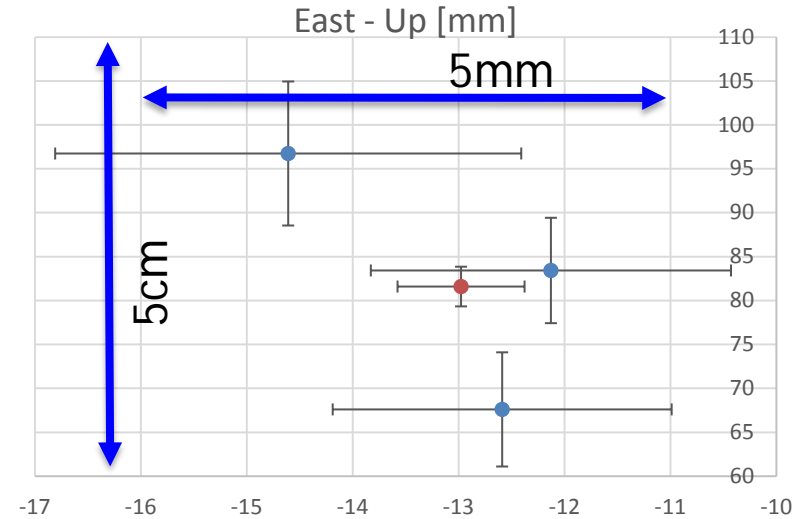
Geodetic VLBI Observation

- **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
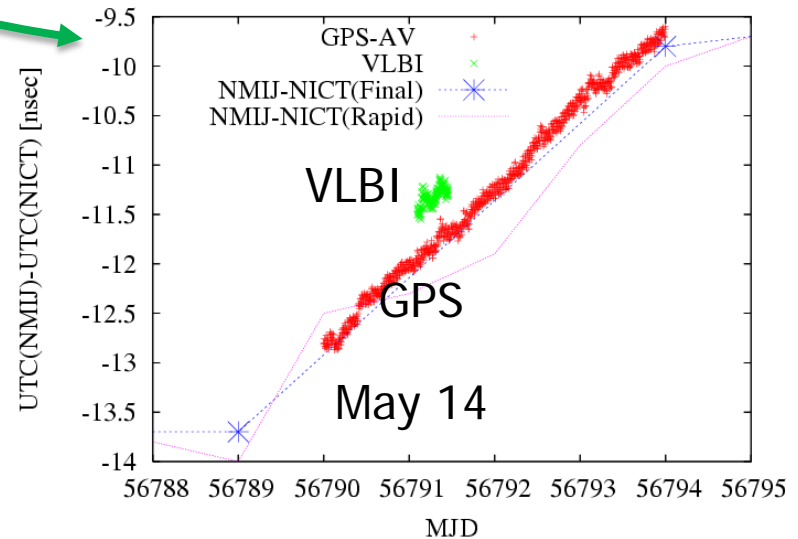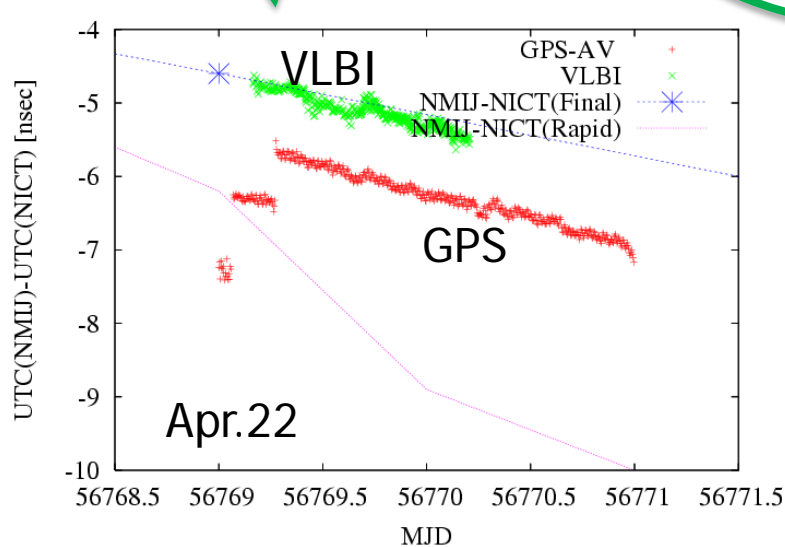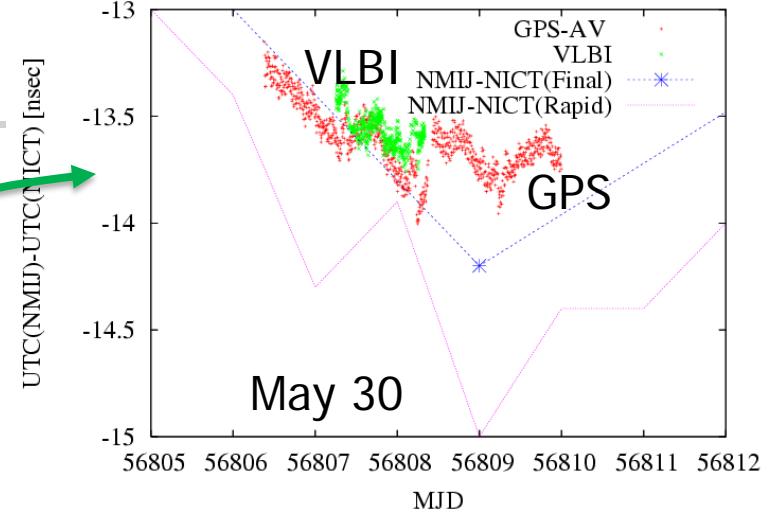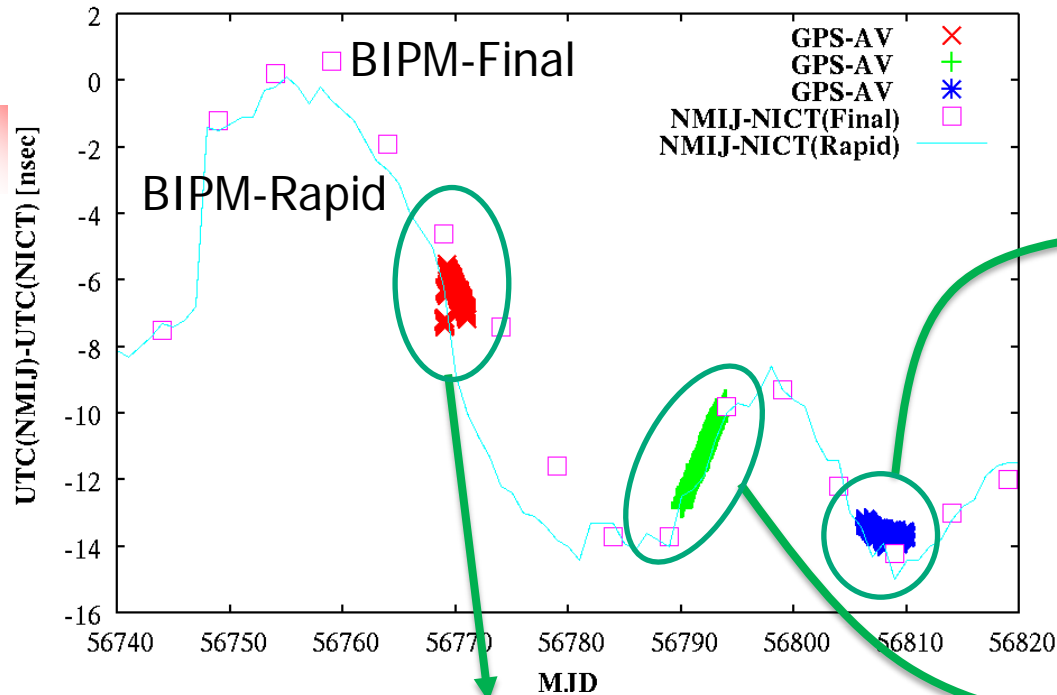

MARBLE1(NMIJ,Tsukuba)

MARBLE2(NICT,Koganei)

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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.
- Analysis:
  - OA,OB->AB baseline data conversion
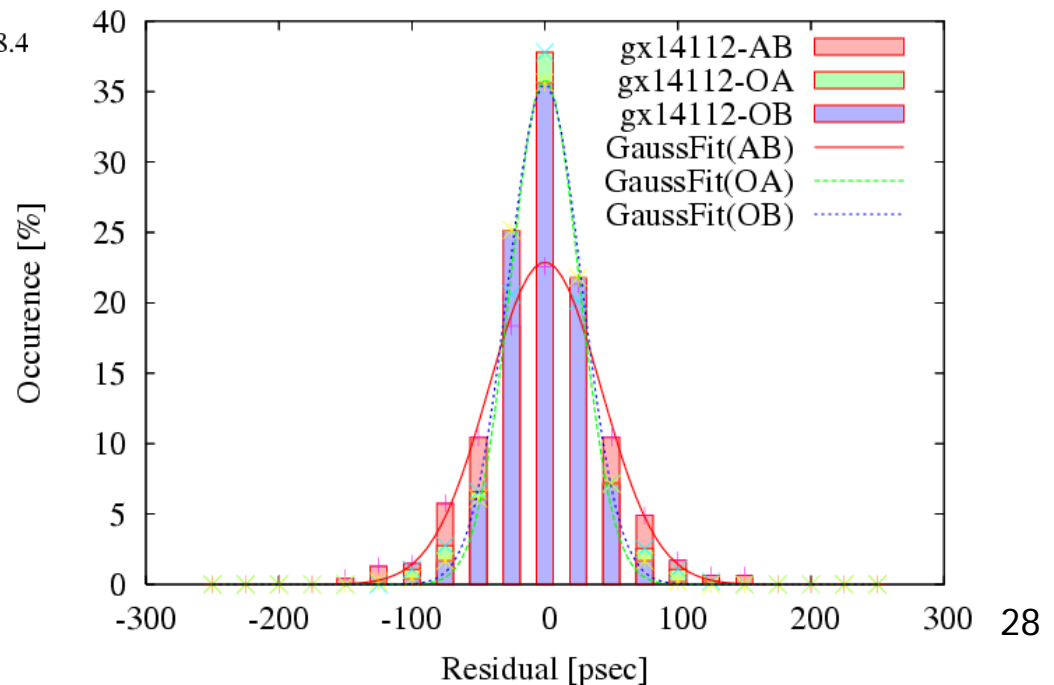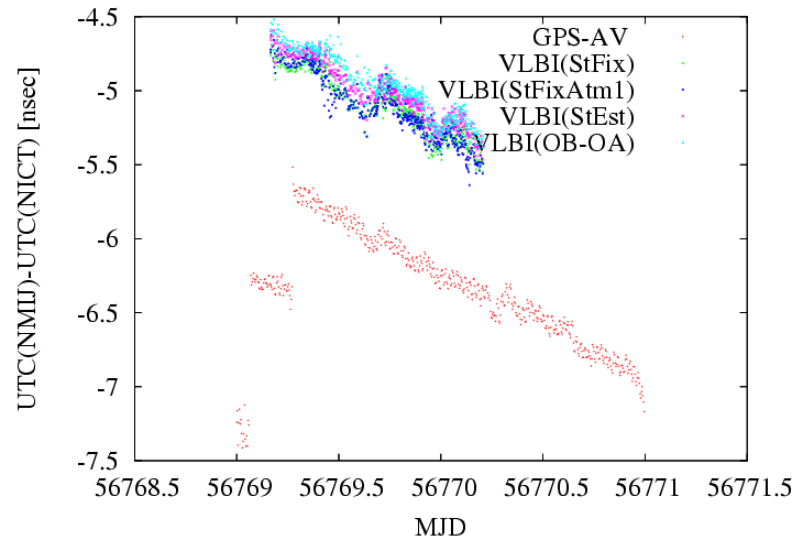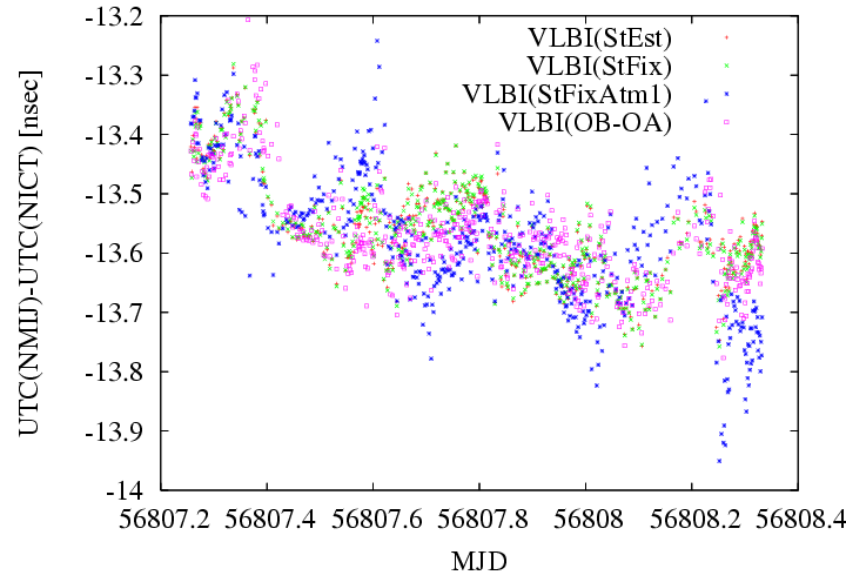 - $\tau_{21} = \tau_{31} - \tau_{32} - \dot{\tau}_{21} \times \tau_{32}$

Time comparison Analysis

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.

Nest steps to be done

- Long span VLBI observations for frequency comparison
- Broadband Observations
  - Domestic: Kashima34,Marble1,Marble2
    - Geodetic, Time transfer experiments
  - International: We are planning to perform intercontinental broadband observation with MIT/Haystack.
- Target precision:

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)

Thank you for Attention!

AB Baseline Data

E-U [mm]

E-N [mm]