IAA Correlator Center 2013 Annual Report

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Abstract The activities of the six-station IAA RAS correlator include regular processing of national geodetic VLBI programs Ru-E, Ru-U, and Ru-F. The Ru-U sessions have been transferred in e-VLBI mode and correlated in the IAA Correlator Center since 2011. In addition, the new FX correlator is being designed.

1 General Information

The IAA Correlator Center is located at and staffed by the Institute of Applied Astronomy in St.-Petersburg, Russia.

The IAA Correlator Center is devoted to processing geodetic, astrometric, and astrophysical observations made with the Russian national VLBI network Quasar.

2 Component Description

The ARC (Astrometric Radiointerferometric Correlator) (Figure 1) was the main data processing device in the IAA Correlator Center in 2013. The ARC was designed and built in the IAA RAS from 2007 - 2009. The correlator has XF design and is based on FPGA technology.

The ARC is a six-station, 15-baseline correlator. It is able to process up to 16 frequency channels on each baseline, for a total of 240 channels. The correlator accesses two-bit VLBI signals with 32 MHz maximal clock frequency. The maximal data range from each station is 1 Gbit per second. The correlator requires VSI-H input VLBI signals, and it is equipped with Mark 5B playback terminals.

Since 2011, the DiFX software correlator has been used for some astrophysical experiments. DiFX is installed at the IAA on a Sun Fire X4450 Server as a virtual machine under the VMware.

3 Staff

- Igor Surkis — leading investigator, software developer;
- Voytsekh Ken — GPU software developer;
- Alexey Melnikov — DiFX processing, scheduler of the Ru-sessions;
- Vladimir Mishin — software developer, data processing;
- Nadezda Sokolova — software developer;
- Yana Kurdubova — software developer;
- Dmitry Pavlov — software developer;
- Violet Shantyr — software developer, post processing;
- Vladimir Zimovsky — leading data processing;
- Ekaterina Medvedeva — data processing;
- Alexander Salnikov — leading e-VLBI data transfer;
- Ilya Bezrukov — e-VLBI data transfer.

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Fig. 1 View of the six-station ARC correlator, showing four racks containing (left to right) signal distribution and synchronization system (SDSS) and three Mark 5B playback units, two correlator crates and KVM, three correlator crates, and one more cabinet with SDSS and three Mark 5B playback units.

4 Current Status and Activities

4.1 Ru Sessions

The ARC correlator was used for processing all of the national geodetic VLBI observations in the IAA Correlator Center in 2013. The Ru-E and Ru-U geodetic VLBI sessions were carried out in IAA RAS.

The three-station, 24-hour EOP determination Ru-E sessions were carried out once per week, as in 2012.

The two-station, one-hour UT1-UTC determination sessions in e-VLBI mode were carried out once per day. The Ru-U sessions were executed with frequency channel bandwidth 8 MHz and total bitrate 256 Mbps. The data transfer speed from stations to correlator was improved in 2012, and near to realtime correlation processing with data bitrate 256 Mbps was achieved.

4.2 DiFX Processing

In 2013, the DiFX software correlator continued to be the main spectral line source processing tool. Target sources are Orion KL, W49N, W3OH, and W75. It is used to correlate data streams of 16-64 Mbps bitrate. Output data resolution was up to 8,192 spectral channels which allows achievement of a frequency resolution of 0.25 kHz for W3OH in L-band. 41 Ru-P experiments were scheduled and observed in 2013, including Crab nebula observations at L-band. Several experiments to monitor RFI were conducted. One experiment with 2 Gbps bitrate and standard wideband geodetic frequency mode and one experiment with 2 Gbps and 512 MHz bandwidth in X-band were done. The latter experiment is planned to be processed in early 2014. Three experiments were done with the Effelsberg radio telescope in collaboration with the Max Planck Institute for Radioastronomy. Data were transferred from Bonn to Saint Petersburg using tsunami protocol at data rates up to 400 Mbps. Medicina and Noto also joined

one experiment and e-transferred data to Saint Petersburg directly from the stations to the Correlator Center. DiFX is installed on a GNU/Linux VMware virtual machine on a Sun Fire X4450 Server. Test installation on a new hybrid-blade cluster was done.

4.3 FX Correlator Design

The design of a new FX software correlator intended for the new small antenna VLBI network was started in 2012. The correlator design is supposed to process data streams of up to 16 Gb/s from each observatory. VLBI data are recorded from four frequency bands with bandwidths of up to 1024 MHz in one circular polarization or up to 512 MHz in two linear polarizations using 2-bit sampling. The input data format is VDIF. The correlator computes cross-spectra with a resolution of up to 4,096 spectral channels and extracts up to 32 phase calibration tones in each frequency band of each station.

In 2013, we elaborated the correlator's structure and developed the two-station software prototype. "T-Platforms" company developed and mounted the high-performance computing cluster at IAA (Figure 2). The software was installed and successfully tested and benchmarked.

The main conception of the correlator comes from the DiFX correlator, although it has several distinctive features. The most significant one is the usage of graphical processing units (GPUs) for the main computations such as bit repacking, Fourier transformation, doppler tracking, spectra multiplication, and phase cal extraction.

The correlator equipment includes a data transfer system based on fiber optic cable, power supply, conditioning system, and high performance compute cluster. The correlator's hardware is based on hybrid blade server technology. Each blade server contains two Intel CPUs and two Nvidia Tesla GPUs. The present hardware of the one-baseline correlator's prototype contains five blade servers made by "T-Platforms" company, which are inserted into chassis. The cluster also includes power supply and power distribution units, two cache servers, one head server, data storage with capacity of 20 TB, an infiniband data commutator and a fiber optic commutator. The cluster's components are mounted in a cabinet.

Fig. 2 View of the high-performance computing cluster based on the hybrid blade servers.

The correlator's topology consists of head, station, and correlation software modules. The head module controls all interblock processes and collects the results. Each station module processes data stream from one station and provides phase calibration signal extraction, data synchronization, delay tracking, and bit repacking. Each correlation module provides cross- and autocorrelation spectra computing for all the stations.

Pcal extraction is realized using the method proposed by S. Pogrebenko. According to this method, data are shifted by the offset frequency, so the phase tones are in the equidistant frequency spacing. The

shifted data are divided into frames with a size of doubled pcal tones, and then all the frames are summed. As a result, white noise from the cosmic data is averaged to zero, and only the phase tone information remains. Then the FFT should be accomplished to get the pcal data.

The cross-spectra computing algorithm is realized in the following way. The received data blocks from the station modules are copied to the GPU's DRAM, where unpacking of bits to single-precision numbers and the fringe rotation are done. Then the FFT operation is completed, and finally the obtained data are transferred to the spectra multipliers kernel, where they are multiplied together and averaged within the chosen time period. The output spectra are transferred to the head module.

For six stations with data streams of 16 Gbps, these algorithms require 76 Fermi GPUs for near real-time processing.

5 Future Plans

The next two years will be devoted to development of the cluster and software for the near-real time six station correlator. "T-Platforms" company will have developed and mounted a high-performance computing cluster which will contain 40 blade servers by June, 2014.