# Broadband VLBI experiments at 6GHz to 14GHz range between Kashima 34 m and Ishioka 13 m

Kazuhiro Takefuji,
Kondo Tetsuro, Hideki Ujihara,
and Mamoru Sekido
NICT/Kashima VLBI group

# Contents

- Broadband project “GALA-V” for T&F
- Broadband Experiments
  - Kashima 34m and two compact antennas
  - Kashima 34m and Ishioka 13m

# Re-definition of “second”

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

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

# T&F VLBI Observation

KASHIMA 34m


**34m Antenna NICT Kashima**

Cassegrain Focus

Compact#2

**1.5m**

**NICT Koganei**

UTC(NICT)

Compact#1

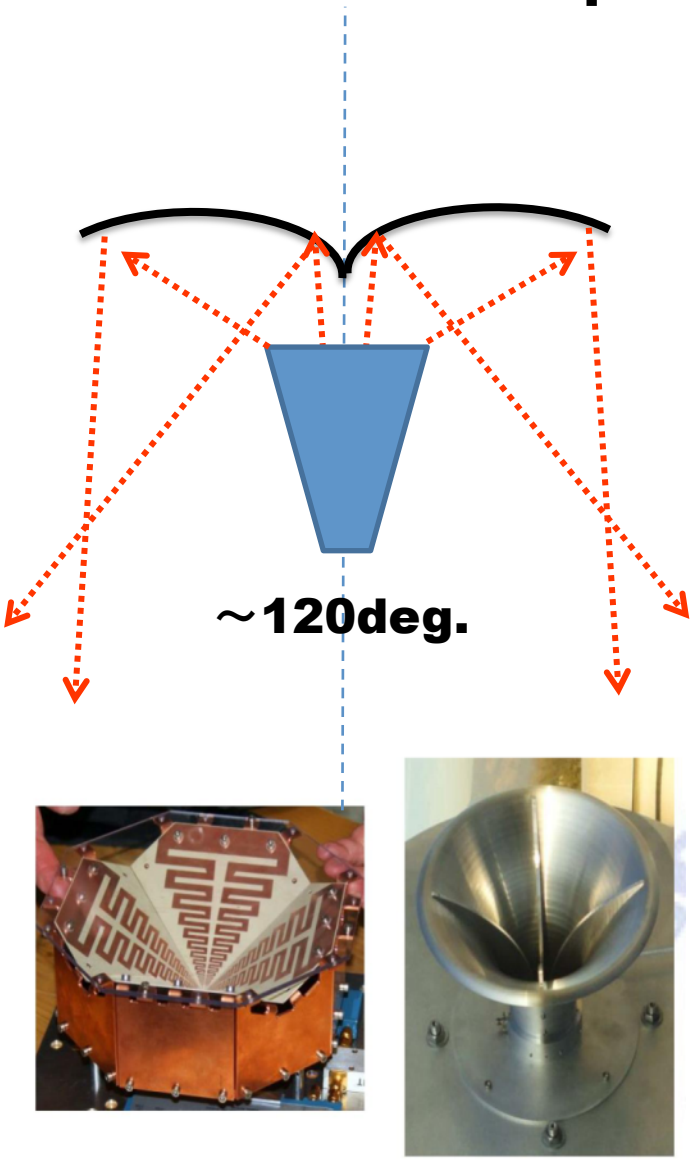
**1.6m**

**NMIJ Tsukuba**

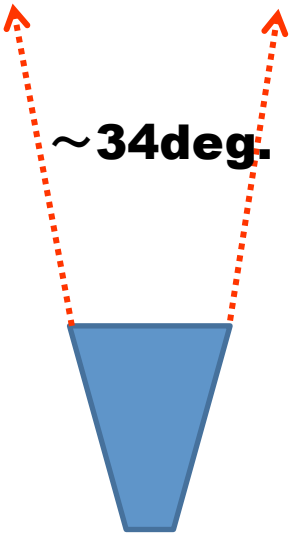
UTC(NMI J)

We want measure frequency difference between two atomic standards!
We need better SNR !!

# Development of Gala-V Feed



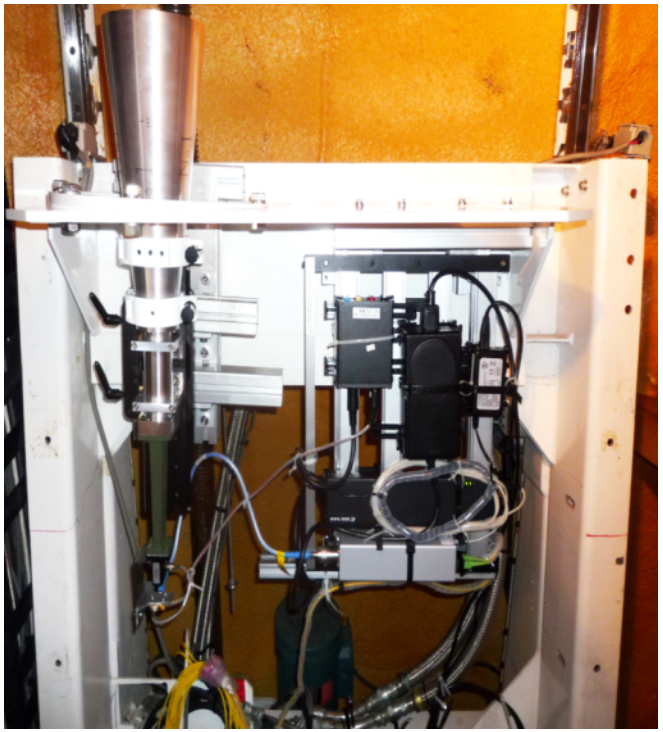

Broadband and
Narrow beam
width

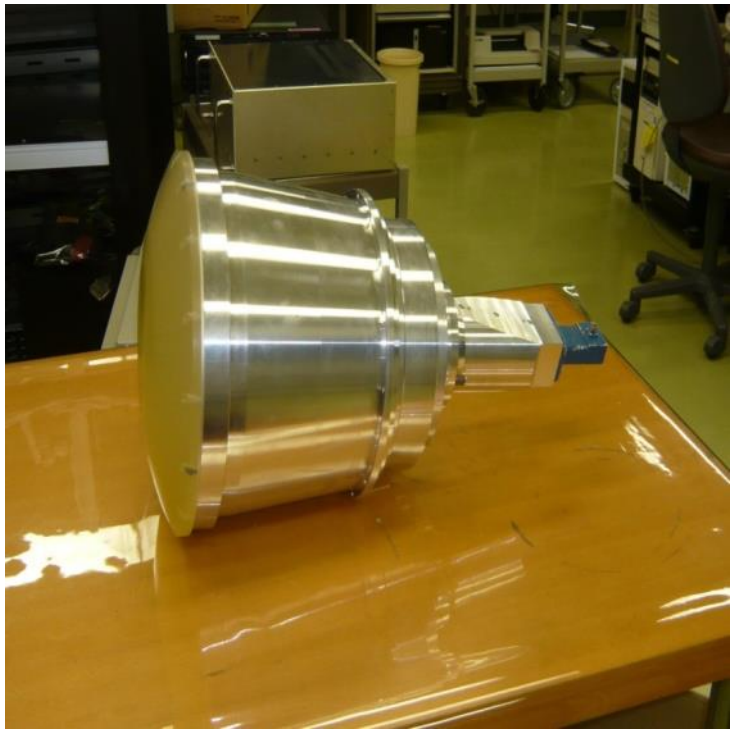




# Broadband Feed for Cassegrain optics Kashima 34m antenna

Designed by Dr.Ujihara

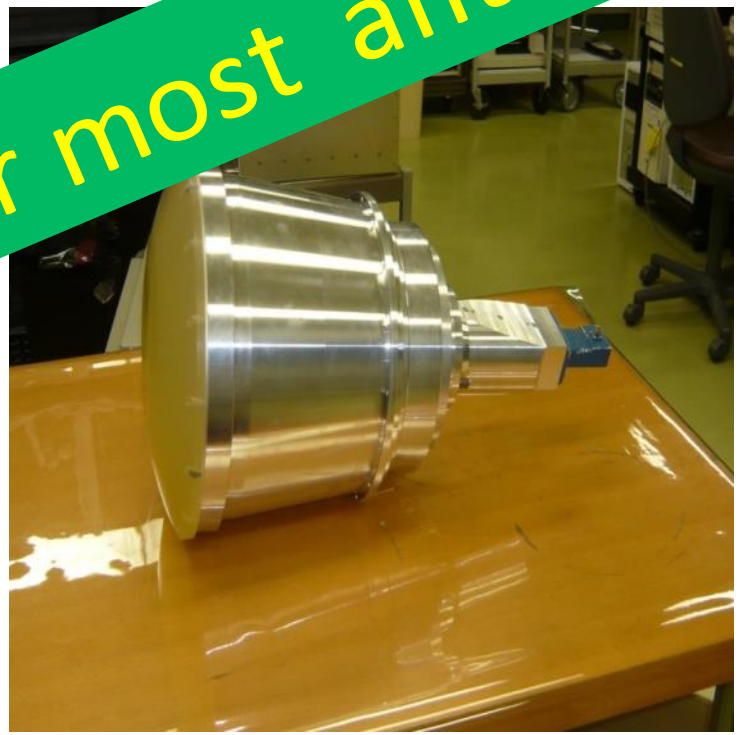




**IGUANA-H Feed (6.5-15GHz)** **NINJA Feed (3.2-14.4GHz)**

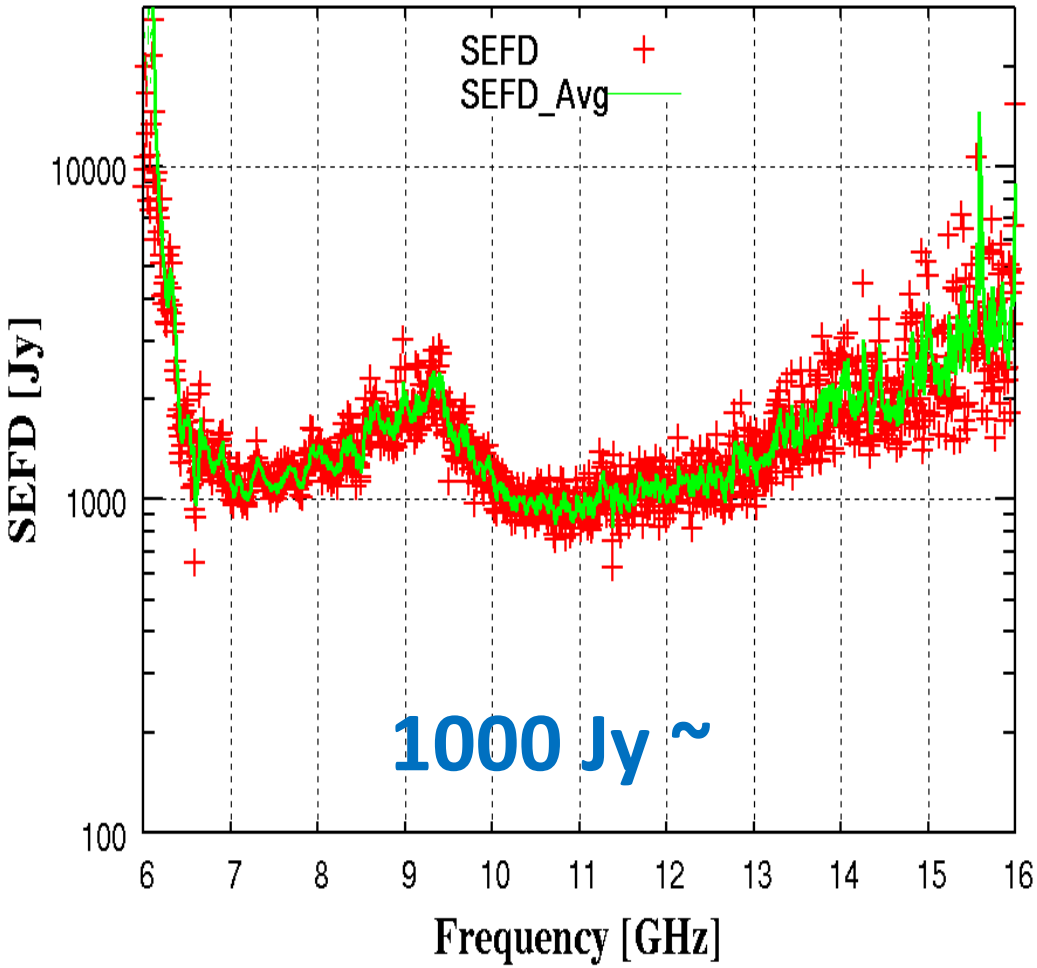

# Broadband Feed for Cassegrain optics Kashima 34m antenna

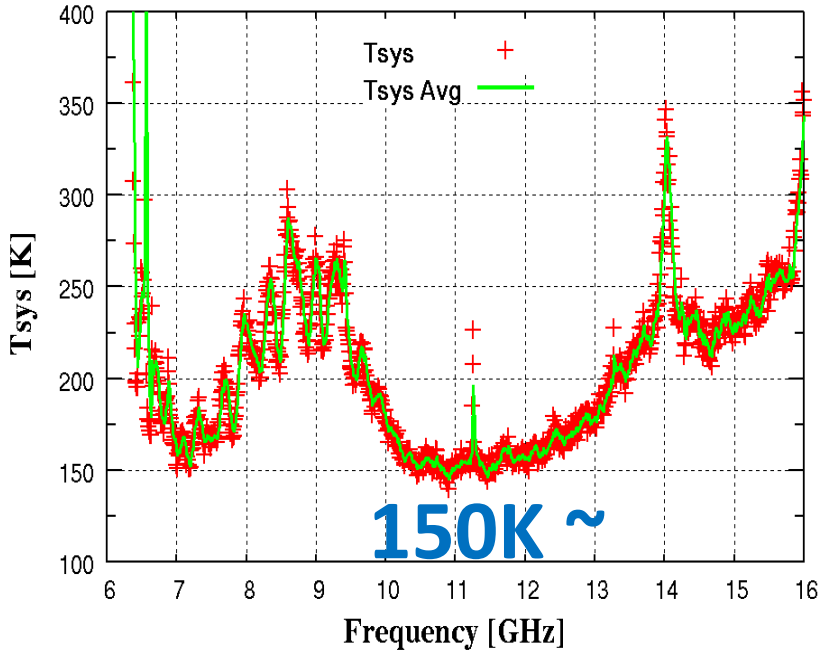
Versatile feed for most antennas

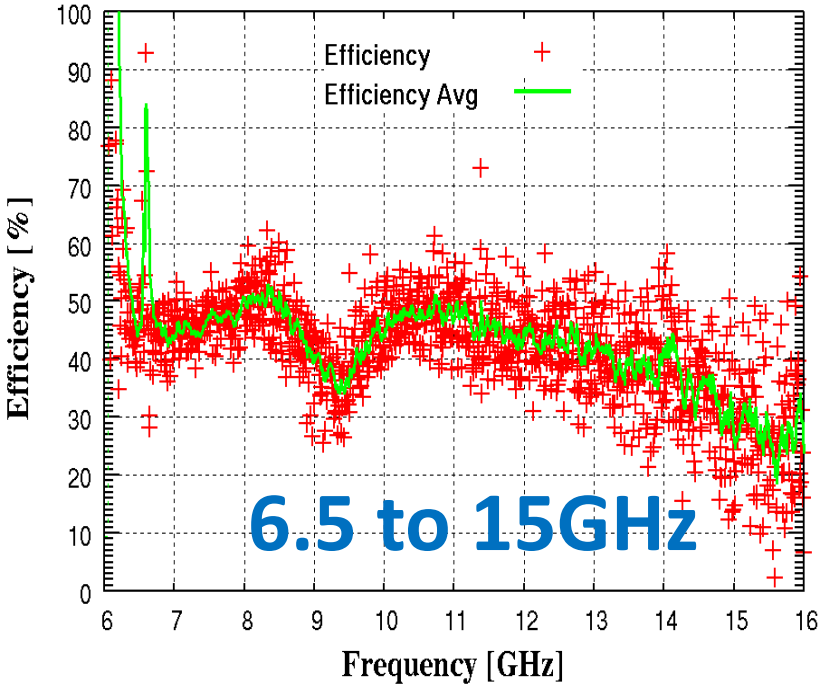


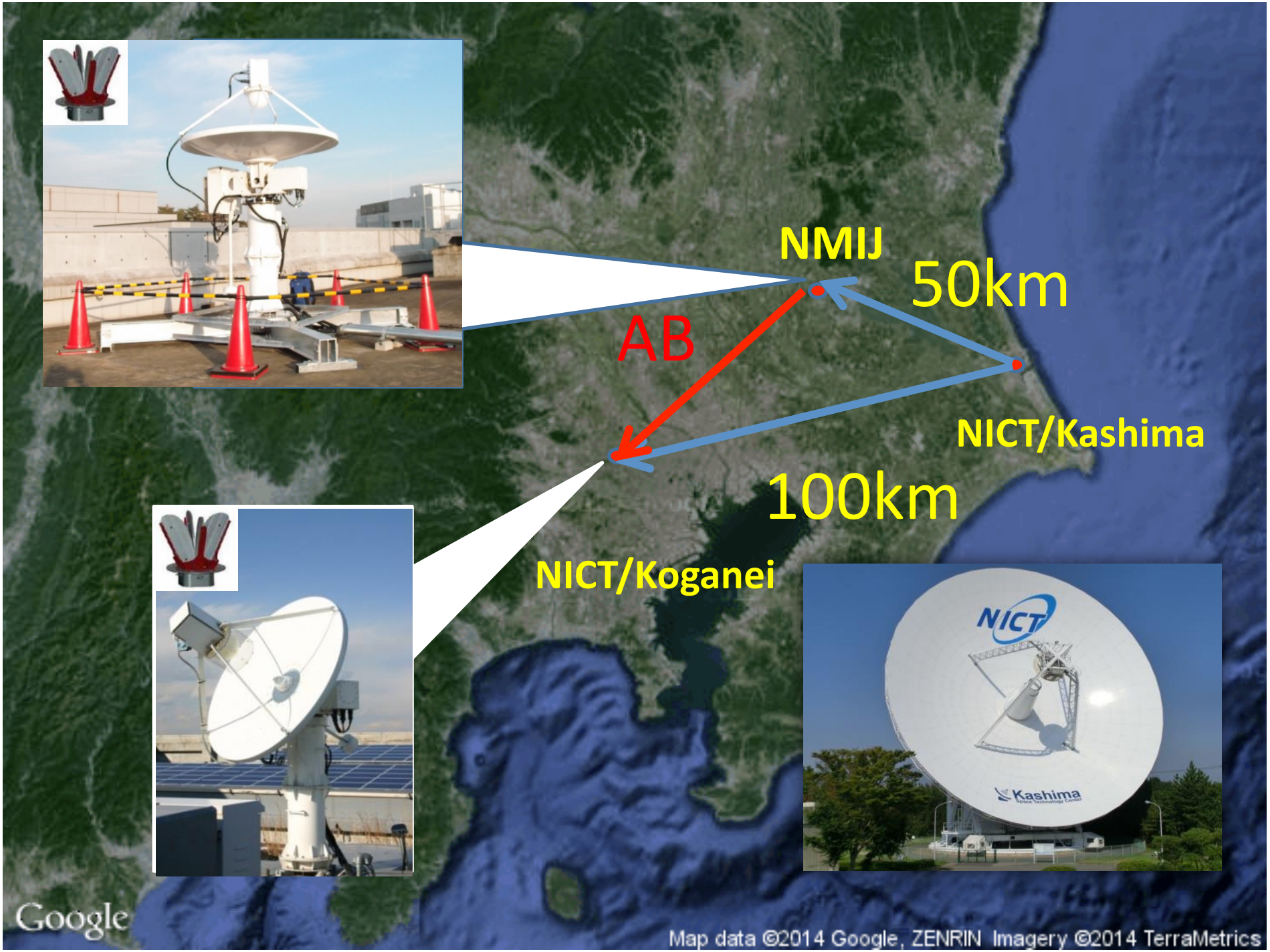
**IGUANA-H Feed (6.5-15GHz)** **NINJA Feed (3.2-14.4GHz)**

# Performance of the broadband system




NMIJ
50km
AB
NICT/Kashima
100km
NICT/Koganei
NICT
Kashima
Google
Map data ©2014 Google, ZENRIN Imagery ©2014 TerraMetrics

# VLBI among two compact antennas

- 26 hours from 2015/094 UT3:00
- Each 1GHz bandwidth of C and X band

# Fringe detection

| SNR>=5.5 | C-band<br>6.1 to 7.1GHz | X-band<br>8.1 to 9.1GHz |
|---|---|---|
| compact #1 | 736/746（98.7%） | 730/747（97.7%） |
| compact #2 | 646/747（86.5%） | 680/746（91.2%） |

Compact #2 has obviously bad detection rate

# Fringe detection

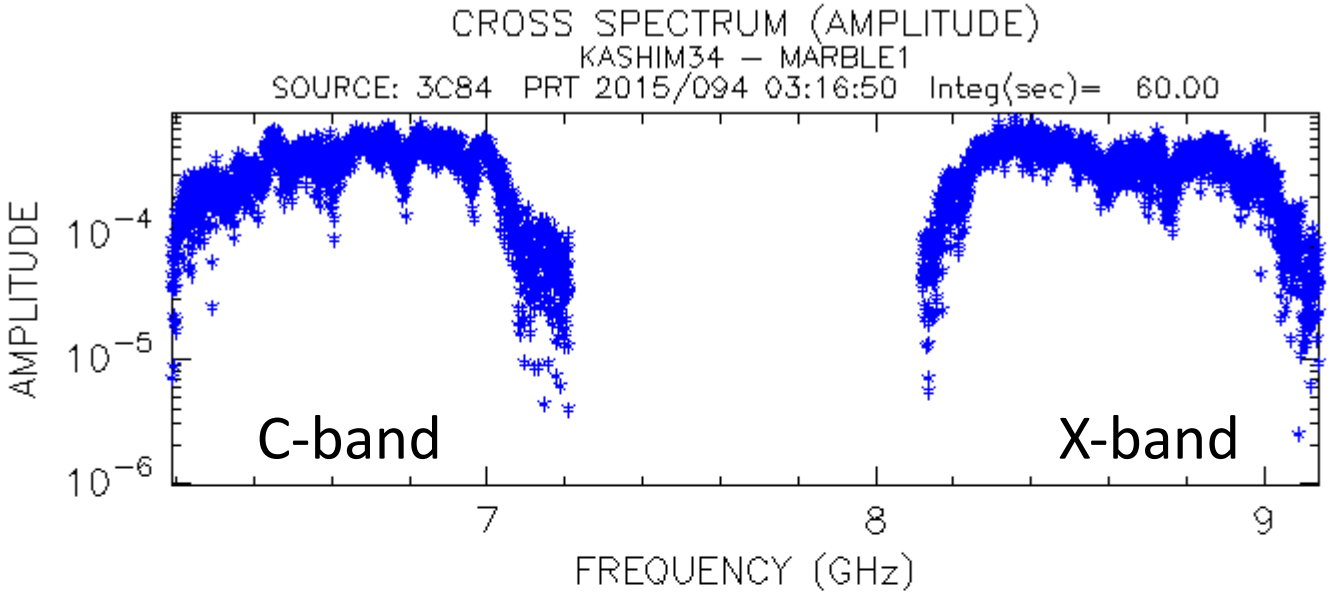
| SNR>=5.5 | C-band 6.1 to 7.1G | 9.1GHz |
|---|---|---|
| compact #1 | 736/ | 730/747（97.7%） |
| comp | 6/747（86.5%） | 680/746（91.2%） |

Bandwidth Synthesis was performed!

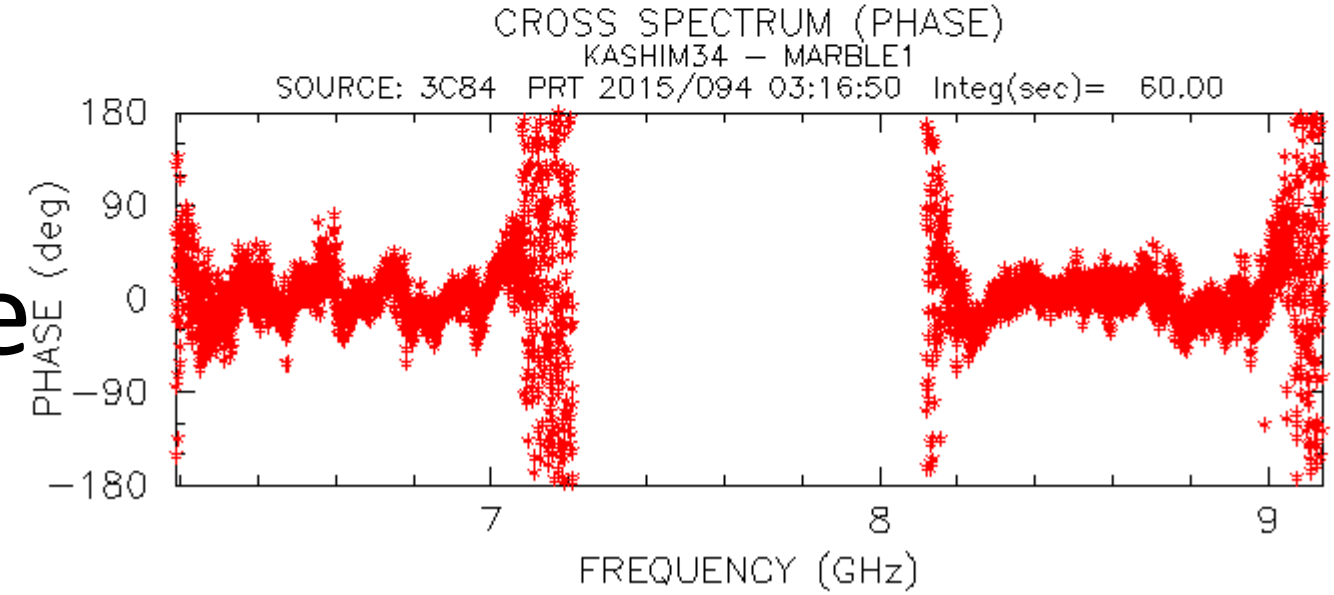
Compact #2 has obviously bad detection rate

# Performed BWS to C/X band

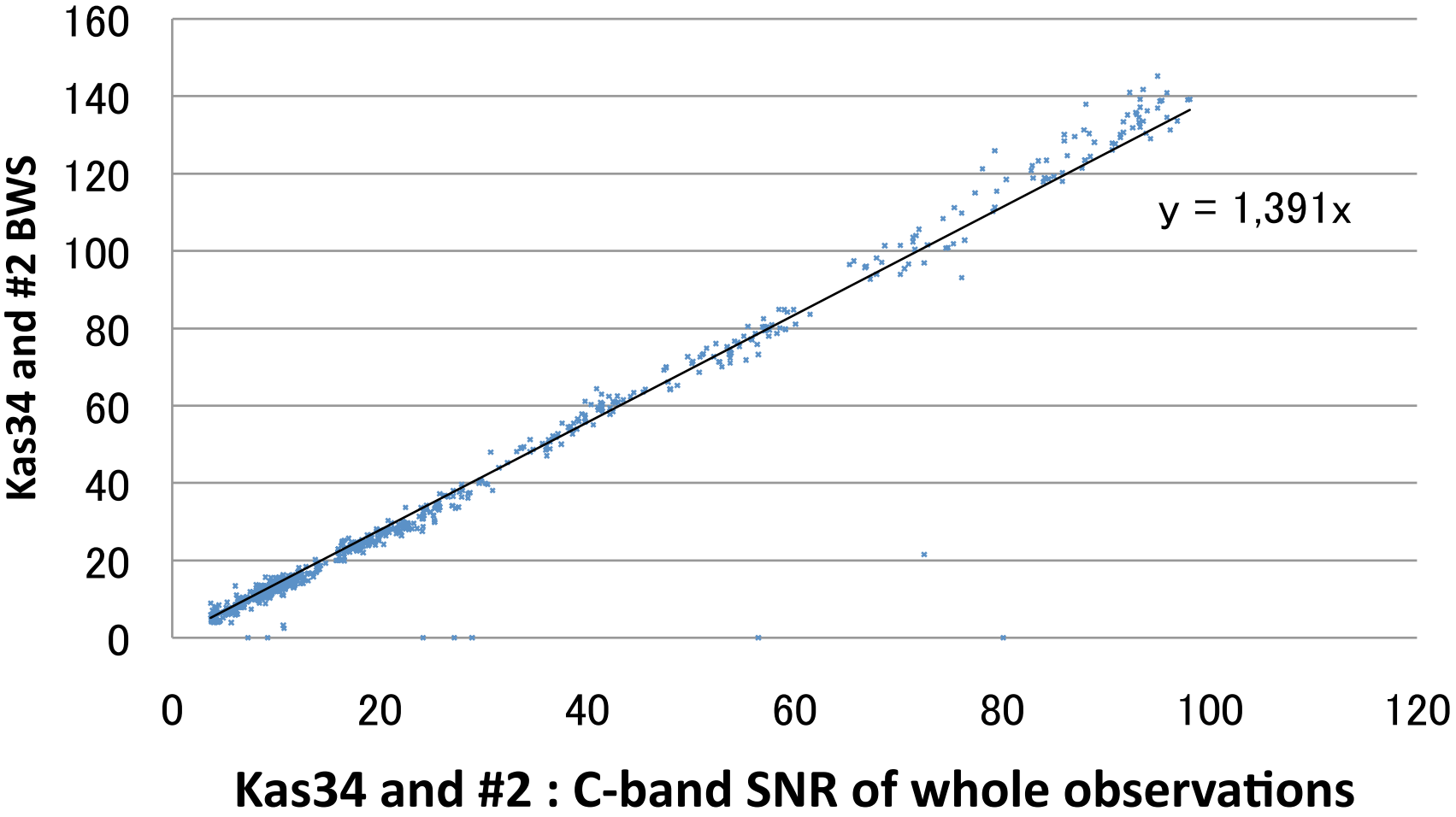
Amp




Phase



# SNR improved by a factor of 1.4 ($= \sqrt{2}$) after Bandwidth synthesis

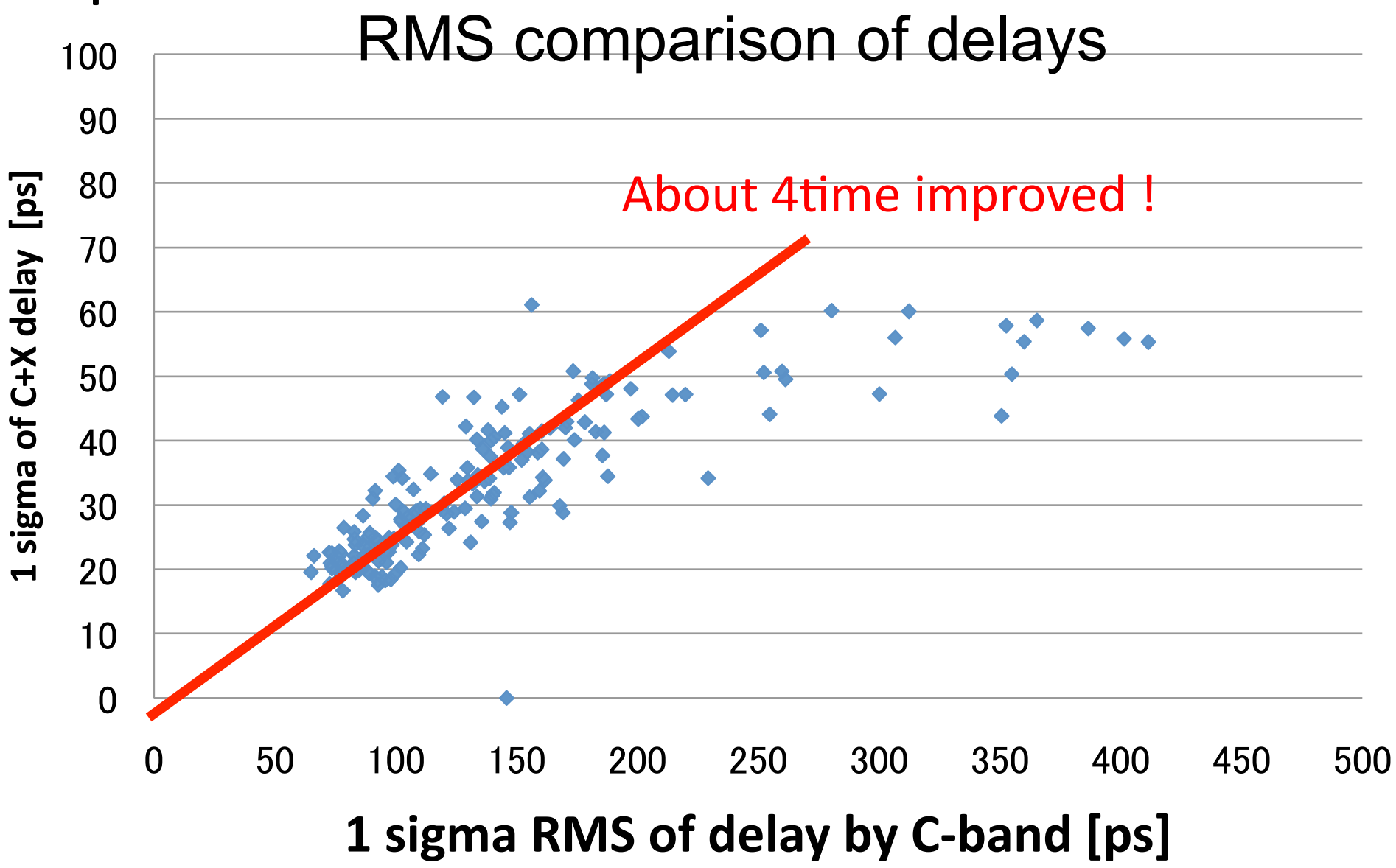


# Fringe detection after BWS

| SNR>=6.0 | After BWS |
|---|---|
| compact #1 | 735/739（99.5%） |
| compact #2 | 701/740（94.7%） |

About  60 observations (8%) could be recovered!

**Compact #2**

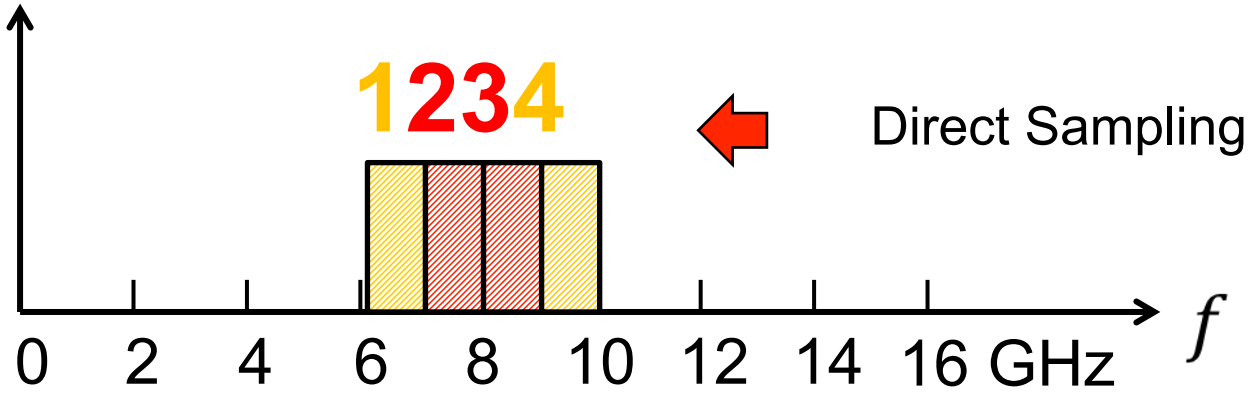

RMS comparison of delays
About 4time improved !
1 sigma of C+X delay [ps]
100
90
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
400
450
500
1 sigma RMS of delay by C-band [ps]

- RMS of delay improved by a factor of about 4
  - Reason1: Bandwidth was 3 times wider
  - Reason2: SNR improved 1.4 times better
- BWS is useful even for small compact antennas

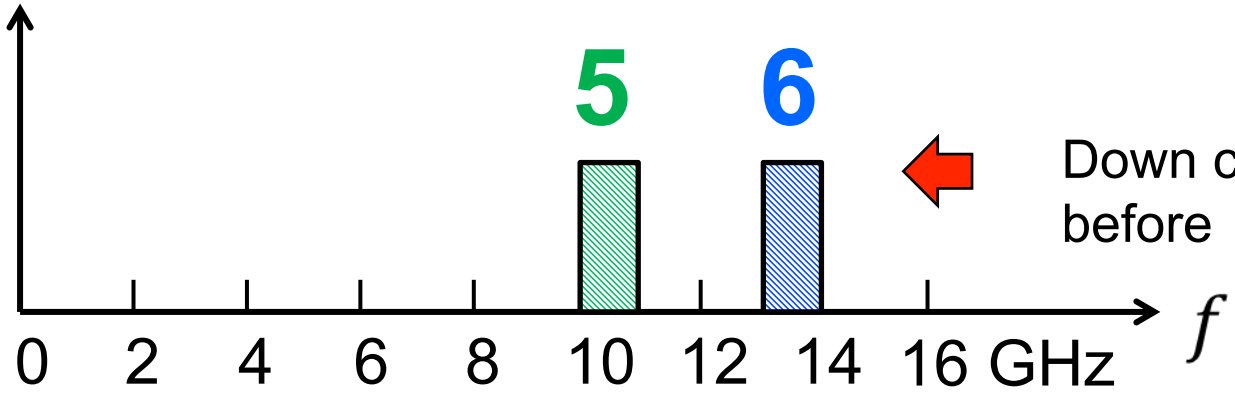
# KASHIMA－ISHIOKA Broadband Exp. Jan. 2015

# Frequency allocation 6GHz to 14GHz

BW 1024MHz each

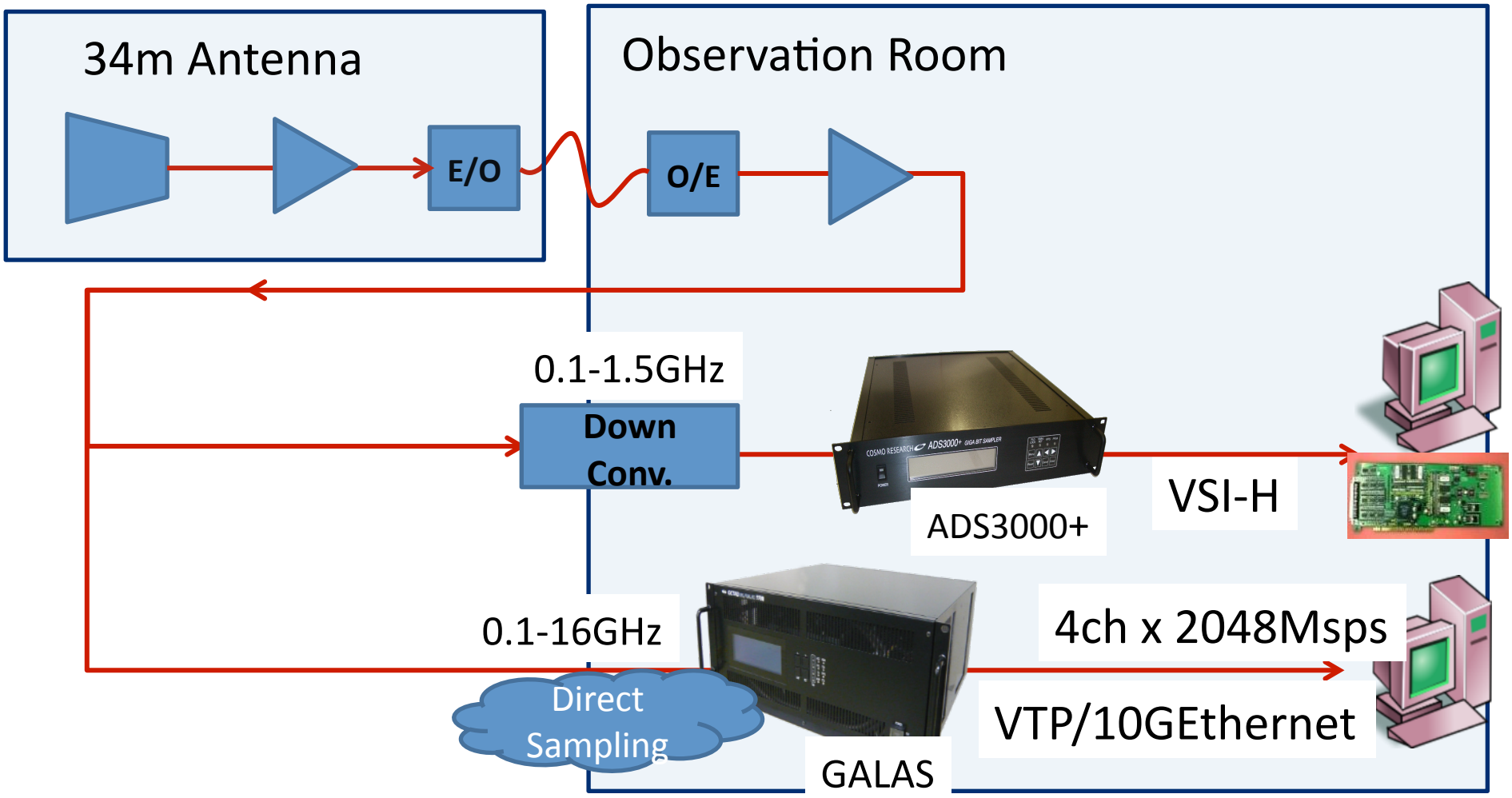



Direct Sampling, GALAS

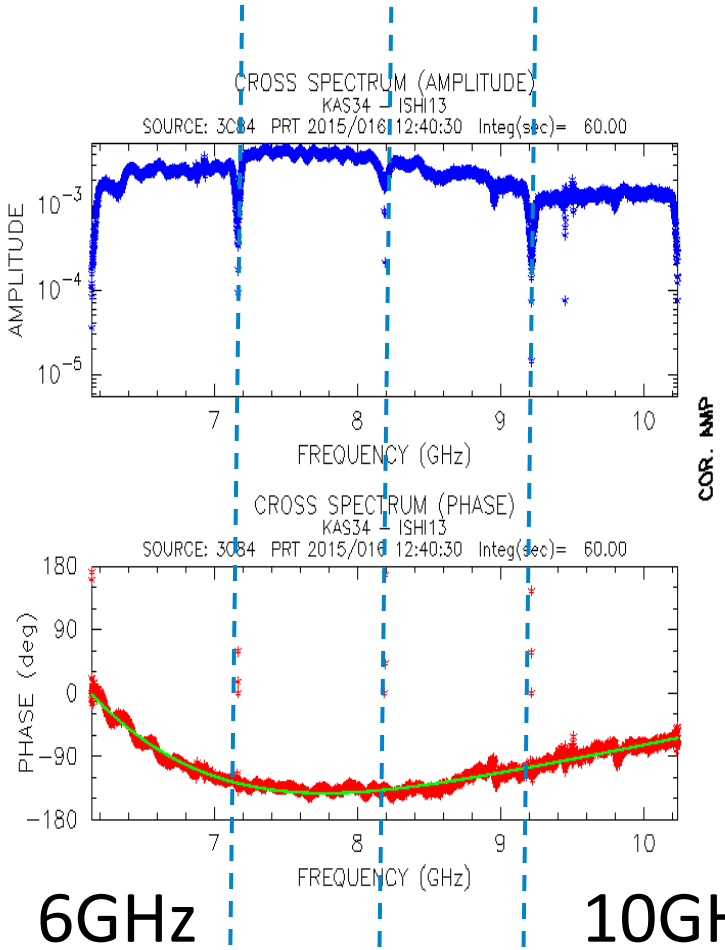


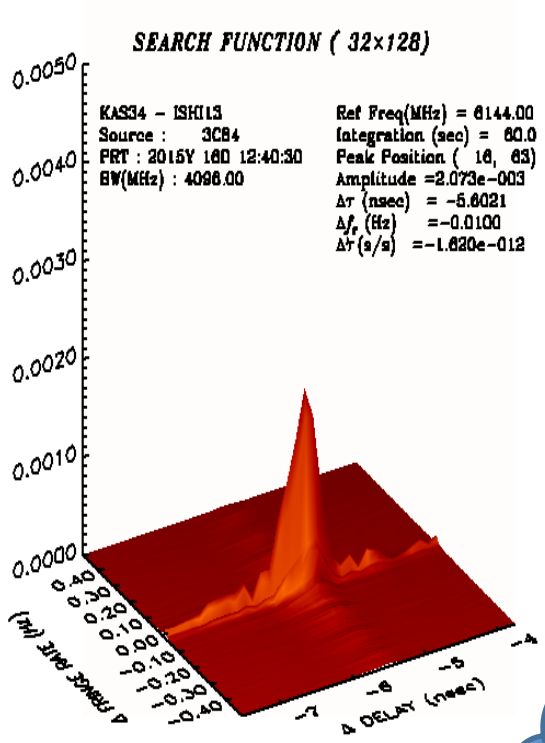

Down conversion
before ADS3000+

# Signal Path and DAS



# Bandwidth Synthesis of #1,#2,#3,#4
# （Direct Sampling by GALAS）
# Every bands have already connected!



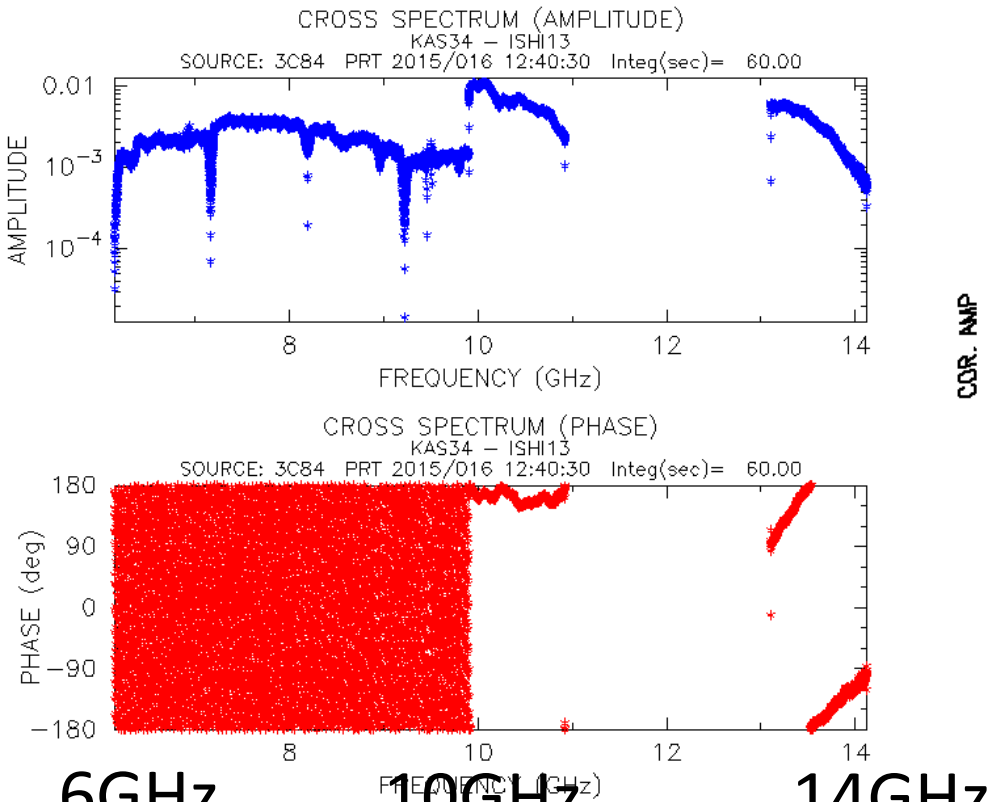




6GHz 10GHz

processing was done by Dr.T.Kondo

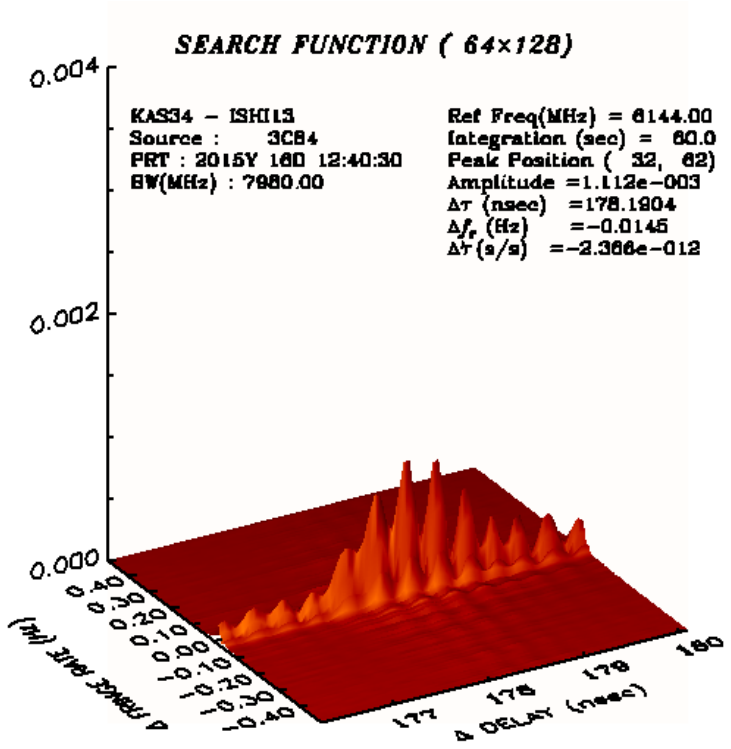
# If we simply connected…

## Cross spectrum



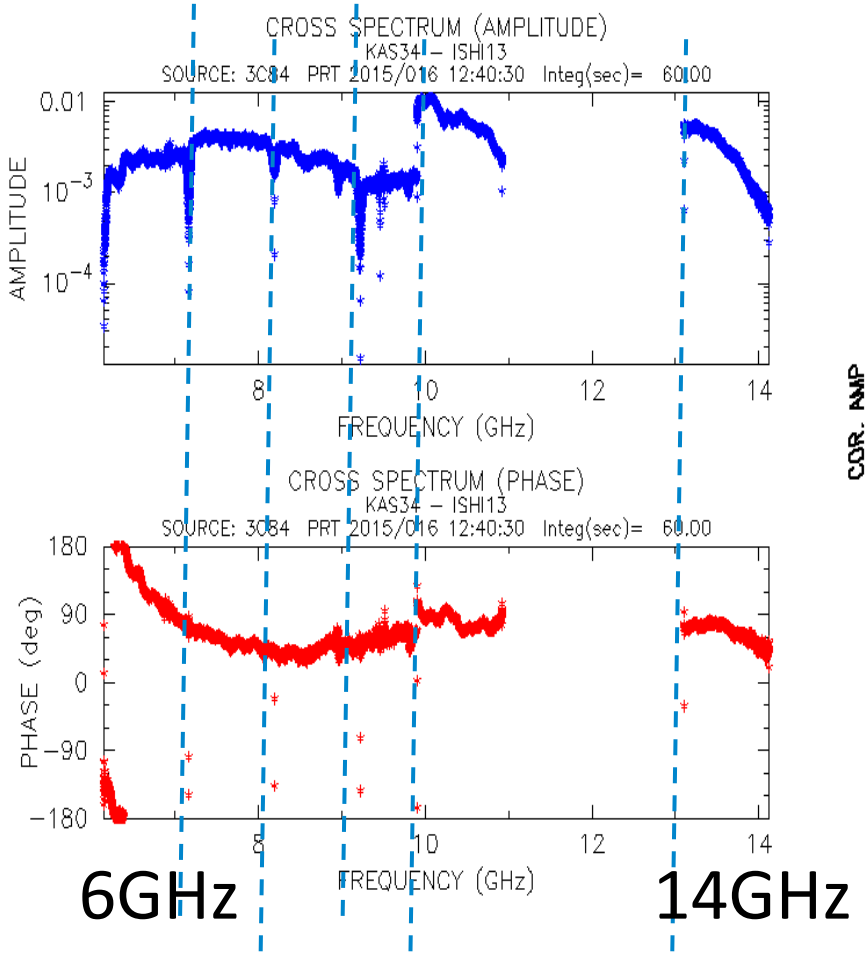

6GHz 10GHz 14GHz

## Search function

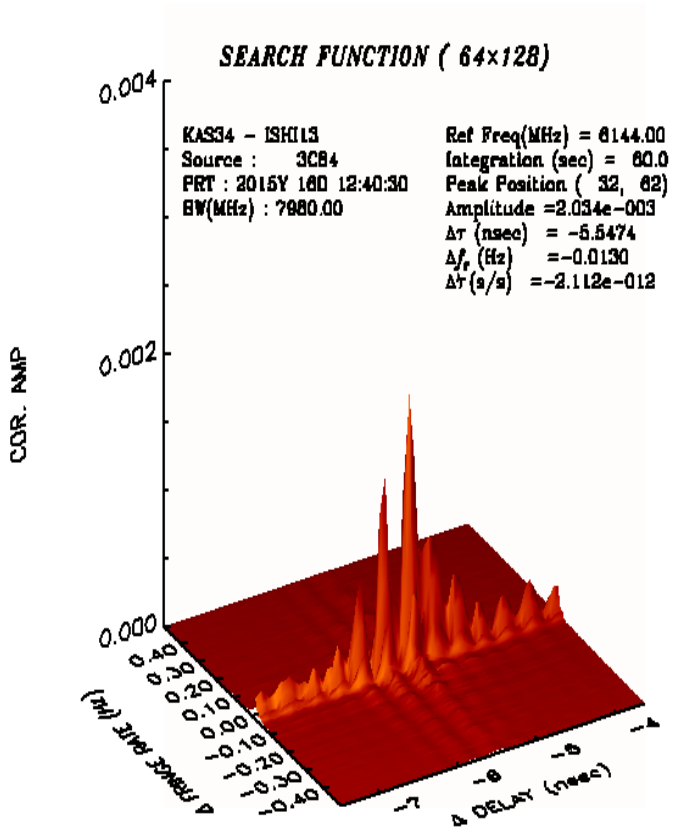


# Bandwidth Synthesis(#1-#6) after inter-band delay correction

## Cross Spectrum

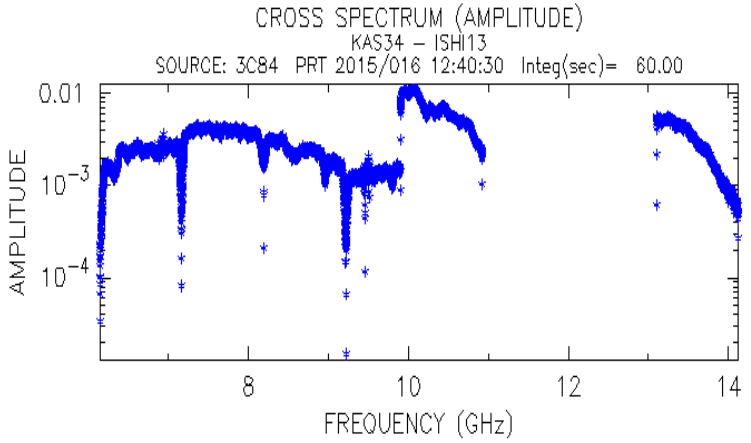


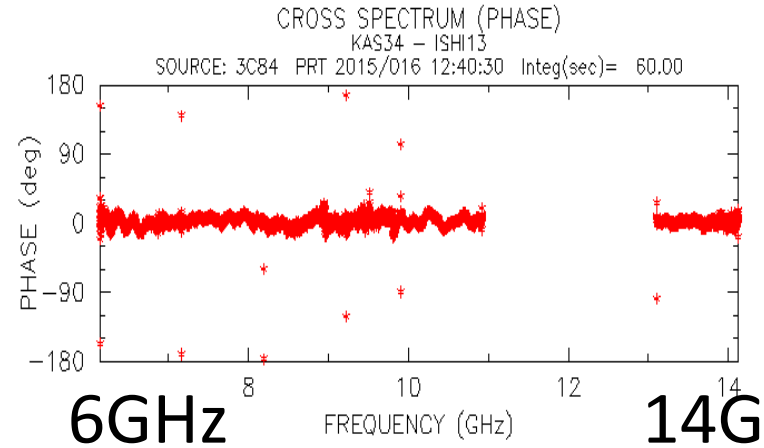

## Delay Resolution Function



# Super Bandwidth Synthesis after inter-,intra-band delay correction

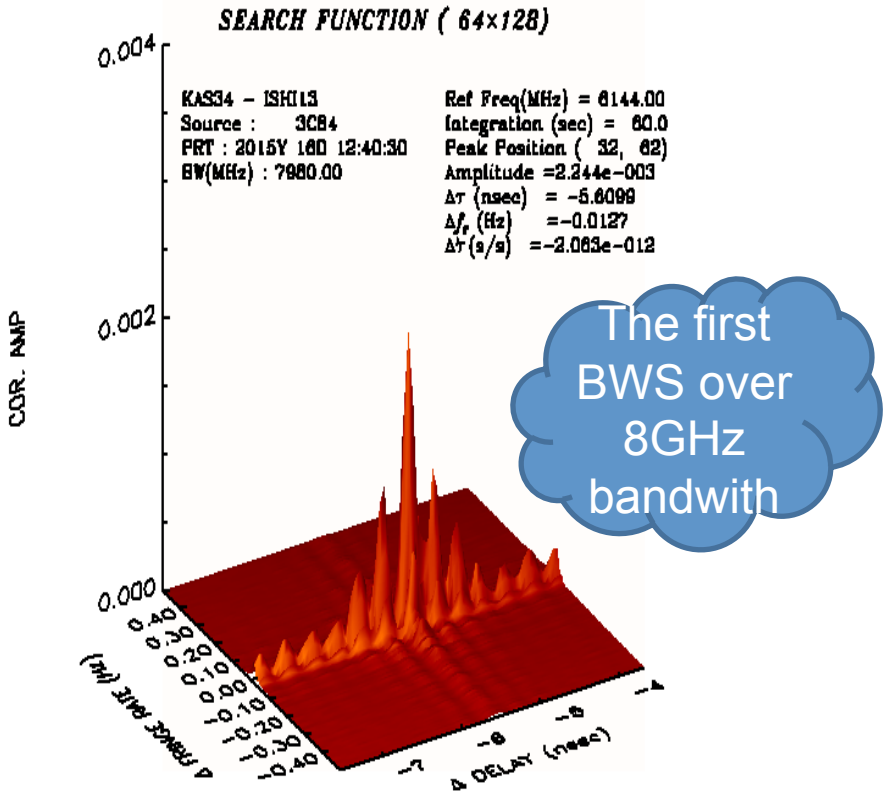
## Cross Spectrum




6GHz 14GHz

## Delay Resolution Function

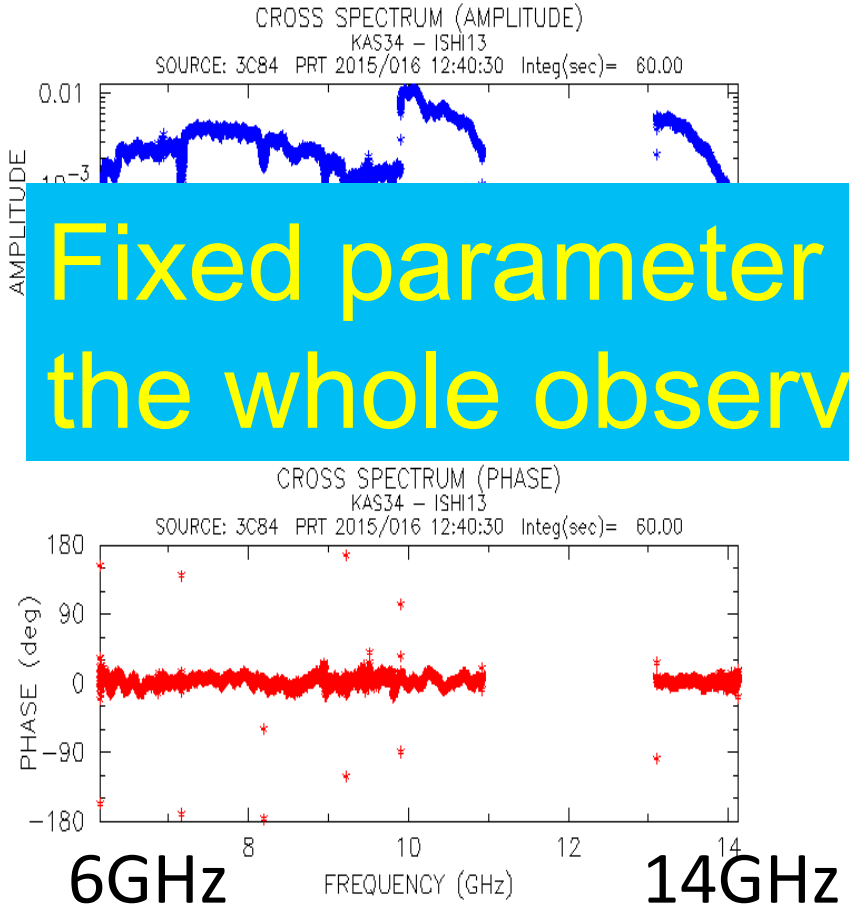



The first BWS over 8GHz bandwith

Theoretical delay precision is 27 femto sec.

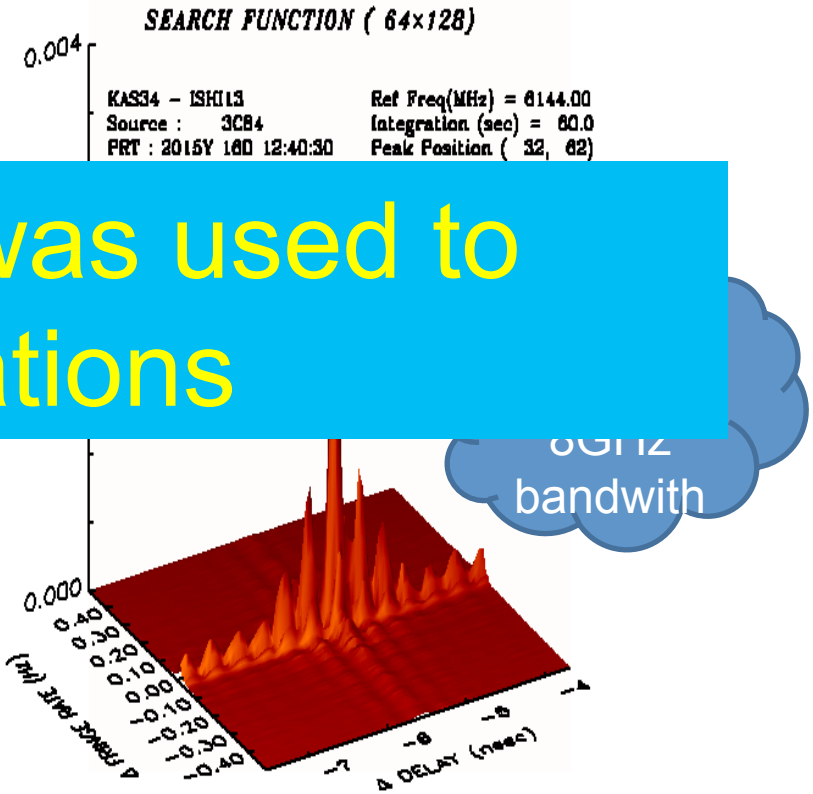
# Super Bandwidth Synthesis after inter-,intra-band delay correction

## Cross Spectrum




6GHz 14GHz

## Delay Resolution Function

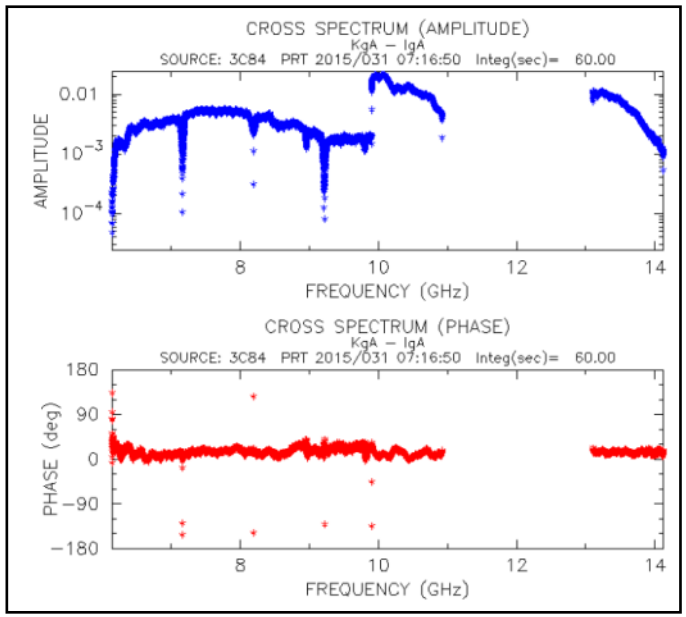


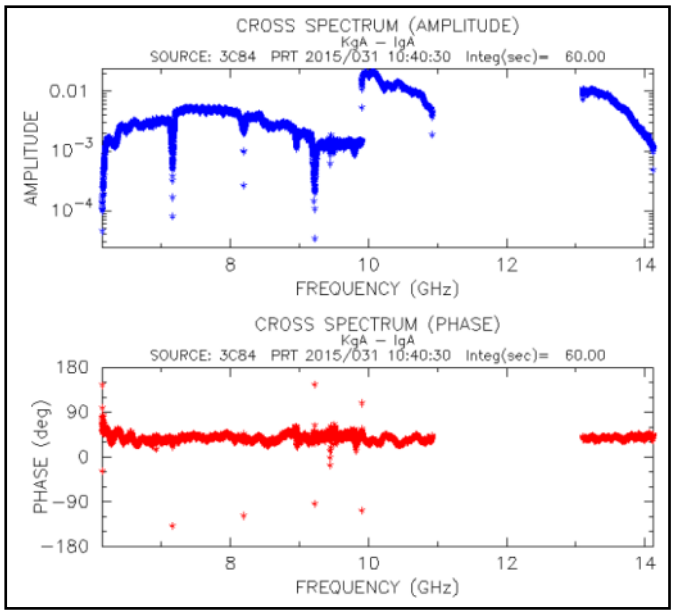

8GHz bandwith

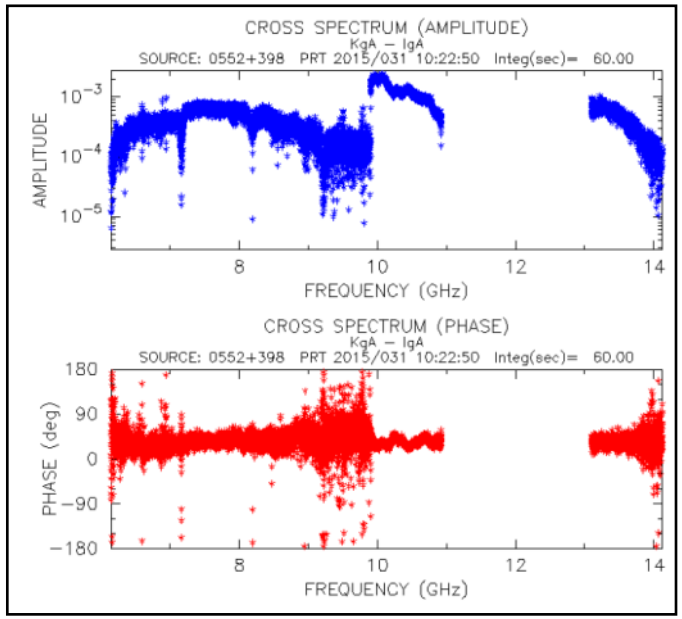
Theoretical delay precision is 27 femto sec.

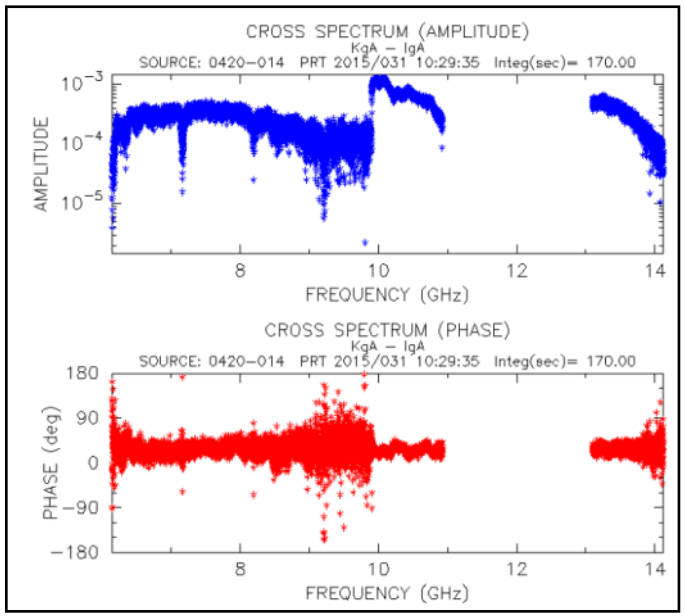
Fixed parameter was used to the whole observations

# Successfully connected phases in another scans

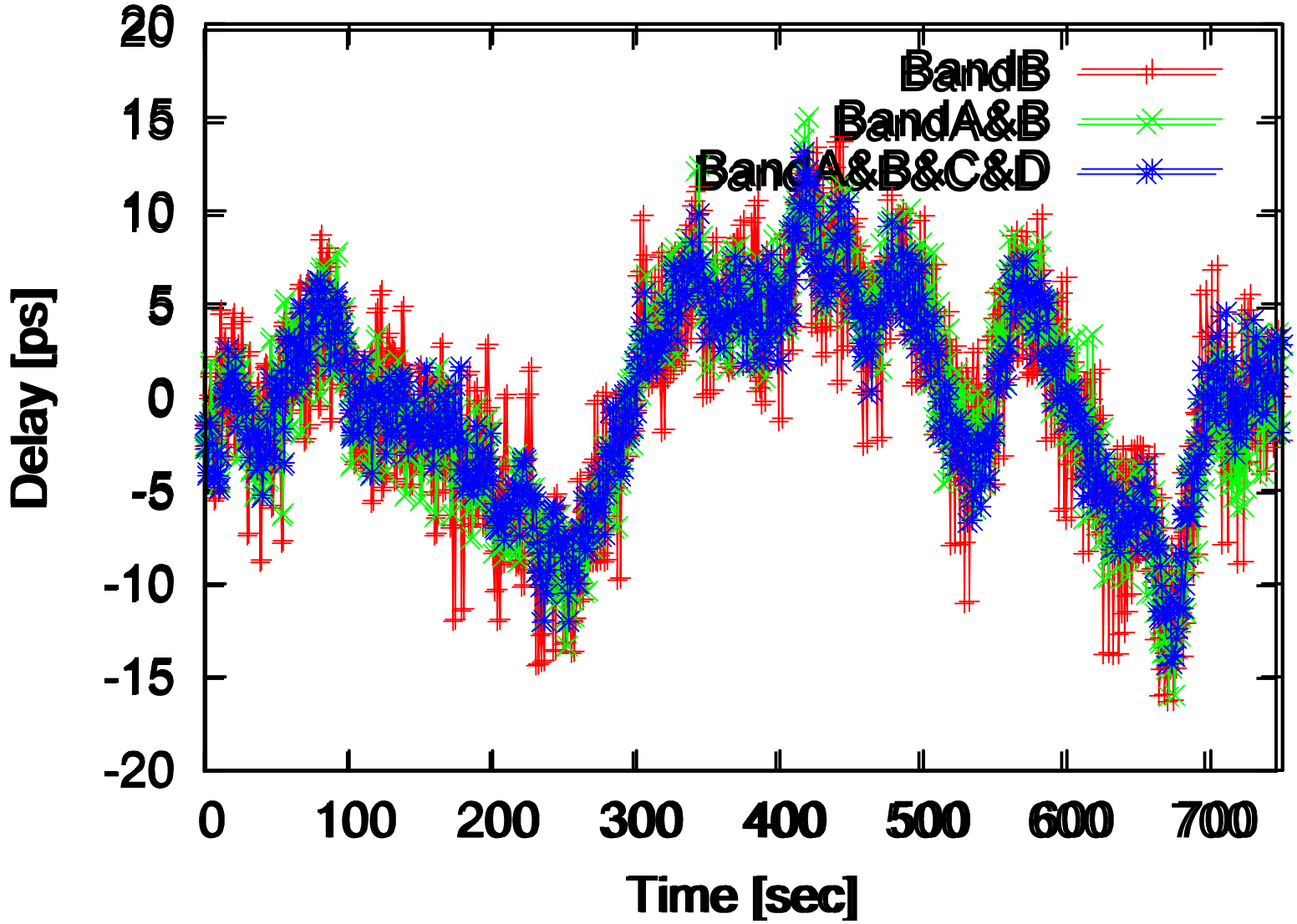


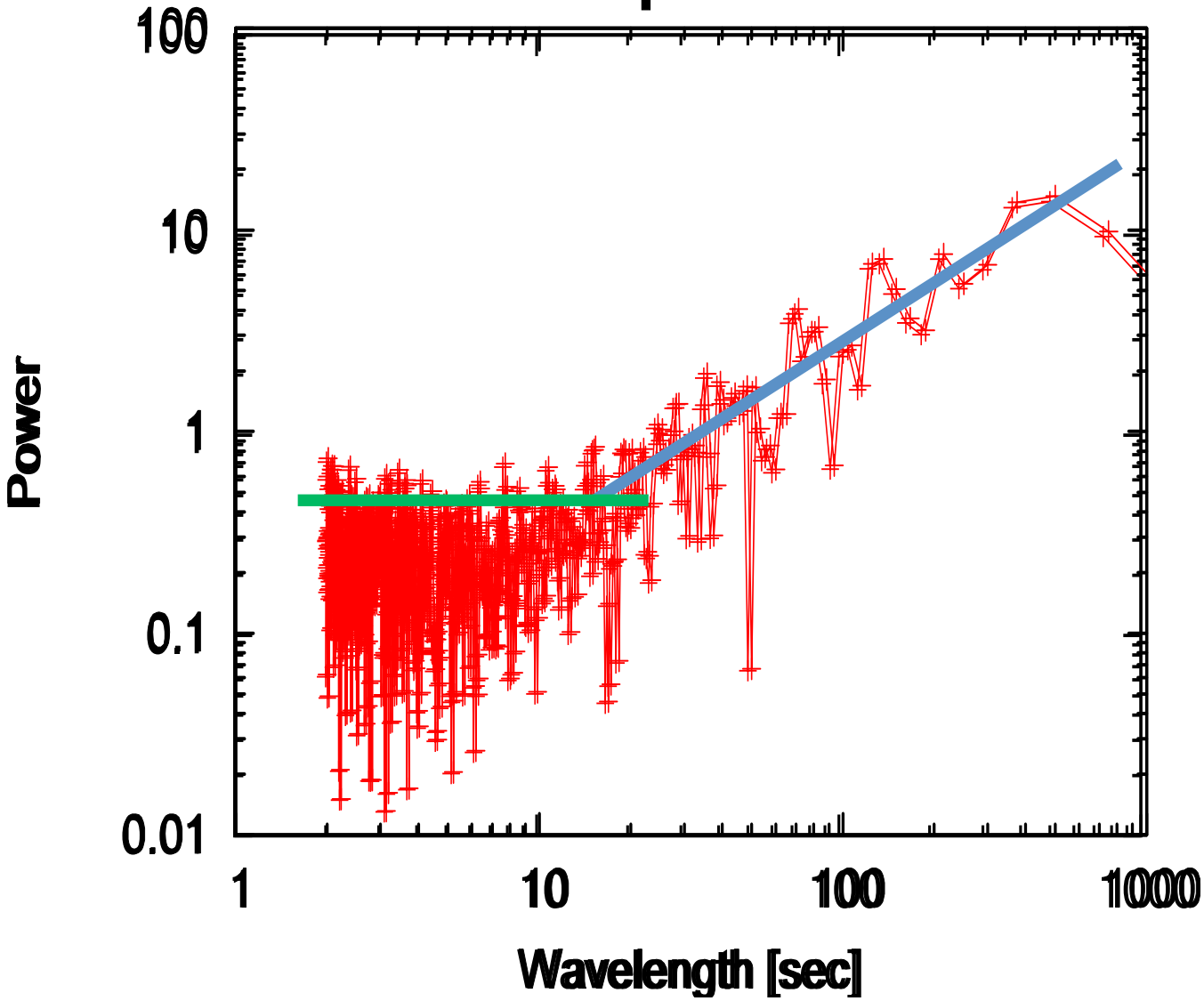
# Delay variations in 15min tracking




RMS is clearly seen better, depending on bandwidth

+-10 ps variation can be seen even in 15 min

# Noise spectrum




Behavior of white noise component is observed until about 15sec

One source has a duration of 7.5 sec integration In VGOS specification

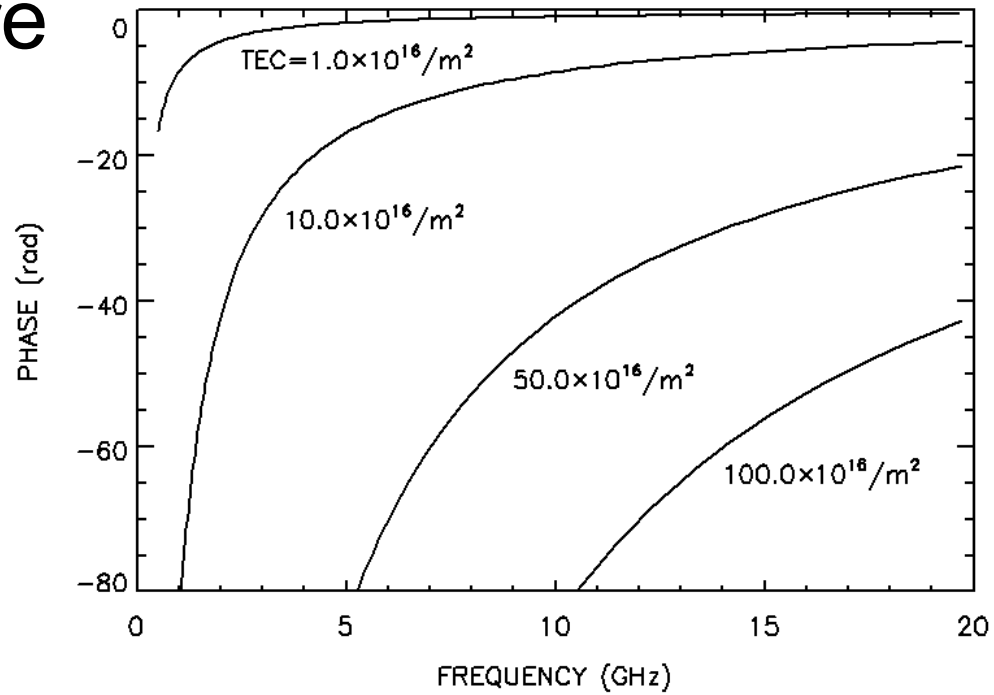
# RMS in 1sec

| Band width | RMS/sec [ps] | Remark |
|---|---|---|
| 1GHz | 3.08 | Band #2 |
| 2GHz | 2.01 | Band #1 and #2 |
| 4GHz | 1.29 | Band #1 to #4 |
| 4GHz | 0.96 | After intra-band correction |
| 8GHz | 0.60 | All 6 Bands |

If we perform 7.5sec integration like VGOS,
RMS will become 200 femto second !

# In case of much longer baseline

- The residual phase will include ionospheric delay
- Also include Core-shift delay by source structure




**We need a VLBI partner to obtain such a data!**

# Let's make a broadband VLBI!


- We thank GSI people for making a VLBI between Kashima and Ishioka
- Broadband Feed Development is supported by NAOJ-fund(Prof. Fujisawa et al.)