Broadband VLBI System GALA-V

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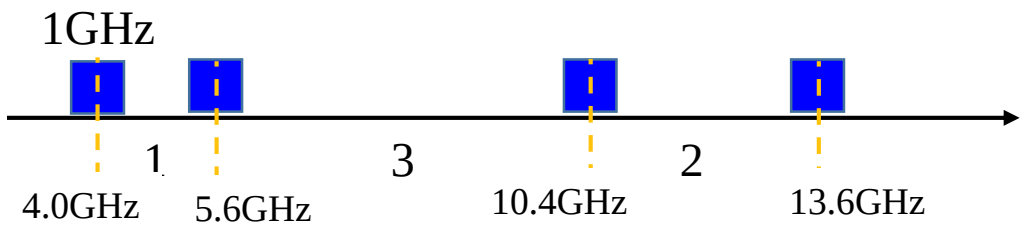
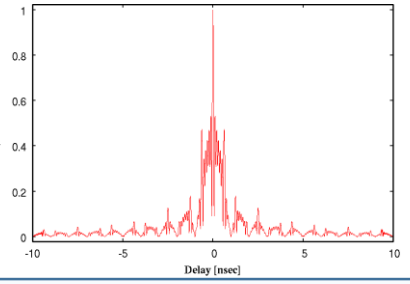
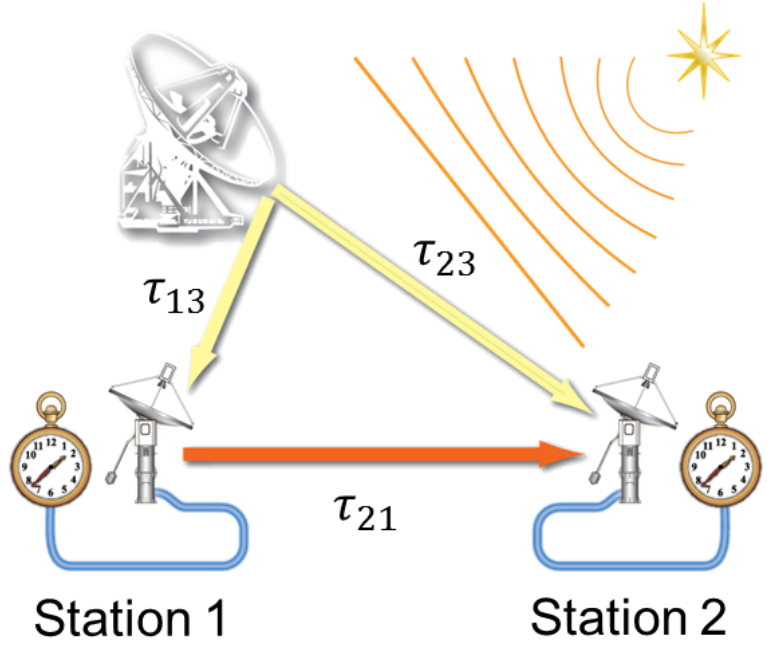
GALA-V Project Overview

Frequency comparison by using Transportable Broadband telescopes

- Radio Frequency： 3-14 GHz (VGOS Compatible)
- Data Acquisition： 4 band (1024 MHz width)
  - Nominal Freq. Array: Fc=4.0GHz, 5.6GHz, 10.4GHz, 13.6GHz
  - Effective Bandwidth：3.8GHz (10 times more than Conventional)

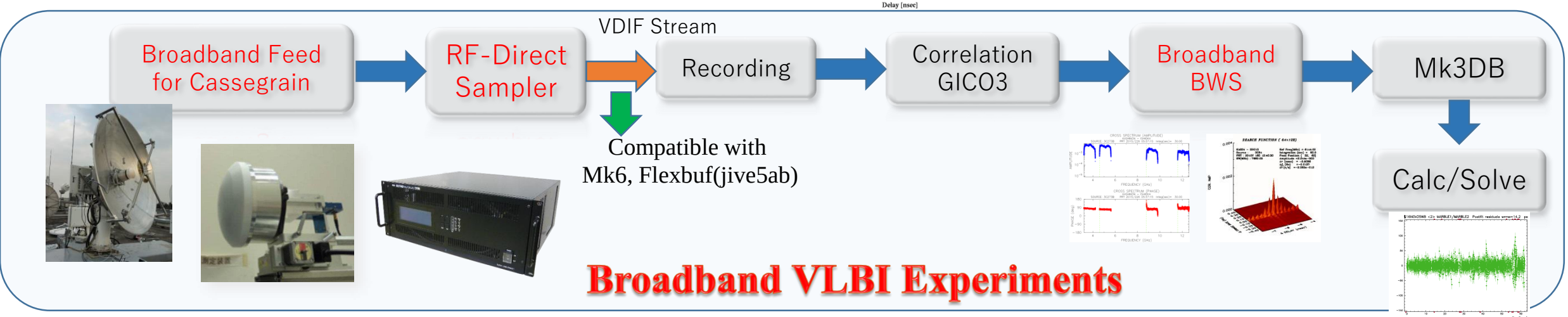






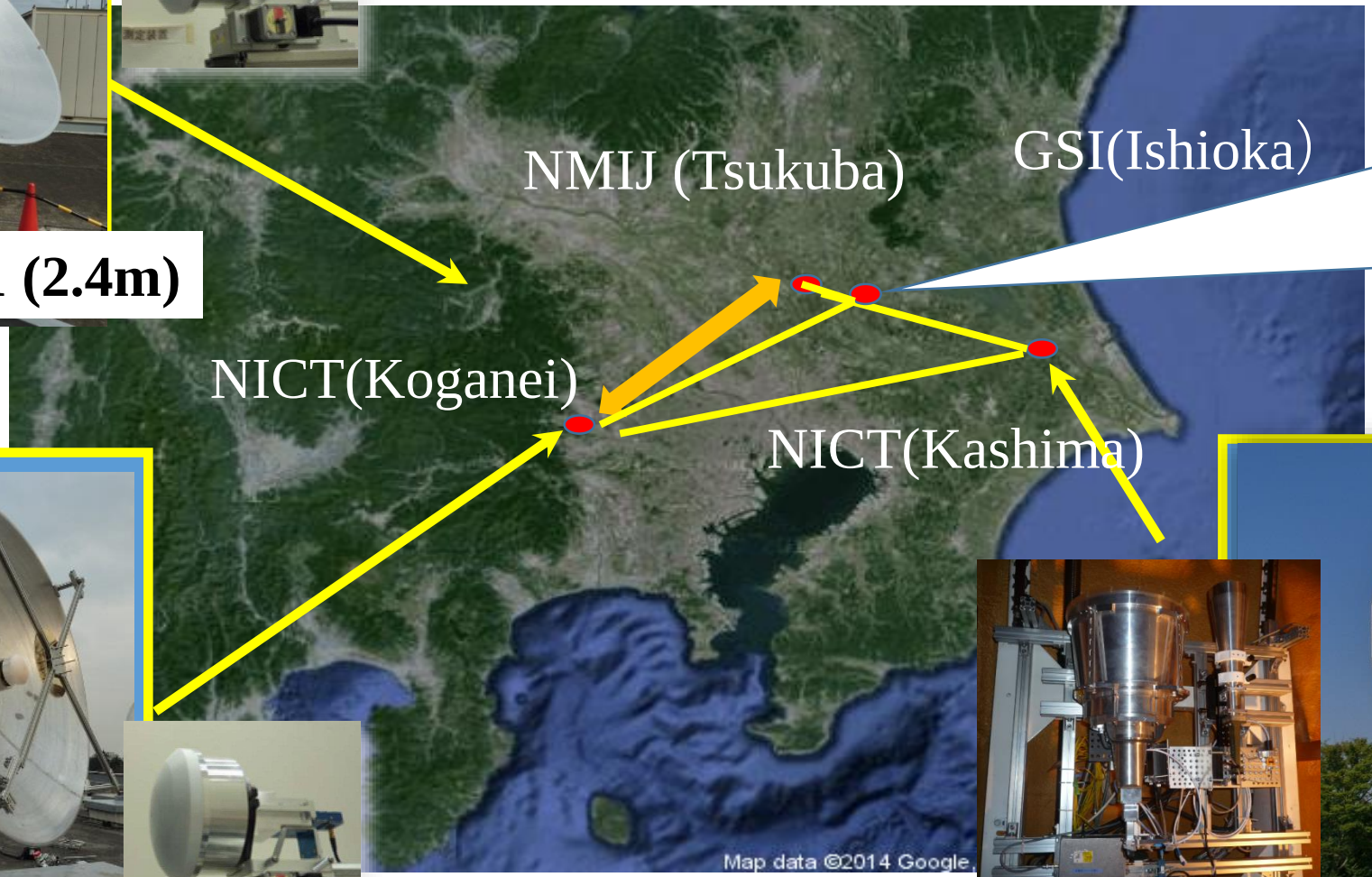
$$\tau_{21} = \tau_{13} - \tau_{23}$$

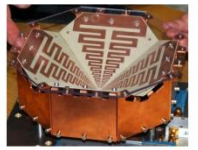
By using closure delay relation.



Broadband VLBI Stations in Japan

MARBLE1 (2.4m)





Ishioka 13m

MARBLE2(2.4m)

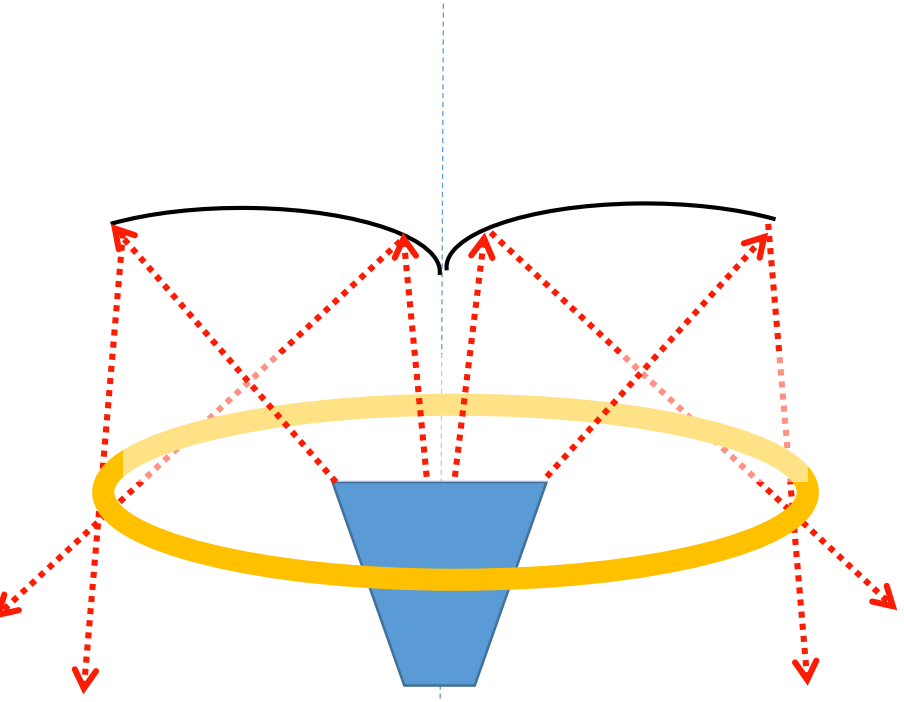
NINJA Feed
For Marble

Broadband
NINJA Feed

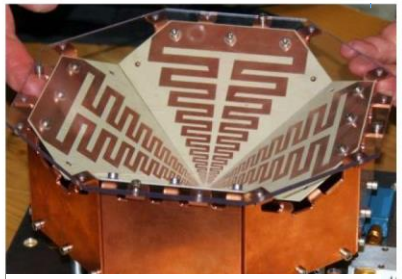
Kashima 34m

Reason why NICT Developed own Broadband Feeds

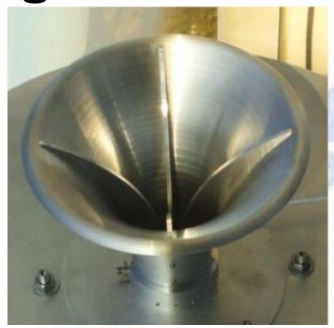
Requirement of
Broadband Frequency
and **Narrow beam width**



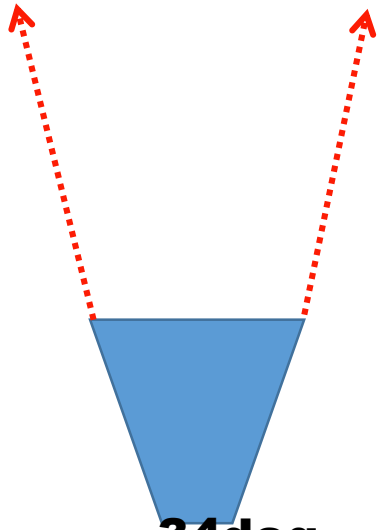
~120deg.



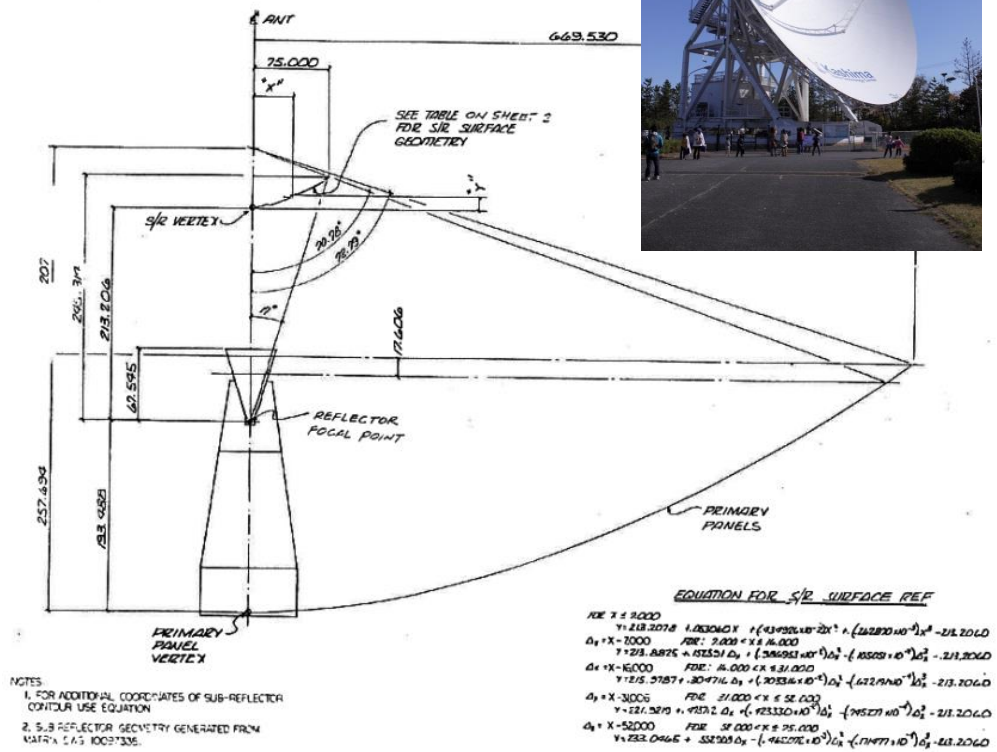
Eleven Feed



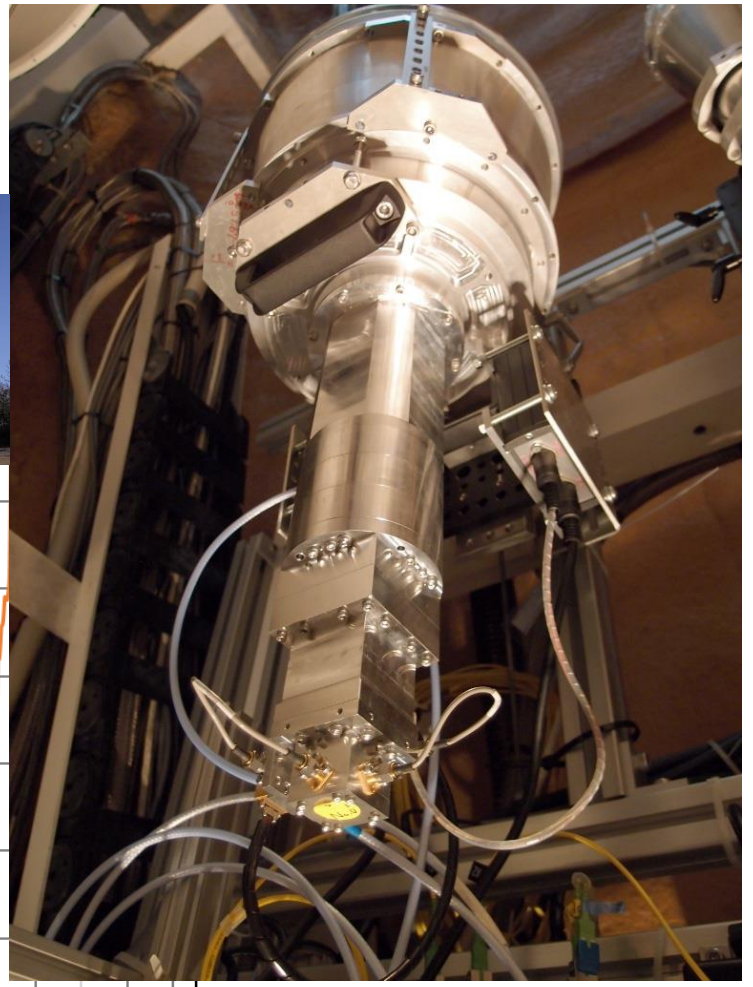
QRFH



~34deg.

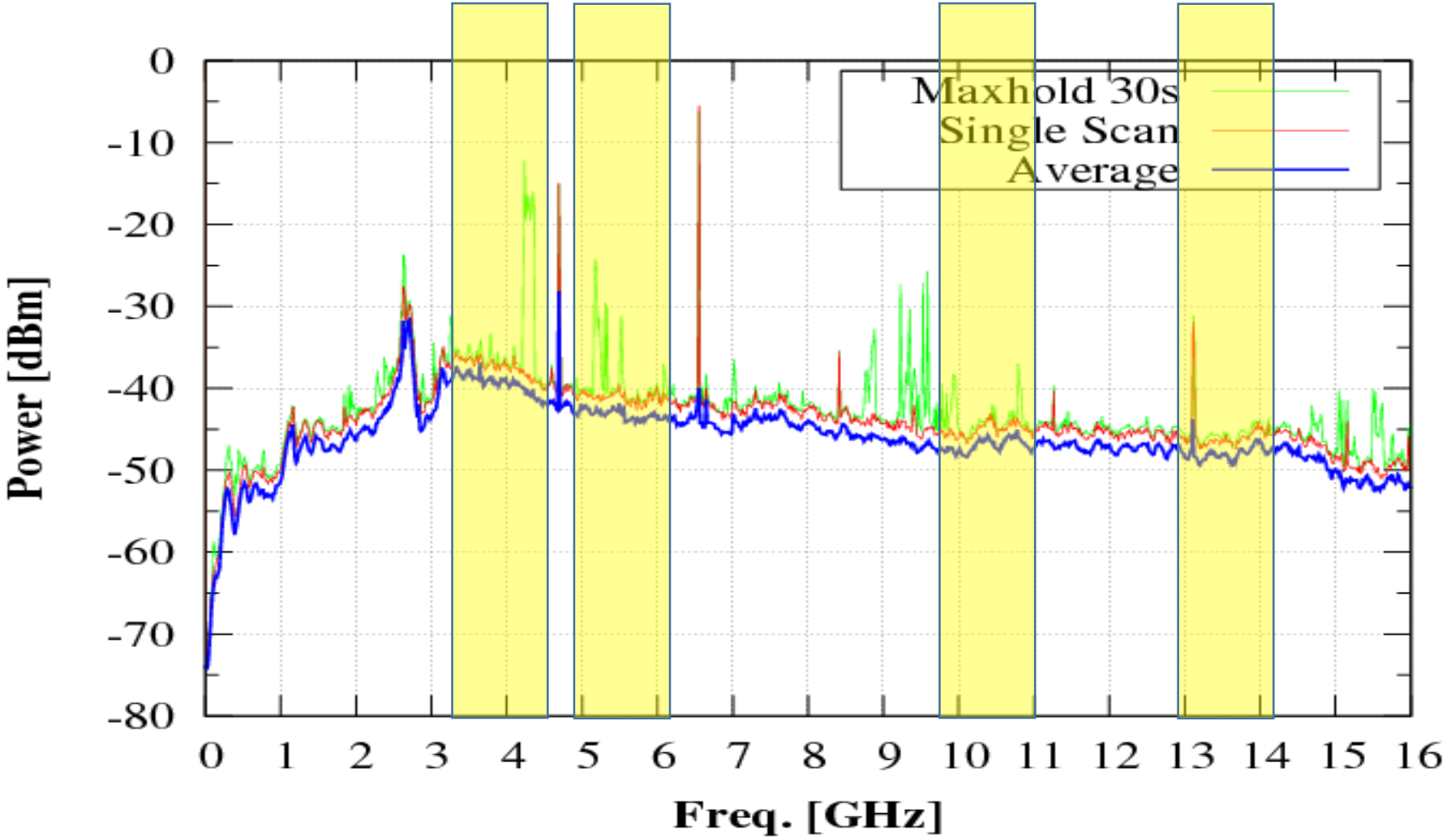


NINJA Feed Dual-Pol mounted in July



Poster:Ujihara G07-P-10

Current State at Kashima 34m
Broadband Signal



RBW=3MHz
Whole BW~12GHz

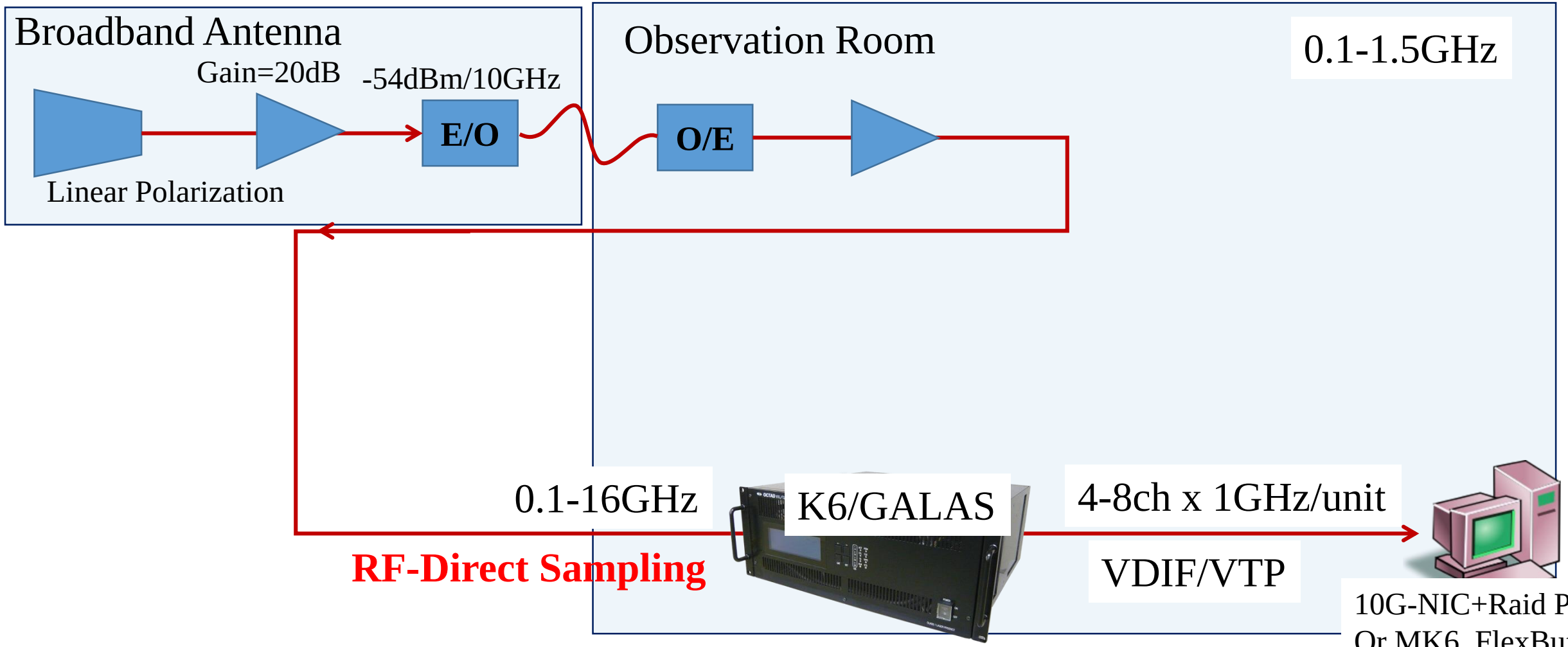
N=12GHz/3MHz
=36dB

Total Powe~-45+36
=-9dBm
< -5dBm (RFI)

Data Acquisition System

300k=-174 dBm/Hz
-74dBm/10GHz

We have to be careful to compromise (1)avoiding saturation of system and (2) increase of noise figure, as discussed by Chris(2012) .



As close as Zero Redundancy

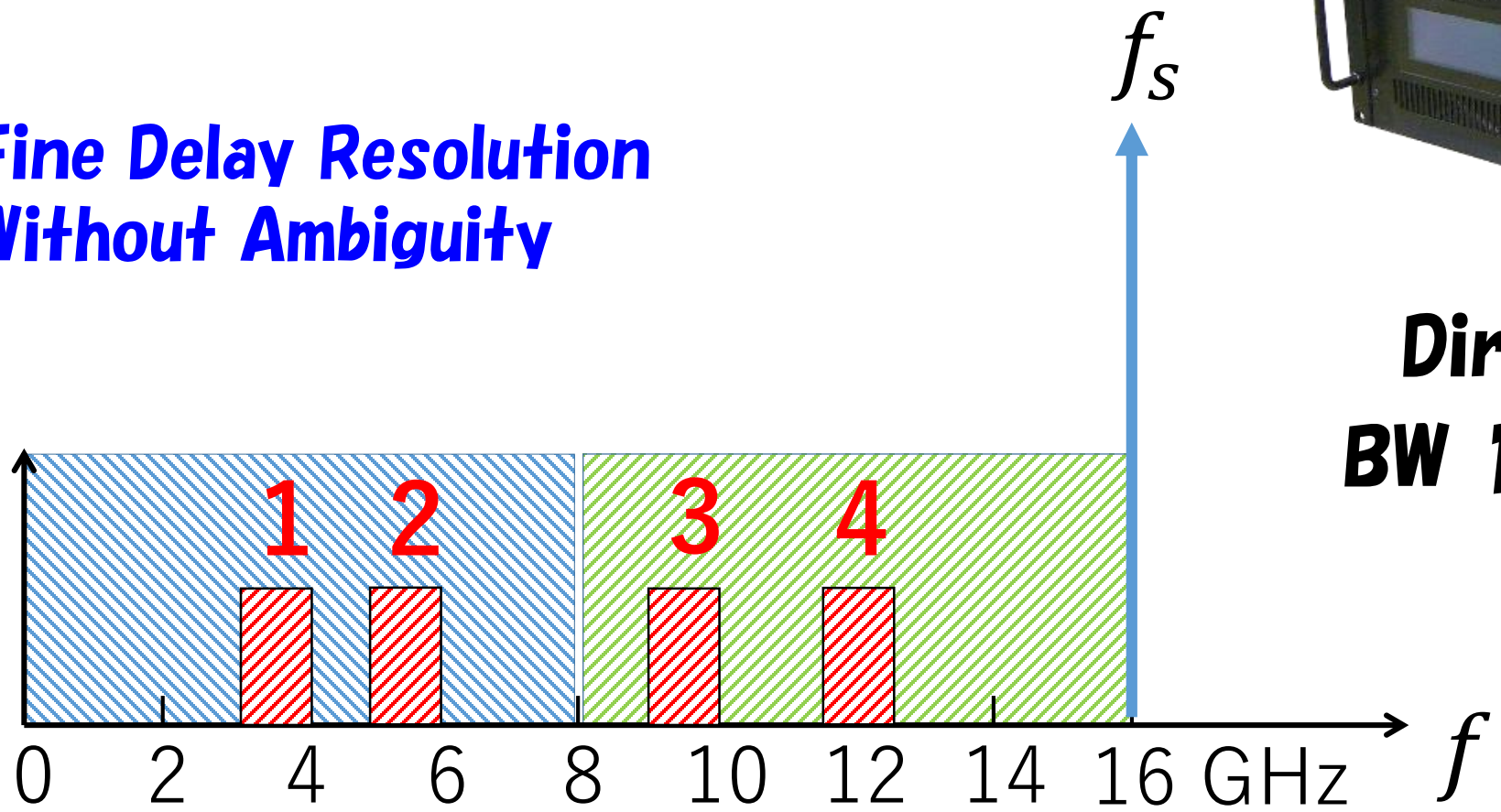
Frequency allocation

Direct Sampling

BW 1024MHz each

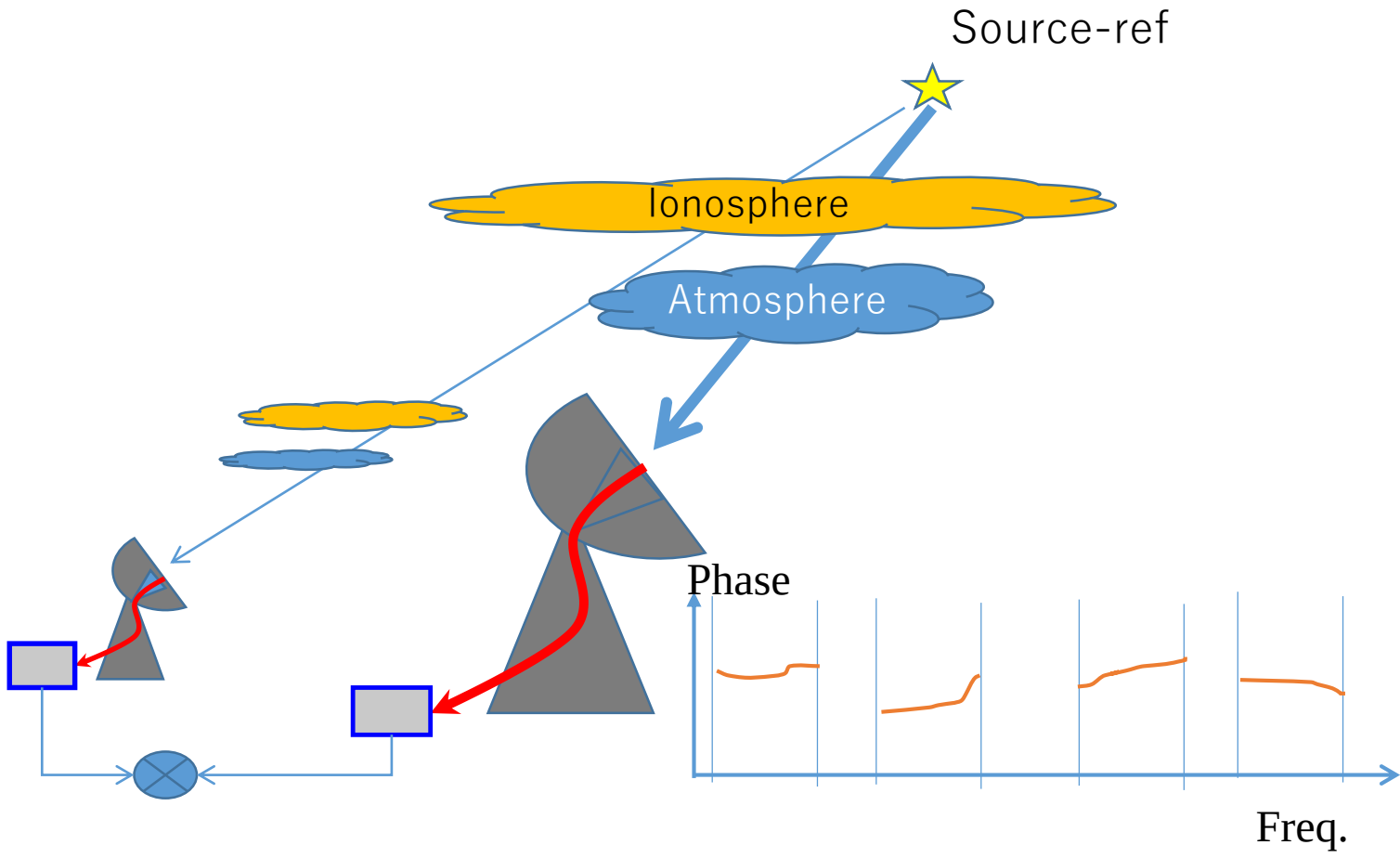
Fine Delay Resolution

Without Ambiguity



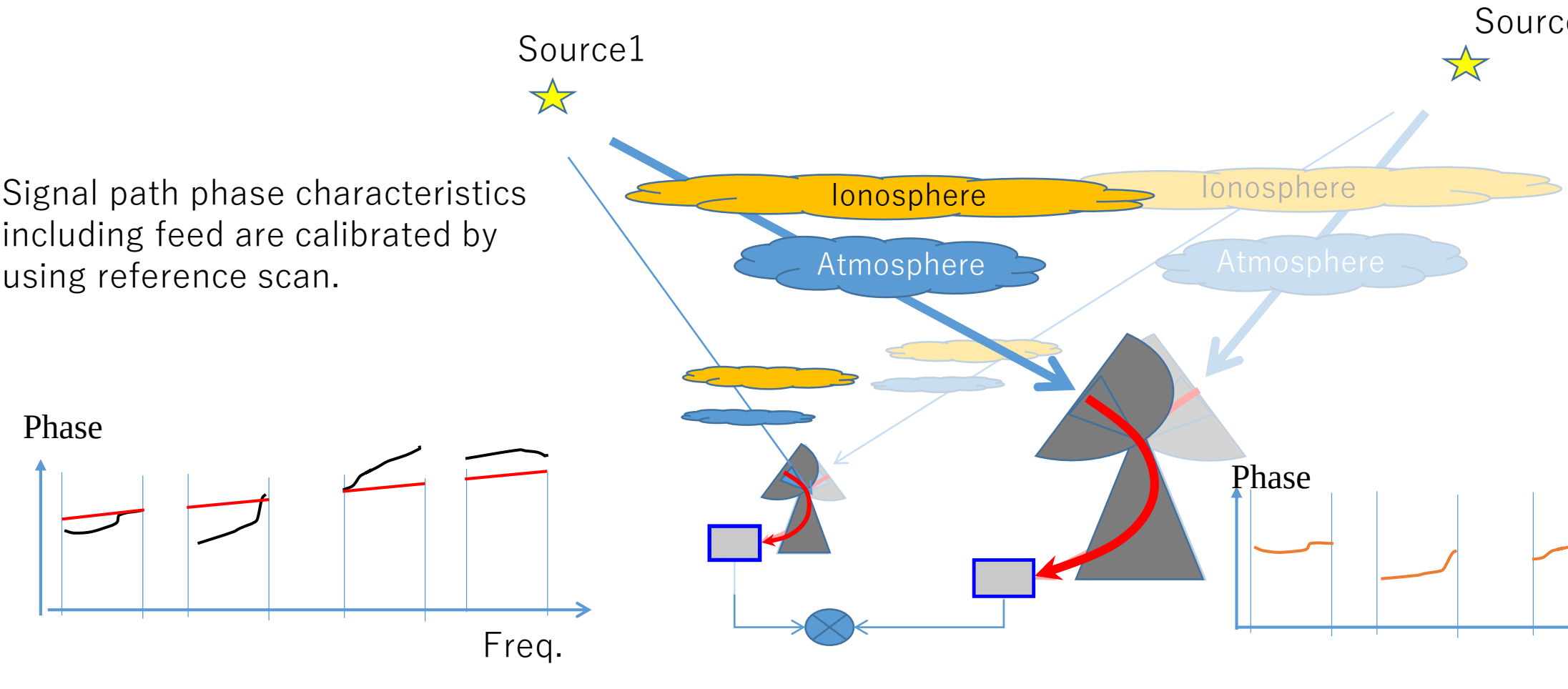
Lower Edge= 3.2, 4.8, 8.8, 11.6GHz

Procedure of Broadband Phase Calibration with radio source



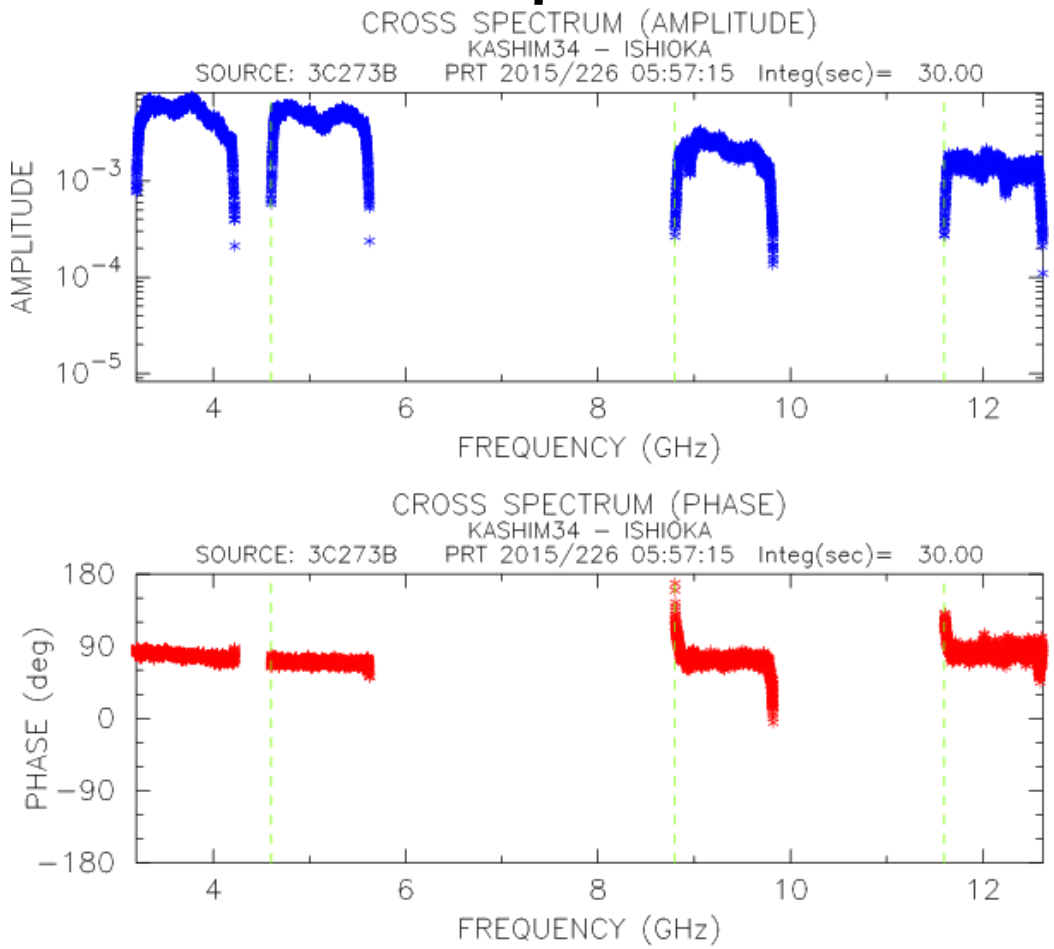
Procedure of Broadband Phase Calibration with radio source

Signal path phase characteristics including feed are calibrated by using reference scan.

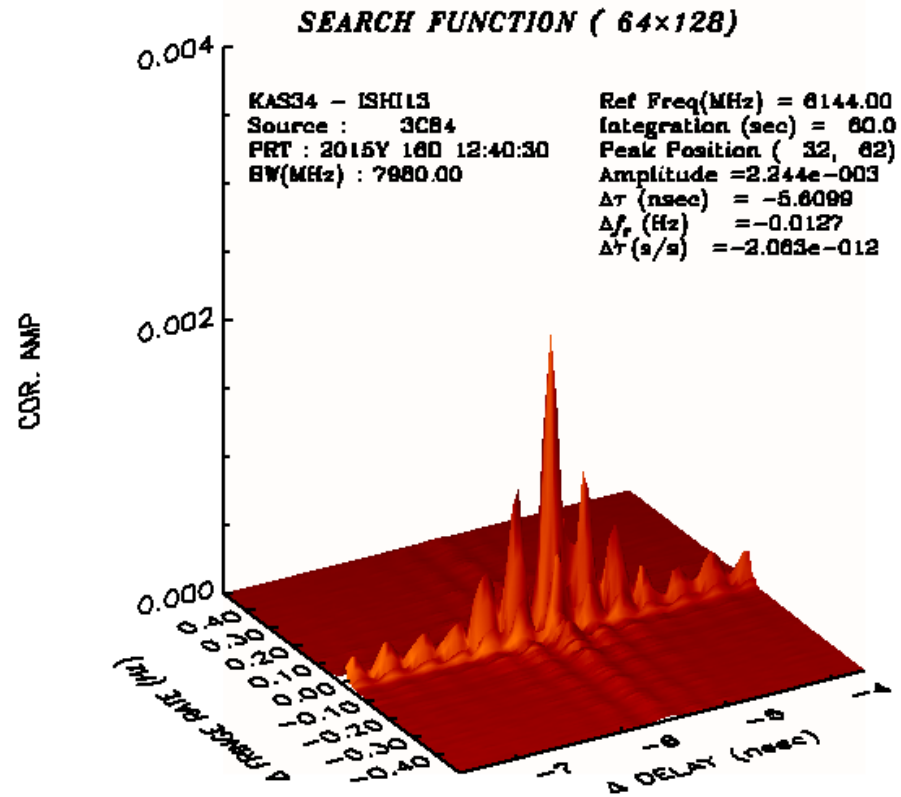


Full Bandwidth Synthesis #1-#(6-14GHz)

Cross Spectrum

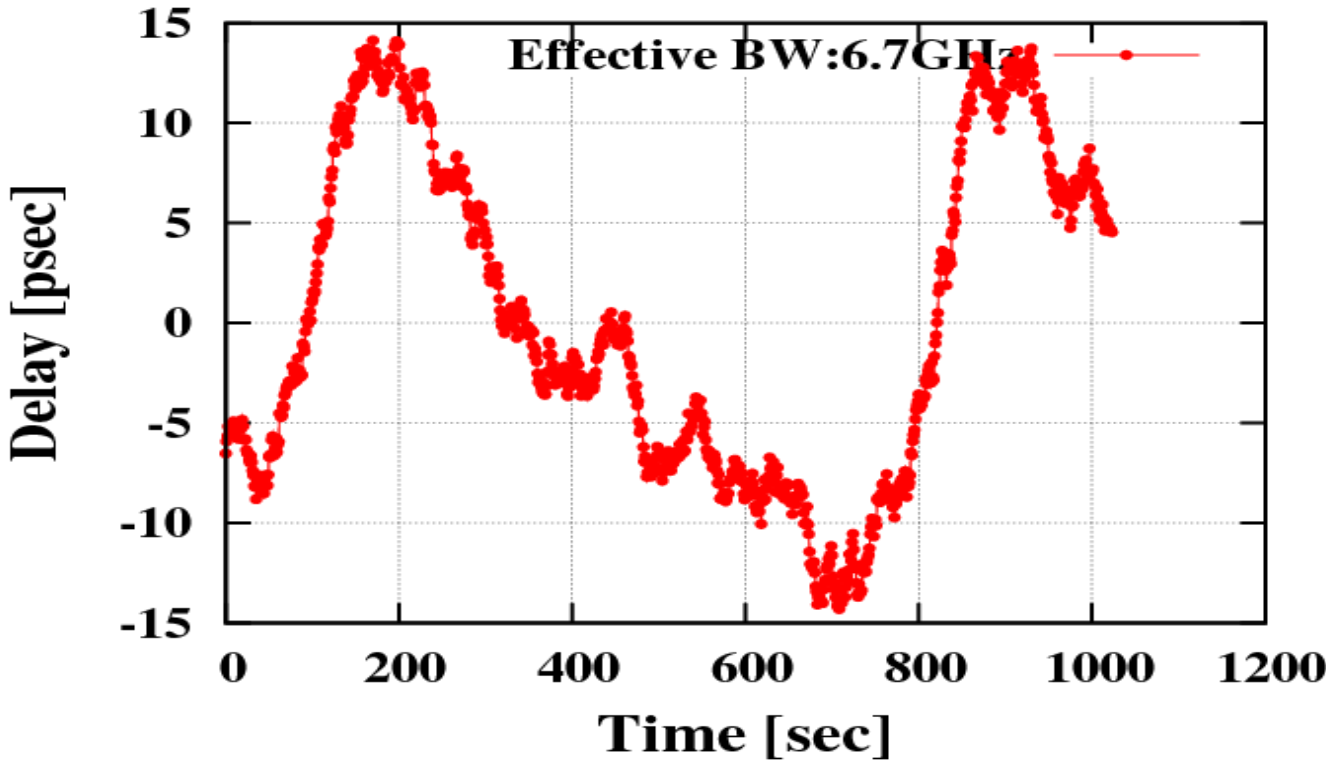


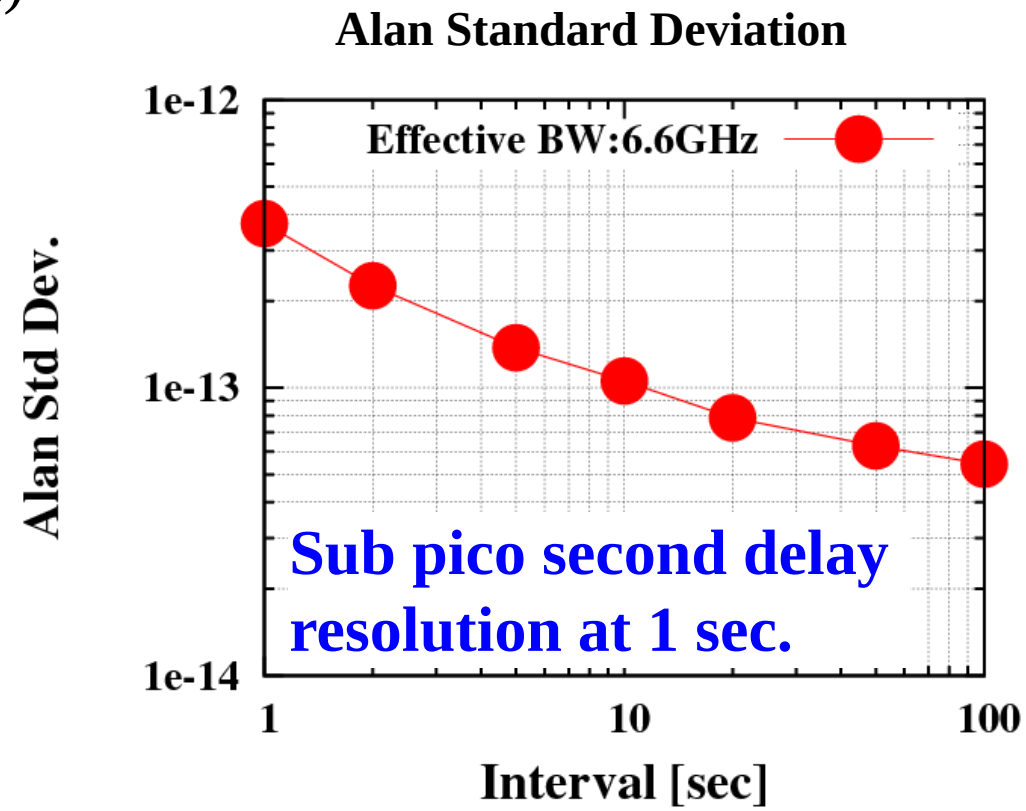
Delay Resolution Function



Delay Behavior Broadband Group Delay (3.2-12.6GHz) Kashima34 – Ishioka 13m

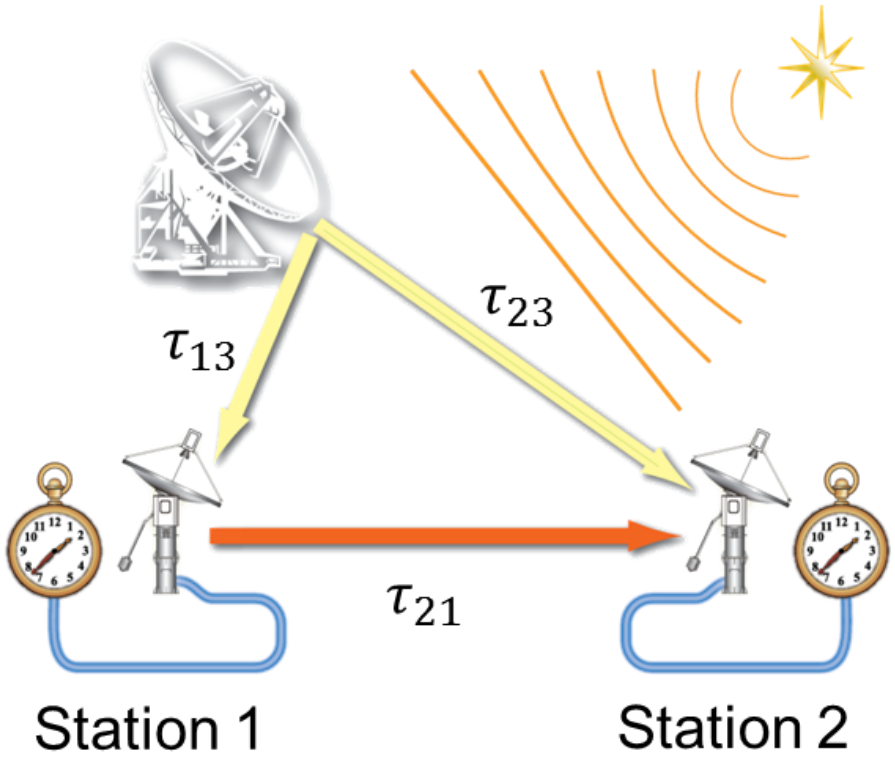
Exp. on 14 Aug.2015,
Freq. array=(Lower Edge=3.2, 4.8, 8.8, 11.6GHz)





Broadband VLBI Data

‘Small – Small’ Baseline

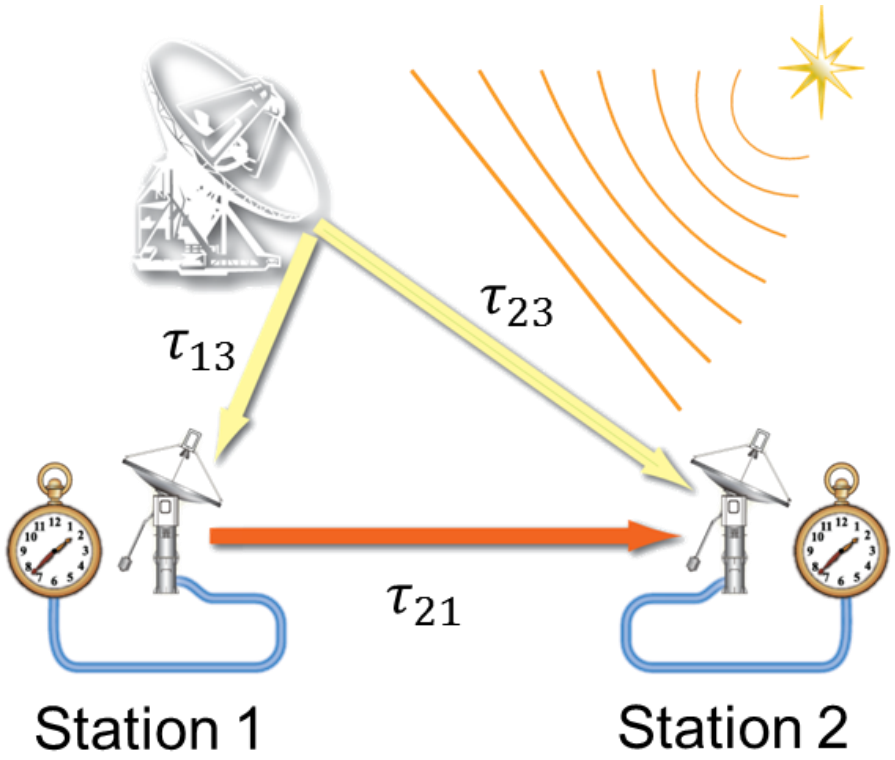


‘Small – Small’ Baseline

- Closure delay relation used for ‘small-small’ baseline.

$$\tau_{21}(t_1) = \tau_{23}(t_1) - \tau_{13}(t_1) - \tau_{13}(t_1)\dot{\tau}_{12}$$

- Advantage of Small Antenna:
  - Quick Slew and Small Distortion
  - Large Diameter’s effects are canceled out.
  - Lower Cost
- Disadvantage:
  - Lower Sensitivity,
  - source structure effect in closure delay.



Delay Precision

Broadband(small-small)

v.s.

Conventional 8180-8680MHz

S/X **500MHz(T2 session)**

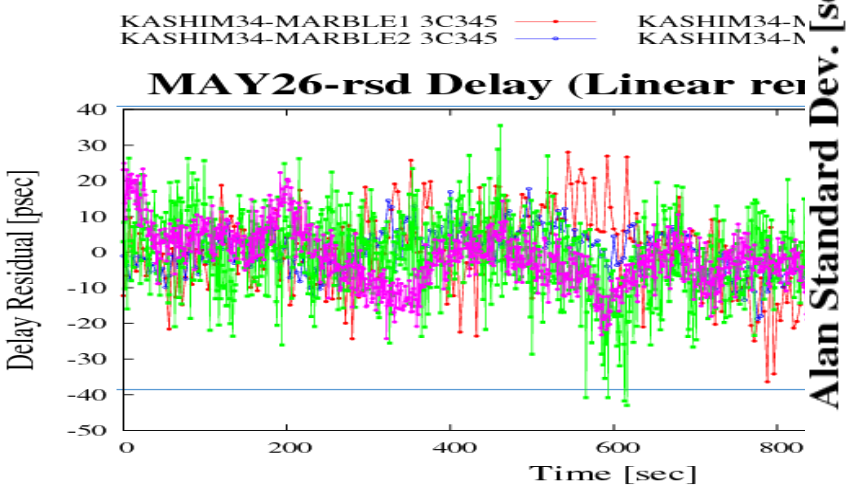
2.4m Diameter

1.6m Diameter

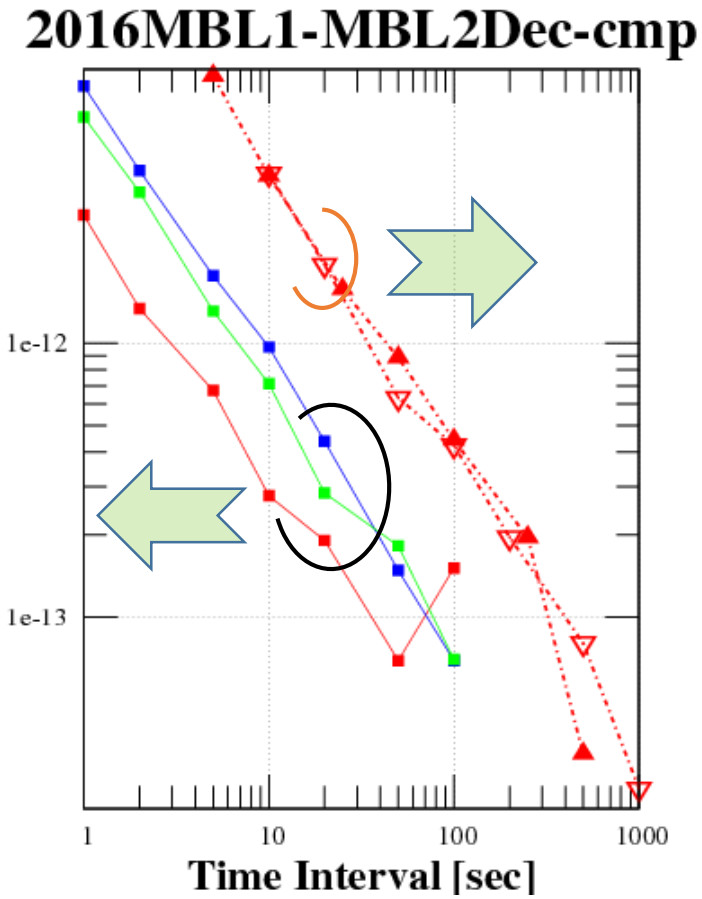
3C273B

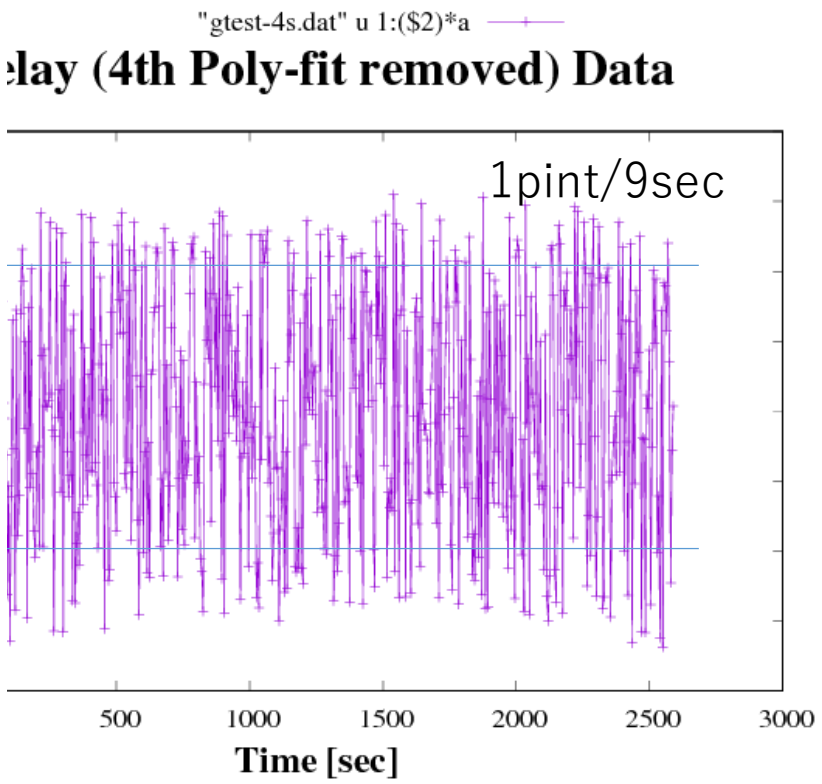
4C39.25

Broadband ‘small-small’ bas
by closure delay



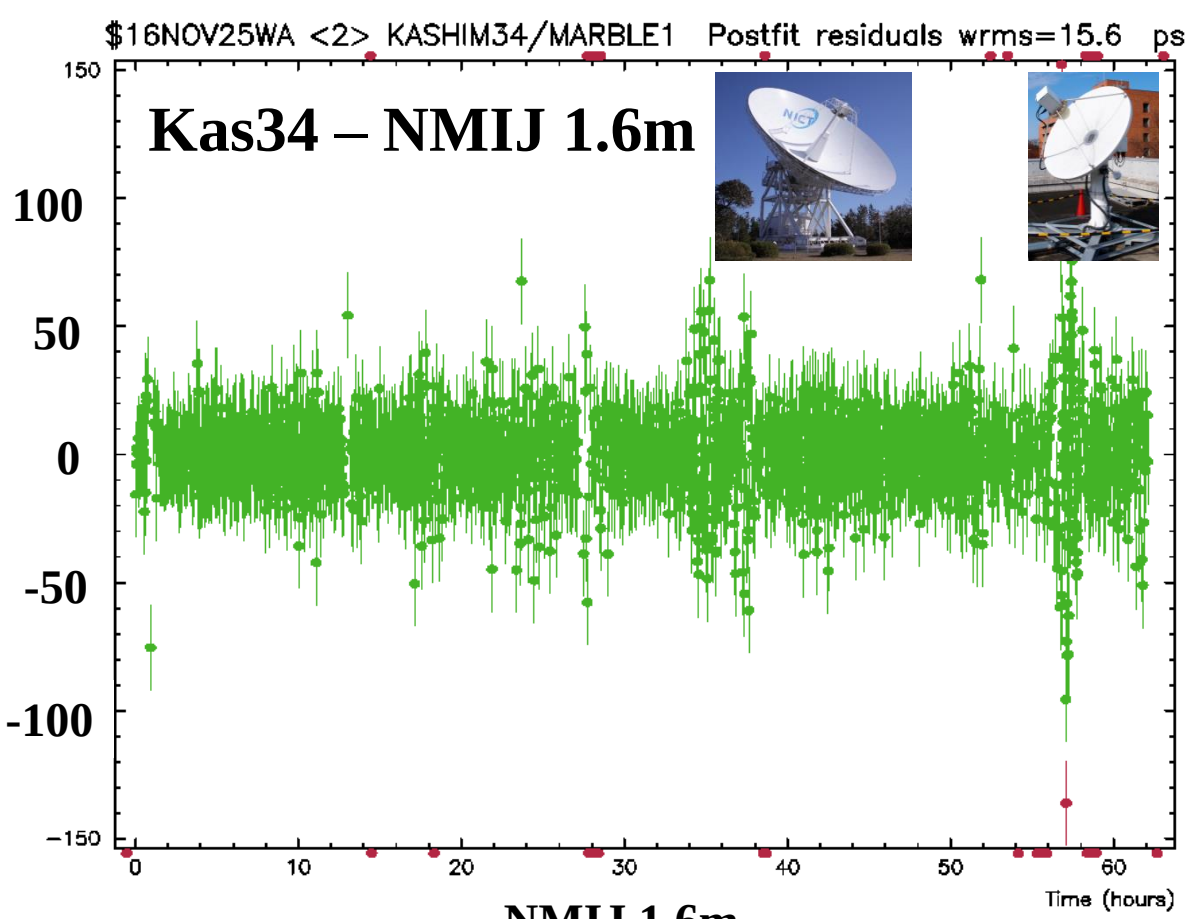
1pint/1sec

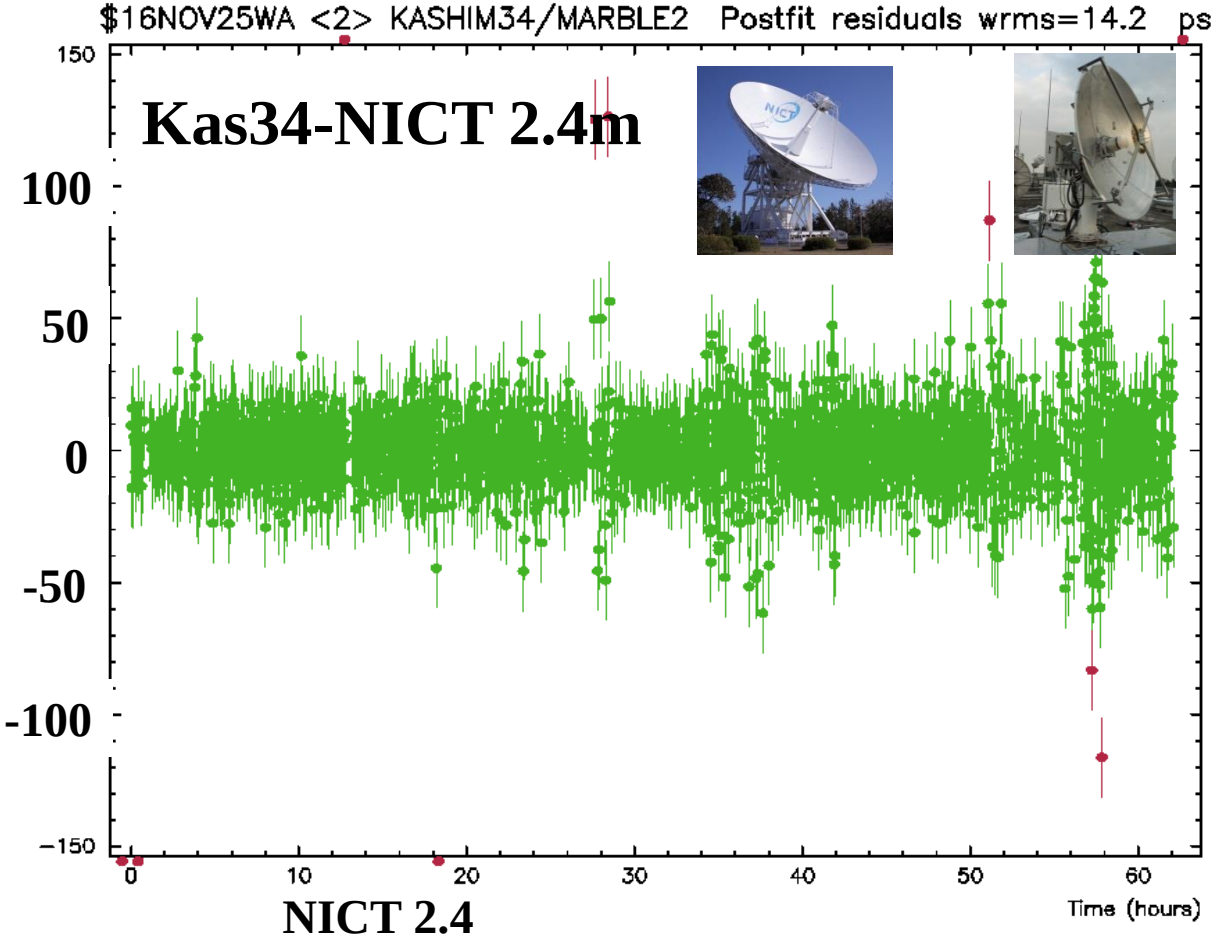




CALC/SOLVE Broadband(5.4-11G Hz) Residual

WRMS Delay Residual ~ 16ps





NMIJ 1,6m

X ：-3962279099.2 mm 1.9 mm
Y ： 3308886482.2 mm 1.5 mm
Z ： 3733538092.1 mm 1.8 mm

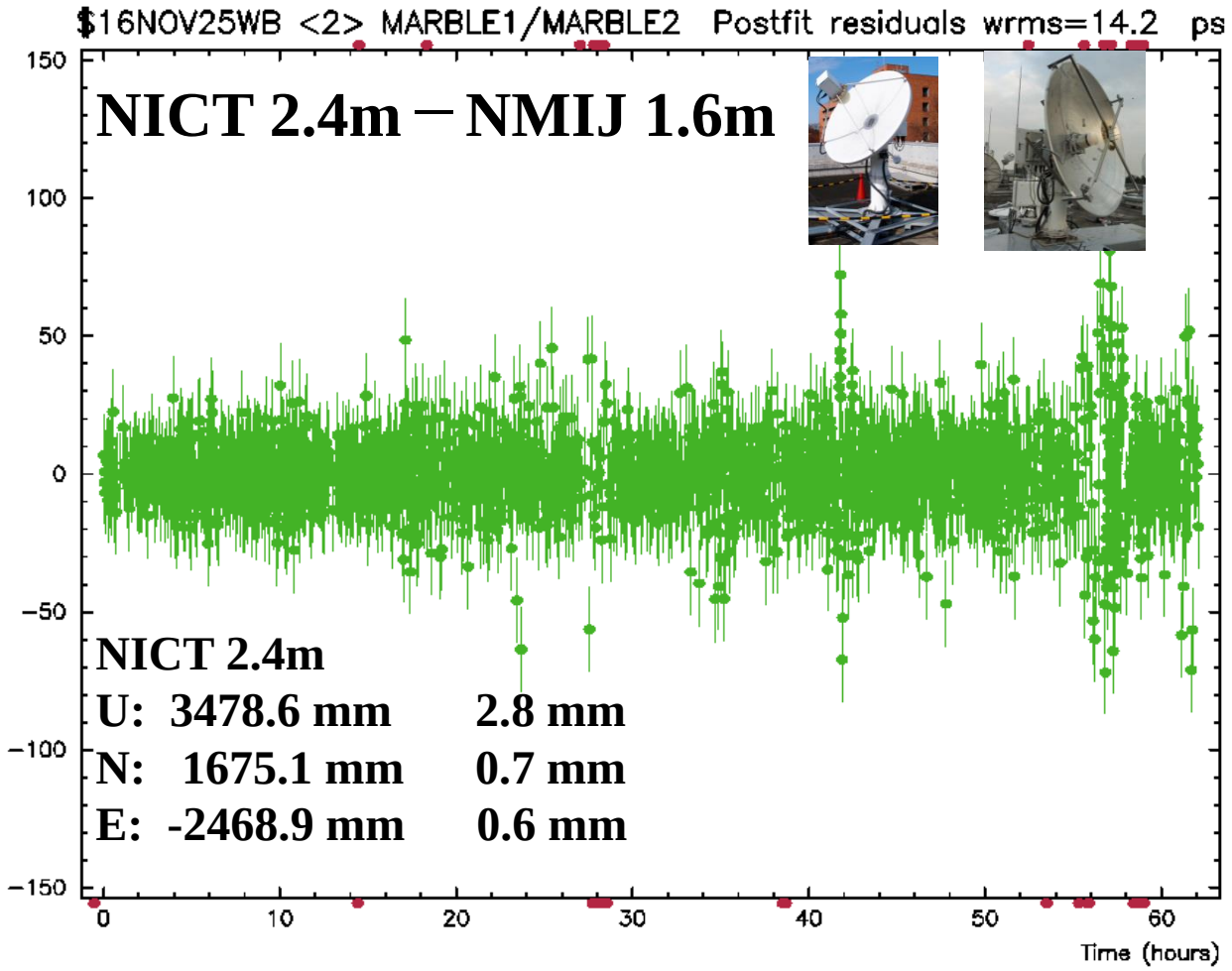
NICT 2.4

X: -3942068754.6 mm 1.8 mm
Y: 3368281011.8 mm 1.5 mm
Z: 3702003908.5 mm 1.7 mm

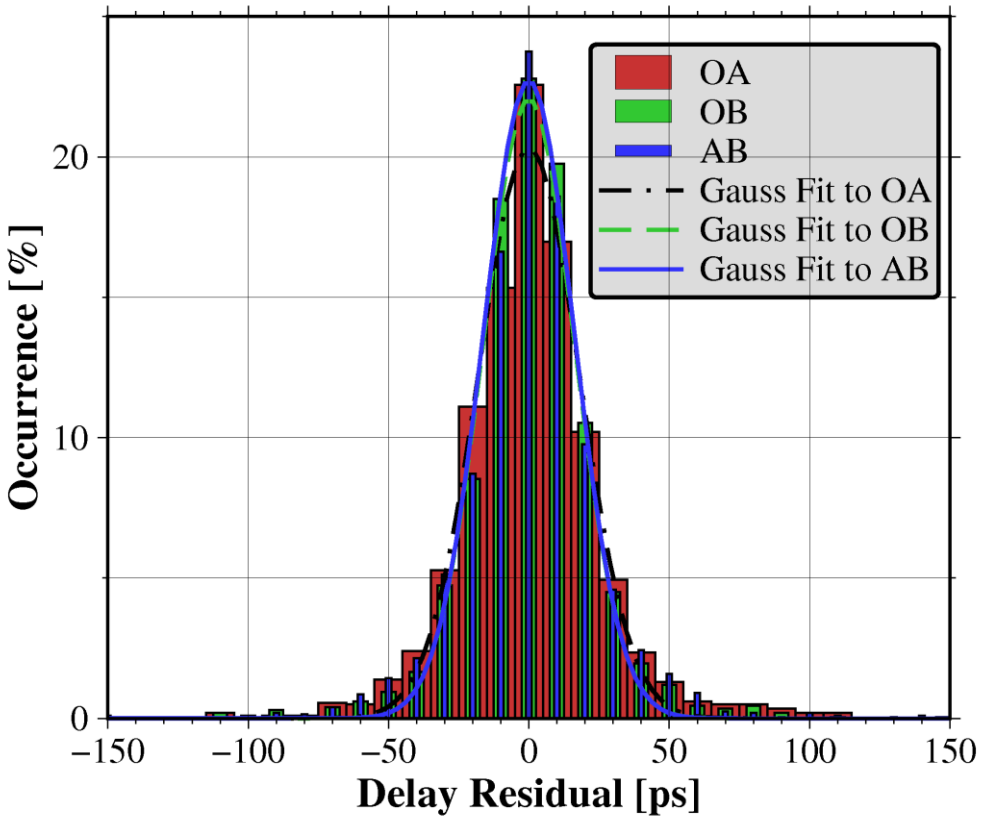
CALC/SOLVE Broadband (5.4-11G Hz) Residual

$$\tau_{21}(t_1) = \tau_{23}(t_1) - \tau_{21}(t_1) - \tau_{21}(t_1)\dot{\tau_{23}}$$

WRMS Delay Residual ~ 15 psec



O:Kashim34
A:MARBLE1 NMIJ 1.6m
B:MARBLE2 NICT 2.4m



CALC/SOLVE Legacy X-band (**BW=1GHz**) Residual

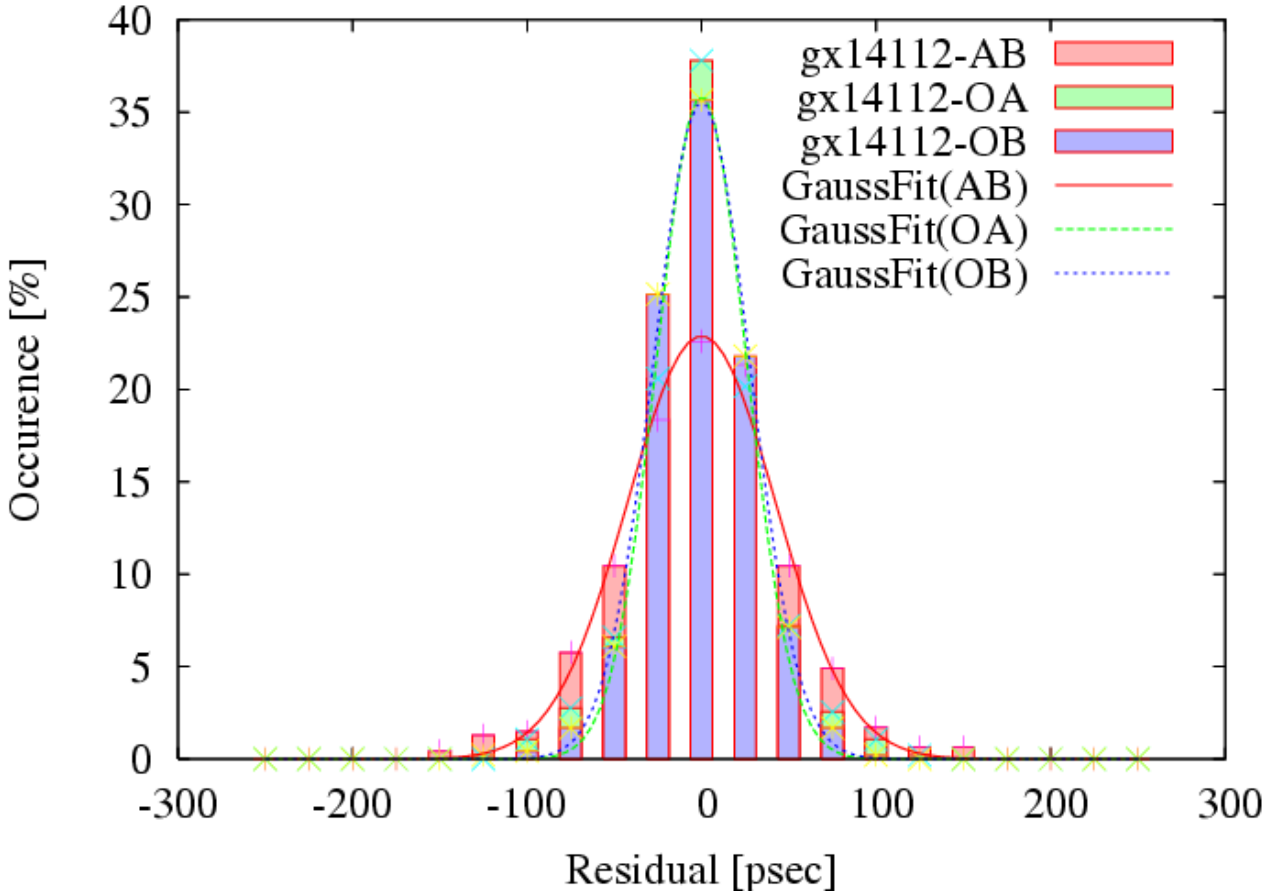
$$\tau_{21}(t_1) = \tau_{23}(t_1) - \tau_{21}(t_1) - \tau_{21}(t_1)\dot{\tau}_{23}$$

OB ~ 27 psec

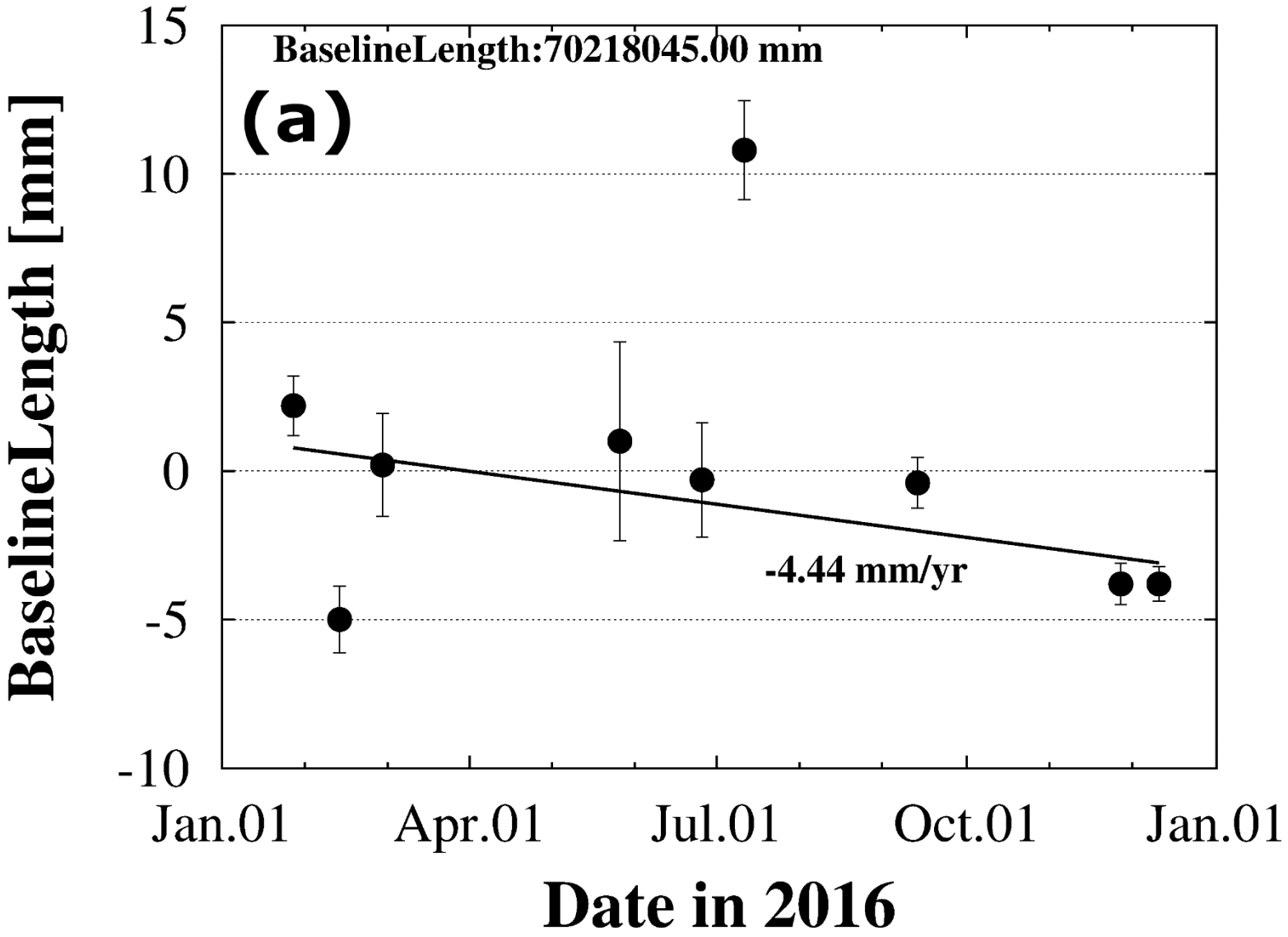
OB ~ 26 psec

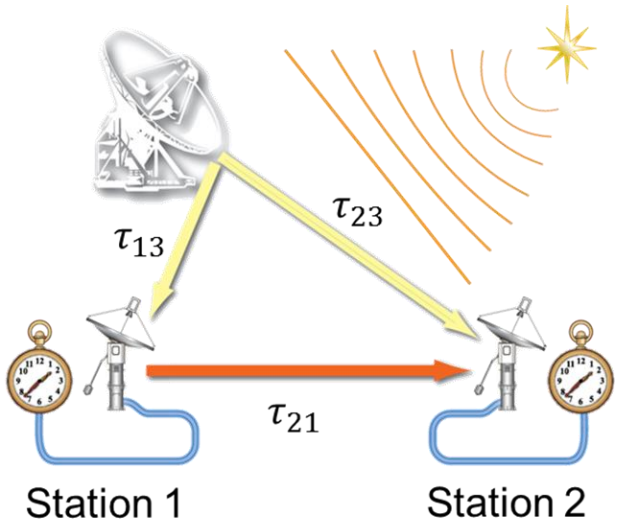
AB ~ 44 psec

O:Kashim34
A:MARBLE1 NMIJ 1.6m
B:MARBLE2 NICT 2.4m



Position Solution of MBL1-MBL2

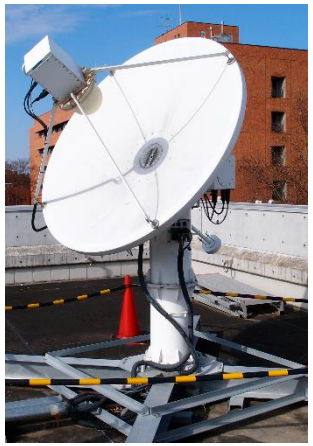




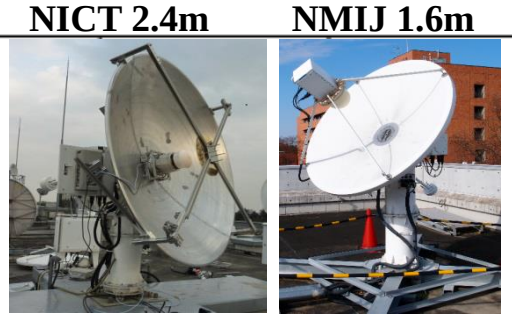
$$\tau_{21} = \tau_{13} - \tau_{23}$$

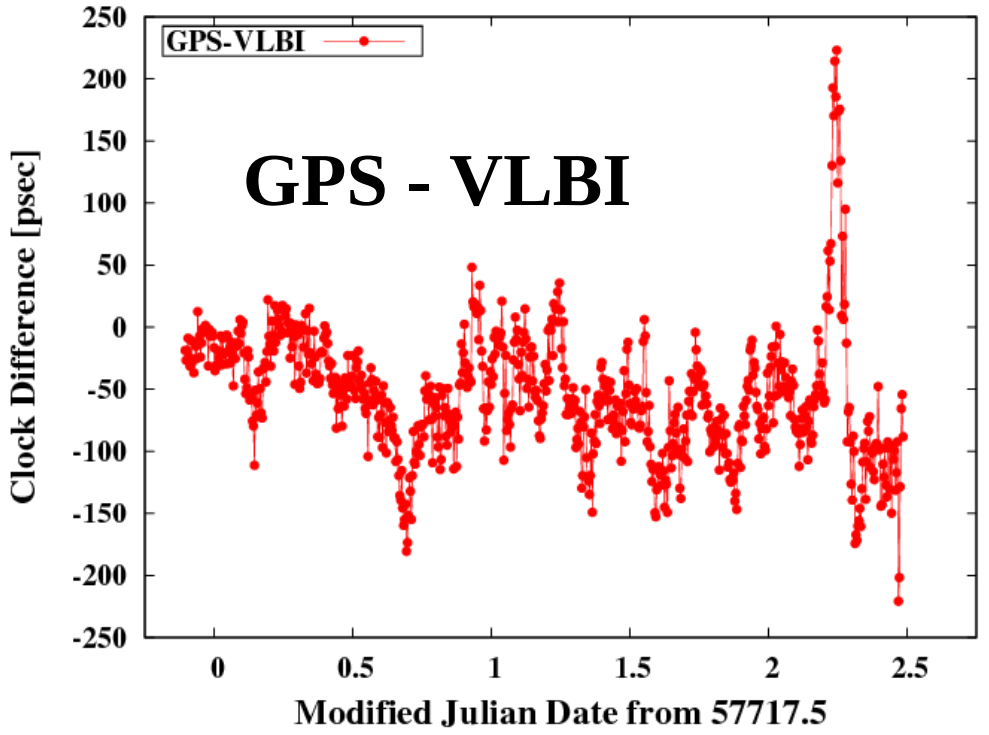
NICT 2.4m

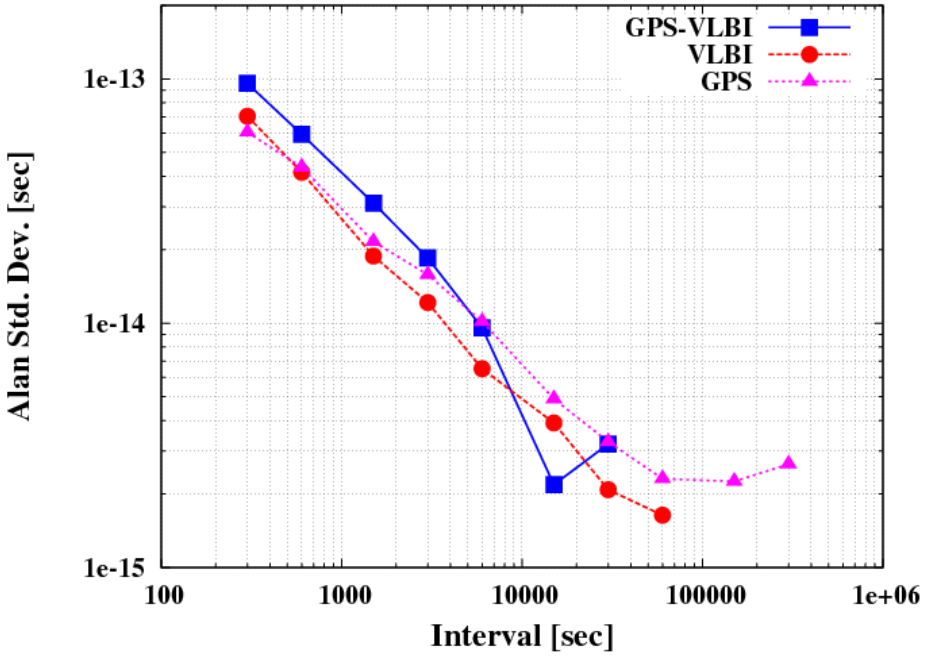
NMIJ 1.6m



Clock Comparison via VLBI and GPS-ppp
2016Nov25 UTC(NICT) – UTC(NMIJ)



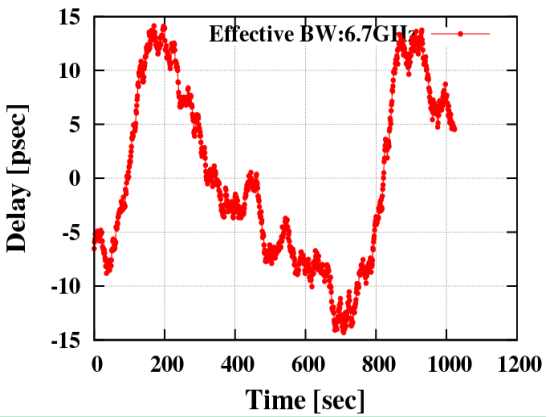


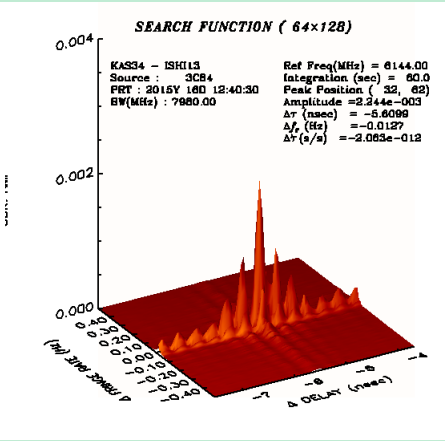


Summary

Broadband Feed: NINJA

RF-Direct Sampling K6/GALAS





Broadband bandwidth Synthesis

1. Our Broadband VLBI System demonstrated **sub-pico second** delay precision. ⇒**Encouradging high precision observation of VGOS.**
2. Our Broadband VLBI system demonstrates that even small diameter antenna pair (1.6m,2.4m) works for geodesy by using broadband (3-12GHz) system and joint observation sensitive antennas.
3. Broadband Channeling is relatively tolerant to RFI.

Thank you for Attention

Acknowledgements

- Development of Broadband Feed was supported by a grant (2013-2014) of Joint Development Research from National Astronomical Observatory of Japan(NAOJ).
- Broadband experiments with Ishioka Station was kindly supported by GSI.
- Highs speed research network environment is supported by JGN.