First Fringes with BRAS on VLBI Network “Quasar”

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Abstract Two 13-m antennas will be built at the Badary and Zelenchukskaya observatories of the VLBI network “Quasar”. These antennas will be equipped with new VGOS hardware being developed by the Institute of Applied Astronomy (IAA). While waiting for the small antennas, the first test sessions with VGOS technology were made with the 32-m antennas. A special VLBI session with the Broadband Acquisition System (BRAS) prototype was performed in late 2012 using the single baseline Svetloe–Zelenchukskaya. The main goals of this experiment were to test BRAS in a real environment and to compare it with the existing DAS R1002M.

Keywords BRAS, VLBI, fringe test

1 Introduction

A special VLBI session was performed in late 2012 to test BRAS, which was developed at the IAA [1, 2]. The test session was carried out using the Svetloe–Zelenchukskaya baseline, and the VLBI data was registered and recorded using the DAS R1002M with a Mark 5B recorder and using the BRAS prototype with a Mark 5C recorder. All scans were then transferred and correlated at the IAA Correlator [3]. Analysis and comparison of results were made using software packages PIMA, HOPS, and AIPS.

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2 Station Equipment and Setup

The Svetloe and Zelenchukskaya sites have 32-m antennas and are equipped with X/S receivers. Each station is equipped with DAS R1002M and Mark 5B+ for standard geodesy. The BRAS prototype and Mark 5C recording system were connected to the receiver output in parallel to the standard equipment.

For the standard system, a wideband geodetic X/S frequency setup was chosen. This setup includes 16 channels with center frequencies from 8212.99 to 8932.99 MHz and 16 MHz filters. Spanned bandwidths are 752 MHz in X band and 156 MHz in S band.

The BRAS prototype was able to record a single 512 MHz frequency channel, and it was adjusted to cover bandwidth from 8592.00 to 9104.00 MHz. The real BRAS bandwidth was reduced to 400 MHz by filters to fit the end of the receiver band.

In both cases, 2-bit sampling was used. The total sampling rate for the standard system was 1024 Mbps and, for the new system, was 2048 Mbps. Pcal was on.

3 Detection Limits and Source Choice

Using the following formula for the signal to noise ratio Q:

$$Q = 0.88 \cdot S\sqrt{\frac{2n\Delta f\tau}{SEFD_1 SEFD_2}},$$

a minimum detectable flux S_{min} can be estimated. SKED catalogs provide SEFD values for Svetloe and Zelenchukskaya equal to 400 Jy. Assuming lower s/n ratio for detection $Q_X = 10$, scan duration $\tau = 60$ s, and $n = 8$ X-band channels with $\Delta f = 16$ MHz, lower

detectable flux density should be 37 mJy in case of a wideband geodetic setup. For the new system, a single 400 MHz bandwidth channel $S_{min} = 21$ mJy was used.

Table 1 Sources for Ru-TEST074 session.

IVS name	Number of observations	X band total flux, Jy	X band unresolved flux, Jy
4C39.25	239566	10.295	3.878
1803+784	201043	2.119	1.307
0059+581	289083	1.736	1.366
2320+506	2498	1.109	0.479
3C371	85725	1.021	0.415
0716+714	28223	0.755	0.646
1300+580	88230	0.474	0.400
0901+697	126	0.135	0.147
0611+665	117	0.099	0.024

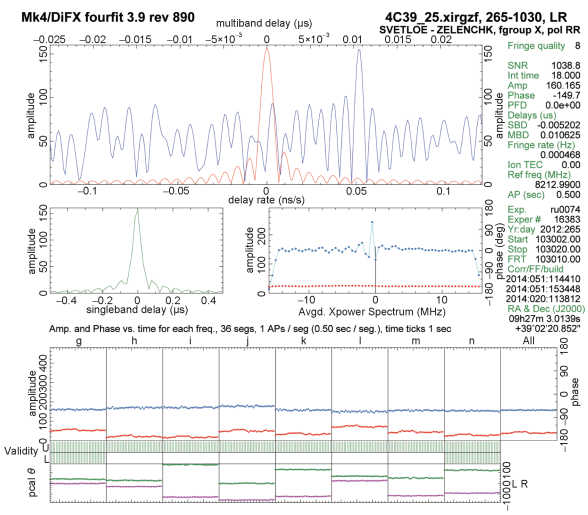

Fig. 1 HOPS fringe plots for scan at UT 10:30, source 4C39.25, standard geodetic X band.

Sources for the experiment were chosen according to the minimum flux density $S_{min} = 21$ mJy from the RFC 2012c catalog [5, 6, 7, 8, 9, 10] and the SKED source catalog. The list of sources and the parameters from RFC 2012c are presented in Table 1.

Source 0611+665 has never been observed with the "Quasar" VLBI network. Source 0901+697 was observed several times in the Ru-A observing program by 20-minute scans. Other sources are regularly observed. All sources have calibrator code "C".

4 Experiment Description

Test session Ru-TEST074 was carried out on September 21, 2012 and consists of three stages:

- the first — starting at UT 10:30, trial 20 s scan of bright source 4C39.25 during receiver cooling,
- the second — starting at UT 13:30, trial 20 s scan of 4C39.25, and
- the third stage — main experiment, starting at UT 17:00, consequent 60 s scans of remaining sources separated by five minute gaps to transfer data and maintain the Mark 5C recorder.

Data from Mark 5C was transferred manually after scan recording. The first scan was repeated at UT 10:40.

First scans were immediately transferred to the IAA Correlator via the Internet, and the fringe test was performed using the DiFX software correlator [4] to check that standard equipment works well and to find fringes with new DAS. Third stage scans were recorded at local storage and were transferred the next day.

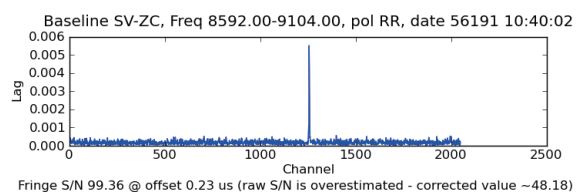

Fig. 2 First fringe with BRAS, DiFX plot of one second of data, 2 μs delay window, scan at UT 10:40, source 4C39.25.

5 Data Processing, Results and Analysis

The first three scans at UT 10:30, 10:40, and 13:30 of bright source 4C39.25 from Ru-TEST074 were correlated almost online right after recording and transferring to the IAA Correlator. Figure 1 shows fringes in X-band from HOPS for scan 10:30 recorded using standard geodetic equipment. The s/n ratio for scan 10:30 achieves 1038 units and for scan 13:30 — 1595. For broadband scans, several trial DiFX runs were performed with different delay windows and accumulation periods. Finally, a first fringe was found (Figure 2).

Table 2 Calculated signal to noise ratios for broadband and standard systems.

Software	Scan, Source/ Setup	17:00 1300+580	17:05 3C371	17:10 0901+697	17:15 1803+784	17:20 0716+714	17:25 0611+665	17:30 0059+581	17:35 2320+506
PIMA	1x16 MHz	48.22	64.03	13.86	151.95	107.31	7.87	370.5	23.01
AIPS	1x16 MHz	32.4	45.8	10.4	115.9	72.7	3.8	139.9	15.4
PIMA	8x16 MHz	143.81	199.14	42.46	452.31	309.34	27.36	1089.85	60.81
HOPS	10x16MHz	183.5	253.5	54.4	572.5	399.5	34.3	1391.4	79.0
PIMA	1x512 MHz	221.15	307.18	66.08	705.53	504.05	42.43	1737.14	111.01
HOPS	1x512 MHz	288.2	404.0	79.9	931.9	661.9	55.1	2299.3	147.2
AIPS	1x512 MHz	156.7	204.0	57.0	342.1	278.7	43.1	381.0	80.8

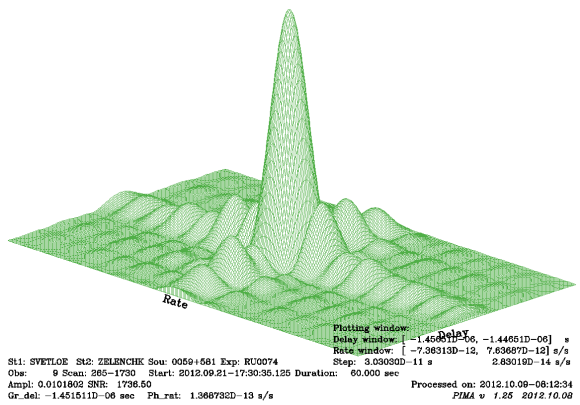

Fig. 3 PIMA 3D fringe plot of 0059+581 source at UT 17:30 using BRAS and Mark 5C.

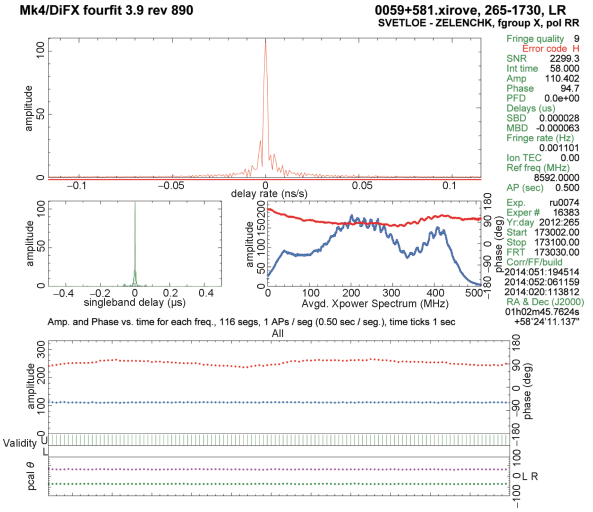

Fig. 4 HOPS fringe plot of source 0059+581, scan at UT 17:30 using BRAS and Mark 5C.

All data were correlated, and fits-idi and Mark IV format files were produced for standard and broadband systems. To estimate improvement from using the broadband system, s/n ratios were calculated. The ratio of broadband system s/n and standard system s/n with eight X-band frequency channels is proportional to the square root of the total bandwidth relation and should be equal to 1.76, because the broadband system has 400 MHz real bandwidth.

AIPS was used at first for data fringe fitting with task FRING, then s/n values were collected from output. Calculated values were a little bit confusing.

The next tool, HOPS, had some restrictions from the box. The maximum number of lags allowed is 2,048. Thus, the delay window for the 512 MHz band is only 2 μs, which is not enough for a fringe search with unknown clock offsets. Mark IV format files need to be produced specially for HOPS.

A much better tool for analysis is PIMA, which has a flexible setup for fringe search procedures and has no problems with only one frequency channel (IF) in a data set. It loads a fits file produced by DiFX. Also it produces beautiful 3D pictures of fringes (Figure 3). Equivalent HOPS fringe plots for the same scan are shown in Figure 4.

Calculated s/n values from the different software tools for both systems are gathered in Table 2. In the second column, the used frequency setup is given, which indicates the number of IFs and the bandwidth of each channel in MHz used in the s/n calculation. The IF bandwidth is 16 MHz for a standard system and 512 MHz for a broadband system.

The least square fit (LSF) average ratio between s/n values from PIMA for 8x16 MHz and 1x512 MHz is 1.6, a little bit less than the expected 1.76. This value was calculated for 400 MHz of bandwidth, but actually 512 MHz was recorded, so we can introduce the correction coefficient, which equals $\sqrt{\frac{512}{400}} = 1.13$. The corrected value is $1.6 \cdot 1.13 = 1.81$. Scan 17:35 got a G-code in HOPS and could be affected by local RFI at Ze-

lenchukskaya. If this point would be removed, then the corrected value would be equal to 1.77, which agrees very well with the expected value. Calculated in the same way, corrected for the 10 IFs and 400 MHz bandwidth, the LSF average of s/n ratios for HOPS is equal to 2.01, which did not agree with expected value.

6 Conclusions

First fringes with BRAS were obtained. Source 0611+665 with only 24 mJy correlated flux density was detected.

The new broadband system BRAS is supposed to replace the previous digital DAS and provide an advantage by 1.77 over standard geodetic mode even with a single frequency channel.

Acknowledgements

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