

## 4-station ground based VLBI pre-launch test of “Radioastron” recording mode

(preliminary results)

On 4 – th February, 2010 joint VLBI observations (rapl01 experiment) were made at 6.28 cm between 100-m Max Plank Institute (Effelsberg, Germany), Puschino 22-m antenna (FIAN ASC, Russia), and two 32-m antennas in Noto and Medicina of the Istituto di Radioastronomia di Bologna (Bologna, Italy).

The goal of an experiment was further working-off the functioning and examination of the ground based radiotelescopes of the “Radioastron” space mission, as well as VLBI-interferometry correlators for recorded data processing. In this short report we present the individual systems parameters, observing procedures and first results of data processing with the ASC software correlator .

For the purposes of comparative analysis the data exchange and separate processing at Bonn correlator ( Max Plank Institute fur Radioastronomy) are foreseeing between the partners. The complete results of this analysis will be published in separate report.

### Station parameters in “rapl01” experiment at 4828 MHz, February 4, 2010

| Station    | Data Recorder | $A_{\text{eff}}$<br>(m <sup>2</sup> ) | Tsys<br>(K) | G<br>[K/ Jy] | SEFD<br>[Jy] | Elev<br>(Deg)<br>3C84 | Elev<br>(Deg)<br>2200+420 |
|------------|---------------|---------------------------------------|-------------|--------------|--------------|-----------------------|---------------------------|
| Effelsberg | Mark-5A       | 4163                                  | 30          | 1.55         | 20           | 70                    | 63                        |
| Puschino   | RDR<br>(ASC)  | 180                                   | 115         | 0.065        | 1770         | 75                    | 45                        |
| Noto       | Mark-5A       | 480                                   | 45          | 0.174        | 260          | 77                    | 54                        |
| Medicina   | Mark-5A       | 480                                   | 30          | 0.174        | 170          | 73                    | 60                        |

$$G \text{ (K/Jy)} = A_{\text{eff}} * 10^{-3} / 2.76$$

$$\text{SEFD} = T_{\text{sys}} / G$$

### Baselines (km)

|           | <b>Ef</b> | <b>Mc</b> | <b>Nt</b> | <b>Pu</b> |
|-----------|-----------|-----------|-----------|-----------|
| <b>Ef</b> | 0         | 757       | 1644      | 2105      |
| <b>Mc</b> | 757       | 0         | 893       | 2167      |
| <b>Nt</b> | 1644      | 893       | 0         | 2616      |
| <b>Pu</b> | 2105      | 2167      | 2616      | 0         |

### Baselines (millions of wavelength)

|           | <b>Ef</b> | <b>Mc</b> | <b>Nt</b> | <b>Pu</b> |
|-----------|-----------|-----------|-----------|-----------|
| <b>Ef</b> | 0,00      | 12,62     | 27,40     | 35,08     |
| <b>Mc</b> | 12,62     | 0,00      | 14,88     | 36,12     |
| <b>Nt</b> | 27,40     | 14,88     | 0,00      | 43,60     |
| <b>Pu</b> | 35,08     | 36,12     | 43,60     | 0,00      |

### Observing schedule

The total recording bandwidth composed of two 16 MHz frequency segments:

16 MHz at Lower side band, RHCP

16 MHz at Upper side band, LHCP.

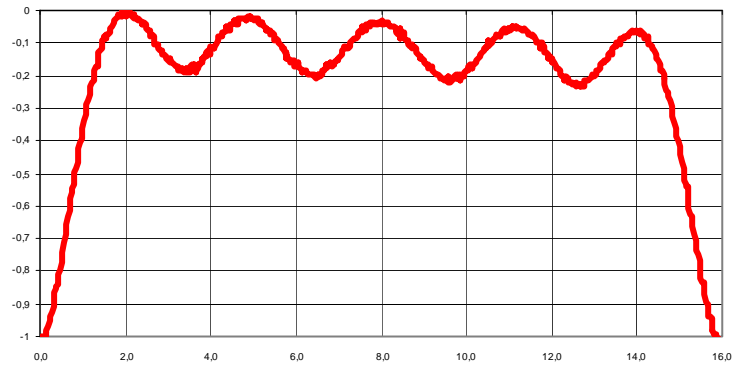
Data acquisition (bits per sample): 1 and 2  
 Elapsed time for experiment: 1.98 hours  
 Number of scans: 12  
 Time in scheduled/ recorded scans: 1.67 hours  
 Total number of baseline hours: 16.67 hours  
 Total recorded data per station: 145 Gbytes

| SCAN     | DAY | START UT | SOURCE          | SCAN      | DAY | START UT | SOURCE     |
|----------|-----|----------|-----------------|-----------|-----|----------|------------|
|          |     | STOP UT  | SOURCE          |           |     | STOP UT  | SOURCE     |
| <b>1</b> | 35  | 15:00:55 | 2200+420        | <b>7</b>  | 35  | 16:05:20 | 0316+413   |
|          | 35  | 15:09:15 | ra6cm1.set(*)   |           | 35  | 16:13:40 | ra6cm1.set |
| <b>2</b> | 35  | 15:10:10 | 2200+420        | <b>8</b>  | 35  | 16:14:35 | 0316+413   |
|          | 35  | 15:18:30 | -               |           | 35  | 16:22:55 | -          |
| <b>3</b> | 35  | 15:19:25 | 2200+420        | <b>9</b>  | 35  | 16:23:50 | 0316+413   |
|          | 35  | 15:27:45 | -               |           | 35  | 16:32:10 | -          |
| <b>4</b> | 35  | 15:28:40 | 2200+420        | <b>10</b> | 35  | 16:33:05 | 0316+413   |
|          | 35  | 15:37:00 | ra6cm2.set (**) |           | 35  | 16:41:25 | ra6cm2.set |
| <b>5</b> | 35  | 15:37:55 | 2200+420        | <b>11</b> | 35  | 16:42:20 | 0316+413   |
|          | 35  | 15:46:15 | -               |           | 35  | 16:50:40 | -          |

| SCAN | DAY | START UT |          | SCAN | DAY | START UT |          |
|------|-----|----------|----------|------|-----|----------|----------|
| 6    | 35  | 15:47:10 | 2200+420 | 12   | 35  | 16:51:35 | 0316+413 |
|      | 35  | 15:55:30 | -        |      | 35  | 16:59:55 | -        |

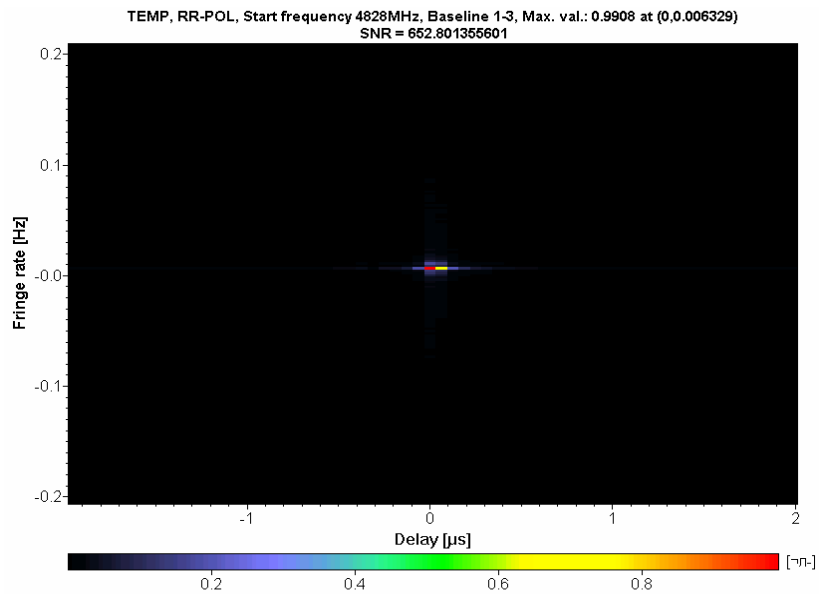
- \*) ra6cm1.set -1 bit per sample mode
- \*\*\*) ra6cm2.set -2 bits per sample mode

**Upper bandpass response at Puschino BBC,  
16 MHz BW (logarithmic scale)**



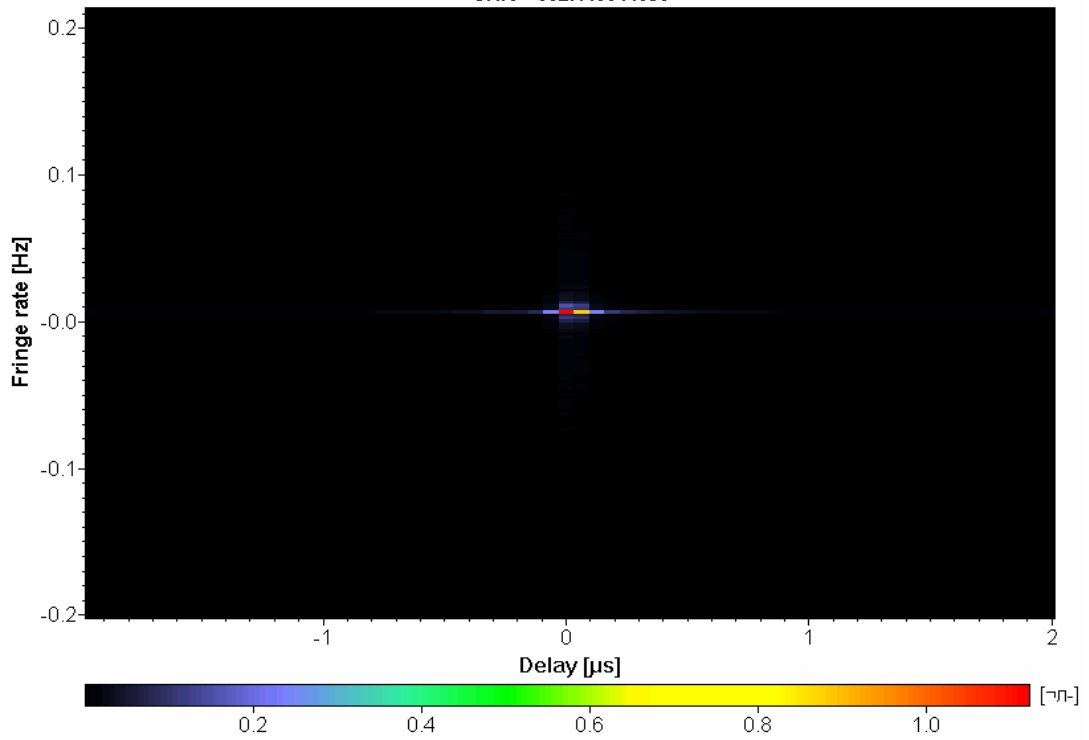
**Fringe rate – delay search results**

Source 2200+420 (BL Lac), Ef-Mc, Scan 3, time interval  $8^m 20^s$ ,  
 “Fringe rate-Delay” plot of Visibility amplitude,  
 1 bit sampling, RHCP, Lower Band



### Upper band

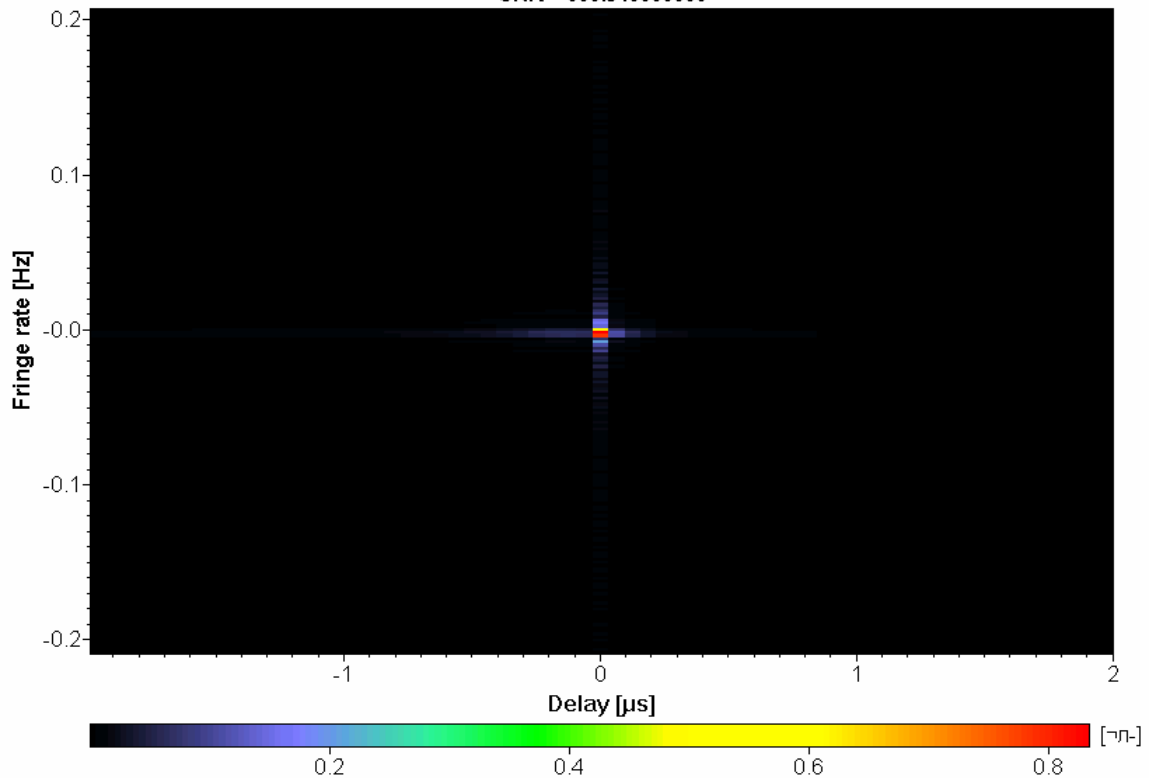
TEMP, RR-POL, Start frequency 4812MHz, Baseline 1-3, Max. val.: 1.1225 at (0,0.006329)  
SNR = 652.445341093



Source 0316+413 (3C84), Ef-No, Scan 7, integration time  $8^m 20^s$ ,  
“Fringe rate-Delay” plot of Visibility amplitude, 1 bit sampling, RHCP, Lower Band

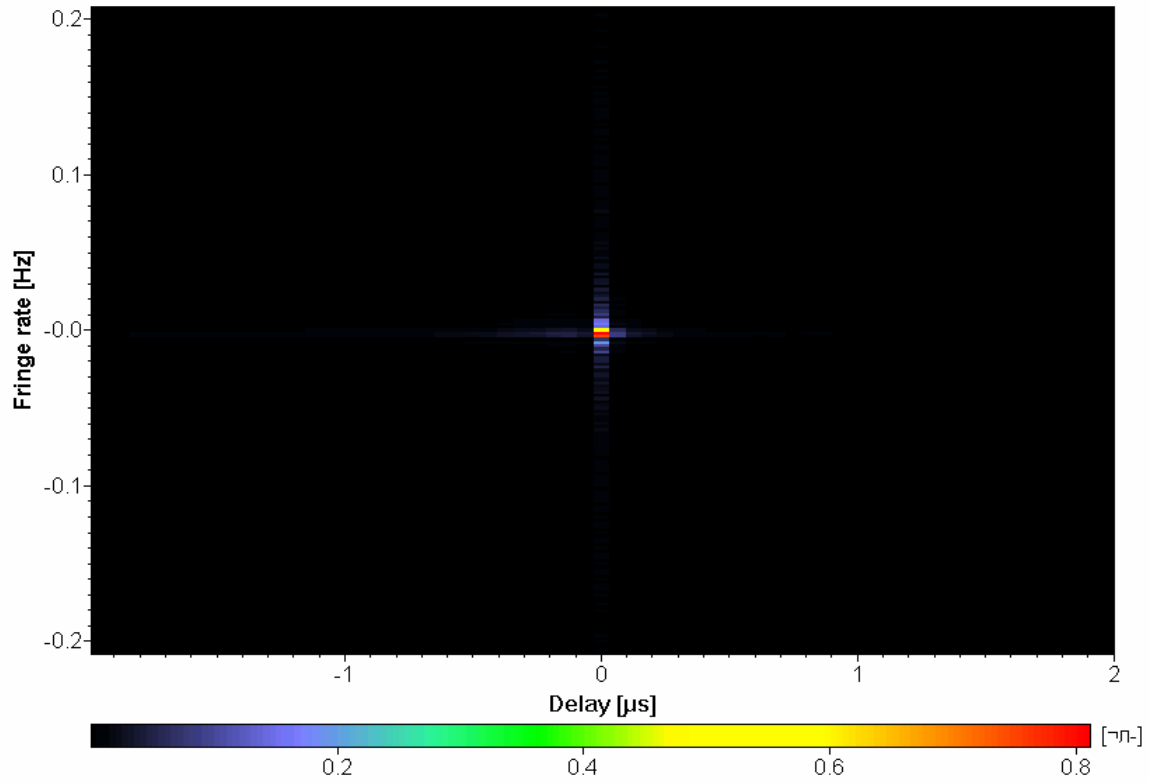
### Lower band

TEMP, RR-POL, Start frequency 4828MHz, Baseline 1-2, Max. val.: 0.8341 at (0,-0.002008)  
SNR = 553.915085306



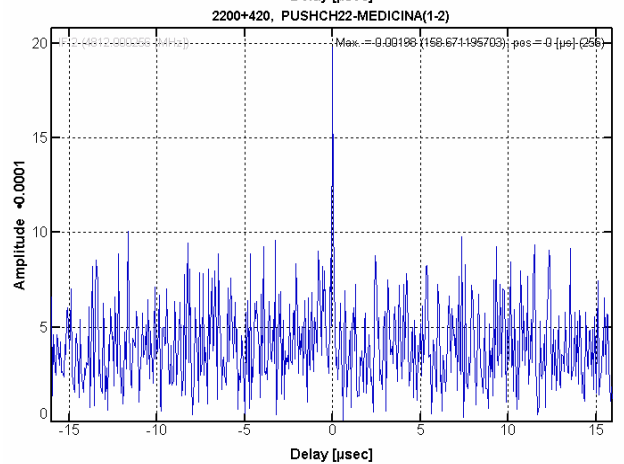
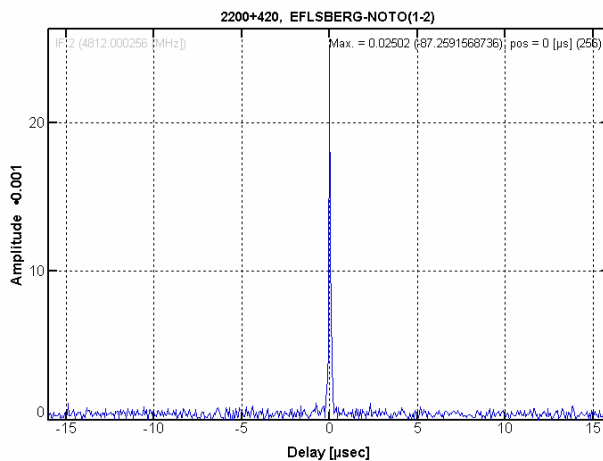
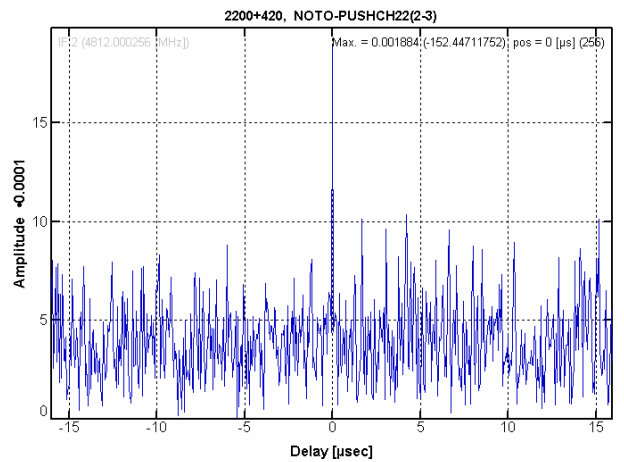
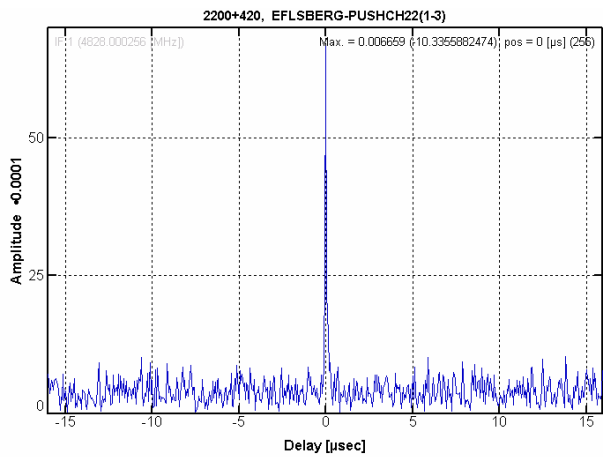
## Upper band

TEMP, RR-POL, Start frequency 4812MHz, Baseline 1-2, Max. val.: 0.8115 at (0,-0.002008)  
SNR = 565.986412085

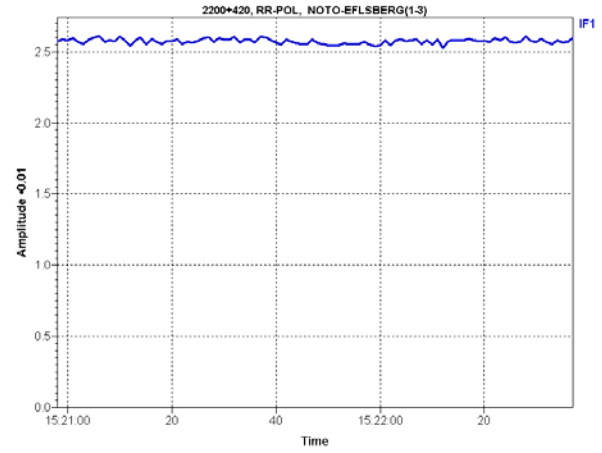
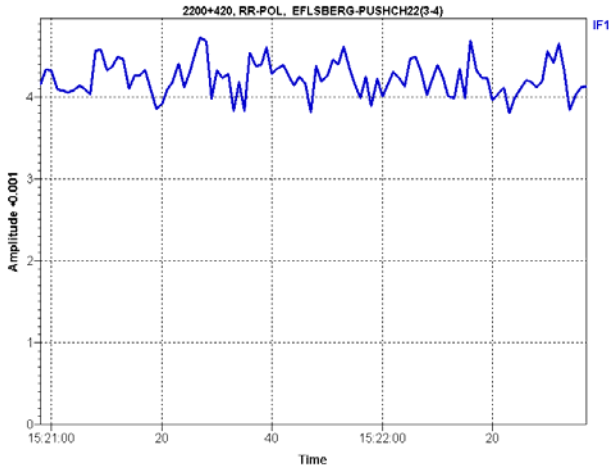


## Amplitude response versus Delay for some baselines

Source 2200+420, date 04/02/2010, time interval 15:20 - 15:30



### Correlated amplitude versus time for some baselines



**Signal to Noise RMS ratio**  
 Source 2200+420 (BL Lac).  
 (Coherent integration time = 0.3 sec)

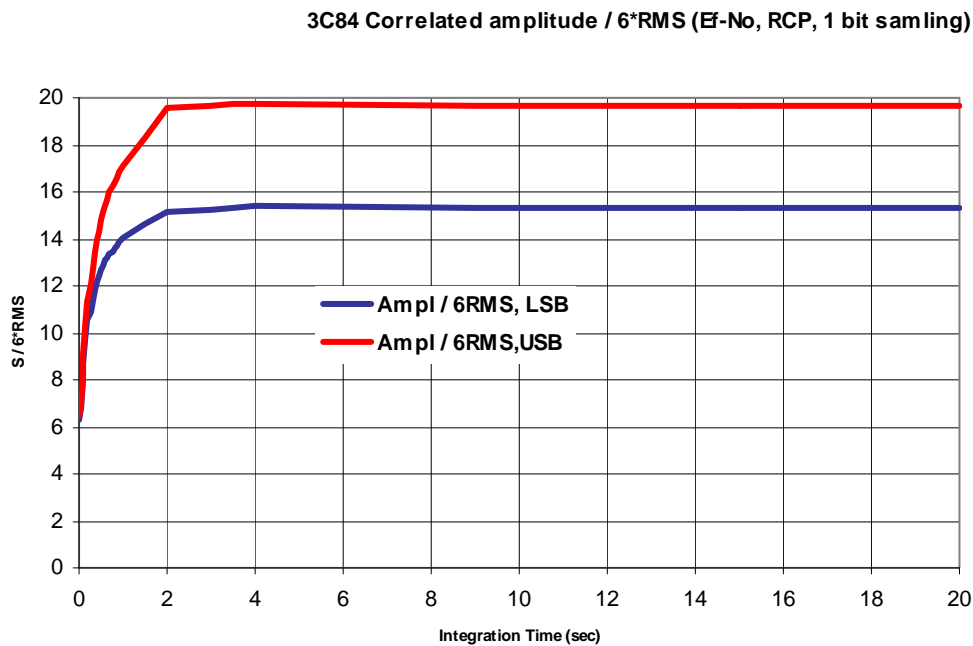
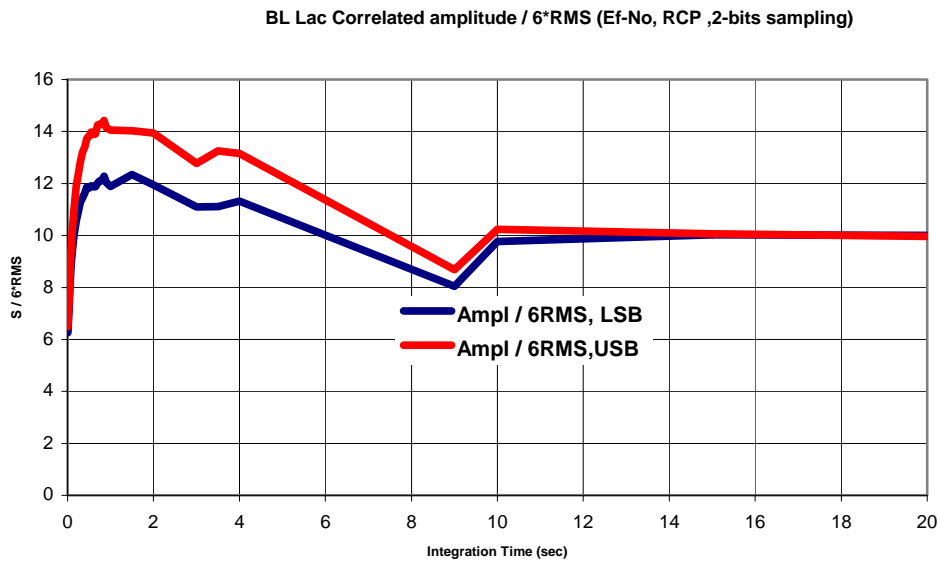
| Baseline       | S/N        | S/N         | Acorr<br>*) |
|----------------|------------|-------------|-------------|
|                | (measured) | (estimated) |             |
| <b>Ef - No</b> | 71         | 110,9       | 2,5         |
| <b>Ef - Pu</b> | 41,5       | 42,5        | 2,5         |
| <b>No - Pu</b> | 10         | 11,8        | 2,5         |
| <b>No -Mc</b>  | 30         | 38,1        | 2,5         |
| <b>Mc - Pu</b> | 14         | 14,6        | 2,5         |
| <b>Ef - Mc</b> | 69,4       | 137,2       | 2,5         |

\*) accepted correlated Flux (Jy), mean value

### Representative phase rates for correlated signals

| Source   | Baseline | Polarisation | Phase rate<br>( $^{\circ}$ /sec) |
|----------|----------|--------------|----------------------------------|
| 2200+420 | No-Ef    | RHCP         | 0.84                             |
|          | No-Pu    | RHCP         | 41.48                            |
|          | No-Mc    | RHCP         | 3.37                             |
|          | Ef-Pu    | RHCP         | 148.45                           |

## Correlated amplitude versus coherent integration time (Ef-No Baseline)



The more thoroughly analysis of full data set for this experiment will be presented in additional paper after comparing processing results received from participating VLBI parties.

As a conclusion we want to emphasize that this VLBI pre-launch ground based “Radioastron” test has been performed mainly due to active and enthusiastic efforts of following radio astronomer’s teams:

1. Max Plank Institute fur Radioastronomy (Bonn, Germany),
2. FIAN ASC, (Moscow, Russia)
3. Istituto di Radioastronomia di Bologna (Bologna, Italy).

---

On behalf of Data Processing Department the report was prepared by Vladimir Kostenko (vkostenko@asc.rssi.ru).