

The first light and fringe with broadband system at NICT



K.Takefuji, M.Sekido, H.Ujihara

NICT, Japan

Contents of presentation

- Frequency comparison by VLBI
- “Gala-V” system development
 - Broadband system development
 - 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)
 - Principle proving

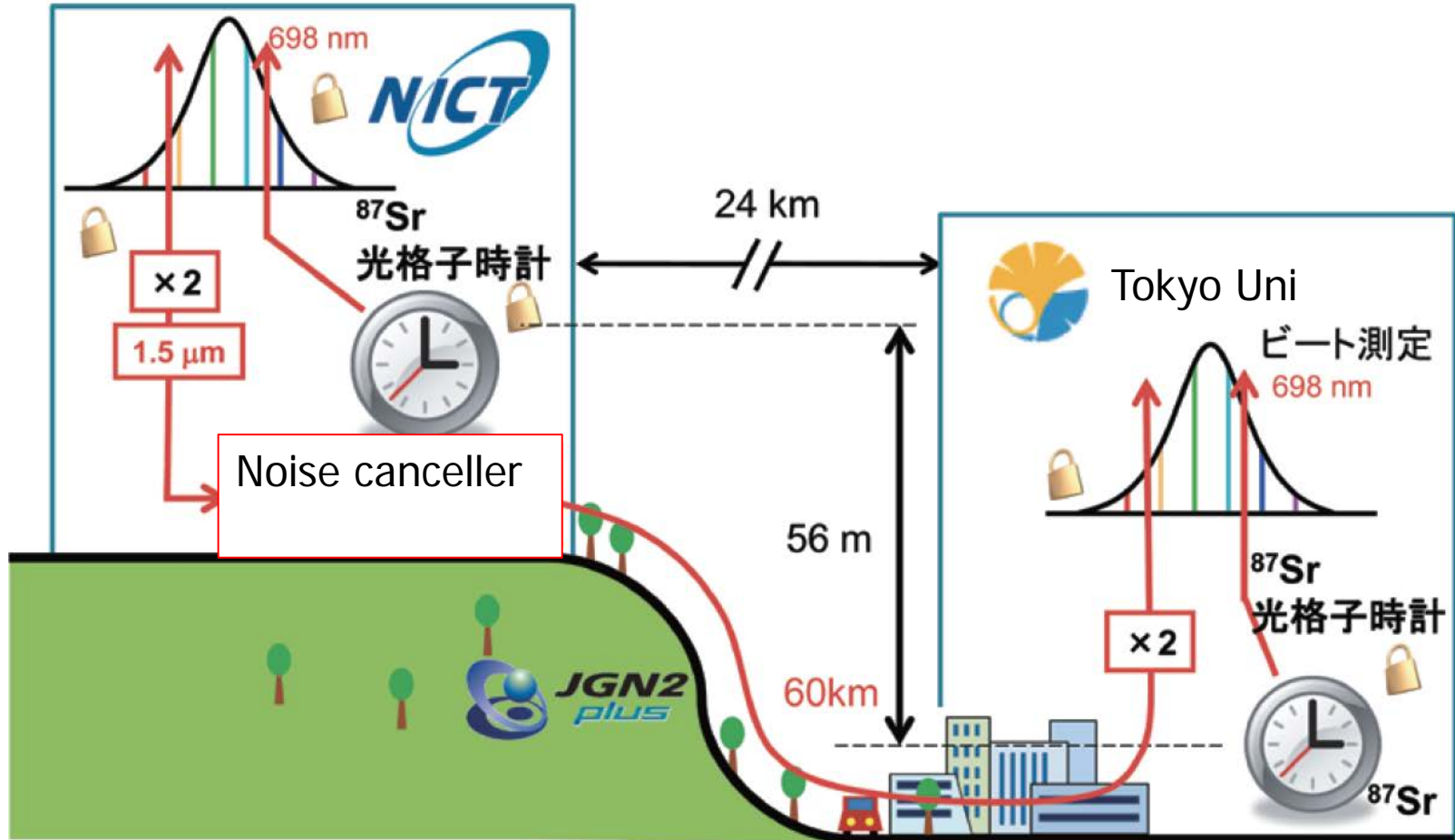
Re-definition of "second"

- Currently defined by Cs atomic clock
 - (9.2GHz, 1.5×10^{-15} @NICT)
- BIPM provides UTC by ensemble average of Cs clock around the world



- Optical lattice clock was invented
- More accurate frequency comparison technique is required (10^{-16})

Measurement by optical-fiber is the best in short baseline

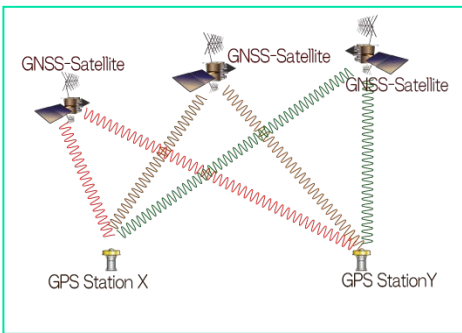


Frequency difference 3~4 Hz

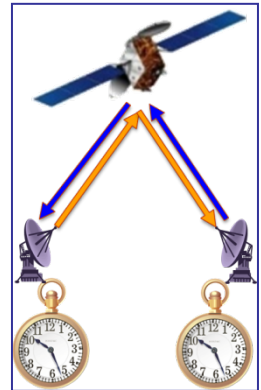
caused by 56m height was detected by Sr optical lattice clock (698nm) (Yamaguchi et al, 2011)

■ Space Technologies over intercontinental baseline

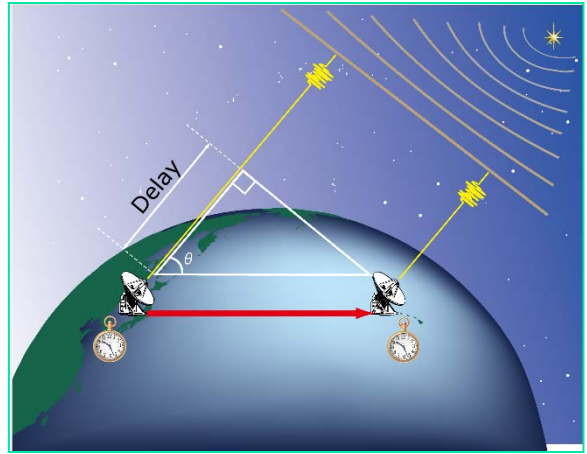
- GNSS(Common view, PPP)
- Two way Satellite Time and Frequency Transfer(TWSTFT)
- VLBI (Very long baseline interferometer)



GNSS

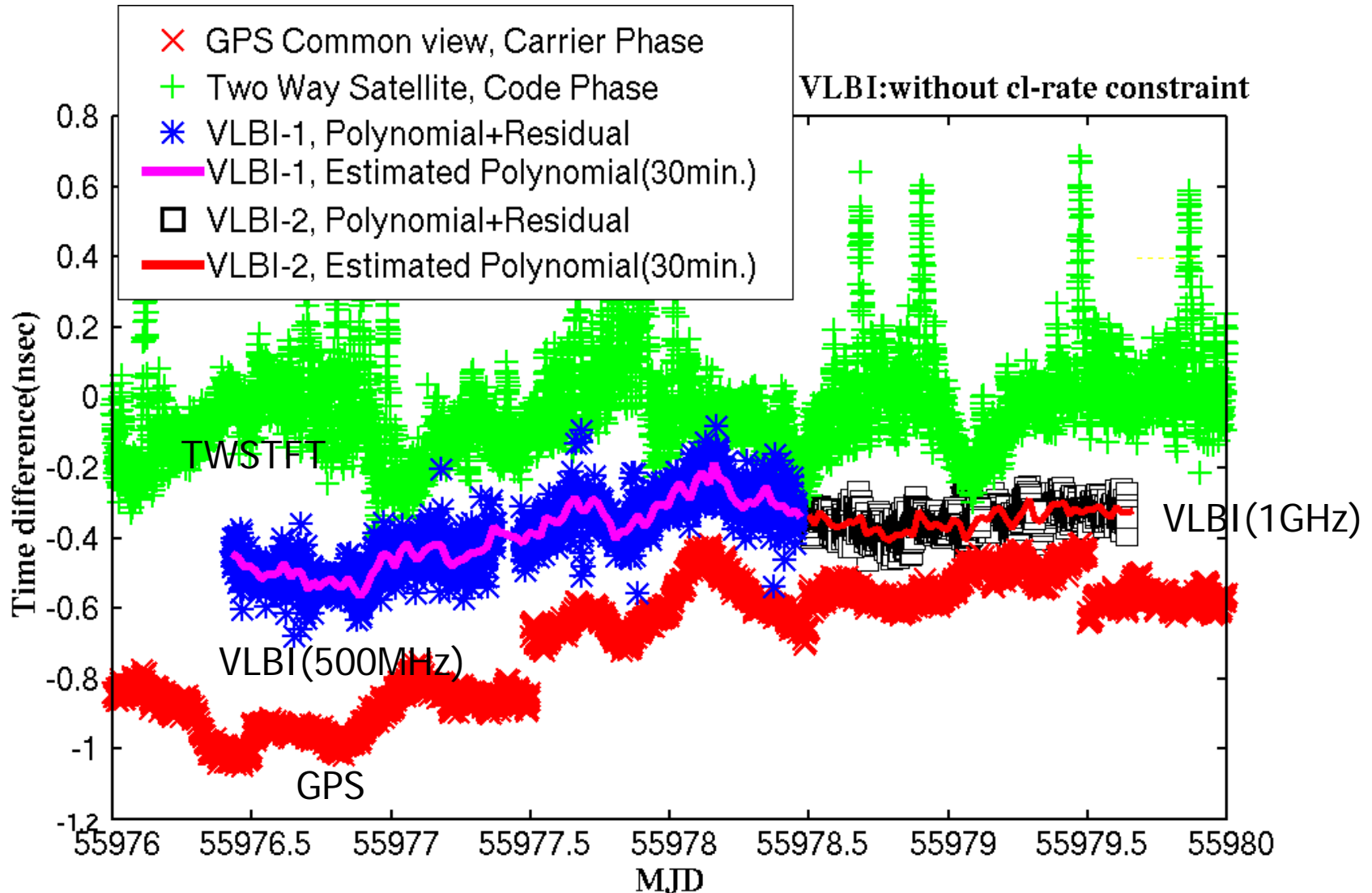


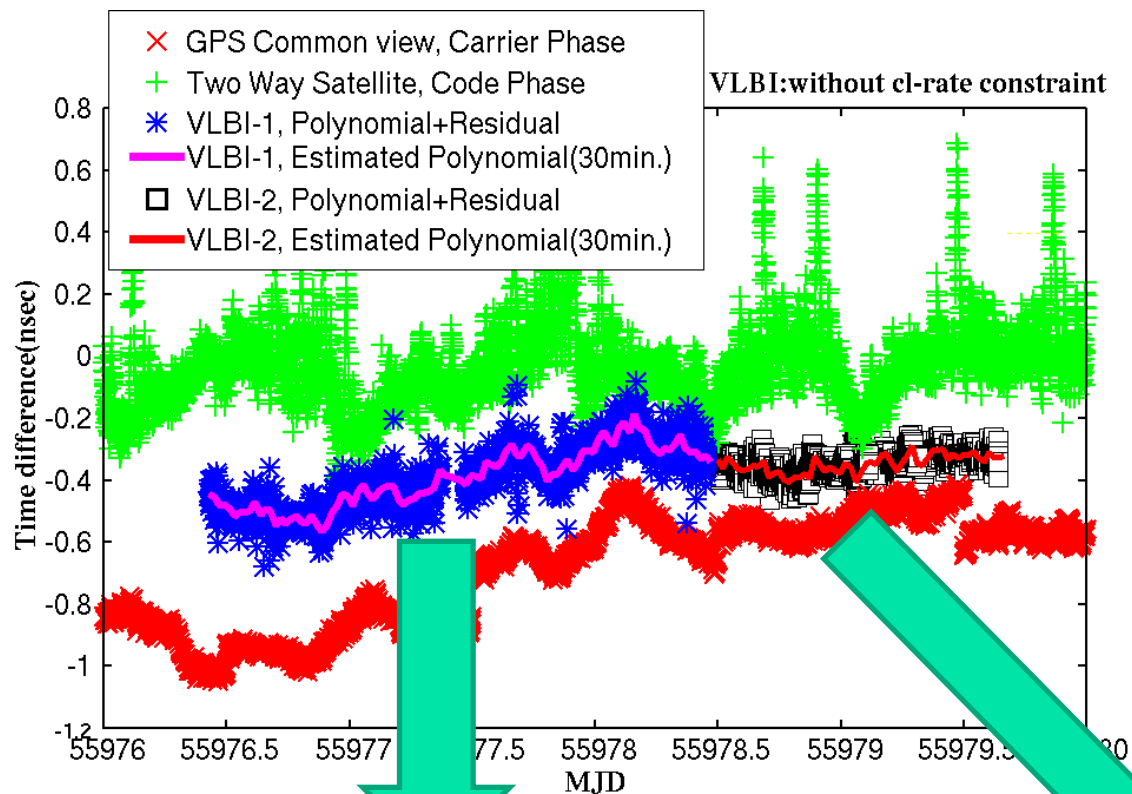
TWSTFT



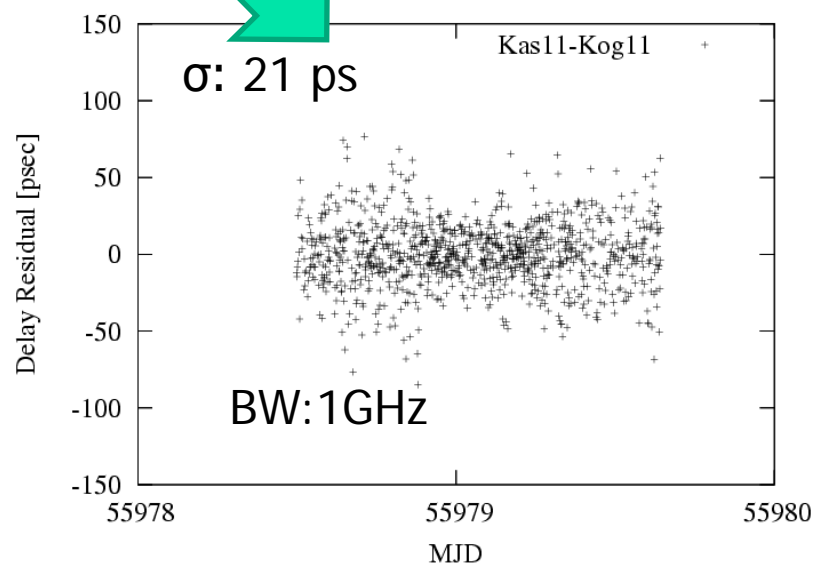
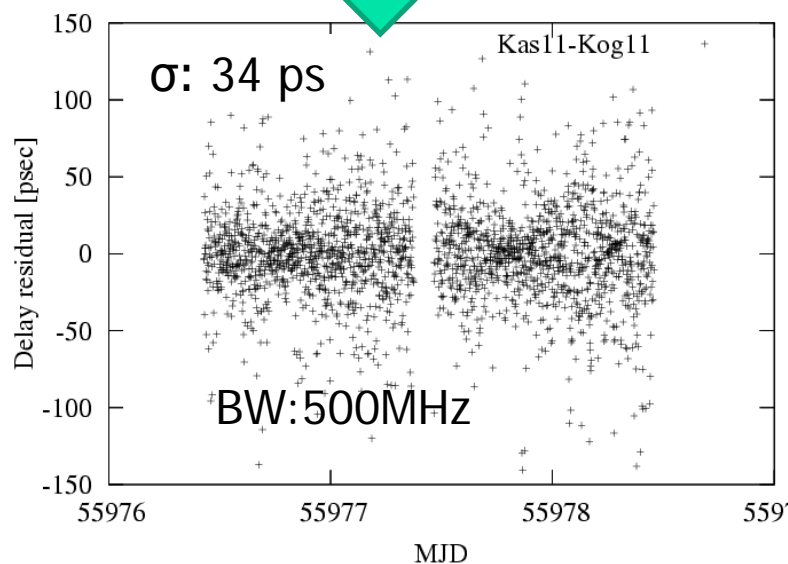
VLBI

Comparison of TWSTFT, GPS, VLBI on 100km baseline Kashima-Tokyo on Feb. 2012





Conventional geodetic VLBI delay residual is improved by expanding frequency band.



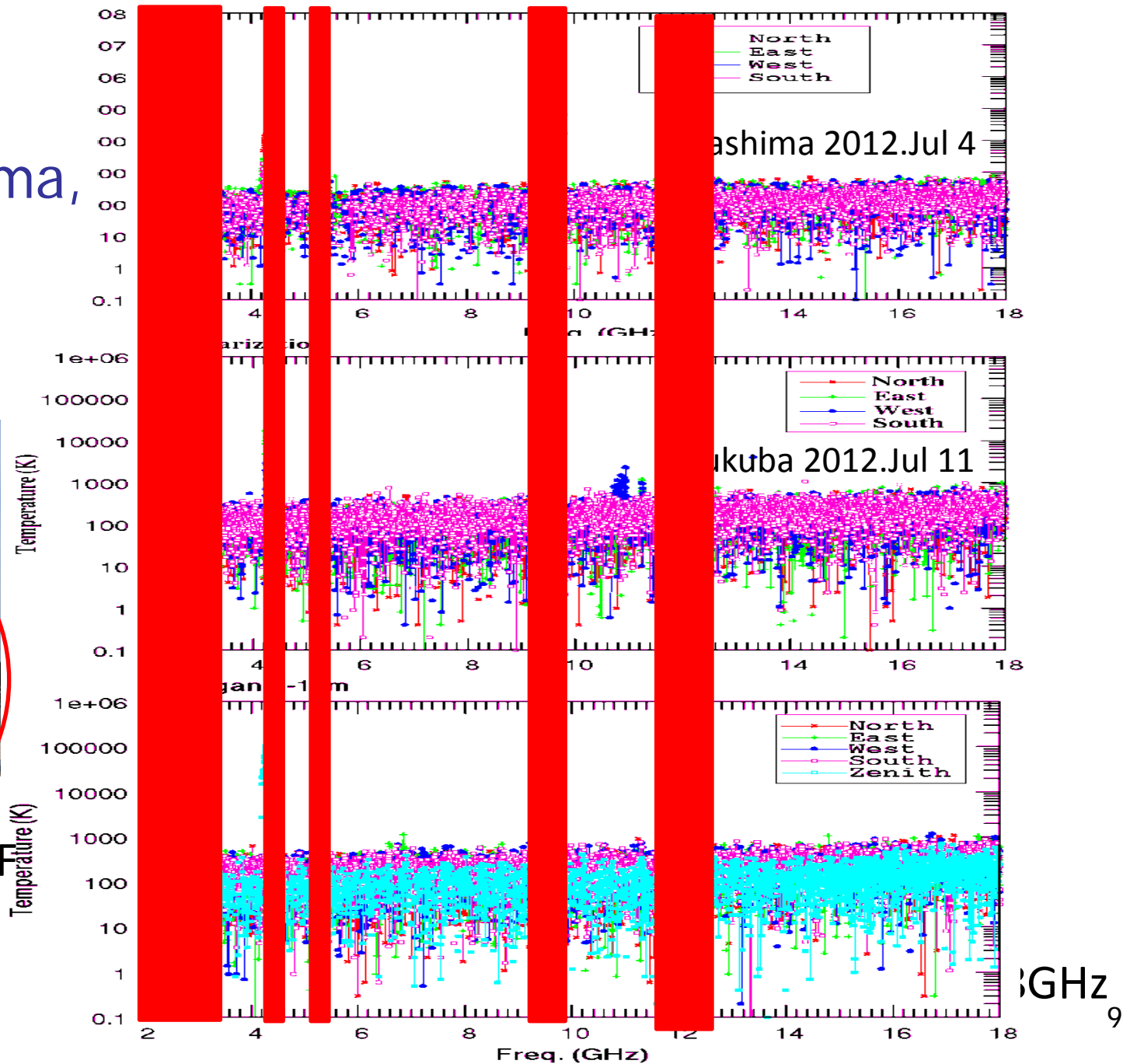
How can we expand
the bandwidth?

4 x 1GHz like VGOS

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



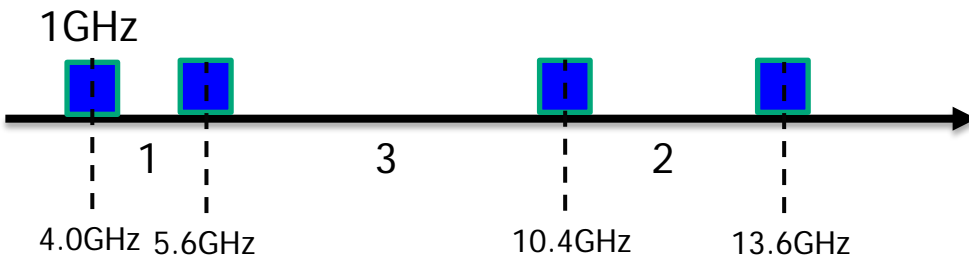
With 3.5GHz HPF
before LNA



Gala-V frequency array

Target Precision: 30 ps -> 7 ps

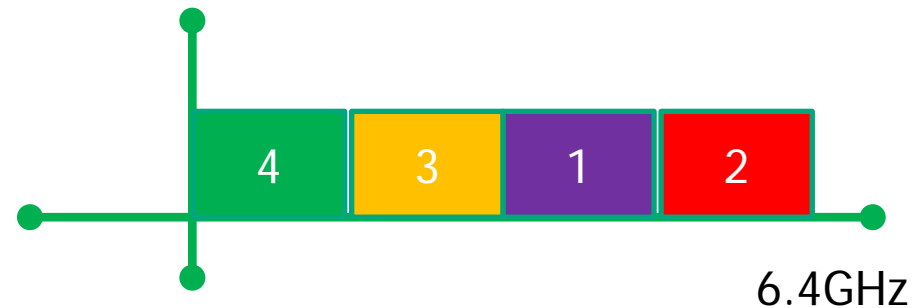
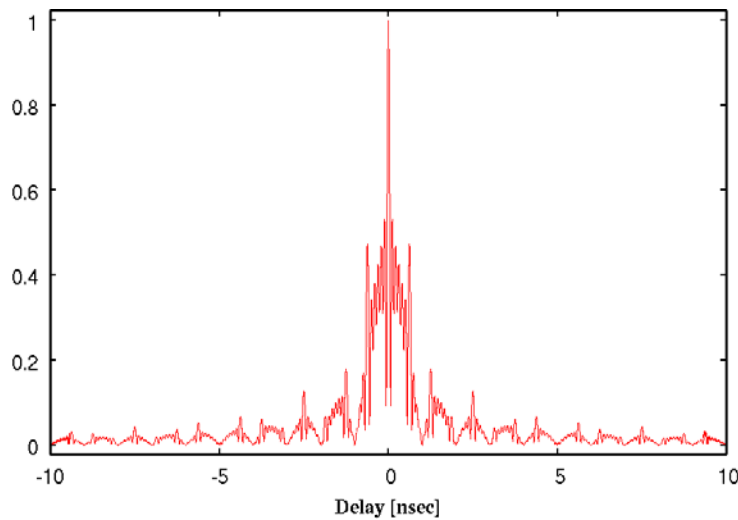
**Bandwidth Synthesis for
10 times wider frequency range**



Direct RF Sampling



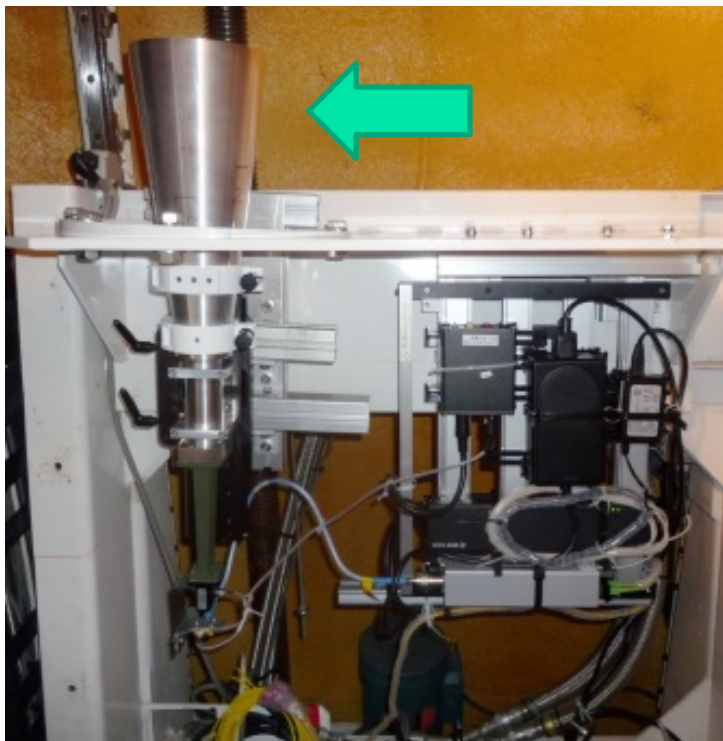
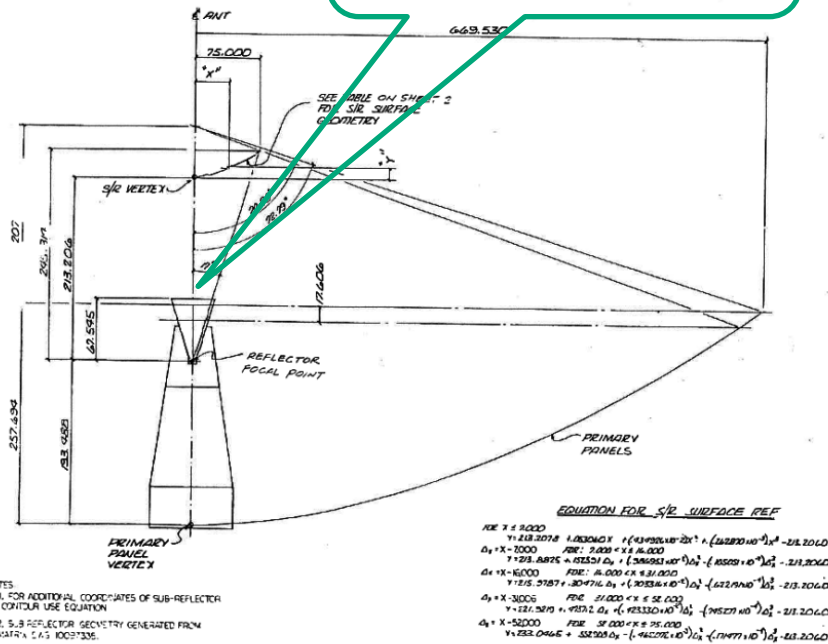
High speed sampler (16GHz)





“Iguana” prototype Feed

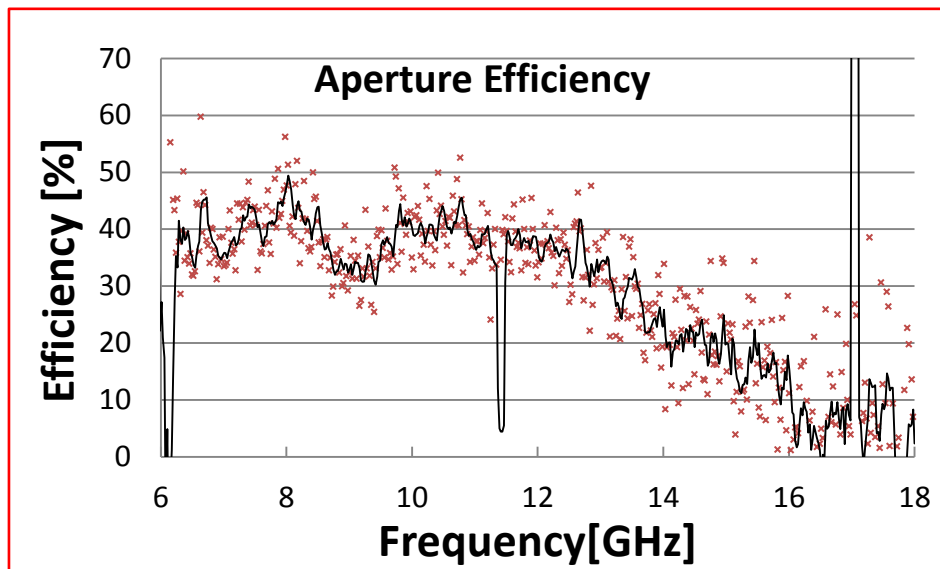
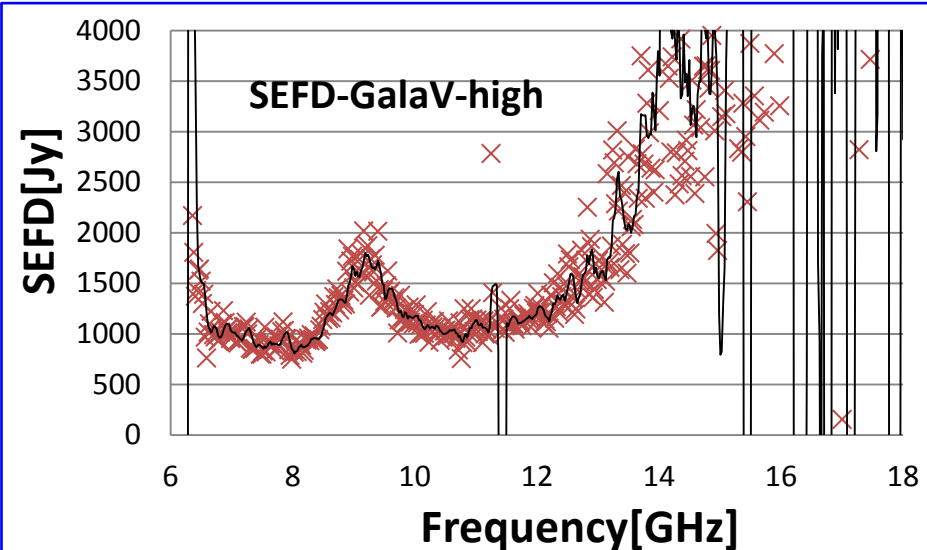
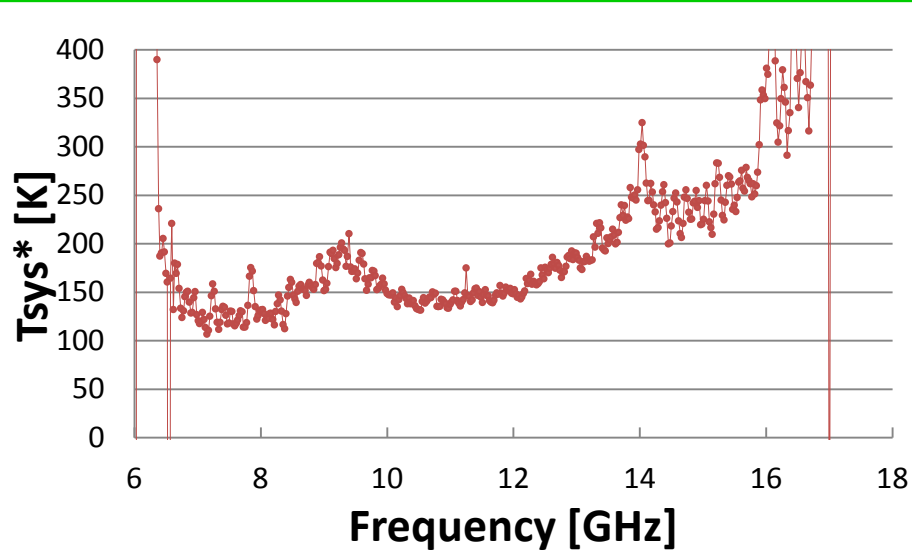
The prototype feed installed to Kashima 34m at the end of 2013.



- A sharp 30 deg beam width over the wide frequency range.
- Sensitivity 6.4-14GHz range at present
- Next upgraded feed with 2-18GHz range is intended.



Performance of the Prototype broadband Feed

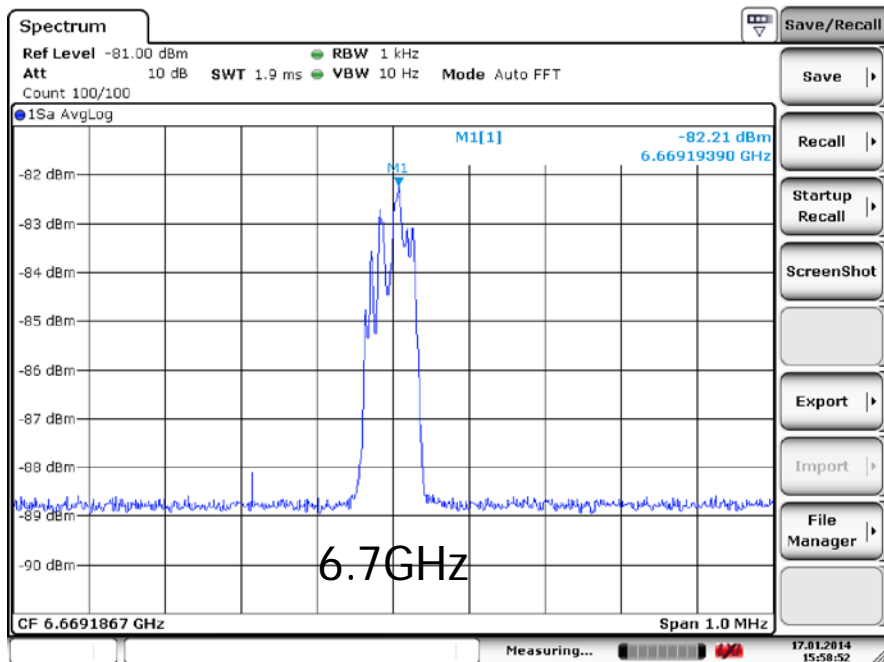




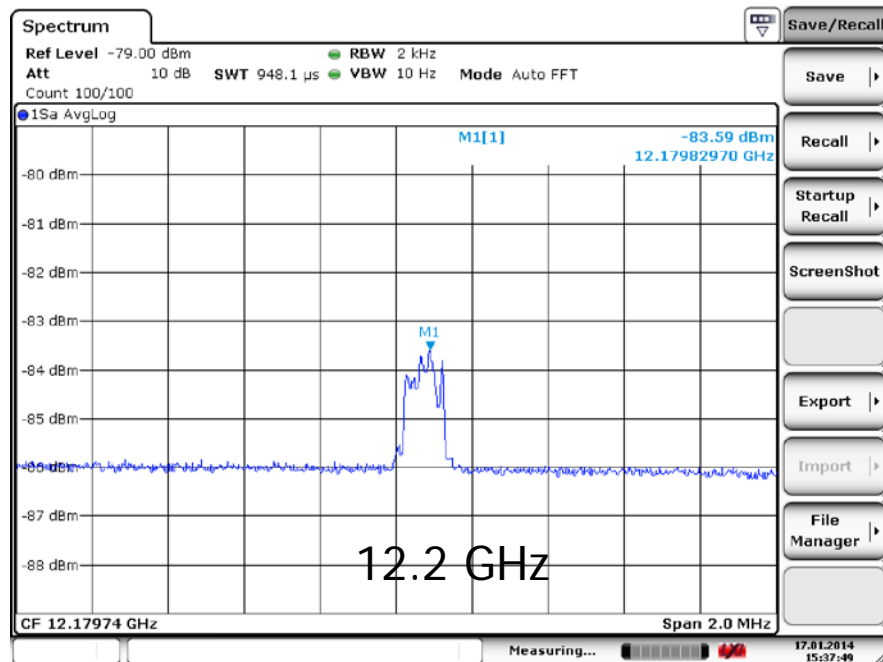
FIRST LIGHT Methanol Maser



- Simultaneous Observation of Methanol Maser lines at 6.7GHz and 12.2GHz on W3OH on 16 Jan.2014.



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



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

VLBI with Gala-V system



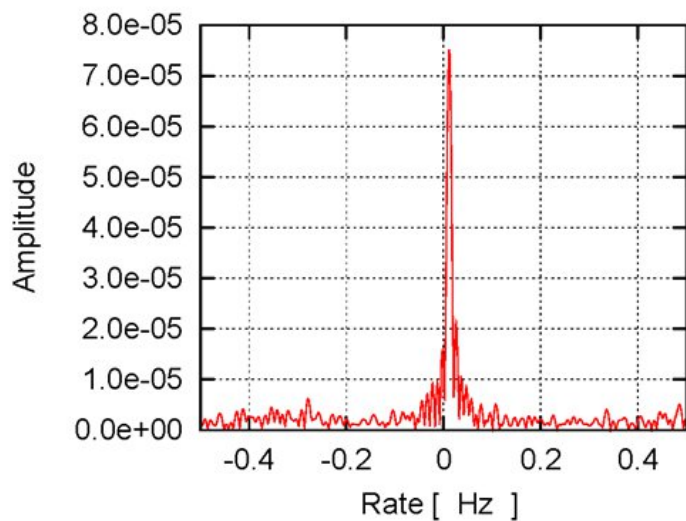
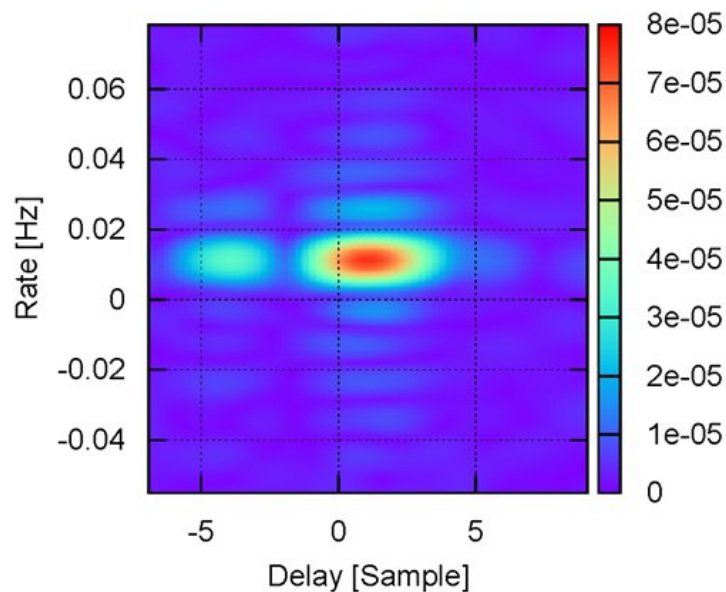
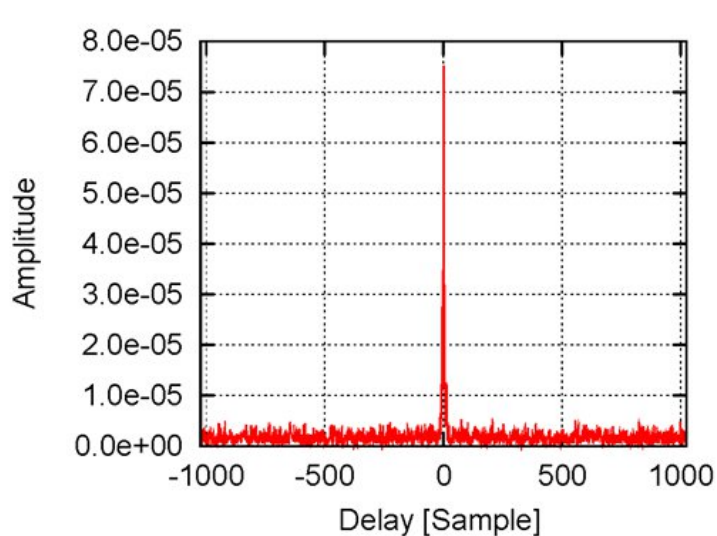
Compact antenna 1.6m



Kashima 34 m

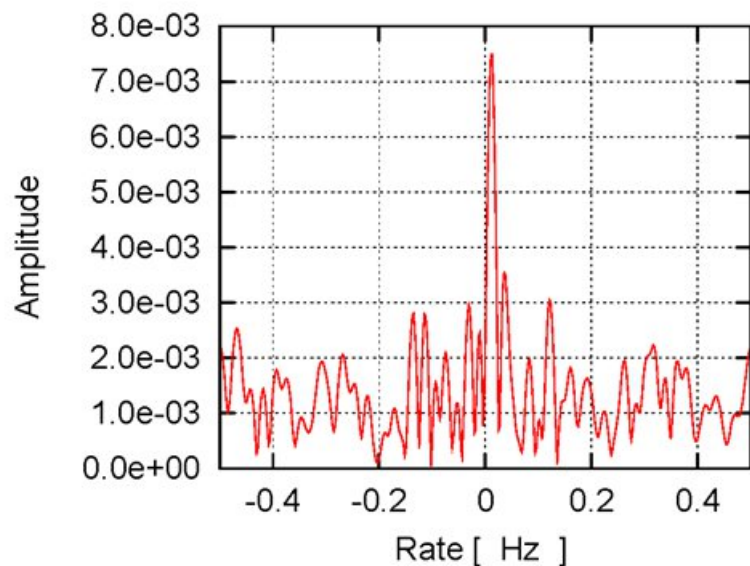
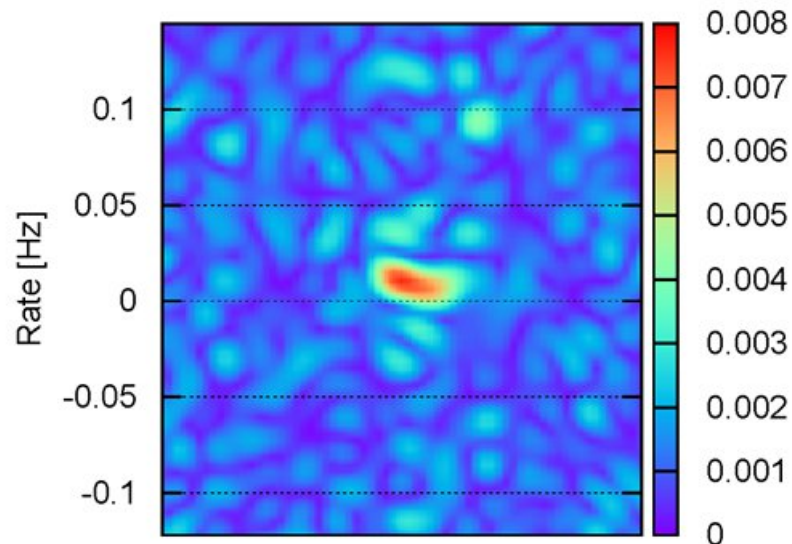
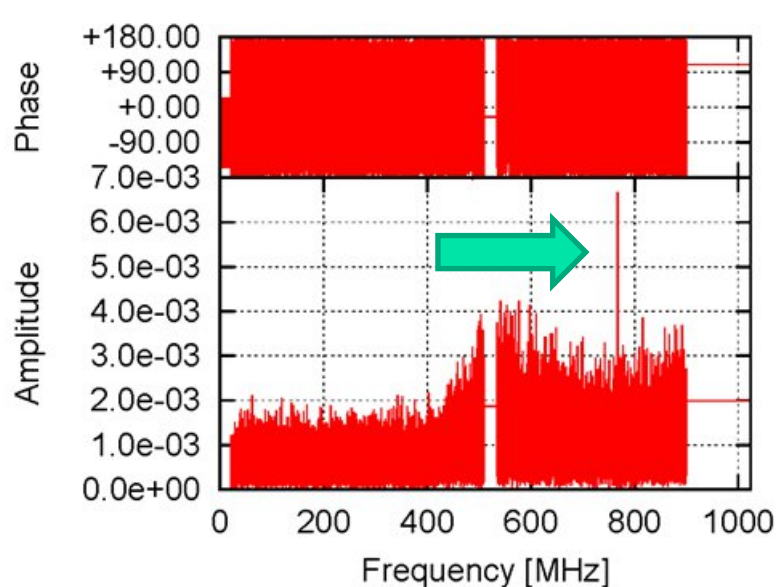
34m – compact#1

Quasar: 3C273B in 12GHz



```
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
```

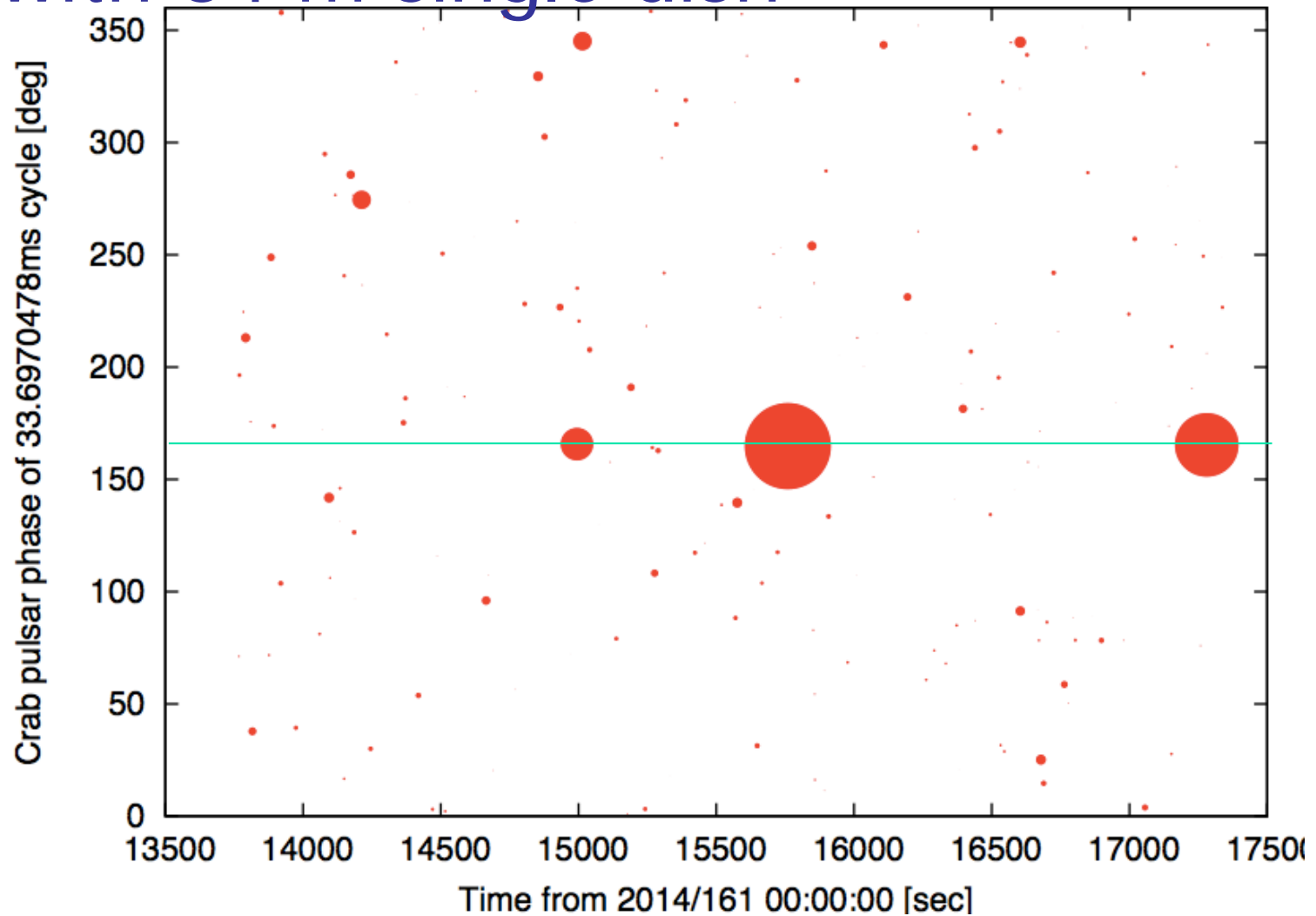
Methanol Maser: W3OH (12.181GHz)



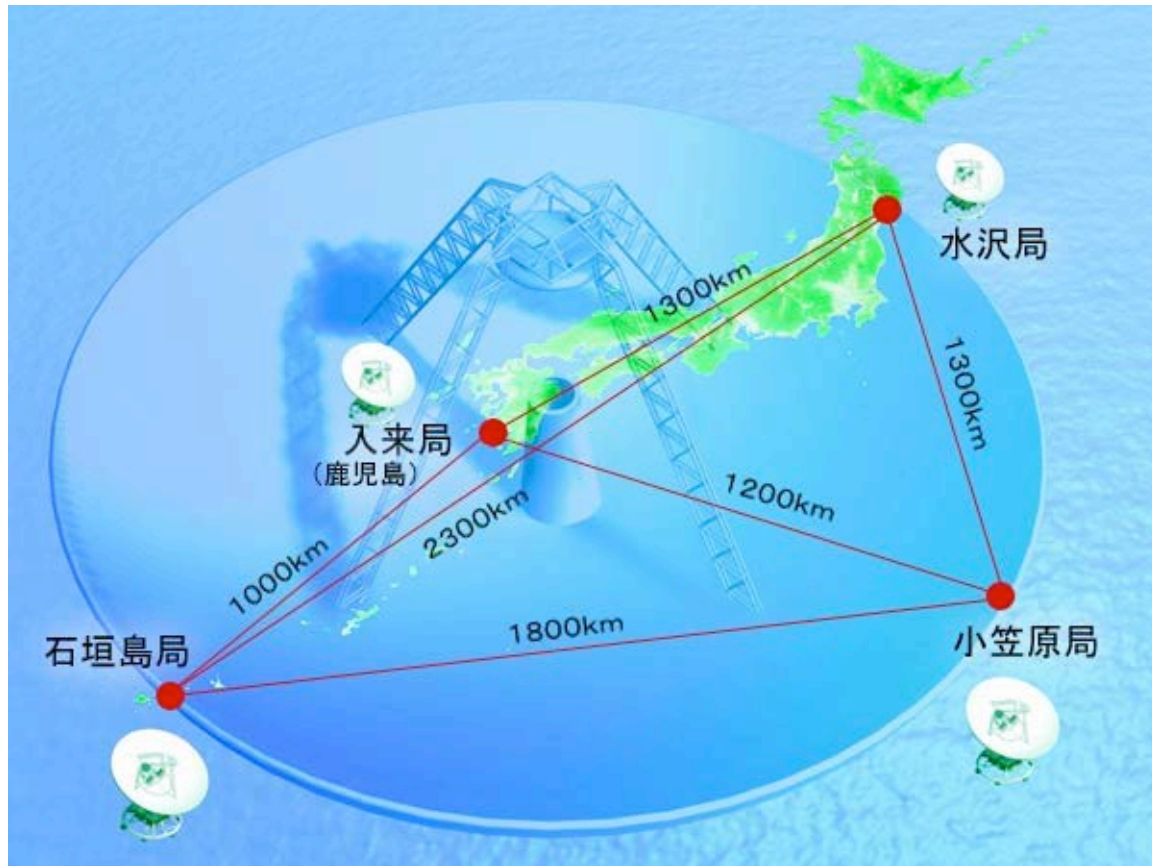
```

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
    
```


Giant radio pulse of Crab pulsar 6GHz with 34 m single dish

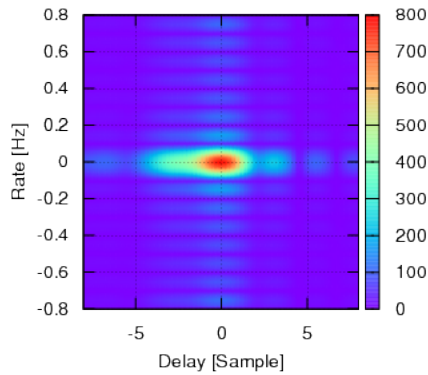
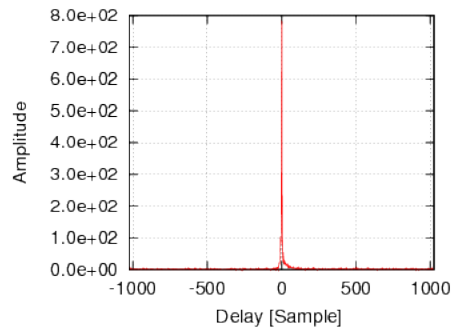


Piggy-back observation with VERA

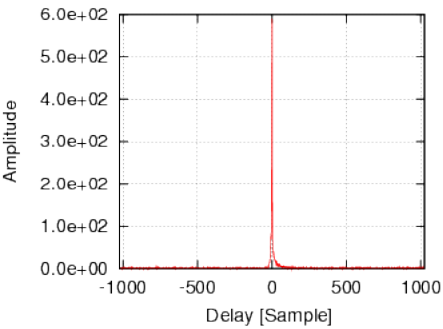
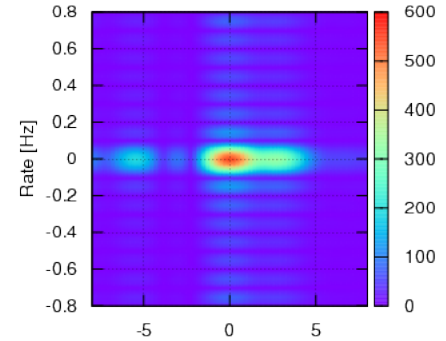
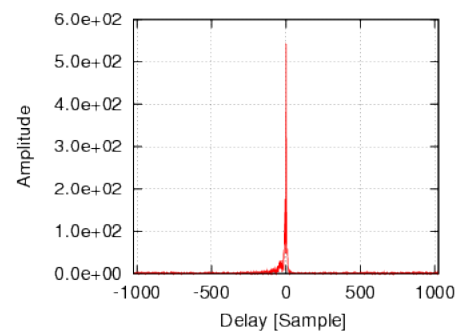
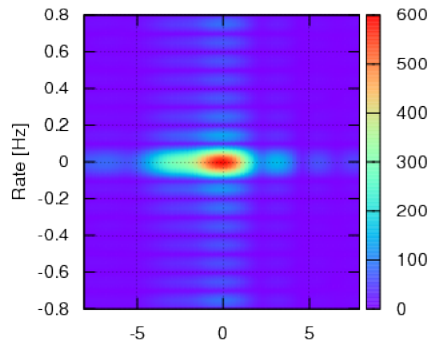
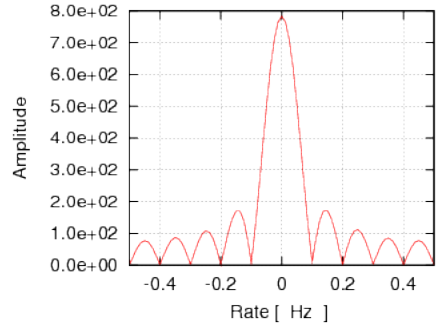


C-band observation on 1-2 Oct 2014

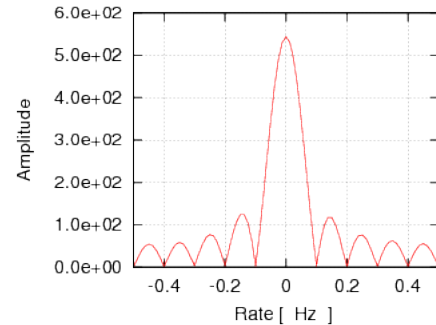
First Fringes with VERA (6GHz)



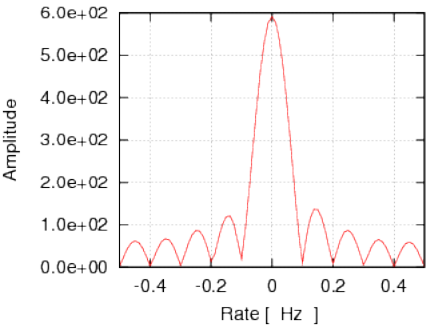
```
Epoch      : 2014/274 12:50:00
Station-1  : KASHIM34
Station-2  : ISHIGAKI
Source     : 3C84
Length    : 10.000000 [sec]
Sampling  : 1024000000 [sps]
Frequency : +6408.000000 [MHz]
Peak Amp  : 78367.191596 [%]
Peak Phs  : 61.470817 [deg]
Delay     : -0.025192 [spl]
Rate      : +0.160217 [mHz]
SNR       : 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
```



T&F VLBI Observation

KASHIMA 34m



34m Antenna NICT Kashima

Compact#2



**1.5m Antenna
NICT Koganei**

Compact#1



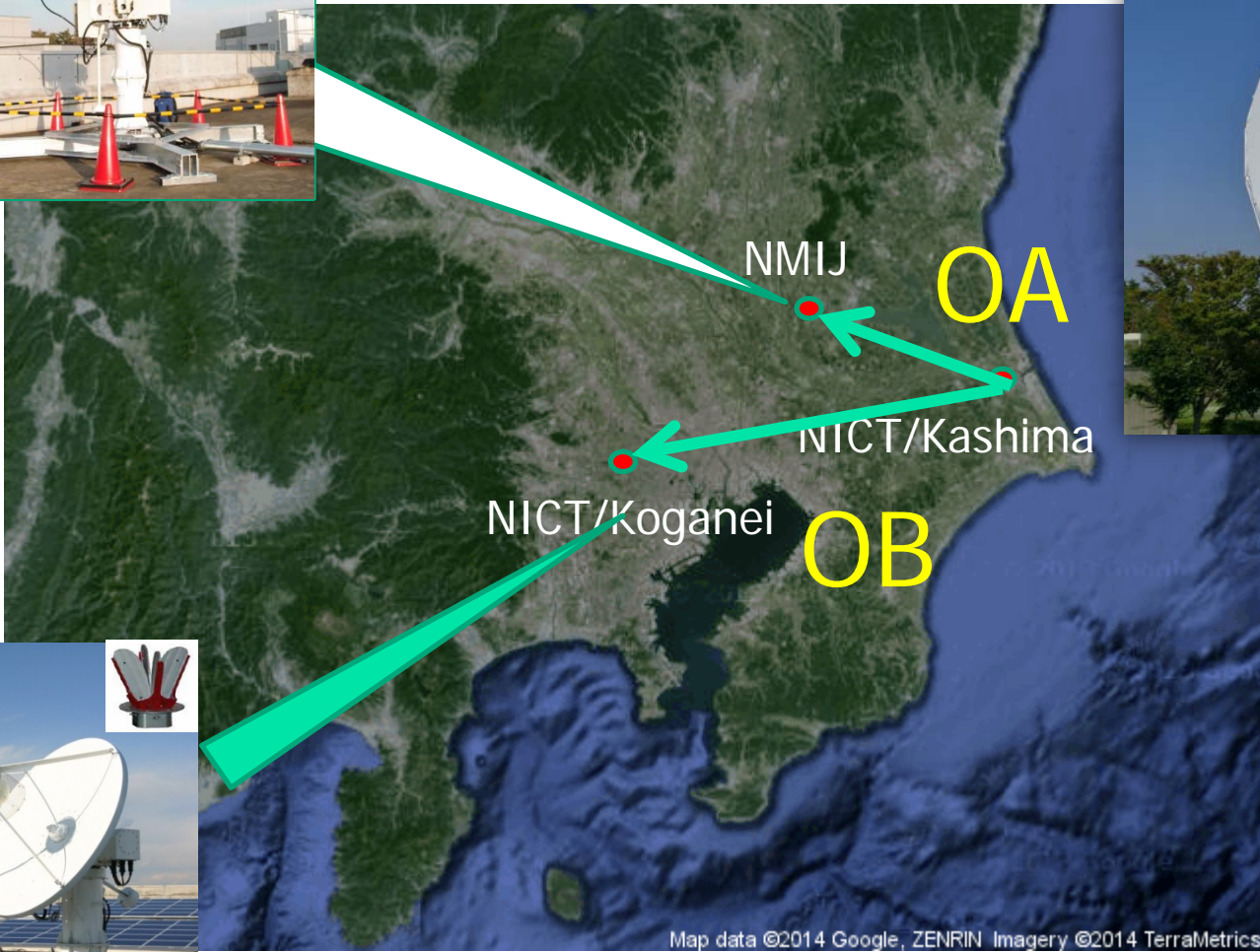
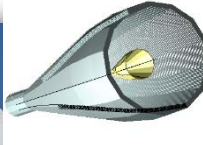
**1.6m Antenna
NMIJ Tsukuba**

Time standard Time standard

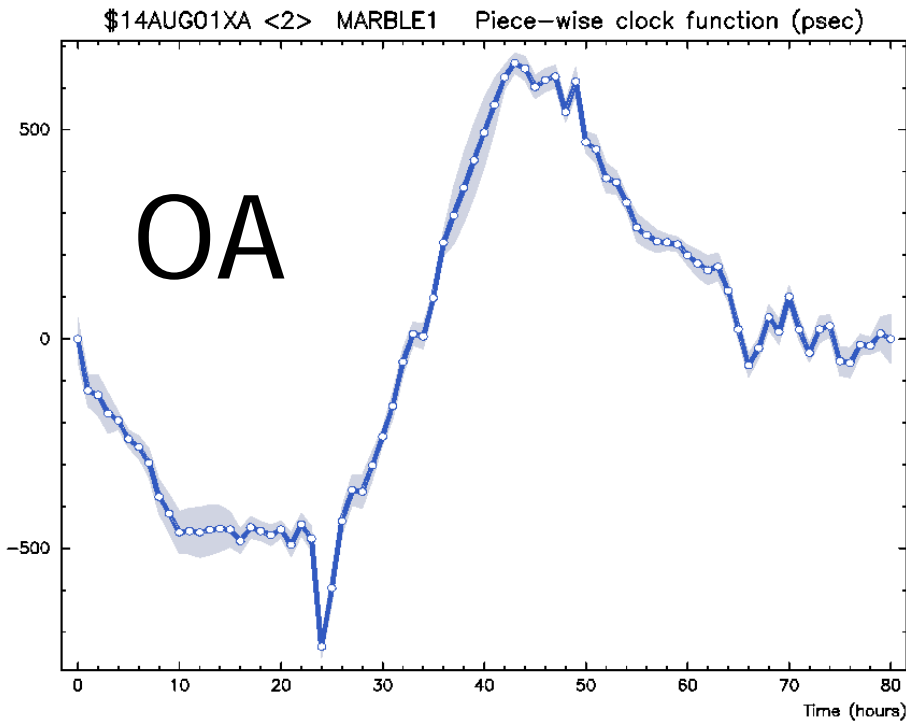
We want measure between two atomic standards 20

T&F VLBI Observation

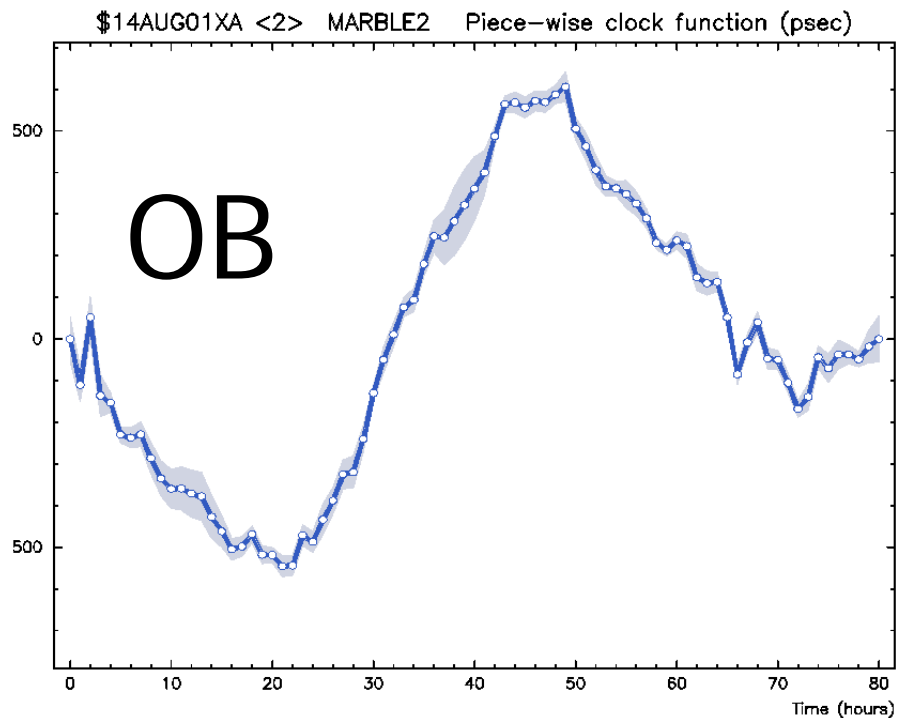
- Stations:
 - Kashima(34m), Tsukuba(1.6m), Koganei(1.5m)
- Radio Frequency:
 - X-band: 8080-9080MHz, Bandwidth: 1GHz
- Experiments:
 - Gx14213: 2014. Aug. 1-3 80 hours.
 - 1993 scans
 - 40 TB in each station !!! 0.12 PB!!



Synchronized clock variation + -500ps

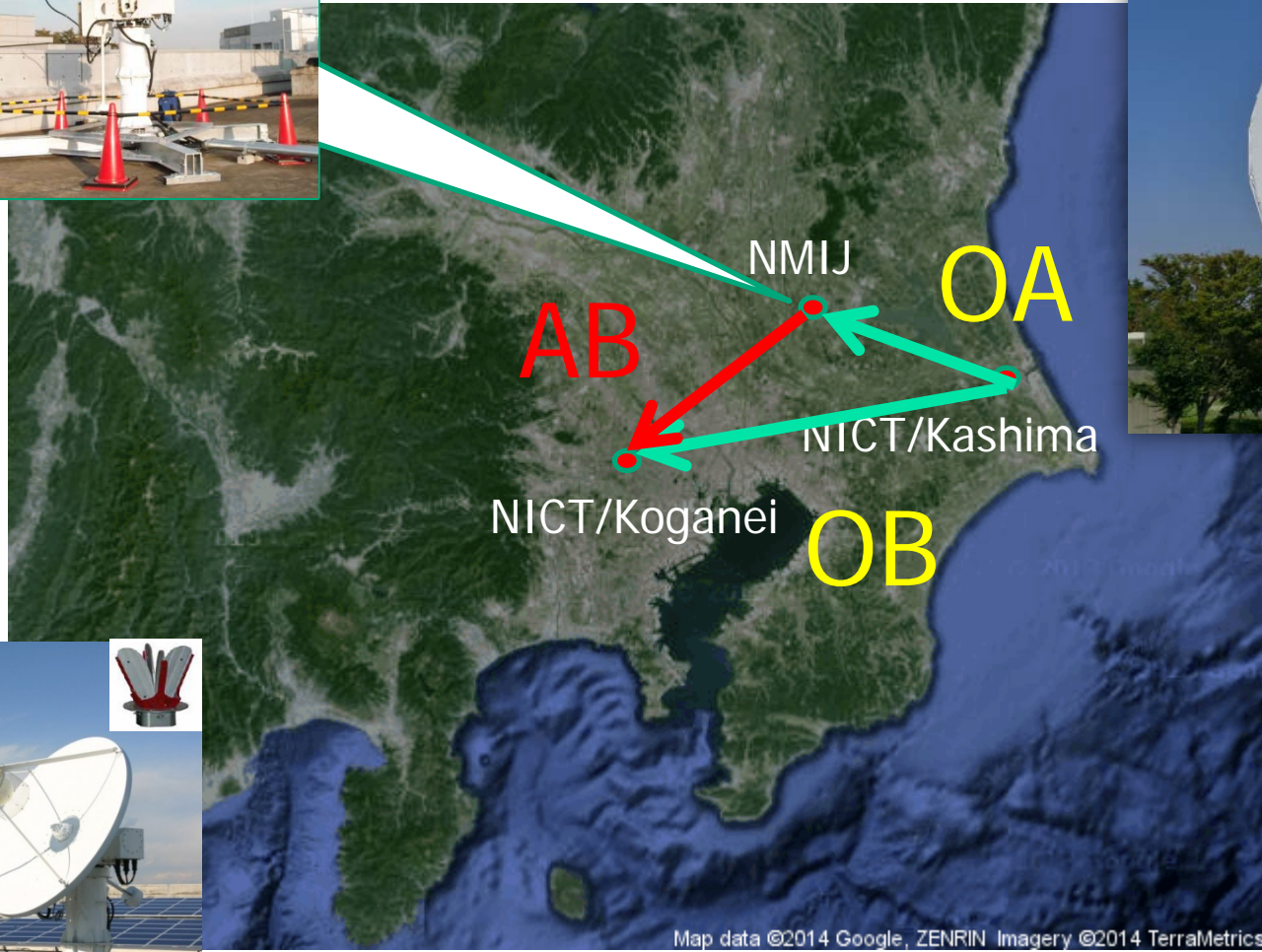


Kashima 34m - #1 compact ant



Kashima 34m - #2 compact ant

It may be caused by H-maser variation of 34 m



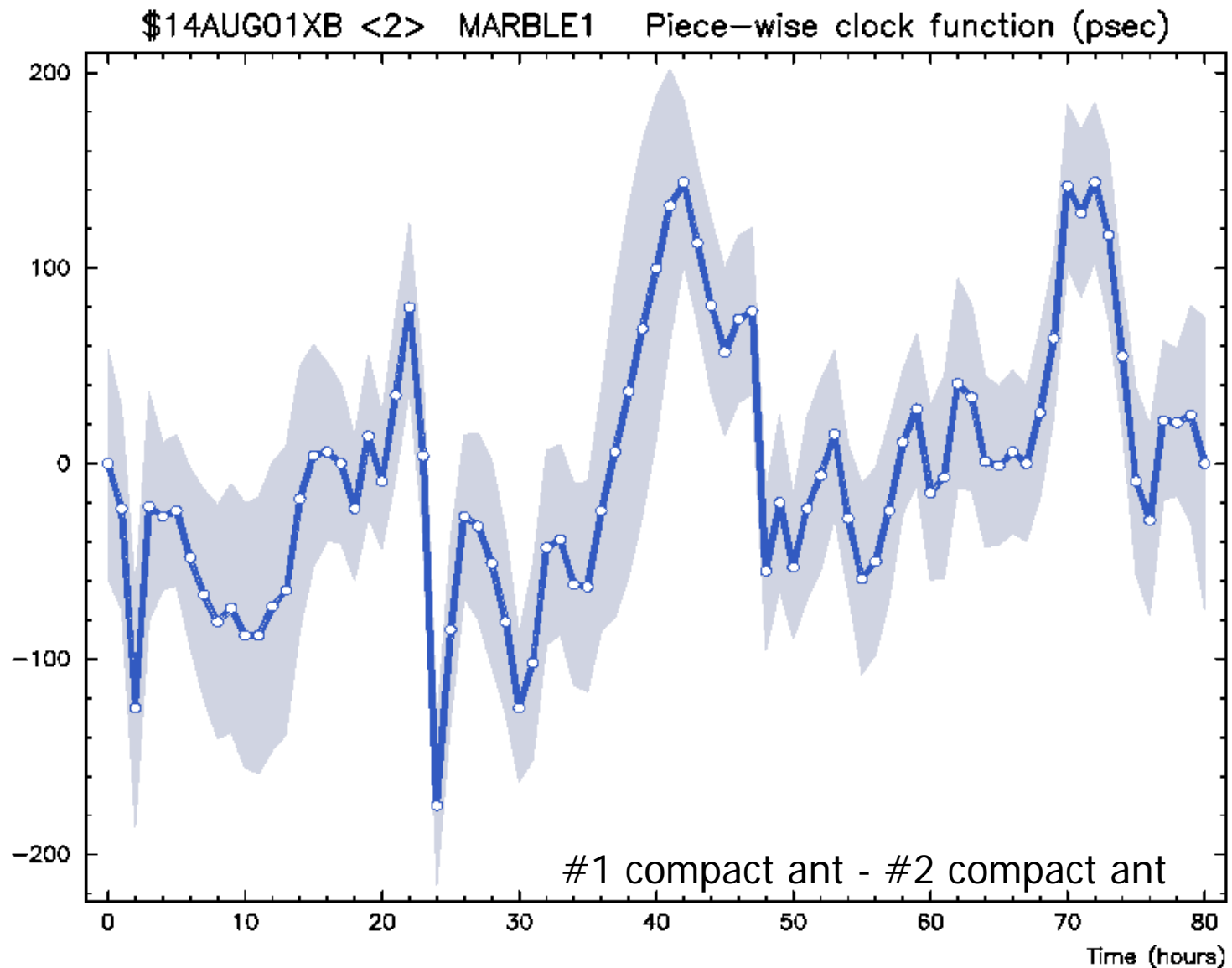
Epoch conversion of delay model

OA+OB \rightarrow AB

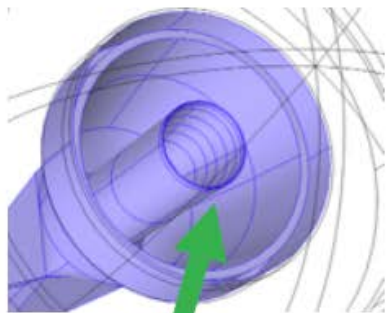
$$\tau_{AB} = \tau_{OA} - \tau_{OB} - \dot{\tau}_{AB} \times \tau_{OA}$$

2nd , 3rd order in longer baseline

After epoch conversion $\pm 100\text{ps}$



Wideband feed development in NICT



We will start 4 bands observation soon!



Gala-V:3.2-14.4GHz

The *EXPRES* network



jive
JOINT INSTITUTE FOR VLBI IN EUROPE

Most of antennas can be upgraded to broad-band !





Acknowledgements

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takefuji@nict.go.jp

Thank you for Attention!