VLBI Technology Workshop
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Development of wideband VLBI system – Gala-V

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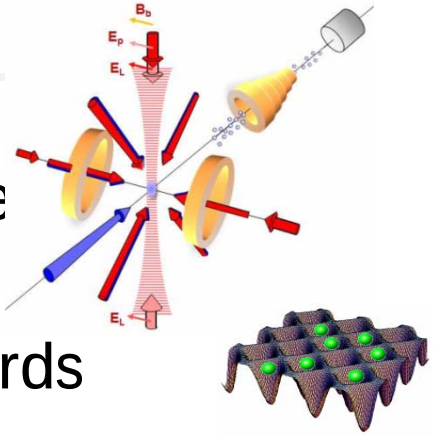
NICT/ Space-Time Standards Laboratory

Mission Target:=

Frequency Comparison of Clocks at Intercontiental Distances

Background-1:

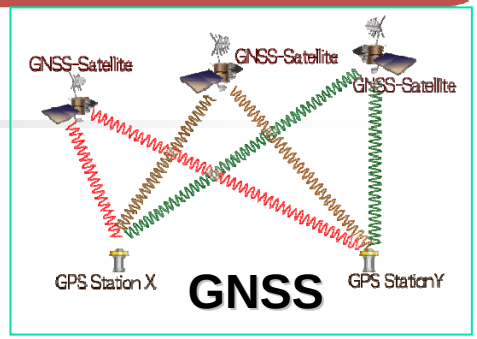


- NICT is the Time Keeping Authority of the National Standard Time JST.
- Development of Optical frequency standards is in progress in this field.
- Primary standard Cs Clock will be replaced by optical clock (e.g. Sr atom 698nm) in near future.
- High precision frequency comparison between optical clocks is important for the process of defining new primary frequency standard (= Re-definition of the “Second”).

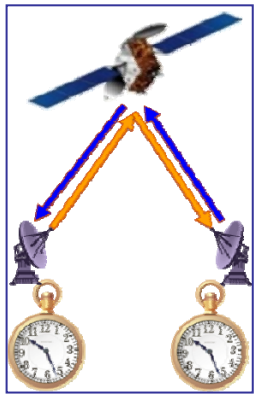
Mission Target:=

Frequency Comparison of Clocks at Intercontinental Distances

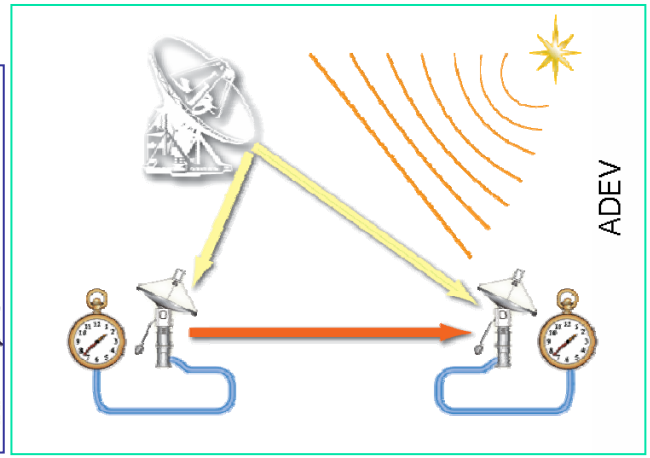
Space Technologies for Distant Frequency Comparison



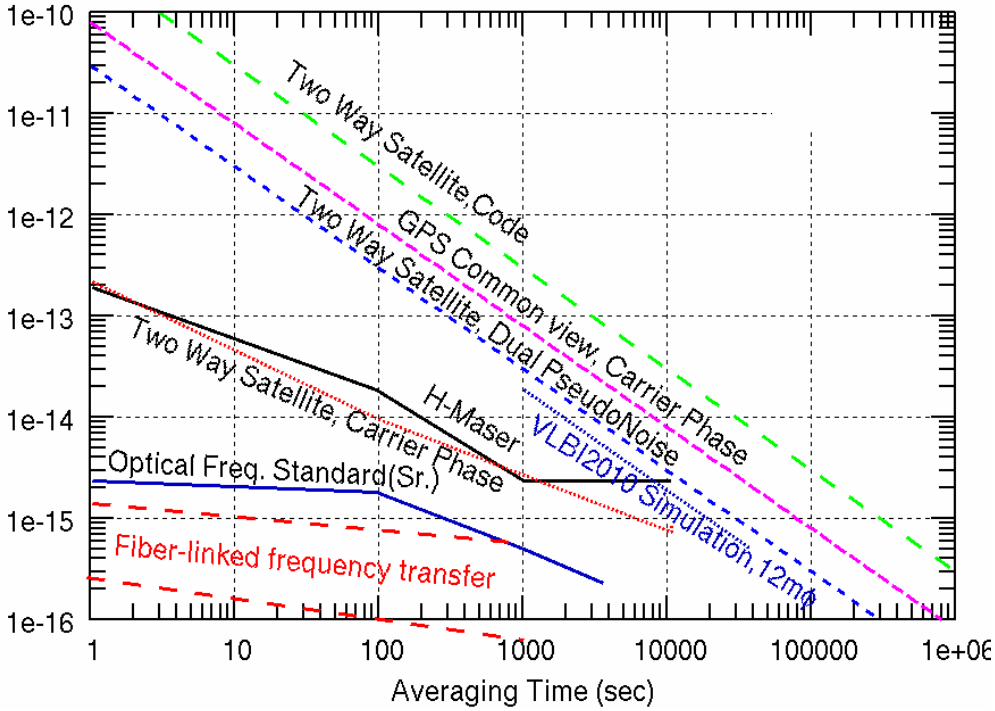
- GNSS(Common view, PPP)
- Two way Satellite Time and Frequency Transfer(TWSTFT)
- **VLBI**



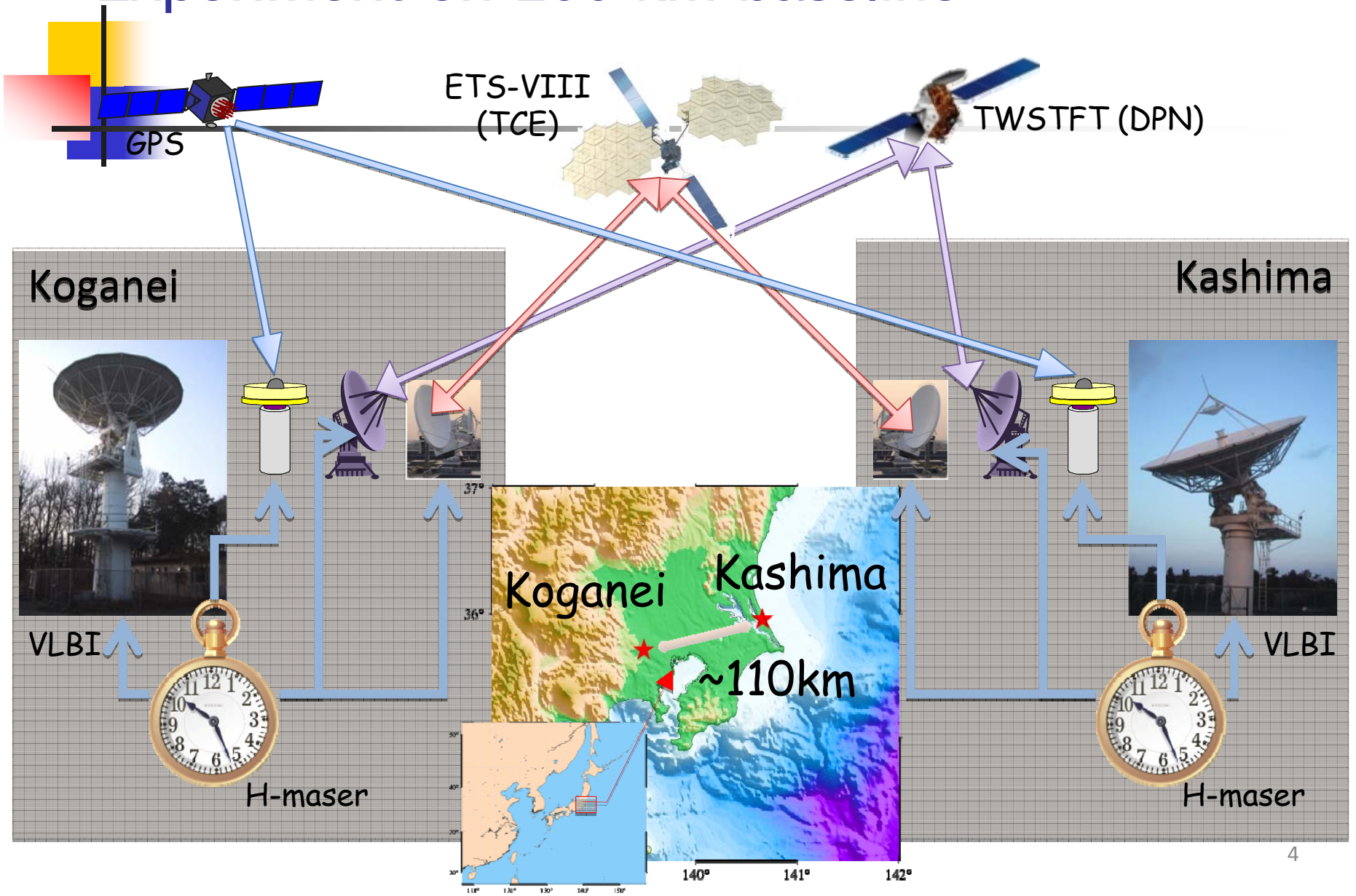
TWSTFT



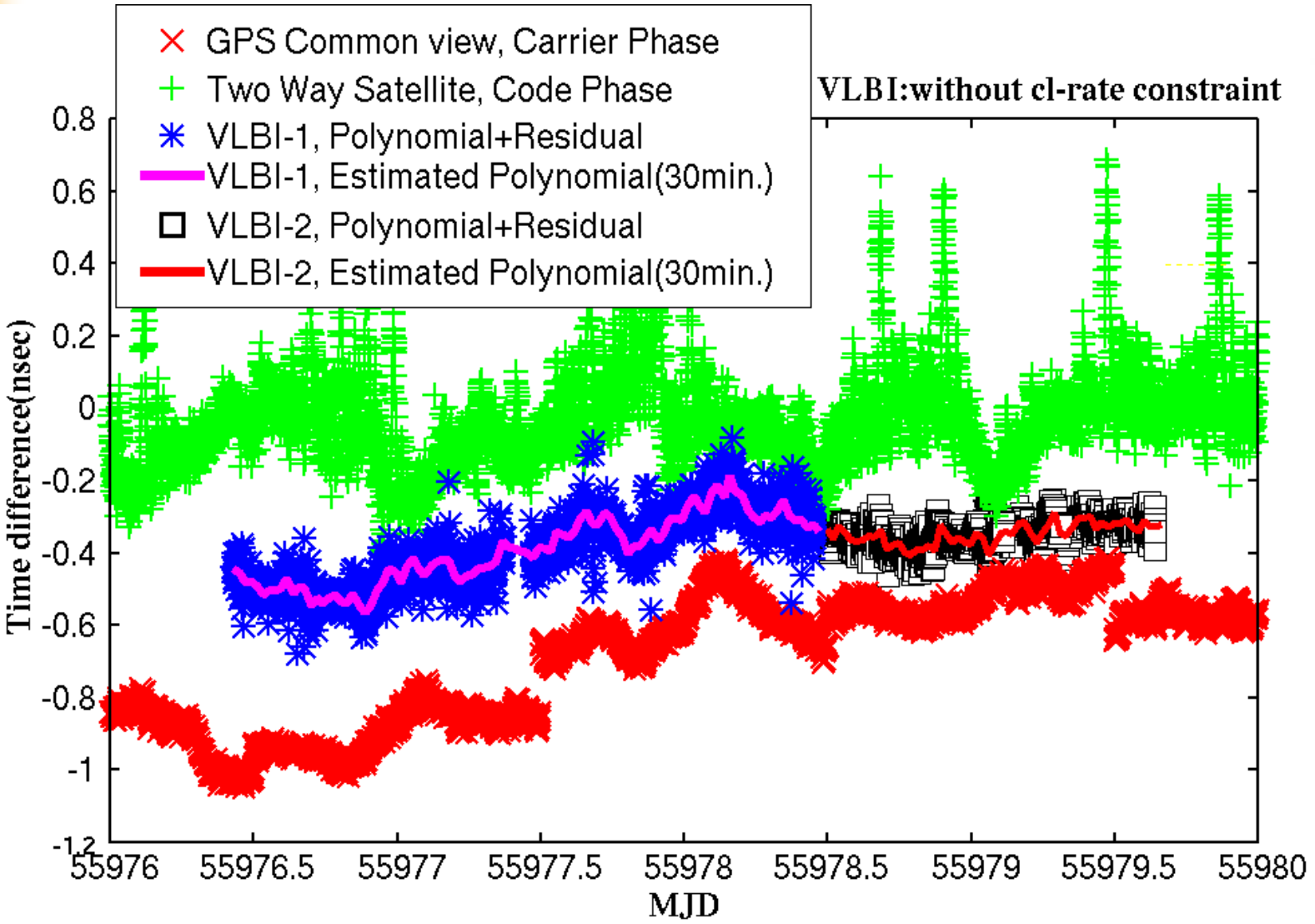
VLBI



Comparison of Frequency Transfer Techniques Experiment on 100 km baseline



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

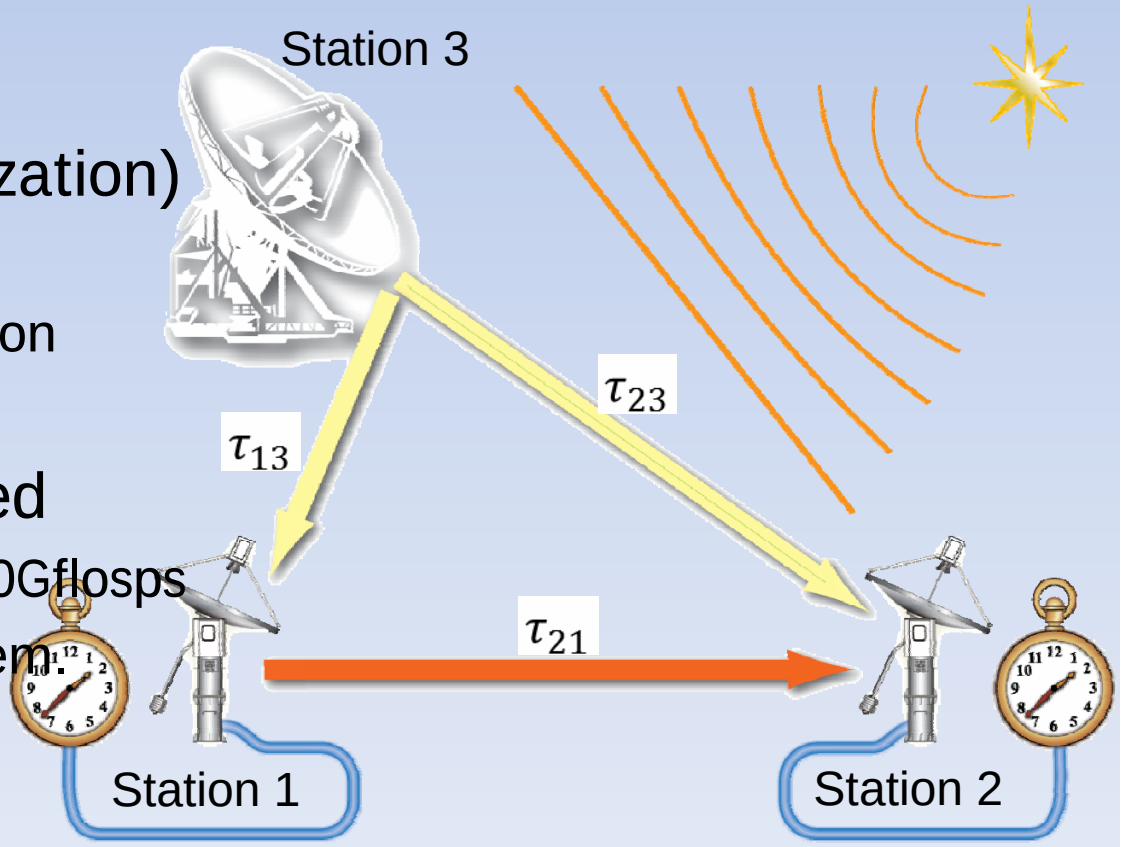


Gala-V project Overview

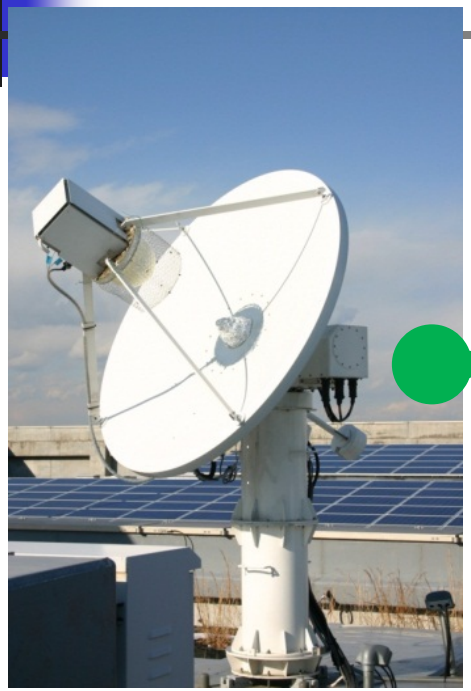
Target Precisiton: 30 ps -> 7 ps

Combination of Small and Large Diamter antennas

- Observation 4 band (1024MHz)
  - Fc = 4.0GHz, 5.6GHz, 9.9GHz, 13.1GHz,
  - Effective BW: 3.8GHz
- Data processing (1 Polarization)
  - GICO3 Software Correlator
  - 2Gbps x 4 = 8 Gbps / Station
  - 40TB/Stn X 3 stn= 120 TB
- Required Processing Speed
  - 100Gflops/1Gbps x 8 = 800Gflosps
  - 8- 16 PCs will deal with them.



1.6/1.5m and 34m VLBI antenna



1.5m compact antenna

Kashima 34m antenna

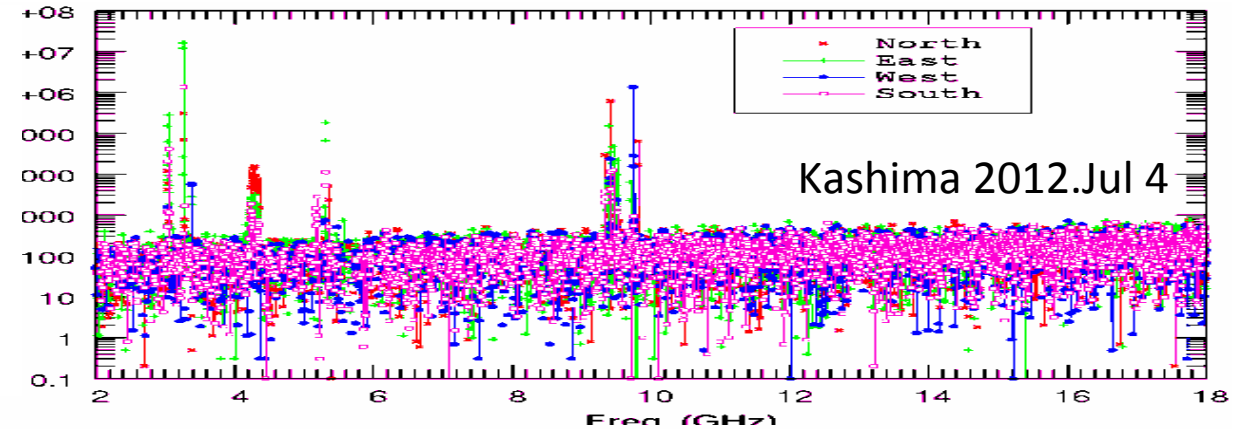
- VLBI2010 semi compliant Observation System is under preparation
  - 1 GHz x 4 band in the 3-15GHz Frequency Range

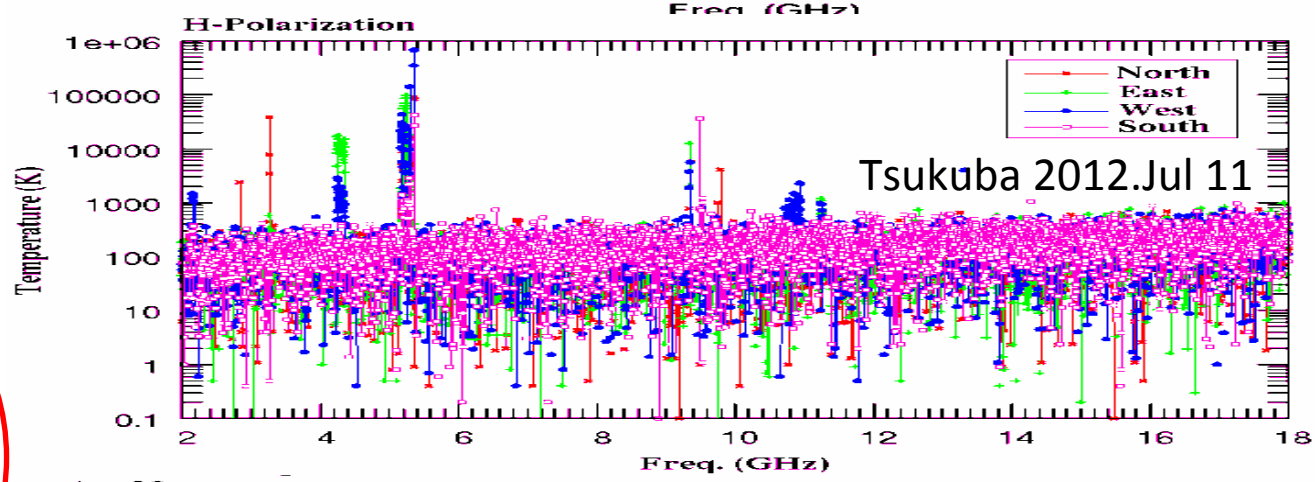
Components of the System

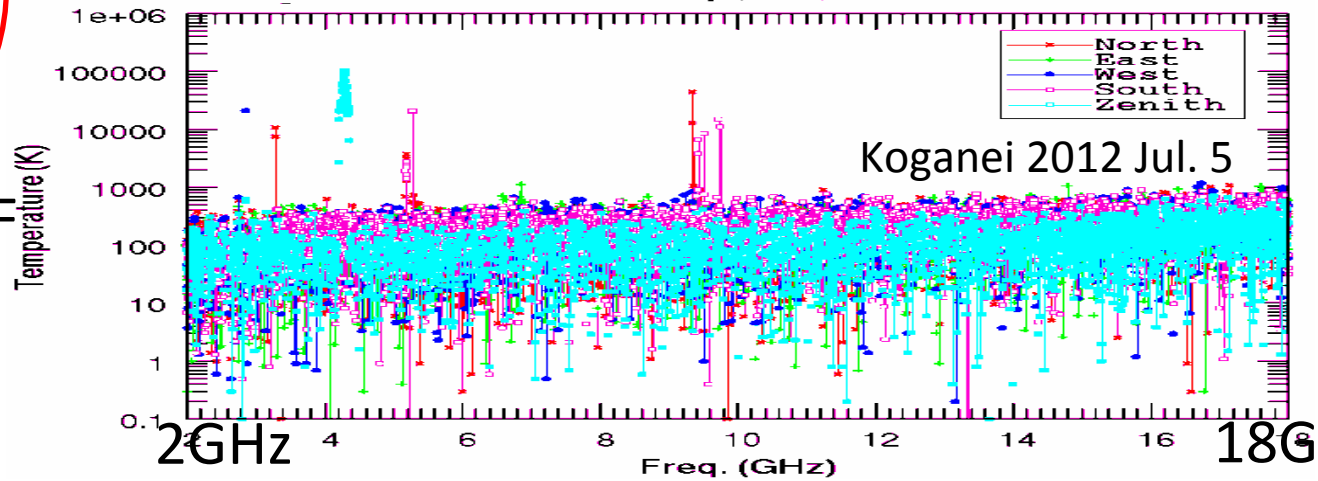
1. Selection of Observation Frequency Band
   - Radio Frequency Interference（RFI）Survey
   - Wide band feed design for existing Radio Telescope (Kashima 34m)
2. Wideband low NF signal Transmission
3. Data Acquisition System
   - Down Converter and ADS3000+
   - Gala-V sampler (GALAS)
4. Phase Calibration Signal
5. Correlation Processing

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

With 3.5GHz HPF before LNA







2GHz 18GHz

The Gala-V Feed “Iguana”.

Requirement:

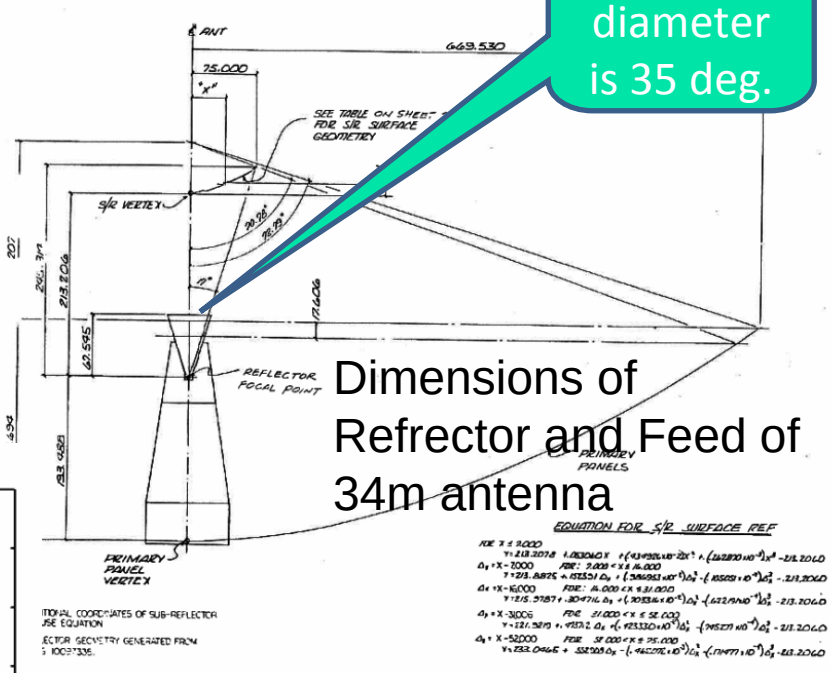
•Beam width of the feed must be ~35 deg. over the wide frequency range

Solution:

•Dividing into two frq.range

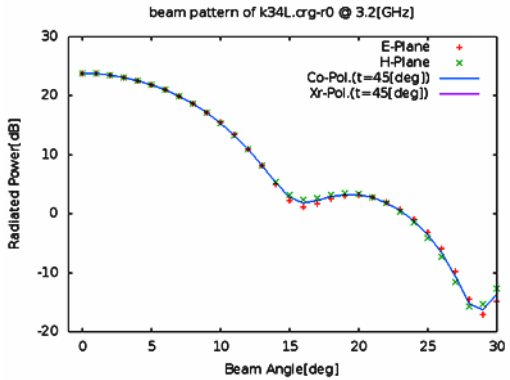
•3-7GHz, 9-14GHz Nested feed

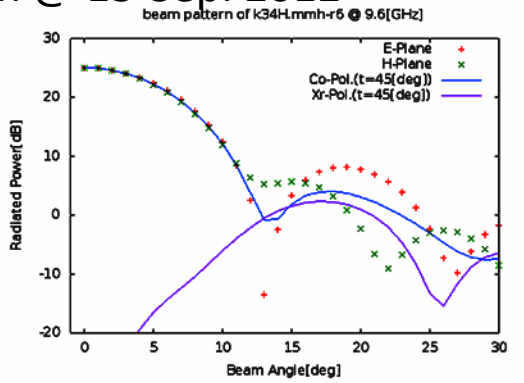
Apparent diameter is 35 deg.

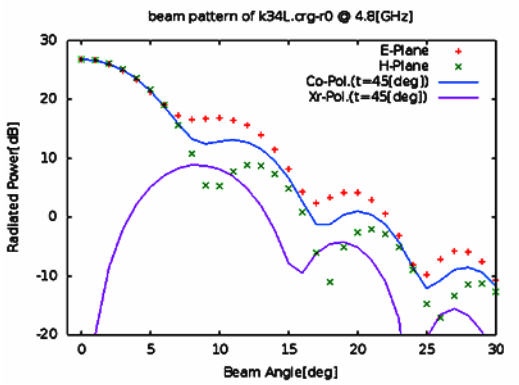


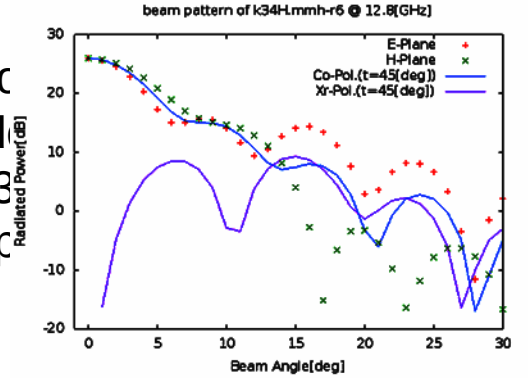
Dimensions of Refrector and Feed of 34m antenna

Preliminary beam pattern @ 13-Sep. 2012









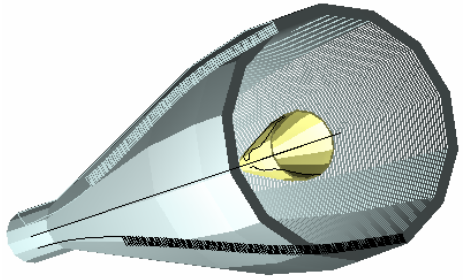
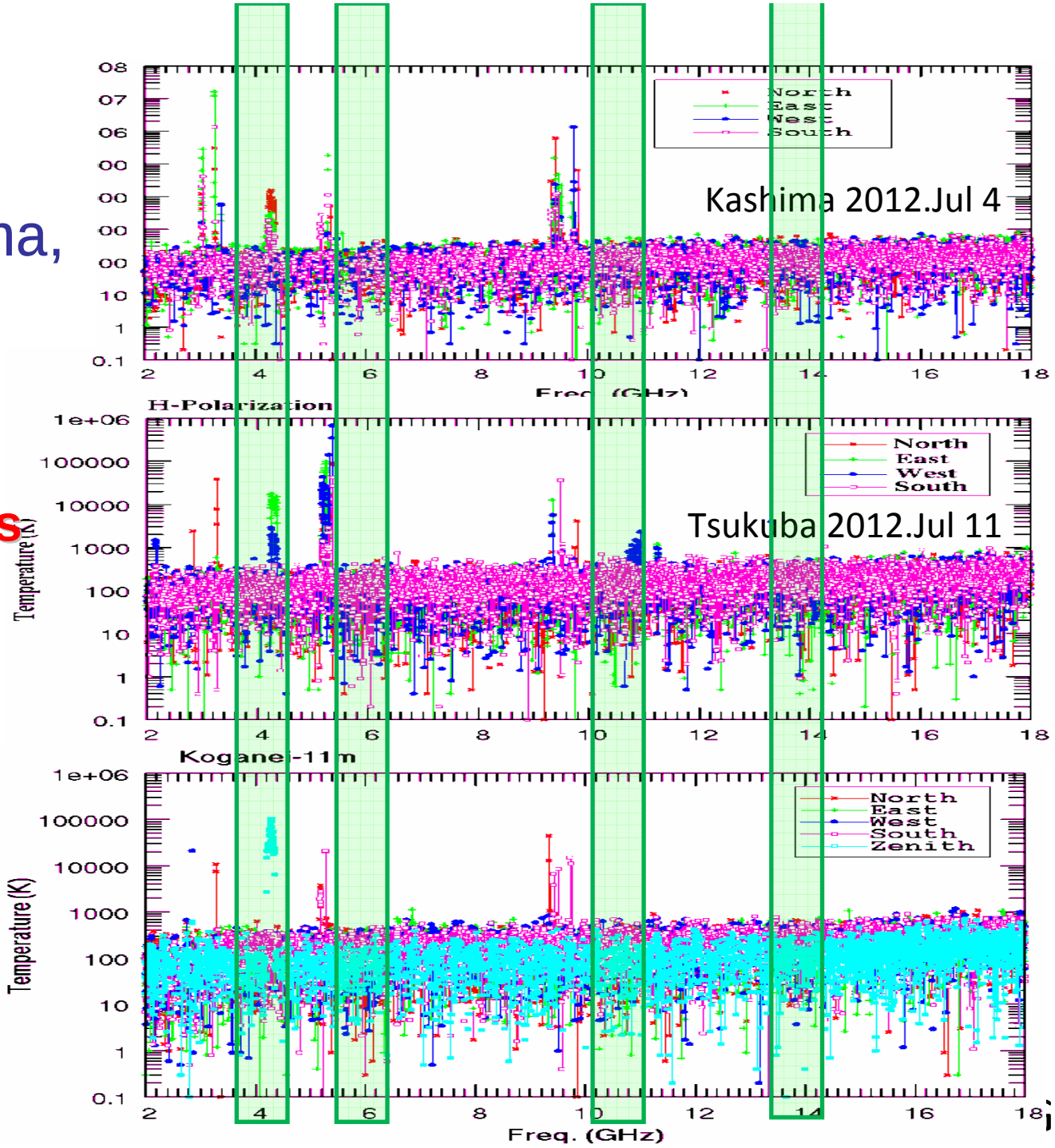


Image of Iguana feed under the development

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

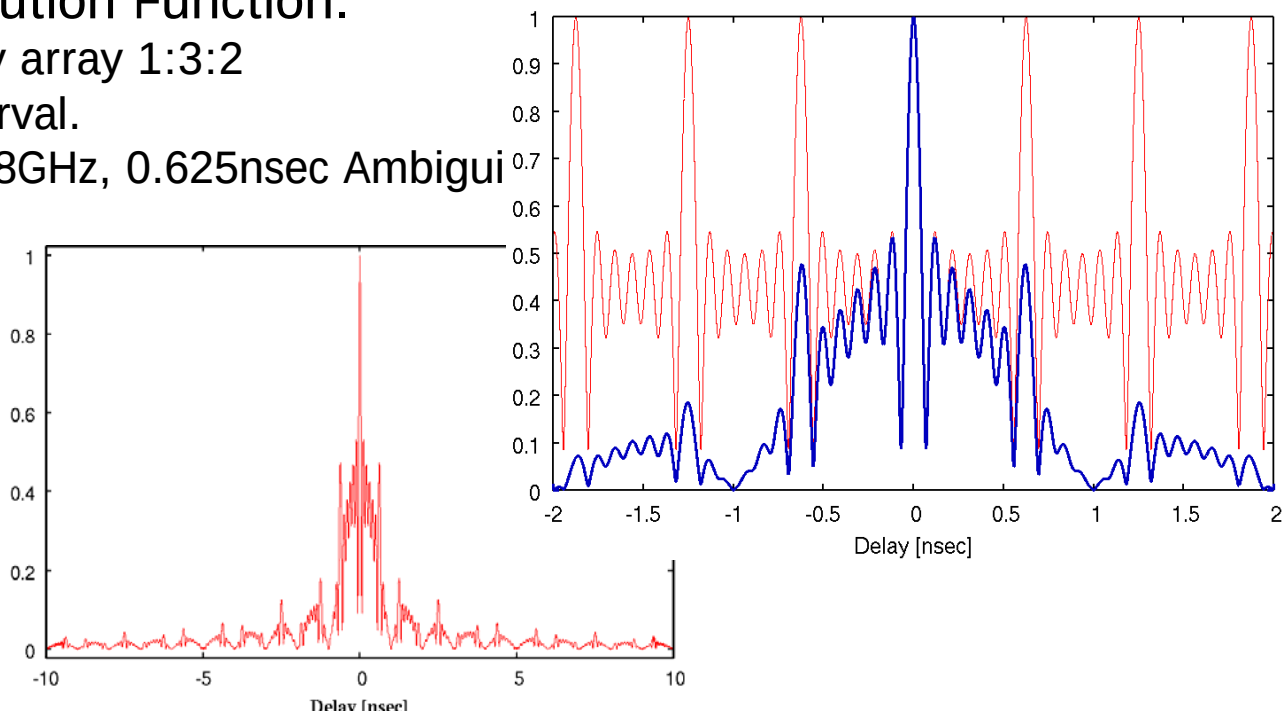
Selected bands
3.5GHz,
5.1GHz,
9.9GHz,
13.1GHz



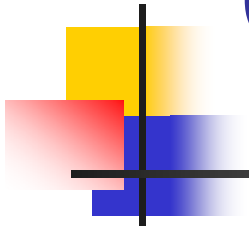
iHz

Selection of Fixed Frequency Array

- VGOS Spec. : Any four 1GHz in 2-14GHz range can be selectable.
  - In Our case: Due to several limiting conditions, we decided to develop the system design with fixed frequency array.
    - Conditions: Resources, Time schedule, Designing narrow beam feed for existing 34m dish
  - Band Edge = **3.5GHz, 5.1GHz, 9.9GHz, 13.1GHz**
- Followings were took into consideration
  - RFI survey at 3 sites including Tokyo. Broadcasting Satellite Signal.
  - Possible narrow beam with wide frequency range for the Kashima 34m telescope
  - Good Delay Resolution Function.
    - Zero redundancy array 1:3:2 with 1.6GHz interval.
    - Effective BW=3.8GHz, 0.625nsec Ambigui



Components of the System



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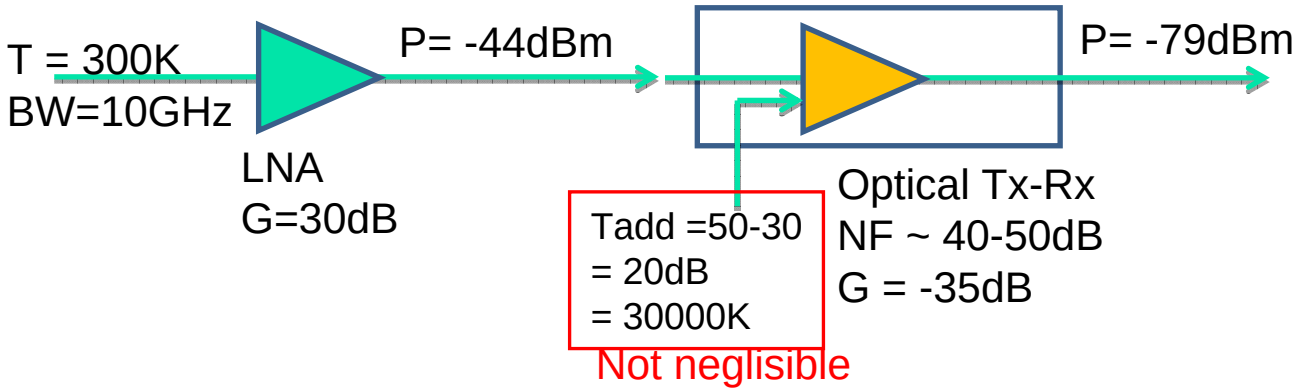
5. Correlation Processing

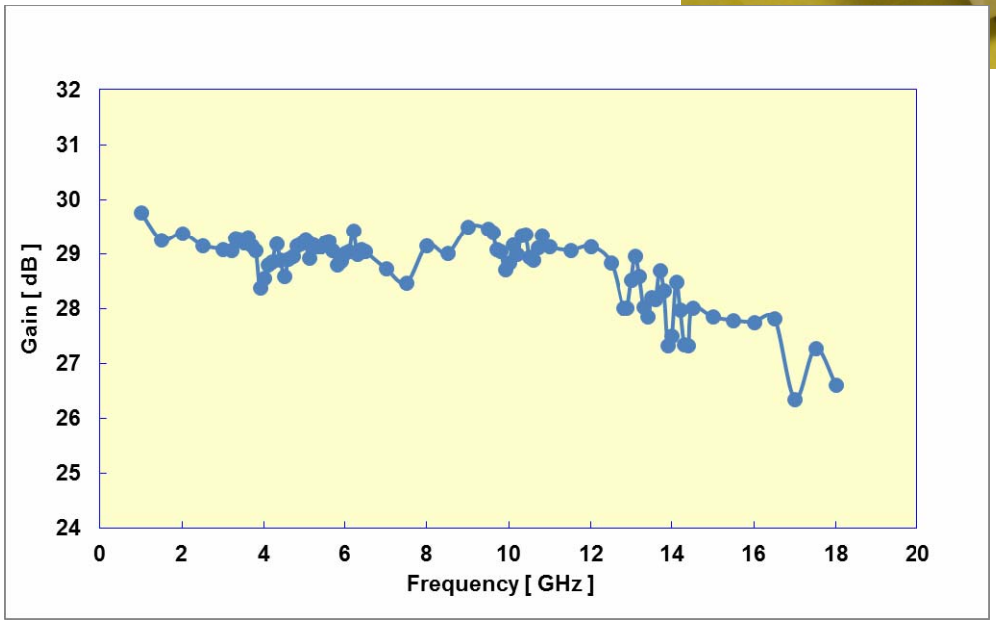
Wideband low NF signal Transmission

- Wideband signal is transmitted from receiver to observation room with optical fiber.
- Low noise optical transmission is important (e.g. Christopher Beaudoin, IVS VLBI2010 Workshop on TechSpec 2012)
  - **10 GHz bandwidth = 100dB gain of total power.**



E18000 from Sumitomo Osaka Cement Co Ltd.

	Parameters
Freq.	1-18GHz
Gain	+20dB
NF	< 5dB
P1dB	- 40dBm
Linearlity	±0.5dB
Flatness	10dBp-p



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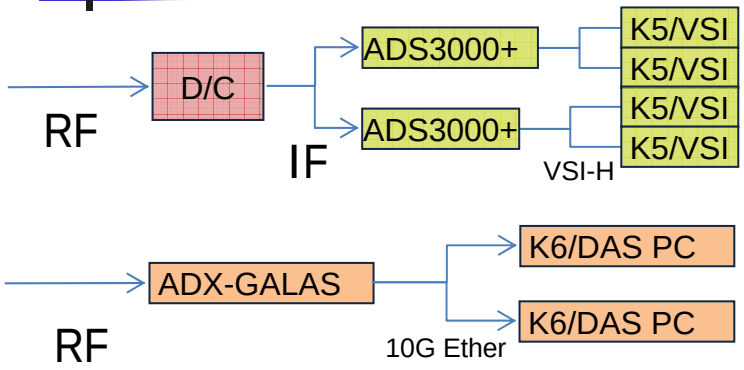
Data Acquisition: 1GHz x 4 Ch

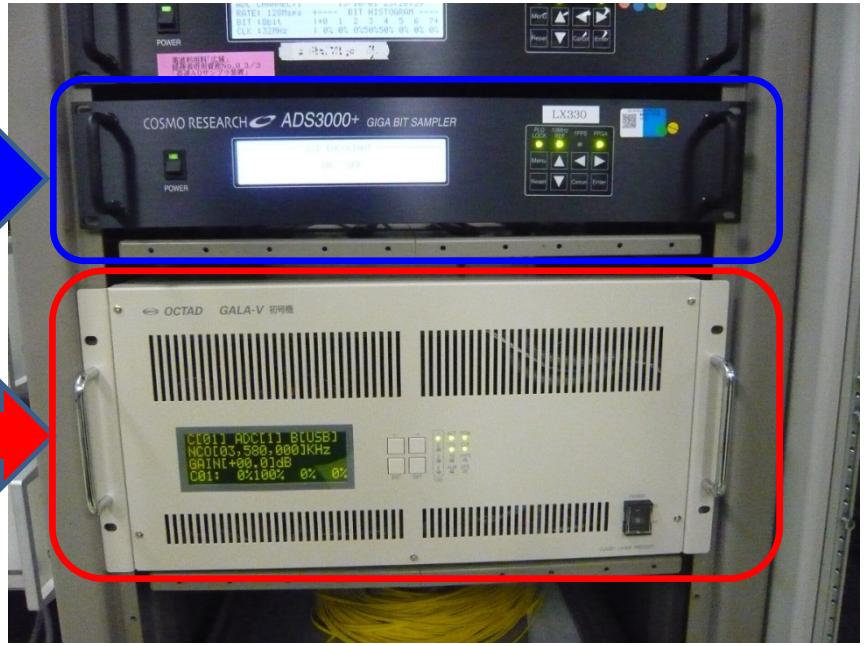


Two Approaches

- Fixed Freq. Down Converter + “ADS3000+”
  - Digital BBC function for legacy mode observation.
- Direct Sampler “GALAS”
  - Digital BBC function for selecting any Frequency
  - Avoiding D/C, simplifying the system
  - Flat Spectrum input is required

ADS3000+ Sampler
DBBC (BW≦32MHz)

Direct Sampler “GALAS”
DBBC(BW=1024MHz)



See Takefuji et al. “Evaluation of the RF Direct sampler “GALAS” for the VGOS Era”

Components of the System

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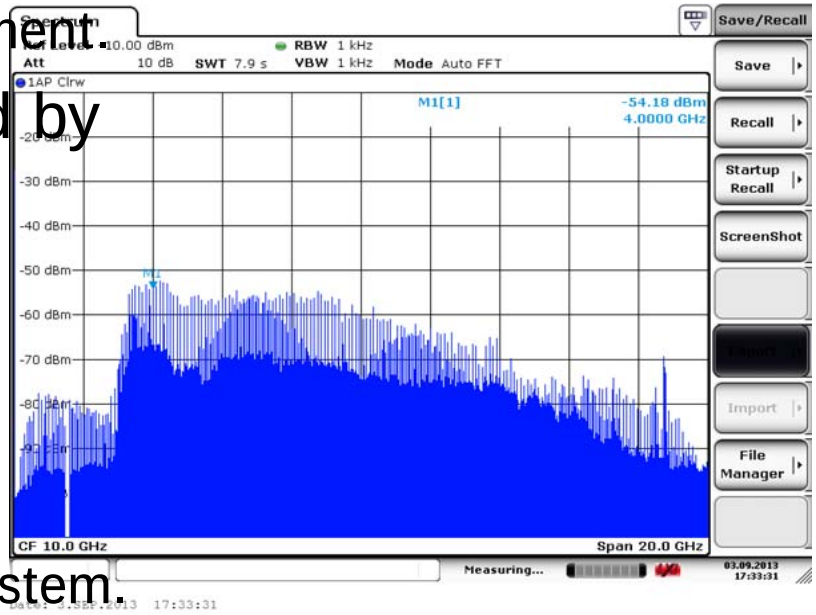
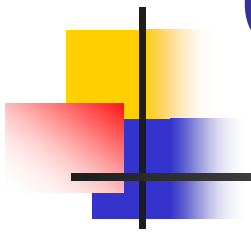
Phase Cal. Signal

- Important for bandwidth Synthesis
  - Key for the precise delay measurement.
- Using digital Phase cal. designed by Haystack
  - Input reference Frequency: 50MHz
    - Reduced number of Pcal tones. Good S/N ratio
    - Less compatible with legacy system.



Components of the System



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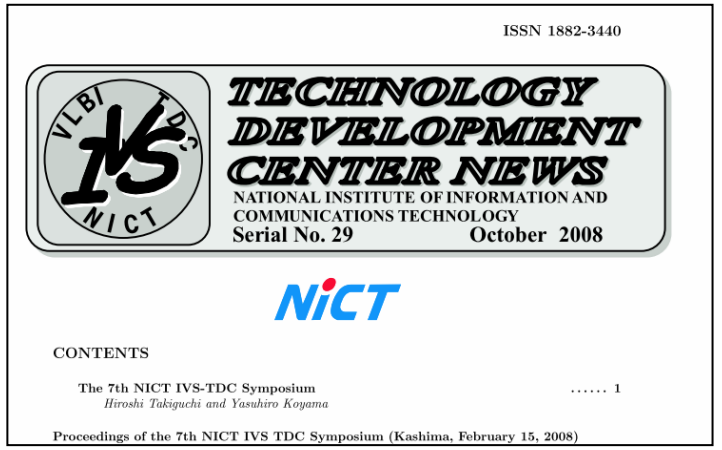
Correlation Processing: GICO3 Software Correlator

- GICO3:originally developed by M.Kimura(2003-2008)
  - 2Gbps processing performance with CPU Xeon X5355
  - 3-4 times better if core i7 CPU
- Data processing (1 Polarization)
  - 2Gbps x 4 = 8 Gbps / Station
  - 40TB/Stn X 3 stn= 120 TB
- Required Processing Speed
  - 100Gflops/1Gbps x 8 = 800Gflosps
  - 8- 16 PCs will deal with them.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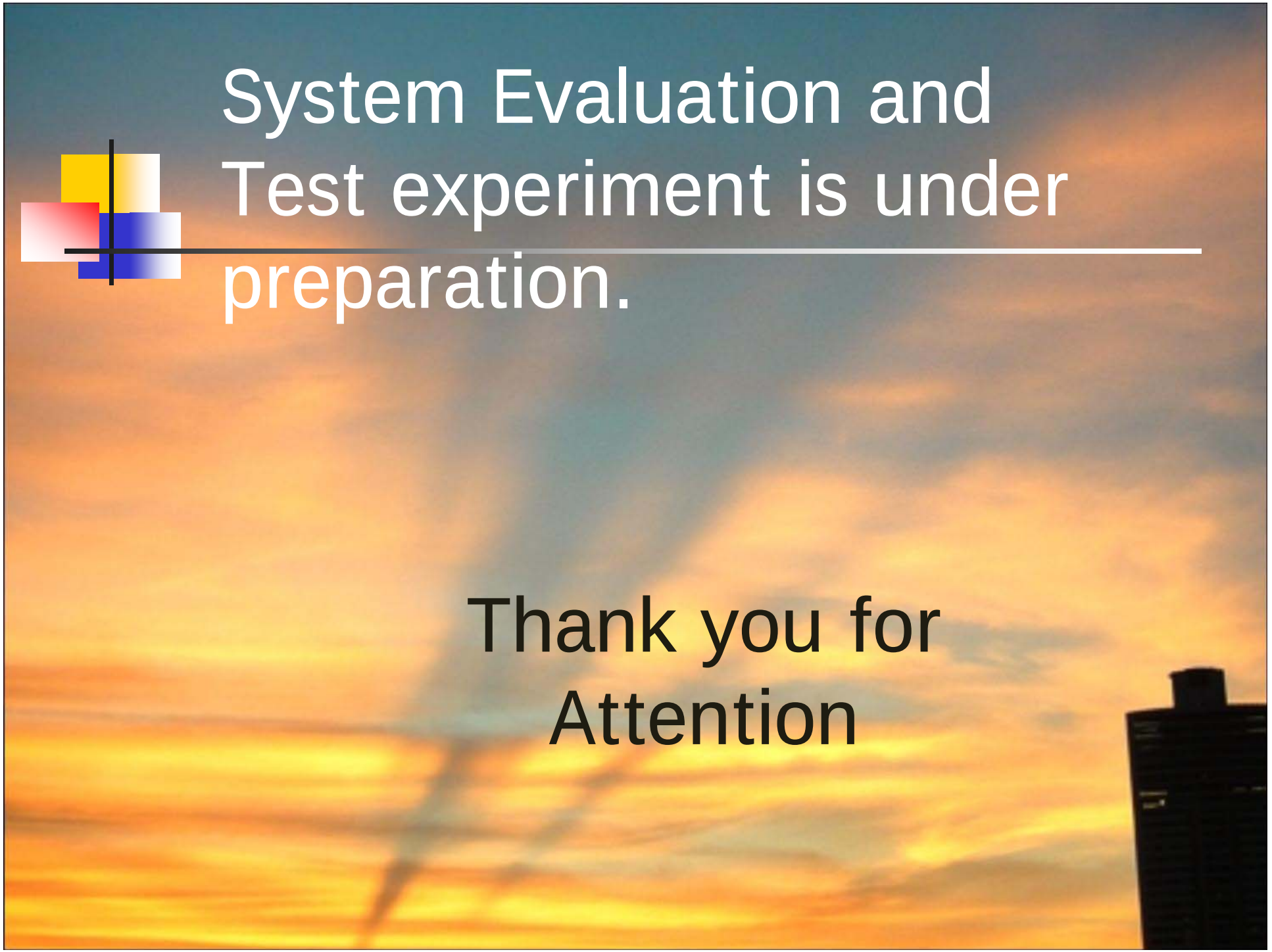
The 7th NICT IVS-TDC Symposium 1

Hiroshi Takiguchi and Yasuhiro Koyama

Proceedings of the 7th NICT IVS TDC Symposium (Kashima, February 15, 2008)


System Evaluation and Test experiment is under preparation.
Thank you for Attention