Results of test e-VLBI experiments with the K5 VLBI system

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Outline

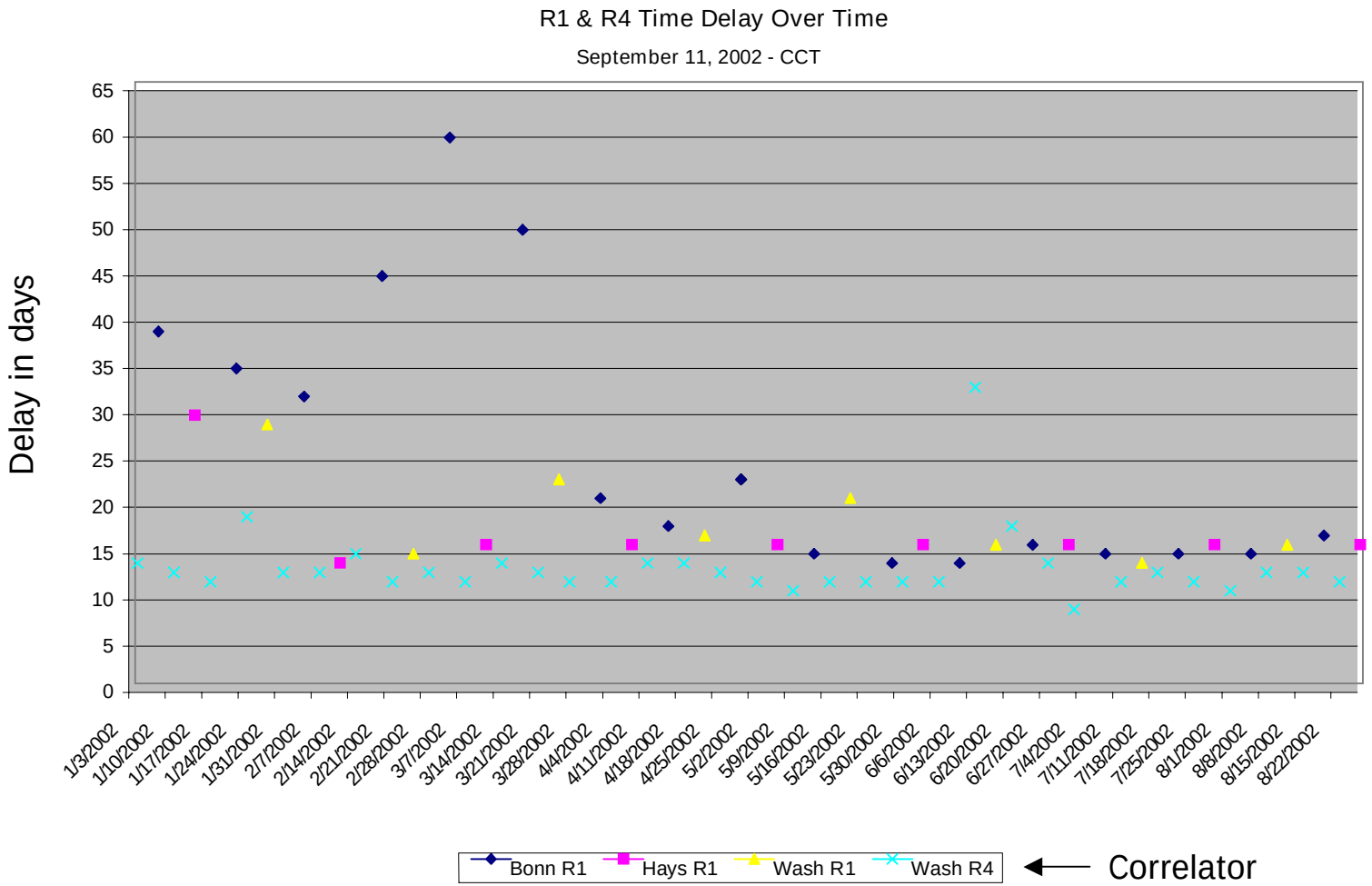
- Why e-VLBI?
- What is K5?
- Network
- Test Experiments
  - Jan.31-Feb.1, 2003 Kashima-Koganei
  - Feb.25, 2003 Kashima-Westerbork
  - Mar.25, 2003 Kashima-Westford
- Future Plan

Why e-VLBI?

- Currently it takes at least 2 weeks to process global geodetic VLBI sessions (mainly shipping time)
- If it become 2 hours, it will improve accuracy of
  - Earth Orientation Parameters at present
  - real-time orbit determination of satellites and spacecrafts
  - positioning
  - navigation
- It potentially expands correlation/observation capacity
  - Currently ~8 stations with hardware correlator
  - 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



What is K5?


K3 Correlator (Center)
K3 Recorder (Right)


KSP Backend


KSP Correlator


K5 Data Acquisition Terminal

K3 System

1983~
Longitudinal Recorder
Open Reel Tapes
Hardware Correlator

K4 System

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

KSP, VSOP,
Gigabit, VERA

K5 System

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

K5 Family : Concept

ADS1000
(1024Msample/sec 1ch 1bit or 2bits)

ADS2000
(64Msample/ch·sec, 16ch, 1bit or 2bits)

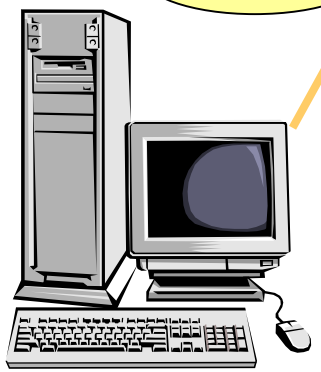
VSI

IP-VLBI Board
(~16Msample/ch·sec, ~4ch, ~8bits)

Correlator
other DAS

Internet

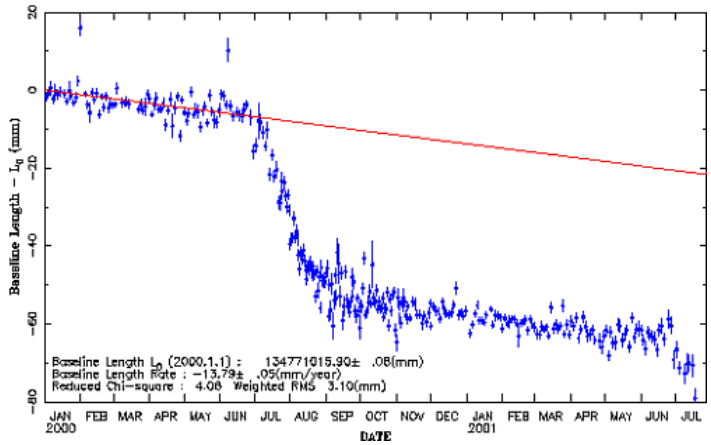
VSI

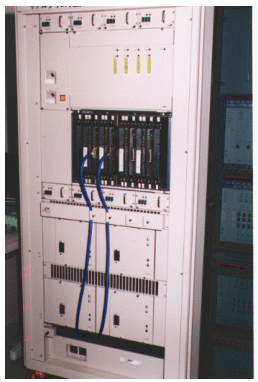


PC : Data Acquisition
Correlation

e-VLBI with K4
ATM Network (1998~2001)

Distance between Kashima and Tateyama



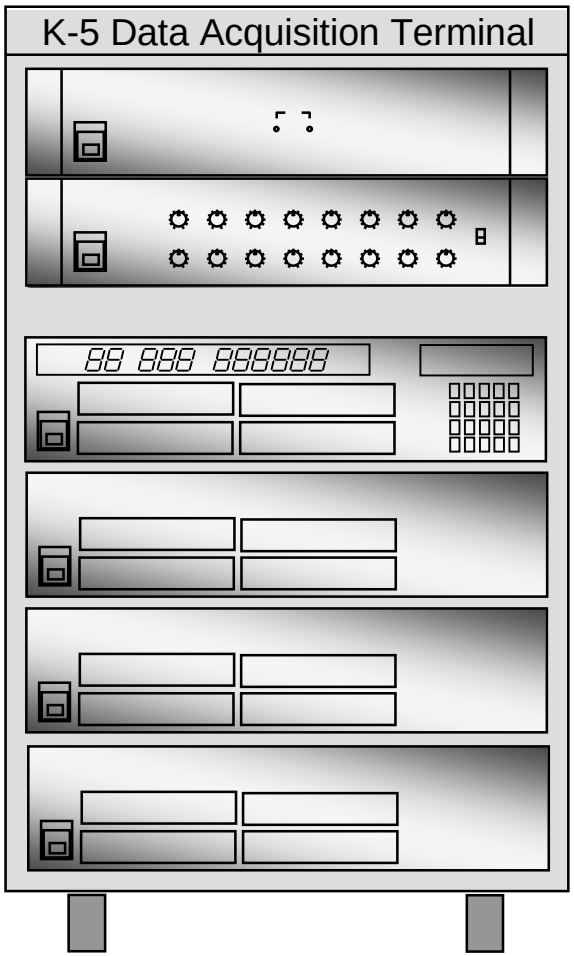


ATM VLBI interface (left)
and Correlator (right)

K5 Data Acquisition System for e-VLBI with IP

- 4 Pentium PCs
  - CPU : Pentium-4
    - 1.2GHz (1st Unit) or 2.4GHz (~2nd Unit)
  - OS : FreeBSD (Linux is also possible)
  - An IP-VLBI board (PCI) in each PC
  - 120Gbyte HDx4x4 ~ 2.8days@64Mbps
- 3 complete units
  - 2 at Kashima and 1 at Tsukuba
- 4 additional units planned
  - Syowa10, Aira10, Chichi10, Shintotu3
- Several experimental units
  - Koganei11, Gifu11, Usuda64, Yamaguchi32, Tomakomai11, Algonquin, Mizusawa20

K5 PC-based Data Acquisition Terminal

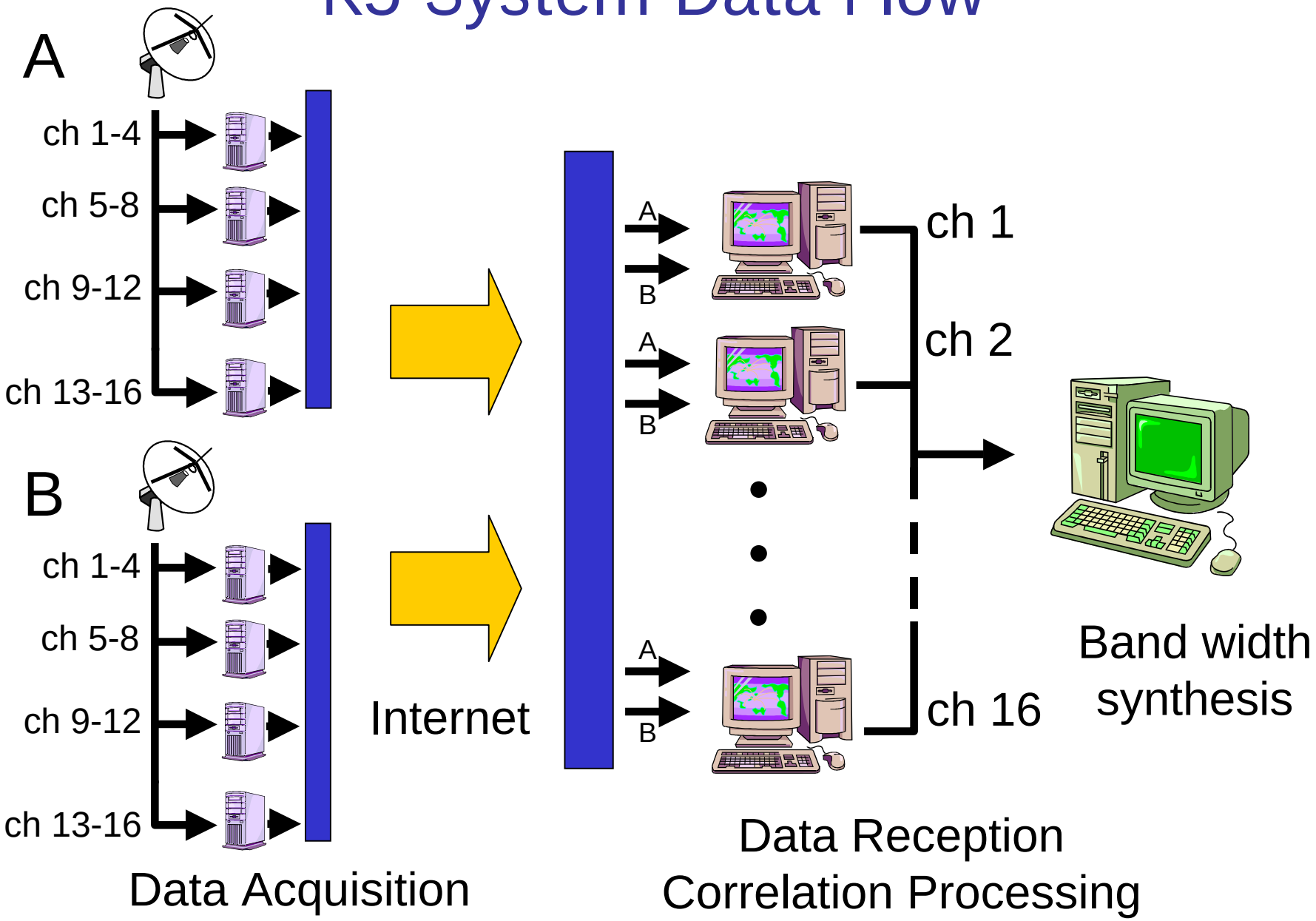


7625A (Reference signal distributor)

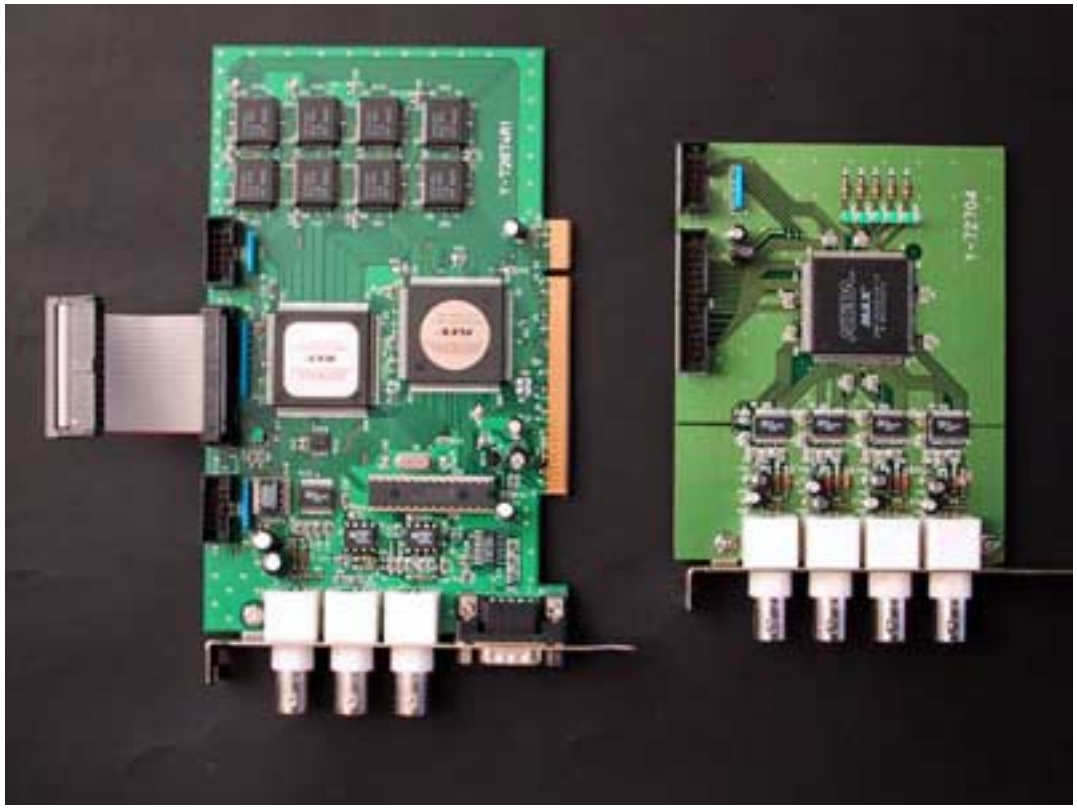
7626 (16ch video amps)

Rack mount PC with
an IP-VLBI board (9260)
and 4 removable HDD x 4

K5 System Data Flow



PCI Data Sampling Board (IP-VLBI Board)



Left : Main board
Right : Auxiliary board

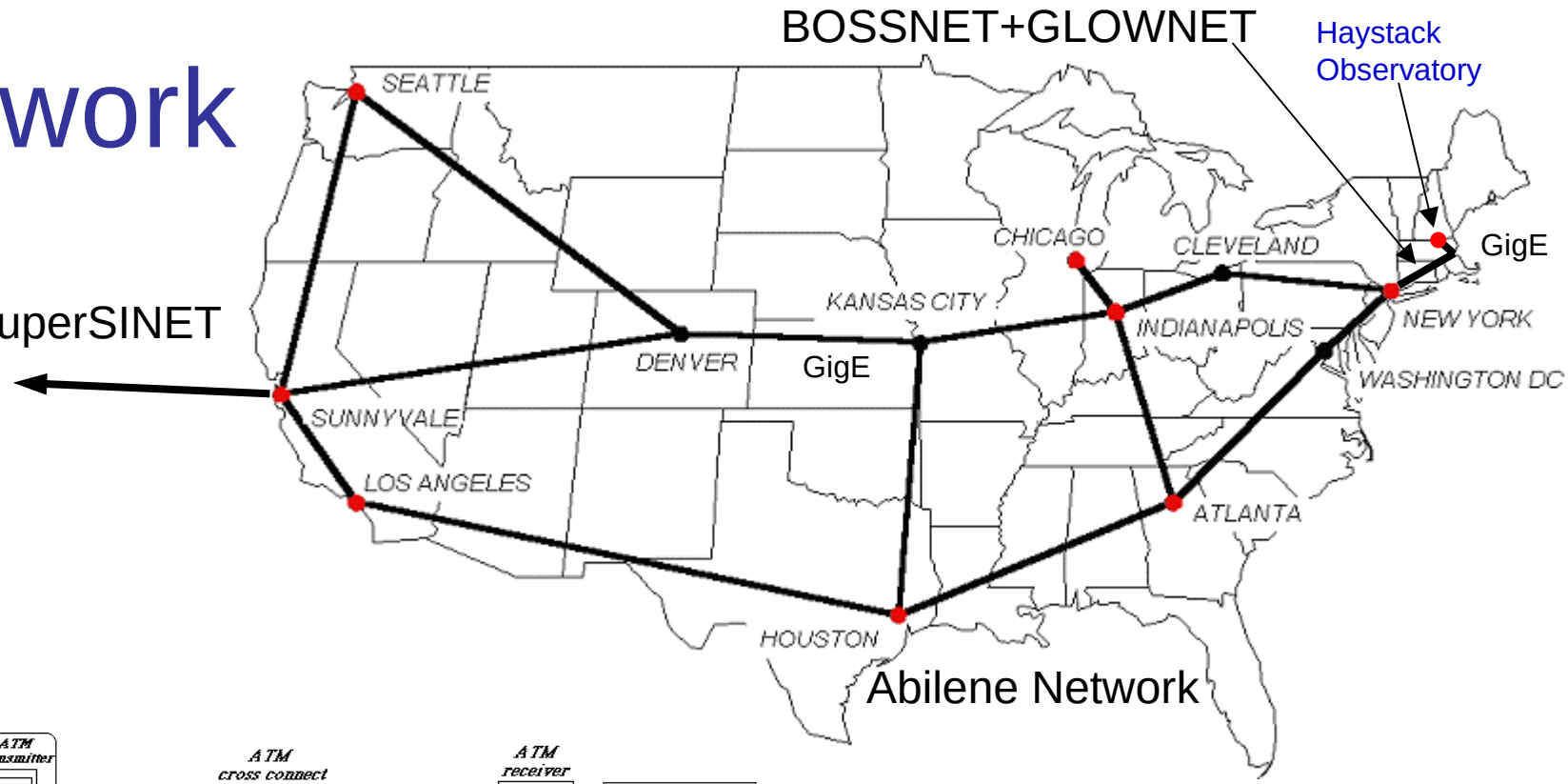
Specifications of the board

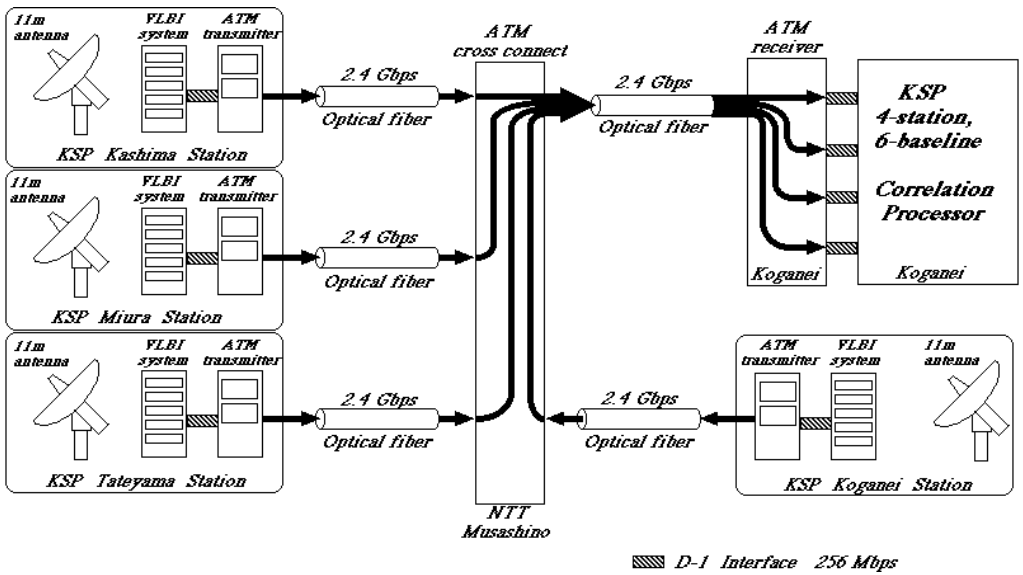
Reference signals	10MHz +10dBm, 1PPS
# of INPUT CH	1 - 4ch
A/D	1, 2, 4, 8 bits
Sampling Freq.	40kHz, 100kHz, 200kHz, 500kHz, 1MHz, 2MHz, 4MHz, 8MHz, 16MHz

Characteristics of K5 Terminal

Item	Characteristic
Reference signals	10MHz (5MHz), 1PPS
Number of input channels	16
Low pass filter	4MHz / 8MHz
Sampling frequency	40kHz, 100kHz, 200kHz, 500kHz 1MHz, 2MHz, 4MHz, 8MHz, 16MHz
A/D resolution (bit)	1, 2, 4, 8
Hard disk drives	120GB (minimum)/ch total > 1.92TB
Maximum sampled data rate	256Mbps (512Mbps)
Real-time VLBI	supported
Typical operation modes	16ch x 4Mbps 16ch x 8Mbps 16ch x 16Mbps
VSI in/out	in : ready, out : under development

Network



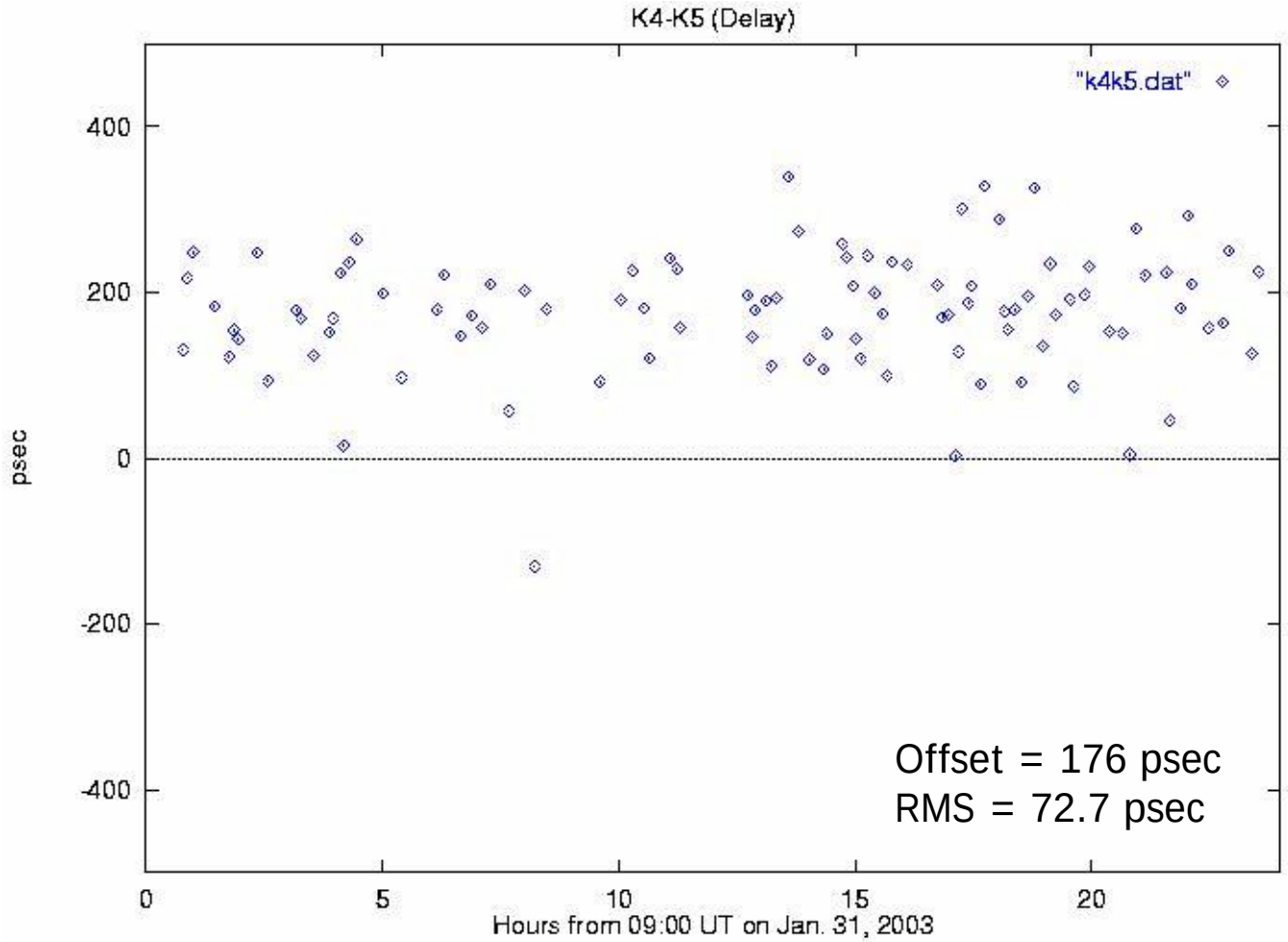


Galaxy Network

Test Experiments 1

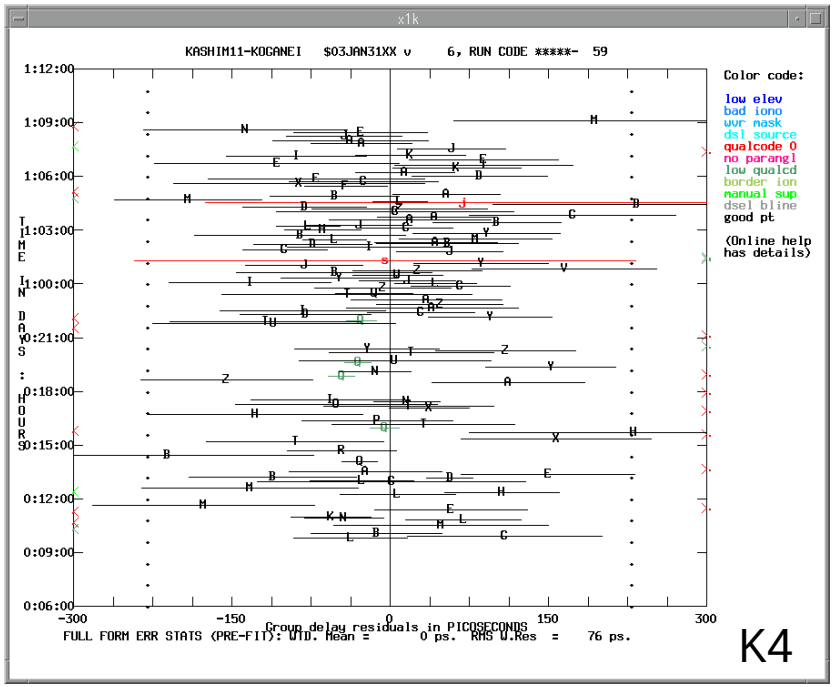
- Jan.31-Feb.1, 2003
  - Kashima11m(K5)-Koganei11m(K5)
  - 24 hours, 56Mbps
  - Comparison with K4

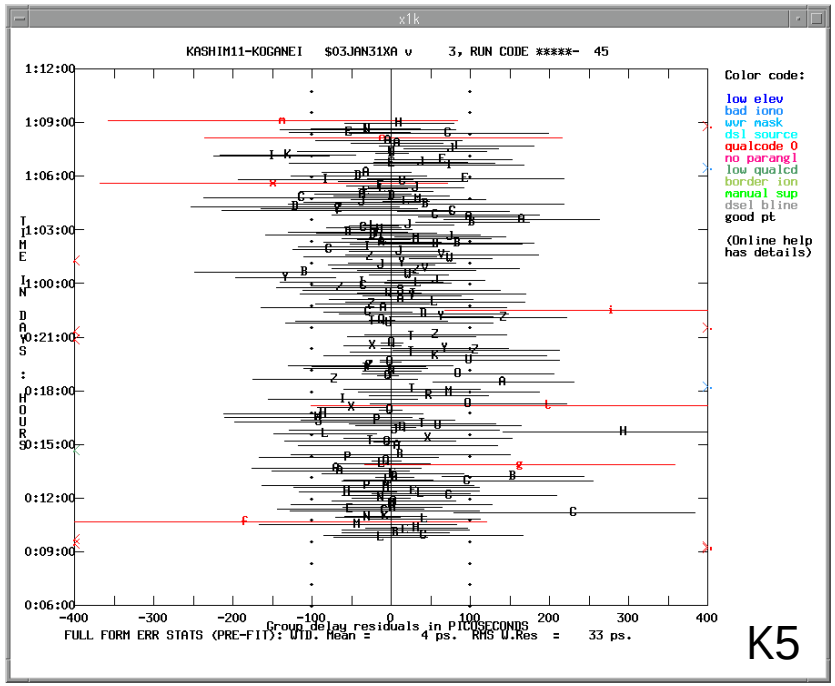
K4-K5 comparison



K4-K5 comparison

Delay Residual



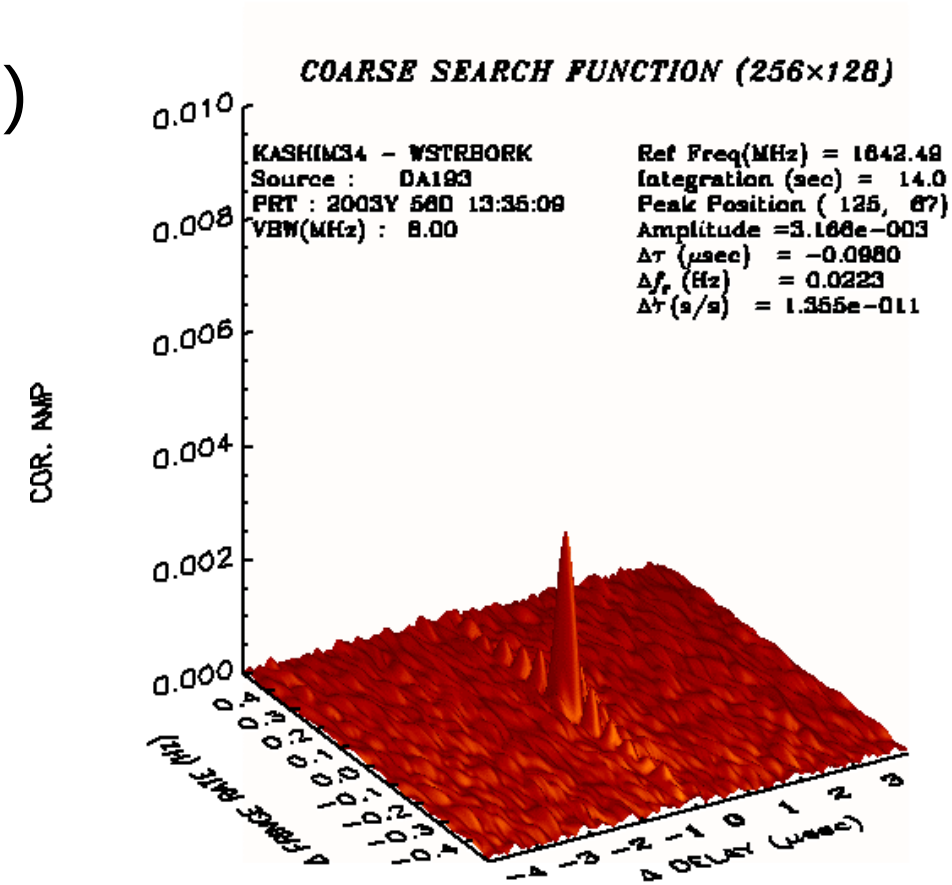


Data Analysis Results

	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

Test Experiments 2

- Feb. 25, 2003 (n031l)
  - Westerbork (Mk5)
    -Kashima34m(K5)
  - 3 scans
  - 16MHz bandwidth
    x 2 ch.
  - 32MHz sampling
  - 2 bits/sample
  - Total 128 Mbps



Test Experiments 3

- 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 1 PC

Bandwidth Synthesis ~ 10 min.

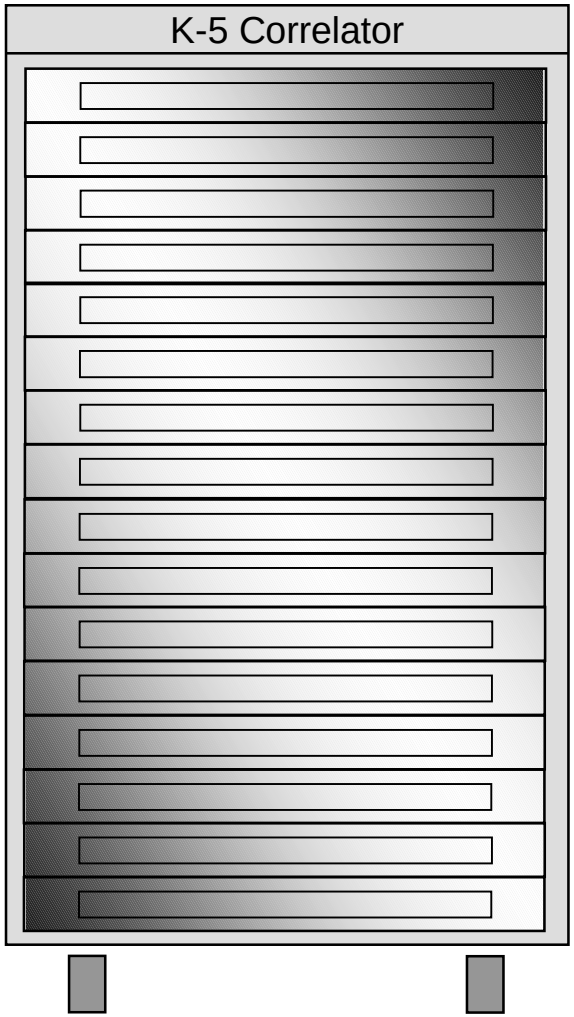
Data Analysis ~ 1 hour

UT1-TAI (at 20:00 UT)
= -32338728.0 +/- 23.90
(micro sec)

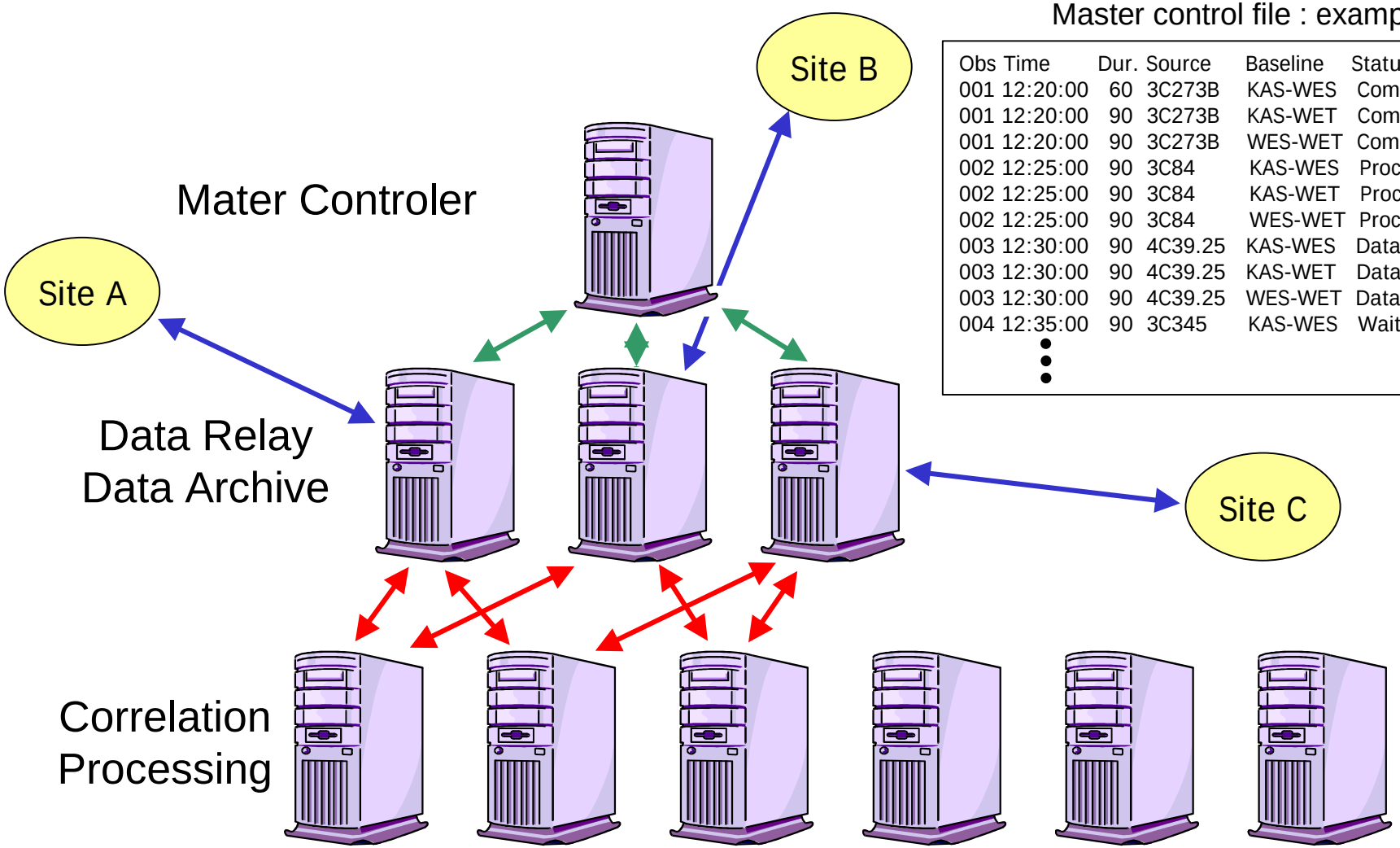
cf. UT1R-TAI (at 00:00 UT)
= -32337951 micro sec. (Mar. 25)
= -32338610 micro sec. (Mar. 26)
(IERS Bulletin B 183, 2 May, 2003)

Future Plan : Correlator

- Array of multiple PCs
  - Distributed Processing
  - Scalable
  - Upgradeable
  - Replaceable



Future Plan : Correlator



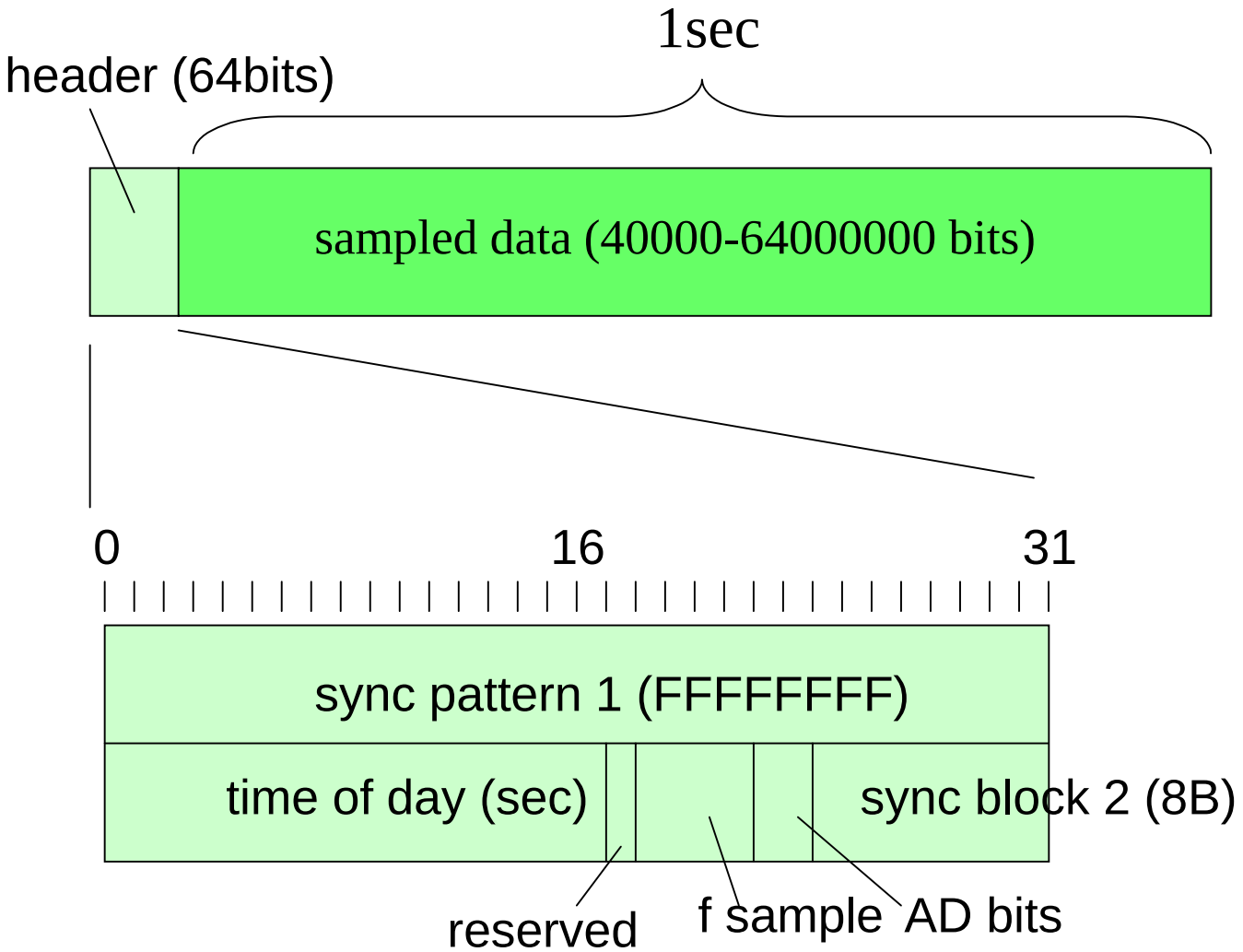
Master control file : example

Obs	Time	Dur.	Source	Baseline	Status
001	12:20:00	60	3C273B	KAS-WES	Completed
001	12:20:00	90	3C273B	KAS-WET	Completed
001	12:20:00	90	3C273B	WES-WET	Completed
002	12:25:00	90	3C84	KAS-WES	Proc. at 01
002	12:25:00	90	3C84	KAS-WET	Proc. at 02
002	12:25:00	90	3C84	WES-WET	Proc. at 03
003	12:30:00	90	4C39.25	KAS-WES	Data Ready
003	12:30:00	90	4C39.25	KAS-WET	Data Ready
003	12:30:00	90	4C39.25	WES-WET	Data Ready
004	12:35:00	90	3C345	KAS-WES	Waiting Data

One example of many possible configurations

Considerations for Data Format

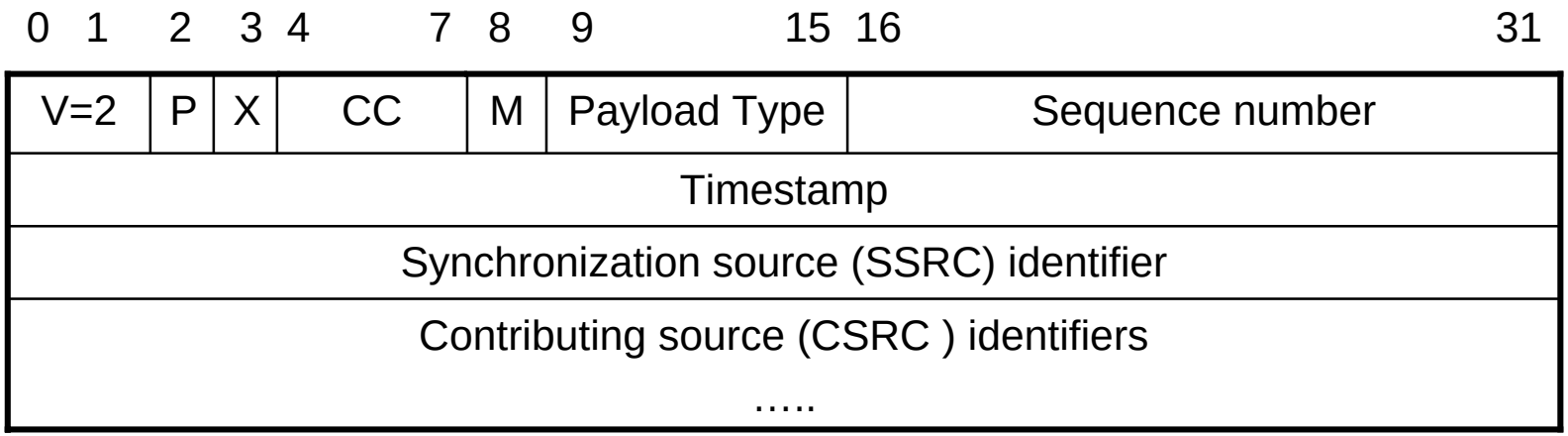
Current K5 Data Format



Considerations for Data Format

- Use RTP for Framework
- Define Payload Formats for e-VLBI

RTP Header



V : Version : Current Version is 2
P : Padding : Packet contains one or more additional padding octets at the end if this bit is set
X : Extension : Fixed header is followed by exactly one header extension if this bit is set
CC : CSRC count : Number of CSRC identifiers that follow the fixed header
M : Marker : intended to allow significant events to be marked in the packet stream

Considerations for Data Format

- Advantages of using RTP
  - designed for high speed data streams which do not require high QoS.
  - definition of payload format for individual application is allowed.
  - can expect to use existing routers and gateways.
  - the same payload format can be used for e-VLBI and conventional VLBI.
    - ➔e-VLBI specific features (sync word, sequence number, etc.) can be transferred in RTP header fields.

Future Plan

- Repeat ftp-VLBI with Kashima-Westford a few times
  - Speed up by expanding buffer size
  - Try 256 Mbps observations
- Develop Correlator CPU Array System in 2003
- Software developments for real-time data transfer in 2003
- Regular (weekly) Mk5-K5 e-VLBI
  - using Tsukuba-Westford baseline for example

Acknowledgements

- Internet2
- SuperSINET
- Galaxy team (CRL, NTT, NAO, and ISAS)
- Haystack Observatory, MIT