

Rapid turn around EOP measurements by VLBI over the Internet



Yasuhiro Koyama, Tetsuro Kondo, and Hiro Osaki
Kashima Space Research Center
Communications Research Laboratory

Outline

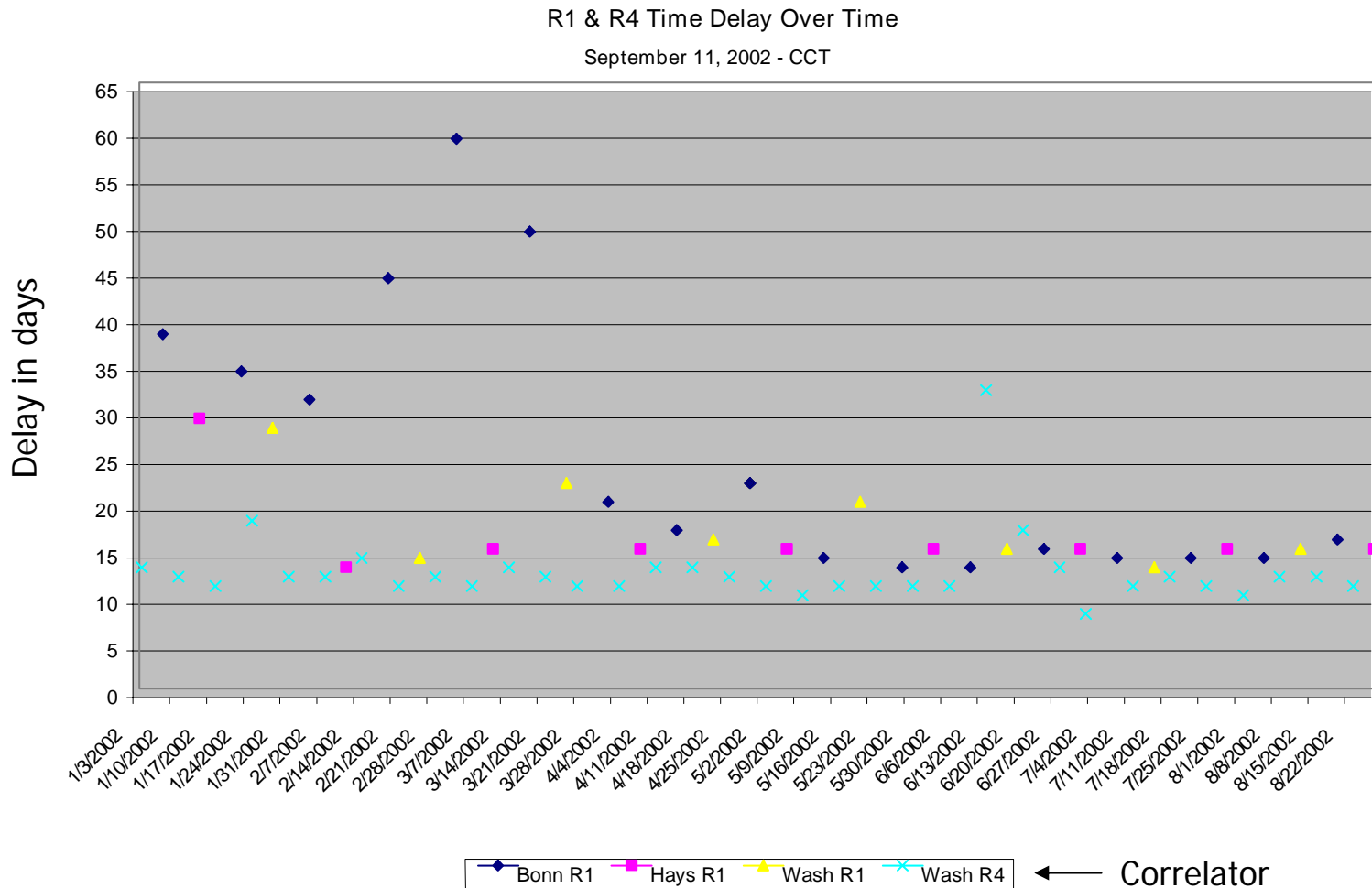
- What is e-VLBI and Why?
- How?
 - K5 VLBI System
 - Network
- Experiments
 - Jan.31-Feb.1, 2003 Kashima(11m)-Koganei
 - Mar.25, 2003 Kashima(34m)-Westford
 - Jun.27, 2003 Kashima(34m)-Westford
- Future Plan
- Conclusions

What is e-VLBI and Why?

- e-VLBI is : Real-time or near-real-time VLBI data processing using high speed network
- Currently it takes more than 2 weeks to process typical global sessions or 1 week for UT1 intensive sessions
- If we can reduce this delay, it will improve accuracy of
 - rapid EOP predictions
 - real-time positioning
 - real-time orbit determination of satellites and spacecrafts
- It potentially expands correlation/observation capacity
 - Currently ~8 stations with hardware correlators
 - Easy scalability with PC/distributed software correlator
 - No Recording Speed Limit with real-time correlation

Why e-VLBI?

To improve timeliness of global VLBI data processing



VLBI Systems for e-VLBI



K3 Correlator (Center)
K3 Recorder (Right)

K3 System

1983~
Longitudinal Recorder
Open Reel Tapes
Hardware Correlator



K4 Terminal

K4 (KSP) System

1990~
Rotary Head Recorder
Cassette Tapes
Hardware Correlator
e-VLBI with ATM



K4 Correlator

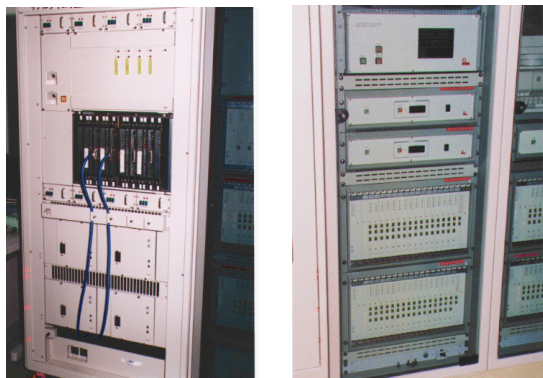


K5 Data Acquisition Terminal

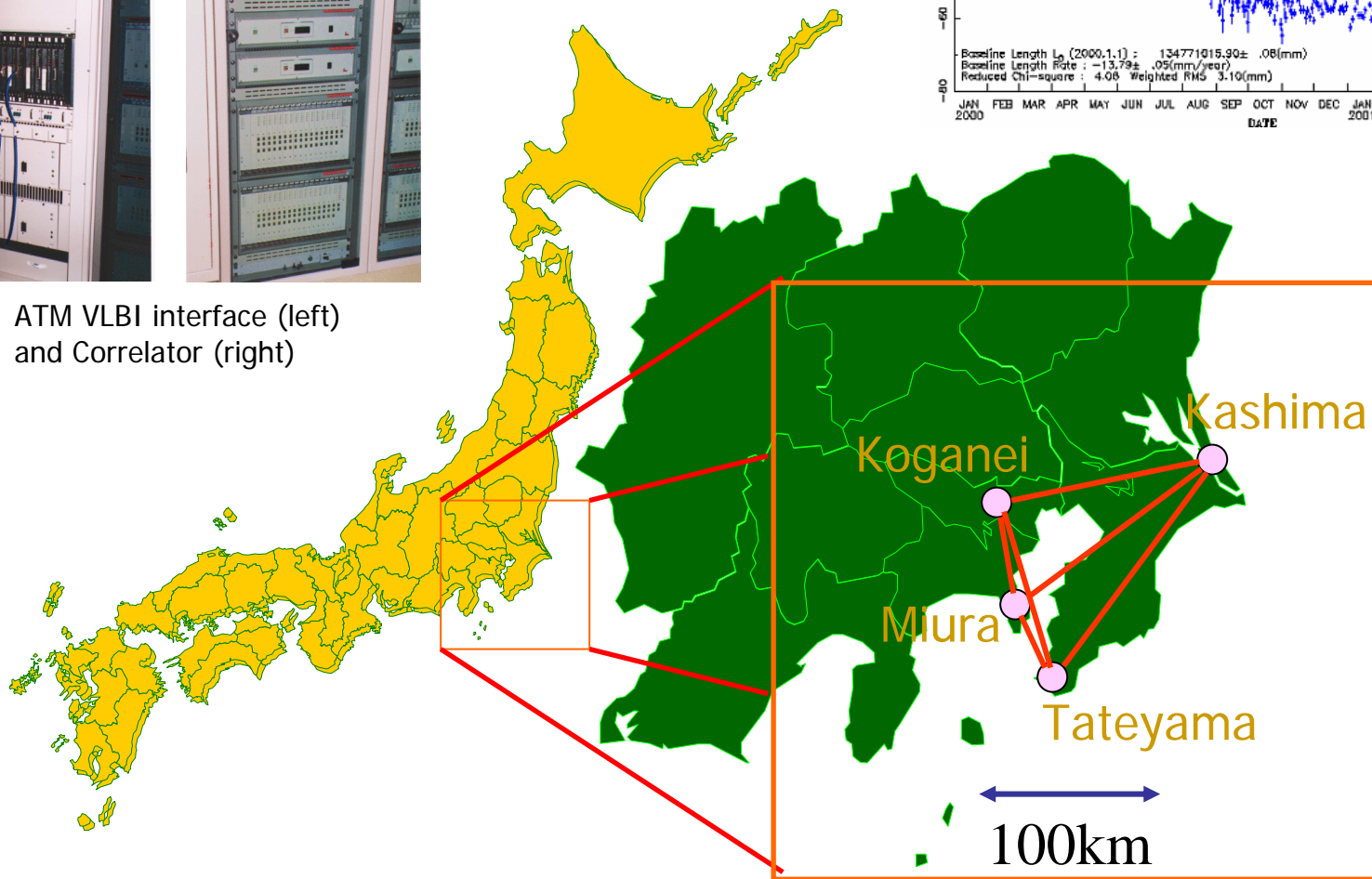
K5 System

2002~
PC based system
Hard Disks
Software Correlator
e-VLBI with IP

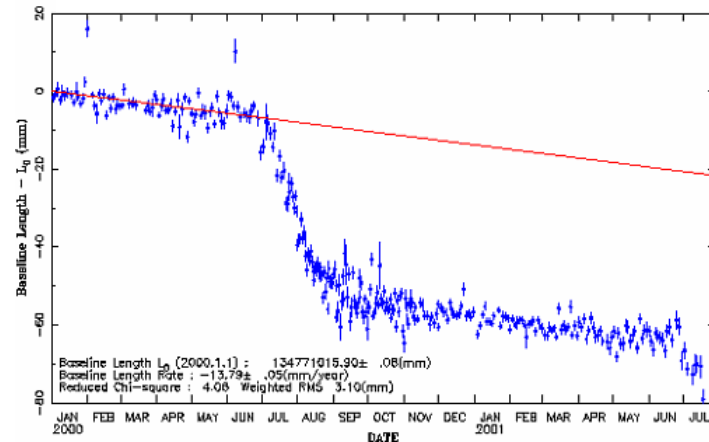
e-VLBI with ATM Network (1998~2001)



ATM VLBI interface (left)
and Correlator (right)



Distance between Kashima and Tateyama

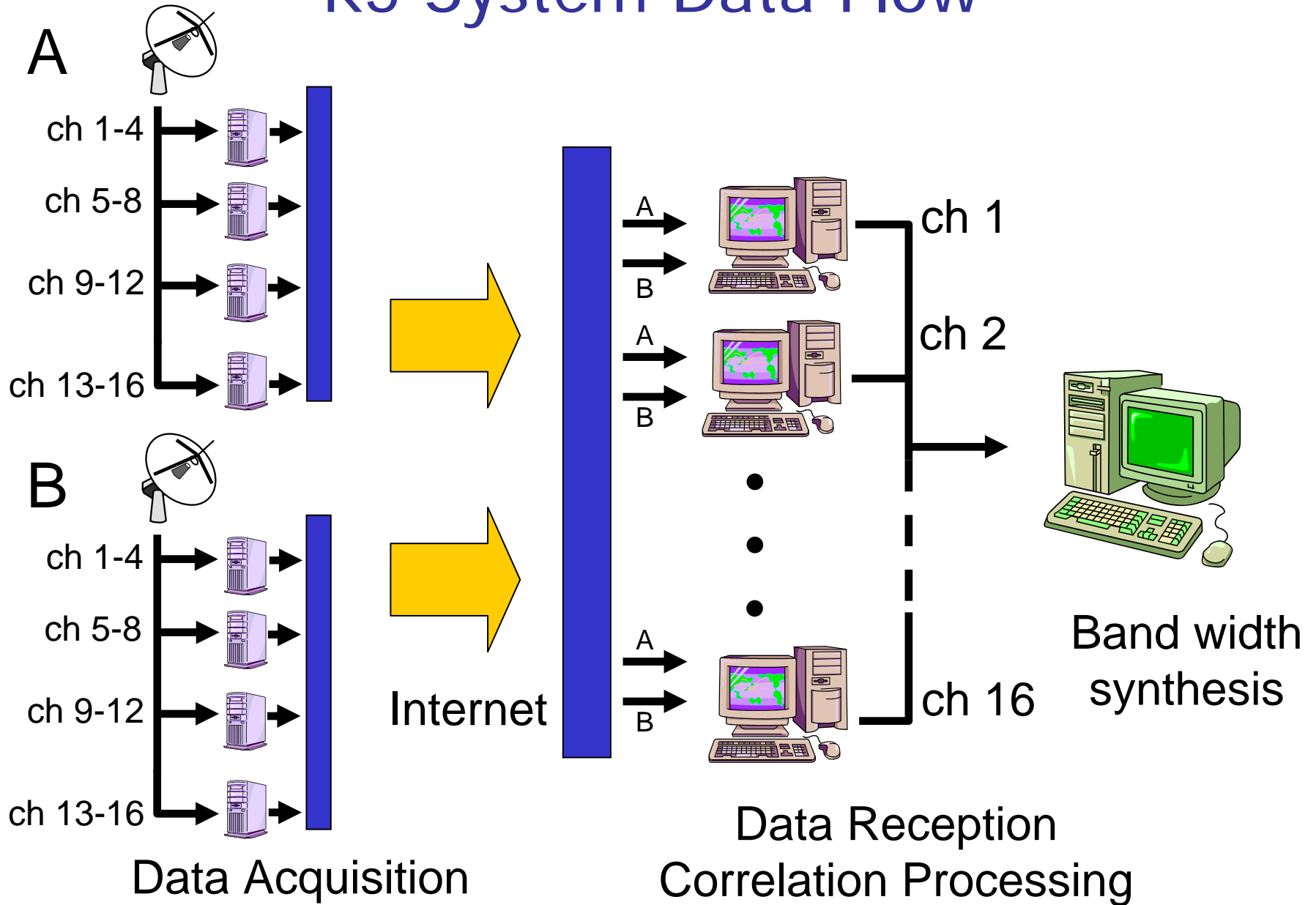


K5 Data Acquisition System for e-VLBI with IP

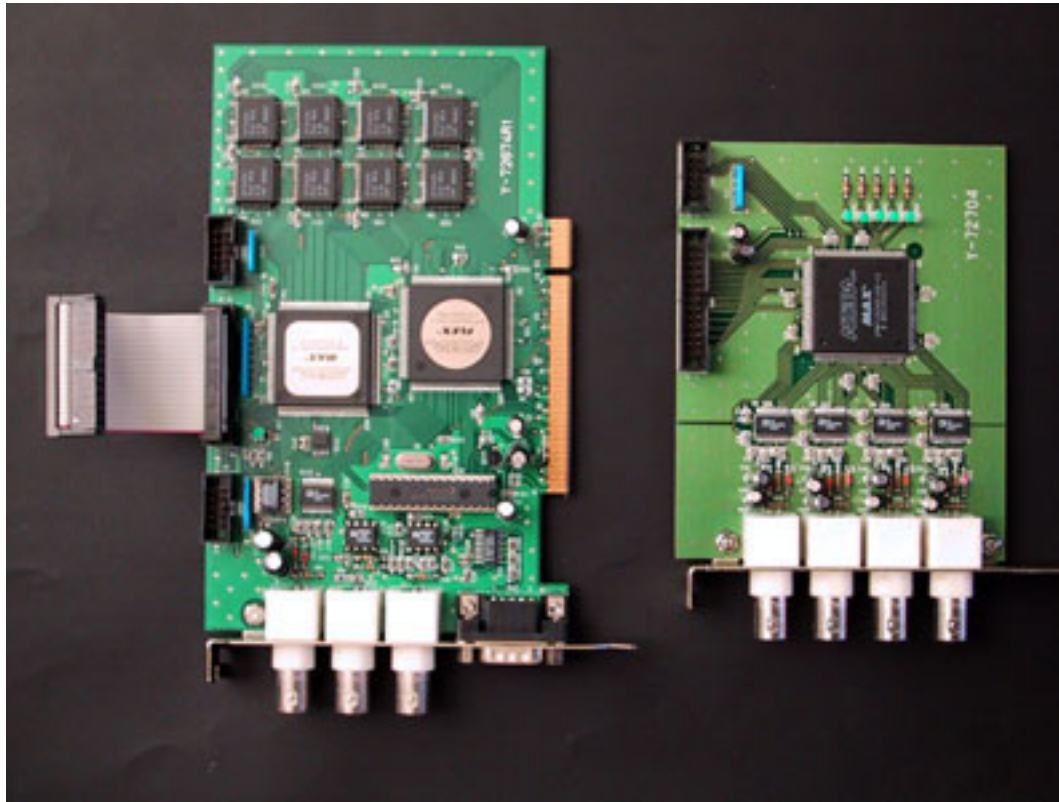
- 4 Pentium PCs
 - CPU : Pentium-4
 - 1.2GHz (1st Unit)
 - 2.4GHz (2nd Unit)
 - OS : FreeBSD (Linux is also possible)
 - An IP-VLBI board (PCI) in each PC
 - 120Gbyte HDx4x4 ~ 2.8days@64Mbps
- 16ch base-band signal amplifier
- Standard Signal Distributor
 - 10MHz and 1PPS signals for 4 units



K5 System Data Flow



PCI Data Sampling Board (IP-VLBI Board)

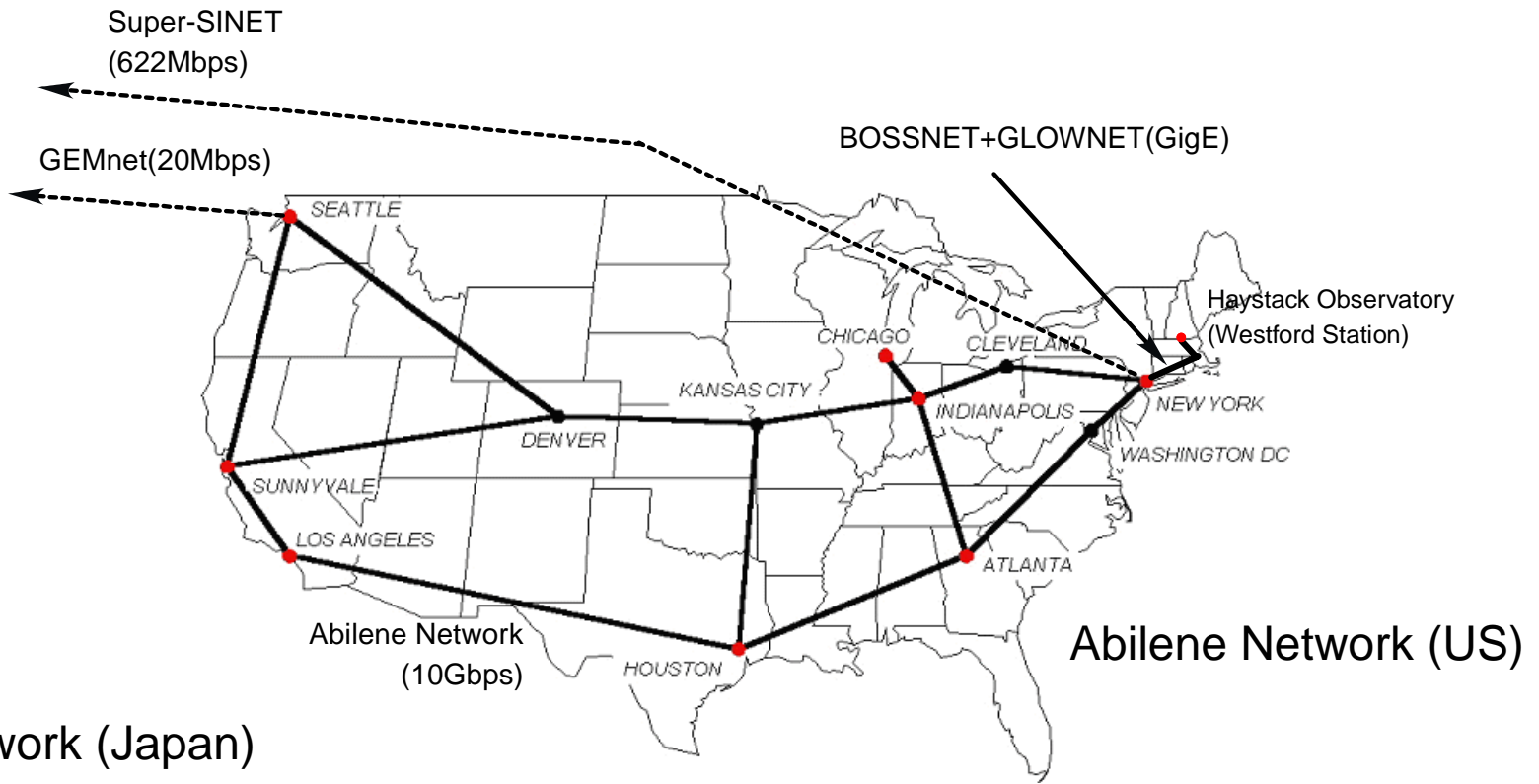


Left : Main board

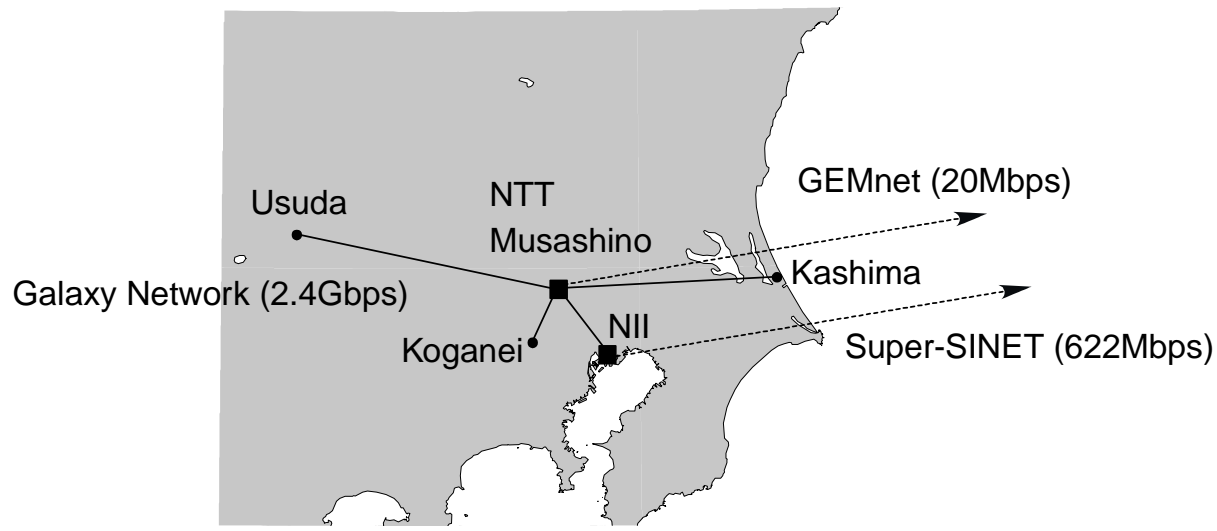
Right : Auxiliary board

Specifications of the board

Reference signals	10MHz +10dBm, 1PPS
# of INPUT CH	1 - 4ch
A/D	1, 2, 4, 8 bits
Sampling Freq.	40kHz, 100kHz, 200kHz, 500kHz, 1MHz, 2MHz, 4MHz, 8MHz, 16MHz
BUS Interface	PCI
OS	Linux, FreeBSD, Win2000



Galaxy Network (Japan)



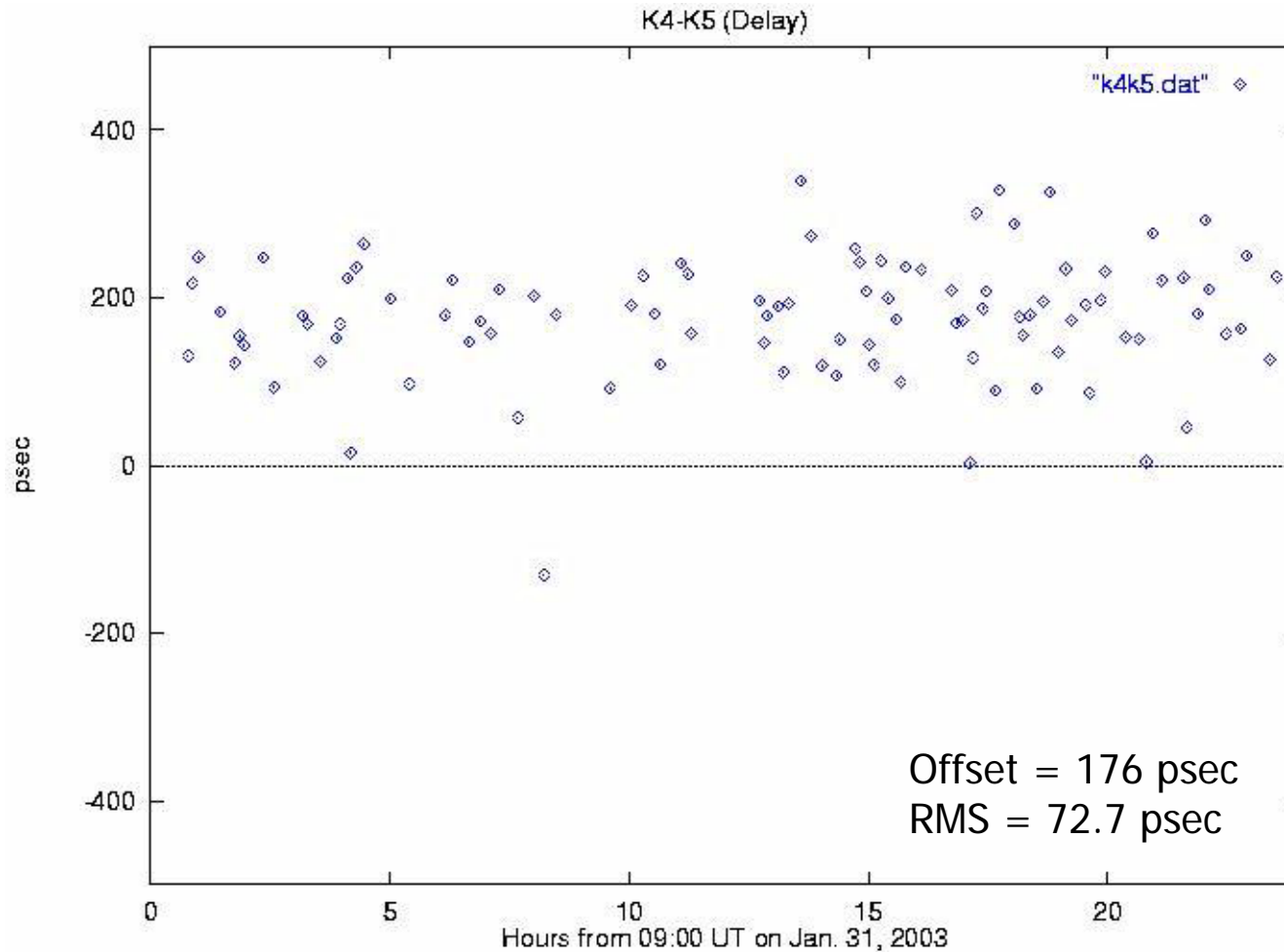
Network

Experiments 1

- Jan.31-Feb.1, 2003
 - Kashima11m(K5)-Koganei11m(K5)
 - 24 hours, 56Mbps
 - Comparison with K4

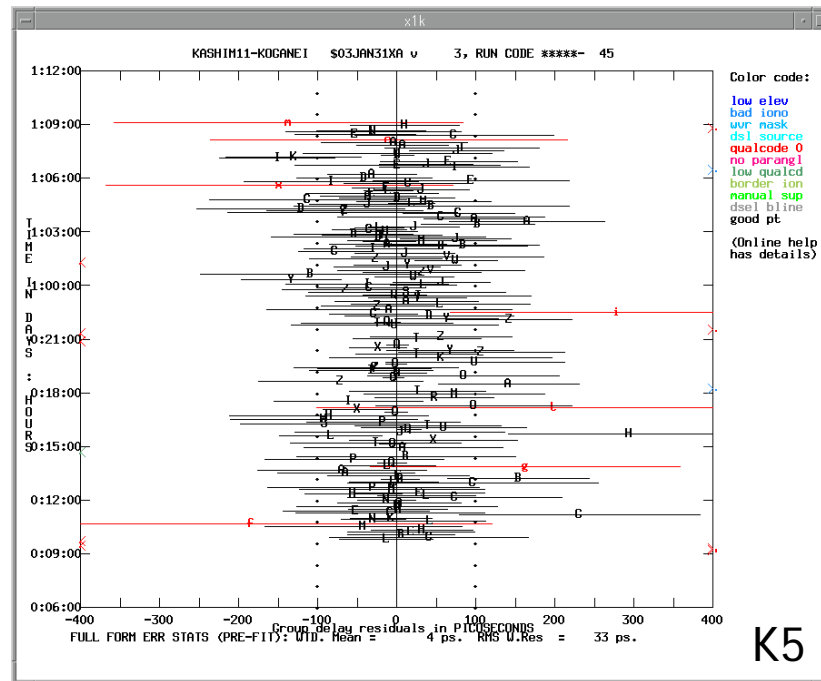
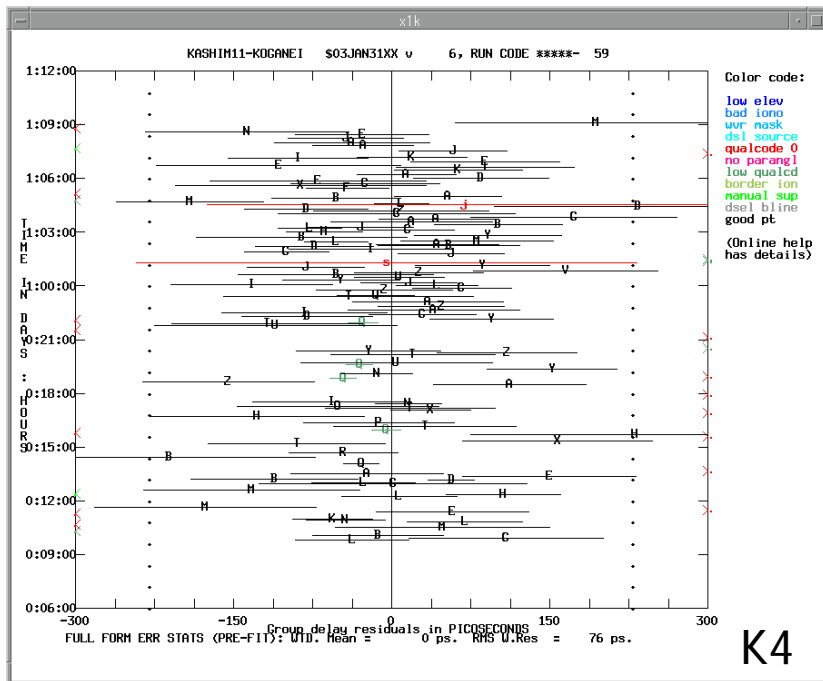


K4-K5 comparison



K4-K5 comparison

Delay Residual



Data Analysis Results

	Baseline Length	Delay RMS	Delay Rate RMS
K4	109099657.0 ± 6.7mm	76 psec	136 fsec/sec
K5	109099641.2 ± 3.2mm	33 psec	92 fsec/sec

Experiments 2

- Mar. 25, 2003 (evlbi4)
 - Westford (Mk5)-Kashima34m(K5), 2 hours, 56Mbps
 - Fringes were found on Mar. 27!



	Source Name	Duration (sec)	File Size (Mark5)	File Size (K5)
1	4C39.25	90	1,620 Mbytes	180 Mbytes x 4
2	1736+455	200	3,600	400 x 4
3	1357+769	90	1,620	180 x 4
4	0059+581	250	4,500	500 x 4
5	2234+282	310	5,580	620 x 4
6	1300+580	140	2,520	280 x 4
7	0955+476	90	1,620	180 x 4
8	2113+293	300	5,400	600 x 4
9	1739+522	500	9,000	1,000 x 4
10	1357+769	90	1,620	180 x 4
11	0059+581	270	4,860	540 x 4
12	2234+282	510	9,180	1,020 x 4
13	1044+719	784	1,4112	1,568 x 4
14	1128+385	180	3,240	360 x 4
15	1300+580	130	2,340	260 x 4
16	0955+476	90	1,620	180 x 4
17	2113+293	390	7,020	780 x 4
18	1739+522	530	9,540	1,060 x 4
19	1357+769	90	1,620	180 x 4
Total		5,034	90,612 Mbytes	40,272 Mbytes

File Transfer ~ 20 hours

Delay = 234 msec

Buffer Size = 64 kbytes

Speed

= 2.2 Mbps / Connection

= 11 Mbps (5 connections)

Correlation ~ 20 hours with 4 PCs

Bandwidth Synthesis ~ 10 min.

Data Analysis ~ 1 hour

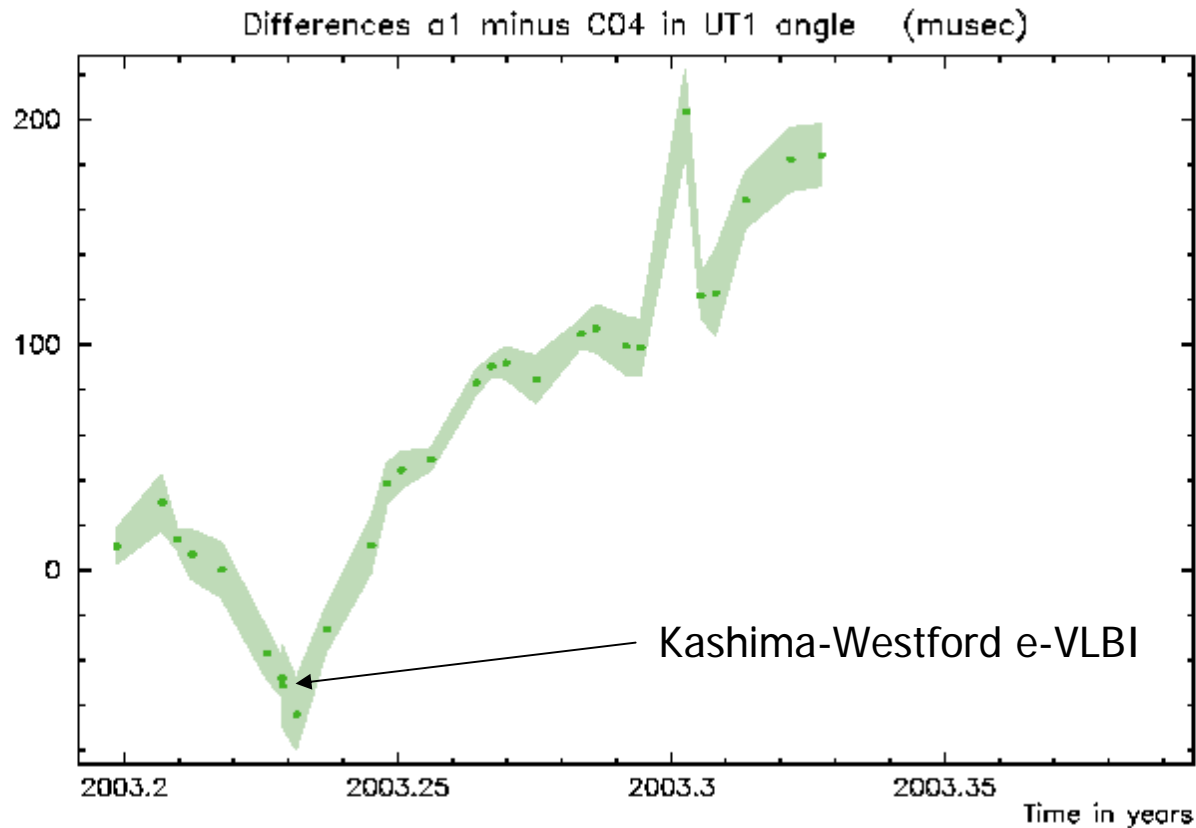
UT1-TAI

= -32338.7280 +/- 23.90

(micro sec)

Experiments 2

UT1-UTC estimation compared with NEOS Intensive VLBI sessions



* Data analysis done by Goddard Space Flight Center, NASA

Experiments 3

- Jun. 25, 2003 (evlbi4)
 - Westford (Mk5)-Kashima34m(K5), 2 hours, 56Mbps
 - UT1-UTC estimation 21 hours after the observations!



Experiments 3

■ Time Sequence (JST)

- 22:00 Observations Start
- 00:00 Observations End
- ~04:20 File extraction and transmission
 - From Kashima to Westford : 107Mbps 41.54GByte in 51m 35s
 - From Westford to Kashima : 44.6Mbps 41.54GByte in 2hr 04m 02s
- ~08:10 File Conversion (Mark5 to K5)
- ~20:30 Software Correlation
- ~21:20 Bandwidth Synthesis Processing, Database Generation, Data Analysis

* Correlation at Haystack Observatory (Mark4 Correlator) finished at 14:19 JST

Future Plan

- Repeat e-VLBI (ftp) with Kashima-Westford
 - Further tuning of the file transfer speed
 - Try 256 Mbps observations
- Start to develop Correlator CPU Array System
- Software developments for real-time data transfer
- Regular Mk5-K5 intensive e-VLBI using international baselines (ex. Tsukuba-Westford)

Conclusions

- Rapid turn-around estimation of UT1-UTC less than one day was successfully demonstrated
- K5 VLBI system showed comparable or better results compared with tape based K4 system
- Full compatibilities between K5 and Mark5 systems have been achieved

Acknowledgements

- Internet2, Super-SINET
- Galaxy Network team (CRL, NTT, NAO, and ISAS)
- Haystack Observatory, MIT
- Goddard Space Flight Center, NASA