Future Fast Radio Bursts (FRB) search with the RATAN-600 radio telescope at 4.7 GHz

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Abstract We have started the search program of the mysterious and rare fast radio bursts (FRB) with the RATAN-600 radio telescope. We have prepared the special antenna - the Western Sector and the secondary mirror (SM5) named by Type-5. The measured effective area of the antenna will be near 1100 meter in square. The three from four new high sensitivity receivers at 4.7 GHz have been already established in the focal plane of SM5. The total frequency band of 600 MHz of each receiver was divided by the microwave filters on four sub-bands of 150 MHz and signals of 12 (16) channels of back-end are recorded with the maximal temporal resolution 0.49 ms. We develop online routine on the powerful PC, analyzing the coming signals in order to find the fast bursts, shifted in time due to the interstellar (or intergalactic) dispersion (DM ~ 100-1000 pc/cm3) in dependence on the sub-band frequencies. Alerts of the such distant (out of the Solar system) events with expected fluences ~1-30 Jy ms and error box of coordinates will be sent to the robotic optical wide-angular small telescopes array constructed in SAO RAS. The relatively big field of view of the four-beam system in the 24-hours survey allows us to detect up to 10 FRB per year. In June 2017 we have carried out the pilot observations of the bright and close pulsar PSR B0329+54 at 2.3 and 4.7 GHz with the wide-bands (120 and 600 MHz, respectively). We have detected the 10-30 pulses with the known spin period P=0.71452s getting in the antenna beams, recorded with time interval 0.49ms. The width of the average pulse is equal to W50=10 ms at 4.7 GHz. Such measurements are well test for the FRB search. We have started of the survey in September 2017.

Keywords: Radio Astronomy, Radiometers, Fast Radio Bursts, Blind Radio Surveys, Dispersion Measure, Pulsars

1. Introduction

The first FRB was discovered [1] in 2007 in archived pulsar data from Parkes telescope. It was a 5-millisecond single radio frequency burst which undergoes the high interstellar (or intergalactic) dispersion. Since the current catalog has ~25 FRBs, lasting no more than a few of milliseconds. They seem to come from sources beyond our Galaxy. Some last longer than others, and the light from a few is polarized. In 2012 [2] had found a repeating FRB121102, meanwhile all the other signals had been single. It was identified: a faint, distant dwarf galaxy around 780 Mpc away, in a star-forming region that is a steady radio source. Many telescopes are looking for FRBs. We have decided to begin in such search with RATAN-600 radio telescope in continuous survey observations with the special antenna and the innovative radiometric four-beam complex with division of each wide-band to four narrow-bands at 4.7 GHz and rapid data-sampling up-to 0.49 ms.

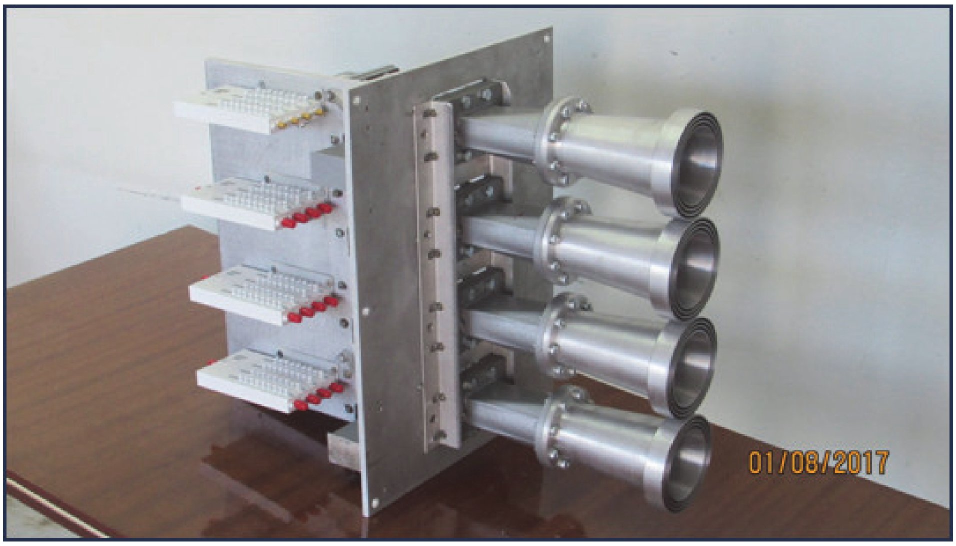

Fig1. *Four-beam radiometer at 4.7 GHz in the test mode in lab.*

2. The current survey

2.1. Receivers

We have used the low-noise radiometer at 4.7 GHz with wide-band 600 MHz and the calculated sensitivity near 3 mK per a second. The four-beam complex with microwave filters, dividing the wide band for four sub-bands, 150 MHz each is shown in ***Fig1***.

2.2. Antenna

The main mirror antenna is the Western sector (WS) of the RATAN-600 radio telescope.

In the WS focus is placed effective secondary mirror SM5 with an enhanced field of small aberrations in the focal plane. We have established WS at elevation of the known calibrator source 3C48 (0137+33), that is very close to the repeated FRB 121102 (0529+33). For search for the new FRB we need a big field of view (FOV). For example FOV of the 13-beams system at Parkes 64m telescope is equal 13* 3.14*13' *13'/4 = 1724 arc min in square for each time slice. For WS and four beams at 4.4-5.0 GHz (a total band 600 MHz) we can calculate the FOV: 4* 3.14*2'*32'/4 = 200 arcmin in square. The cross-section of sky motion will be under the positional angle ~60 deg. Three beams of antenna WS in the angular scale 8'*25' for each are given in ***Fig2.***

We observe a strip of the sky (~600 degrees in sq.) due to the Earth motion per day. The strip of the survey is shown in the Galactic coordinates in ***Fig3***. The strip reaches the Galactic North pole regions at RA=12–13h.

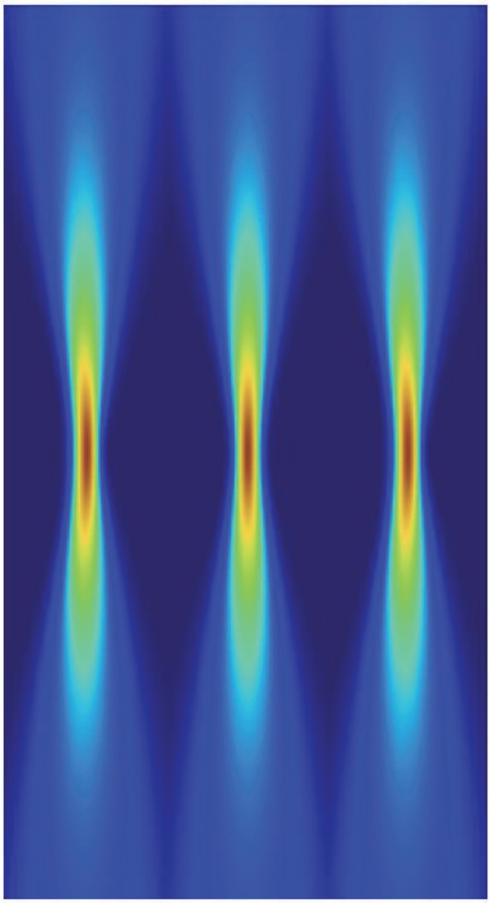

Fig2. *Three beams of the current survey, calculated with real parameters of antenna (h=52.36deg) and the secondary mirror N5 at wavelength 6.7 cm of the multi-channel radiometers.*

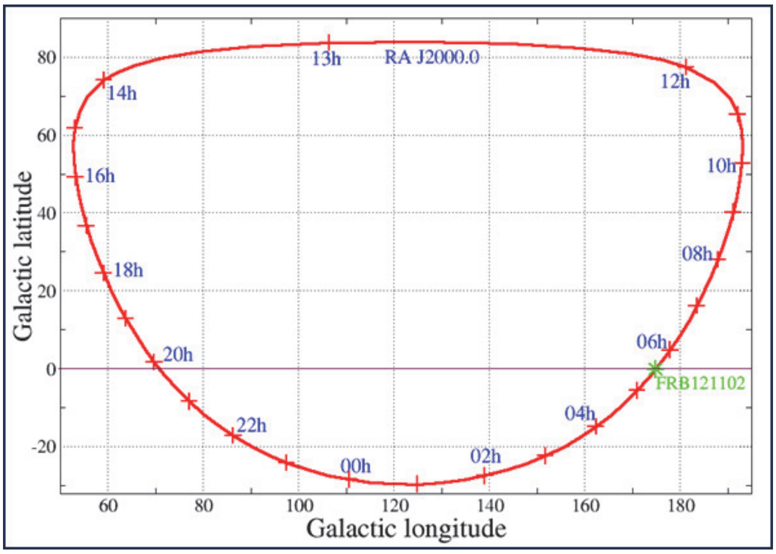

Fig3. *The strip of the pilot survey with the West sector of RATAN-600*

2.3. Some test results

In order to check the rapid data-sampling of the telescope data we carried out ten pilot observations of the bright pulsar PSR0329+54 (P=0.714s) with other wide-band radiometers (2.3, 4.6 and 11.2 GHz) on the “Southern Sector” antenna during the lower culmination of the source (***Fig4***). In each observation we have detected the 5-30 single pulses from pulsar at 2.3 and 4.6 GHz (***Fig5***) and even once at 11.2 GHz. We did not use any following for the source because the antenna was unmoved.

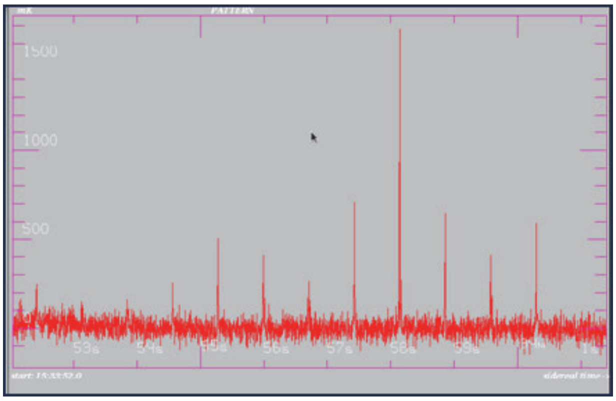

Fig4. *Drift scan of PSR0329+54 at 4.7 GHz*

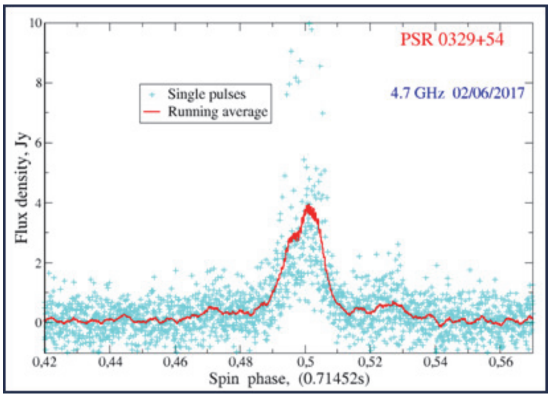

Fig5. *The mean pulse profile of PSR0329+54 at 4.7 GHz*

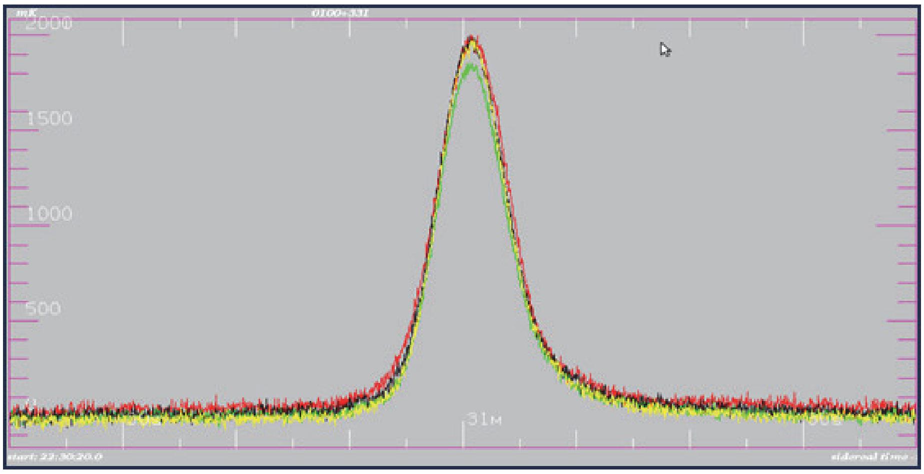

Fig6. *Scans of 3C48 (0137+33) at 4 subbands with sampling 50 ms*

We have detected very variable series of pulses day by day. Sometimes the fluxes in a pulse reached ~10 Jy at 4.6 GHz. We summed all detected pulsed to obtain the mean (from ~50) profile and they are in good accordance with the studies of the PSR0329+54. De-dispersion could be provided by the analysis of the arrival times of a pulse at four narrow subbans. Using the usual formula for $deltaT = 4.15 \cdot 10^6 \, (1/f_1^2 - 1/f_2^2)$ DM we can estimate the delectability of the dispersed signals. For MD = 300 pc/cc the dt will be about 3-4 ms, what could be measured with given complex. Sure we consider signals with deltaT =0 as a local interference or satellites on the Earth orbits.

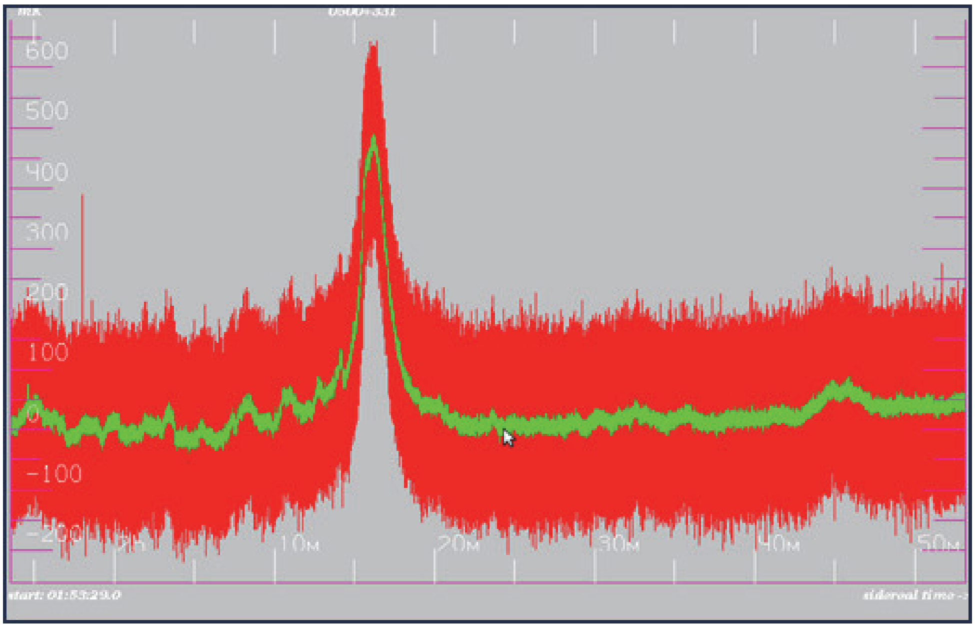

Fig7. *Mean (from 9) scan of the RA:5th hour of the survey. This is a cross-section of the Galactic plane. The pointer is shown the location FRB121102.*

During September - November 2017 we have done more than 70 full daily scans with the three-beam system. The post-data-reduction showed that the night time is most favorable in terms of absence of interference. Most of day-time interference could be easy recognize in the multi-channel observations. The realized sensitivity of the complex is close to 0.6 Jy per a sub-channel for the sampling dt =0.49 ms. For flux density calibration and antenna pointing we have used the known source 0137+33 (3C48) (***Fig6***). We did not detect any signals with high dispersion. The mean scan of during RA (J2000) =5h for 9 the sequential days in November 2017 with original sampling 0.49 ms and compressed to 4.9 ms are shown in ***Fig7***.

3. Conclusion

The search of the FRBs with RATAN-600 radio telescope could be important new field of the rapid radio photometry. We carry out the continuing survey and prepare the real-time data-processing in order to announce about FRB just after its detection. In 2018 we will use new robotic optical telescope near of BTA telescope in order to search for any association with FRB, because the coordinate errors of the RATAN detection will be compatible with beam sizes or about 2x30 arc min. While we concede Parkes telescope in FOV we hope to detect a few of FRB per year. The higher frequency (4.7 GHz vs 1.4 GHz) could be important feature of the current survey, because probably some FRB (FRB121102) has the maximal fluxes at frequency higher 6 GHz [5]. On other side if results of the project will be positive, we will strive to increase the number of the beams or the operating frequencies.

Acknowledgements

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