The EVN Mk IV
Data Processor at JIVE

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— JIVE —

- Operations & PI Interaction
  - New Science Operations & Support Group
  - Pre-observation / Pre-correlation
  - Post-correlation

- The Correlator
  - Features
  - Capacities & Tips
  - New Astronomical Capabilities

- Summary of Recent Enhancements
Review Process

Correlator $\rightarrow$ CDF $(\text{lag-based})$

AIPS++ Measurement Set v.2 $(\text{freq-based})$

GLISH

Review Flagging $\rightarrow$ Diagnostic Plots

IDI FITS

Pipeline

Plots CL Tables

1 year

web-based EVN Archive

PI $\rightarrow$ Public

Private (1yr) $\rightarrow$ Public
Standard Plots of EVN Correlator at JIVE

* a series of plots produced by the pipeline which should be useful in assessing antenna performance and data quality in each experiment (see pipeline description for details).
* a set of calibration tables (in FITS format) produced by the pipeline. These can be down-loaded and applied to the data provided by the EVN correlator.
* a history file associated with the data processed by the pipeline and a summary of what the CLS/NN table contains (typical CL table 3 provides phase, phase rate, delay and amp gain solutions from the calibration). In addition, the original pipeline script is made available together with final versions of the ancillary data (ASHTAB, UVTFLG etc.).

Archived fitfiles of experiment GJ010A

Access status: Private

- g010a.README
  - 340 bytes
- g010a_1_-1.D01
  - 0.040577440 x 10^6 bytes
- g010a_1_1.D01
  - 0.040577440 x 10^6 bytes
- g010a_1_2.D01
  - 0.040577440 x 10^6 bytes
- g010a_1_3.D01
  - 0.040577440 x 10^6 bytes
- g010a_2_1.D01
  - 1.2562169 x 10^9 bytes
- g010a_3_1.D01
  - 1.256468560 x 10^9 bytes
- g010a_4_1.D01
  - 1.040040200 x 10^8 bytes

Pipeline products of experiment GJ010A

- AIPS calibration, table (FITS Format)
- AIPS history file
- Short summary of CLS/NN table contents
- The final pipeline script
- Input parameters for script
- Associated ASHTAB
- UVFLG flagged data
- UVFLG Band-edge Flagging
Specific Correlator Capabilities

Available: (as of 9 Oct 2004)
- 1-, 2-bit sampling
- Cross-polarization
- \( \leq 2048 \) frequency points per SB/pol
- Full-correlator integration times \( \geq 1/4 \) sec
- Total observed data rates \( \leq 1024 \) Mb/s
- Mk III, Mk IV, VLBA, and Mk 5 recorders/formats
- Multiple-mode schedules
- Oversampling \( (2, 4 \times \text{Nyquist} \rightarrow 500 \text{kHz filters}) \)
- \( > 16 \) station correlation \( (\text{via multiple passes}) \)
- Improved 2-bit van Vleck correction

Underway / Not Fully Tested:
- Playback at different rate than recording
- Pulsar gating
- Phase-cal detection

Yet to Come:
- Sub-netting
- Recirculation

Experiment Statistics: (as of 9 Oct 2004)

<table>
<thead>
<tr>
<th></th>
<th>User</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Done &amp; Distributed:</td>
<td>175</td>
<td>104</td>
</tr>
<tr>
<td>Undergoing Review:</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Running/Queued/Waiting:</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>
Correlator Capacity

**Governing Formula:**

\[
N_{sta}^2 \cdot N_{sb} \cdot N_{pol} \cdot N_{frq} \leq 131072 \times \text{Recirc} \times 2
\]

\[
N_{sta} = (4, 8, 12, 16) \quad N_{pol} = (1, 2, 4)
\]

\[
N_{sb} \cdot N_{pol||} \leq 16 \quad N_{frq_{\text{max}}} = 2048 \times 2
\]

**Examples:**

<table>
<thead>
<tr>
<th>Sta</th>
<th>SB</th>
<th>Pol</th>
<th>Frq</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>1</td>
<td>1</td>
<td>2048</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>1</td>
<td>512</td>
</tr>
<tr>
<td>16</td>
<td>8</td>
<td>4</td>
<td>16</td>
</tr>
</tbody>
</table>

**Spectral Resolution afforded ( \( N_{frq} = 2048 \) ):**

<table>
<thead>
<tr>
<th>( BW_{SB} ) [MHz]</th>
<th>( \Delta \nu ) [Hz]</th>
<th>( \Delta v_{1420} )</th>
<th>( \Delta v_{6668} )</th>
<th>( \Delta v_{22235} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>7813</td>
<td>1651</td>
<td>351</td>
<td>105</td>
</tr>
<tr>
<td>2</td>
<td>977</td>
<td>206</td>
<td>44</td>
<td>13</td>
</tr>
<tr>
<td>0.5</td>
<td>244</td>
<td>52</td>
<td>11</td>
<td>3.3</td>
</tr>
</tbody>
</table>

**The Future:**

Recirculation

\[ \mathcal{R} \leq 16 \text{ MHz} / BW_{SB} \]

\( N_{frq_{\text{max}}} \) unaffected

Local \( \rightarrow \) Global Validity
Output Capacity

Raw output (local validity):
- lag-space correlation functions (32 kB/board)
- headers (16 kB/board)

Full-correlator = 1.5 MB/integration
  - Full-correlator \( t_{\text{int, min}} = 1/4 \) sec
  - Half-correlator \( t_{\text{int, min}} = 1/8 \) sec
  - Max. output rate = 6 MB/s

Data Size:

Approximate FITS file growth rate:

\[
\frac{1.75f}{t_{\text{int}}} \text{ GB per hour of observation}
\]

\( f = \) fraction of correlator used

\( \Rightarrow \) Current Record for single experiment \( \simeq 97 \) GB \( \Leftarrow \)

The Future (PCIInt):

- Full-correlator \( t_{\text{int, min}} = 1/64 \) s
- Maximum output rate = 160 MB/s
- Global validity (\( \rightarrow 64 \) kB/board of corr.func.)


**Expanded Fields of View**

**Wide-field mapping limitations:**

- Bandwidth smearing (radial in $u$-$v$ plane)
- Time smearing (azimuthal in $u$-$v$ plane)

For $\lesssim 10\%$ reduction in point-source response (Wrobel 95):

\[
\text{Bandwidth: } FoV \lesssim 49.''5 \frac{1}{B_{1000km}} \frac{N_{\text{freq}}}{BW_{\text{SB MHz}}}
\]

\[
\text{Time: } FoV \lesssim 18.''5 \frac{\lambda_{\text{cm}}}{B_{1000km}} \frac{1}{t_{\text{int}}}
\]

**Example:**

- 8 European stations ($B \simeq 2000$ km)
- 2 L-band subbands, $BW_{\text{SB}} = 8$ MHz, 1 Pol
- $N_{\text{freq}} \leq 1024$; take $N_{\text{freq}} = 512$
- $\Rightarrow$ can use half the correlator $\Rightarrow t_{\text{int}} = 1/8$ s

\[
FoV_{\text{BW}} \lesssim 26.'4 \\
FoV_{\text{time}} \lesssim 22.'2
\]

$cf.$ beam of 25 m antenna $\simeq 24.'75$

- [www.evlbi.org/user_guide/fov/](http://www.evlbi.org/user_guide/fov/)
- [www.evlbi.org/user_guide/limit.html](http://www.evlbi.org/user_guide/limit.html)
Pk. FD = 2.0997 Jy/bm
18.67 x 15.65 mas

Corr. Position shifted 120"
Pk. FD = 2.0343 Jy/bm (down ~3%)
19.82 x 15.29 mas (Ax.Rat. down ~8%)
256 Frq. points, 1/4s integrations
Summary of Recent Enhancements

- **Streamlined, Vertically Integrated PI Help**
  - Pro-active support at all stages
  - Interactive tools on the web
  - Archive: standard plots, pipeline, FITS
  - Disk recording — emphasis on media turn-around

- **Spectral Resolution**
  - $N_{\text{frq}_{\text{max}}}$ remains 2048 per SB/pol
  - Oversampling $\rightarrow$ narrower $BW_{SB}$ (to 0.5 MHz)

- **Reduced Minimum Integration Times**
  - Full-correlator down to 1/4 s
  - Half-correlator down to 1/8 s

- **~ Near Future**
  - $N_{\text{frq}} \overset{\ast}{=} 2\mathcal{R}$ (subject to relevant $N_{\text{frq}_{\text{max}}}$)
    - $\mathcal{R}$ from recirculation ($BW_{SB}$ dependent)
    - 2 from global validity (after Mk5 B)
  - Even lower $t_{\text{int}}$ (towards 1/64 s)
  - Better fractional-bit shift correction
Monte Carlo Simulation of VLBI Data Reduction at JIVE

Successful PI Joining VLBI Illuminati

Delivery of FITS tape

Astronomers getting perhaps a little *too* enthused about the whole VLBI experience