Current Progress Report on New Daejeon Correlator

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Target Array : EAVN

- For KVN, KVN+VERA/JVN, and EAVN.
- And also for the Space-VLBI based on EAVN.

Antenna(s) in the Space
To establish the bigger, more powerful correlator and get the best performance in East Asian VLBI Network, we concluded that KASI & NAOJ join together to develop new Correlator.

MOU between KASI & NAOJ (2005. 7. 7.)
- Development of Korea-Japan Joint VLBI Correlator,
- Common facility of correlation & data center

Joint Development Project was initiated respectively.
Japan : 5 years from April 2005
Korea : 5 years from Jan. 2006
## Specification (1) of KJJVC

**KASI + NAOJ ➔ 2006~2010**

<table>
<thead>
<tr>
<th>Items</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Antennas</td>
<td>16</td>
</tr>
<tr>
<td>Number of Inputs / Antenna</td>
<td>4</td>
</tr>
<tr>
<td>- Input Interface</td>
<td>- 2Gbps VSI-H (32 parallels, 64 MHz clk)</td>
</tr>
<tr>
<td>- Maximum Data Rates</td>
<td>- Total of 8,192 Mbps</td>
</tr>
<tr>
<td>Digitization for Each Inputs</td>
<td>- 2 bits/sample</td>
</tr>
<tr>
<td>- Number of Bits</td>
<td>- 4 levels</td>
</tr>
<tr>
<td>- Quantization Levels</td>
<td>- 1,024 Msamples/sec</td>
</tr>
<tr>
<td>- Sampling Rates</td>
<td>- 512 MHz</td>
</tr>
<tr>
<td>- Input Bandwidth</td>
<td>- Logically Associated Sub-streams</td>
</tr>
<tr>
<td>- Sub-stream Specification</td>
<td></td>
</tr>
<tr>
<td>Maximum Delay Compensation (Largest Baseline Length)</td>
<td>±36,000 km</td>
</tr>
<tr>
<td>Maximum Fringe Tracking (Fastest Phase Drift Cancellation)</td>
<td>1,075 kHz</td>
</tr>
<tr>
<td>Architecture</td>
<td>FX type, with FPGA and DSP chips</td>
</tr>
</tbody>
</table>
### Specification (2) of KJJVVC

<table>
<thead>
<tr>
<th>Items</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFT Processing</td>
<td></td>
</tr>
<tr>
<td>- Freq. Resolution</td>
<td>- 0.05km/sec @ 22GHz</td>
</tr>
<tr>
<td>- Size of FFT points</td>
<td>- 256k/128k/64k/32k/16k/8k Adjustable</td>
</tr>
<tr>
<td>- Word length in FFT</td>
<td>- 16+16 bits fixed point for real &amp; imaginary</td>
</tr>
<tr>
<td>- Scaling</td>
<td>- Yes</td>
</tr>
<tr>
<td>- Re-quantization</td>
<td>- 8+8 bits fixed point for real &amp; imaginary</td>
</tr>
<tr>
<td>△W Correction</td>
<td>Yes</td>
</tr>
<tr>
<td>Correlations</td>
<td></td>
</tr>
<tr>
<td>- Number of Correlation Outputs/Input</td>
<td>- Max. 120 Cross- and 16 Auto-correlations</td>
</tr>
<tr>
<td>- Total Number of Correlation Outputs</td>
<td>- Max. 480 Cross- and 64 Auto-correlations</td>
</tr>
<tr>
<td>- Polarization Mode</td>
<td>- RR or LL ; Full Operation for 16 antennas</td>
</tr>
<tr>
<td></td>
<td>- RR and LL ; Full Operation for 16 antennas</td>
</tr>
<tr>
<td></td>
<td>- RR, RL, LR and LL : Full Op. for 8 antennas</td>
</tr>
<tr>
<td>- Data compression(Binning)</td>
<td>- Yes, 8,192 channels / correlation output</td>
</tr>
<tr>
<td>- Word length</td>
<td>- 32+32 bits Fixed Point for R &amp; I</td>
</tr>
<tr>
<td>- min. max Integration Time</td>
<td>- 25.6msec ~ 10.24sec</td>
</tr>
<tr>
<td>Data Output to Archive (Max.)</td>
<td>1.4 GBytes/sec</td>
</tr>
<tr>
<td>Subarray Operation</td>
<td>2 cases (12 + 4, 8 + 8)</td>
</tr>
</tbody>
</table>
KJJVC Framework

Mark5B → Raw VLBI Data Buffer (RVDB) → VLBI Correlation Subsystem (VCS) → Peta-scale Epoch Data Archive (PEDA)

Correlator Control & Operation S/W

◆ Yellow : NAOJ, Green : KASI
Mark5B playback → VSI compatible : KVN

DIR2000 is in use extensively at VERA.
- VERA 2000, which is modified by NAOJ according to DIR1000, will be used for Playing back DIR2000 tape media for VERA.

OCTADISK : modified using RVDB with 4Gbps recorder/playback developed by NAOJ.

Optical Fiber : Capable of dealing with the full data rate of 8 Gbps.
Change Tape to Disc @ KJJVC/VERA (Planned)

VERA2000

1Gbps
80 min.

4Gbps
6 Hours or longer

OCTADISK

In VERA, parallel operation of tape and disk are now going on.
Purpose:

- Adjust data format as like # of bits per sample, and so on
- Easily synchronize the data while playback (heterogeneous recorder models)
- Maintain the buffering between recorder speed (1 Gbps) and correlation speed (8 Gbps)
Raw VLBI Data Buffer (RVDB)

basic configuration

4 C-ports
2Gbps, nominal

4 D-ports
1Gbps, nominal

VSI Optical Adapter (OCTAVIA)

From Playing Back Units

To Correlator Input Ports

10GbE Switch

OCTADISK

Control PC

OCTADDB

VDIF
VLBI Correlation Subsystem (VCS)  
(2007.8-2009.7)

• 16 Stations, 2Gbps x 4 sub-streams/station

• Correlation : (120 Cross + 16 Auto) x 4 sub-stream

• Serialized data sub-streams in time domain, and Parallel processing in frequency channels after FFT.

• Full polarization observation supported (up to 8 stations)

• Two sub-array modes prepared (12+4 and 8+8).

• Max. data output rate of 1.4GB/sec @ 25.6ms integration
PEDA (Peta-scale Epoch D.A.)

- Max. data rate: 1.4GB/sec @25.6ms integ. (~10% at average operation)
- Need to implement massive storage to save the correlation results with four 10GbE of VCS

PEDA (specification)

- **Architecture**
  - Infiniband

- **Max. Capacity**
  - 1~3 PB for 1 year (EAVN, VSOP-2)
  - 500 TB at initial phase (KVN, KJJVN)

~100 TB
Post-Processing SW configuration

- Developing with Japanese colleagues, NAOJ(CODA) and Kagoshima Univ.(GFS)
- CODA file system (CCcoda ver2.1), FITSgen
  - to reduce the developing efforts & cost, and to have compatibility with MTK FX

KJJVC Post-Processing Software Tools

- VCS correlation output
- CODA Generator
- CODA 2.1 (CCcoda Library)
- CODA File System
  - FITSgen (FITSKJCC)
  - FITS-IDI
- AIPS
- VEDA (VERA Data Analyzer)
- Global Fringe Search (Q-look SW)
  - Continuum
  - Spectral Line
New Building

KASI Headquarter @Daejeon

East Asia VLBI Research Center
(2012.9.13.)
Korea-Japan Correlation Center

- KJCC: ~May 2010
- KJCC Movement: July 2012, Seoul to Daejeon
  - July 2012~current: Daejeon Correlator

(Known as KJJVC, which was the development project name)
Daejeon Correlator

2012.07~ current
Playbacks/DA, Control Server
Memorandum of Agreement
for Korea-Japan Correlation Center Joint Operation
President of KASI, Director General of NAOJ

Executive Board
Manager of Radio Astronomy Center(KASI)
Director of Mizusawa VLBI Observatory(NAOJ)
Vice President (KASI)
Chair of East Asian VLBI Network(international)
Correlator Manager(KASI)
System Engineer(KASI, NAOJ)
System Scientist(KASI, NAOJ)

Operation Group
(KASI)  Operation Group
(NAOJ)

2011. 7. 20.
KJCC - Operation Structure

Executive Board
KVN + VERA(+ EAVN)

Korea-Japan Correlation Center
- Project manager: 1, 1
- Operation manager: 1, 1
- System Engineer: 3, 3
- Operator: 2, 6
- Data quality analyzer: 2, 4

Oper. Support Group
- KVN
- VERA / JVN
- EAVN
- Mitaka Correlator

KASI operates KJCC with supporting operational budget and know-how of NAOJ.
Experiments

- To Verify the performance of Daejeon Correlator

- Observation Code: r11027b
- Array: KVN+VERA combined 7 stations
- Observation frequency: 22 GHz
- Observation time: 9.2 hours
- Correlation mode: C5 (16 MHz BW, 16 stream)
- Integration time: 2.048 sec
- Reference Correlator: Mitaka FX (NAOJ)
  - 5 stations, 1 Gbps
  - Need to change the configuration
  - Now in progress correlation, maybe it is possible to compare with the result next month.
KVN+VERA 7 stations
21 baselines

R11027b, scan267
3C454.3
Before fringe fitting
Raw data spectrum
After fringe fitting

KVN+VERA 7 stations
21 baselines

R11027b, scan267
3C454.3

After fringe fitting
Gain amp(all range)/SNR(3C454.3)

Gain Amplitude(all range)

SNR(scan267, 3C454.3)

~600

~9.2 hours

~20 minutes
Delay/Rate (3C454.3)

Delay(3C454.3) ~20minutes

Rate(3C454.3)
Closure Phase (3C454.3)

~20 minutes
Fig. 3. VLBA image of Sgr A* at $\lambda = 1.35$ cm. The map has been convolved with a gaussian beam of $\text{FWHM} = 6.0 \times 2.8$ mas, P.A. = 3°. Contour levels are -1, 1, 2, 4, 8, 16, 32, 64, and 90% of the peak flux density of 0.77 Jy/beam. Inset: Map convolved with a circular beam of $\text{FWHM} = 2.8$ mas.
~20 minutes, self-cal, amp-cal not applied

Observed data with only KVN

Observed data with KVN+VERA

NRAO512

3C454.3
Future works

- Correlation 2012.Now~
  - Now conducting the test correlation of the KVN, KVN+VERA observation data for confirming the scientific performance of KJCC according to C5(KVN-5, 16MHzBW-16streams) mode.

- Correlation 2013~
  - Now commissioning phase for test observation data, then will start the scientific operation (normal operation) focused on 16MHz BW, 16streams mode from Jan. 2013.

- Upgrading the Data Archive System
  - 2013~