FRATs: a search for Fast Radio Transients with LOFAR

S. ter Veen, H. Falcke, R. Fender, J. R. Hörandel, C. W. James et al.

Citation: *AIP Conf. Proc.* **1357**, 331 (2011); doi: 10.1063/1.3615150

View online: <http://dx.doi.org/10.1063/1.3615150>

View Table of Contents: <http://proceedings.aip.org/dbt/dbt.jsp?KEY=APCPCS&Volume=1357&Issue=1>

Published by the [American Institute of Physics](#).

Related Articles

An absolute cryogenic calibration source for a 2.5 GHz radiometer

Rev. Sci. Instrum. **66**, 4798 (1995)

Linear polarization and the effects of metal reflectors used to redirect the beam in microwave radiometers

Rev. Sci. Instrum. **65**, 2667 (1994)

A 492 GHz quasioptical SIS receiver for submillimeter astronomy

Rev. Sci. Instrum. **65**, 1833 (1994)

A 94 GHz differential radiometer for observations of diffuse sky emission

Rev. Sci. Instrum. **62**, 1293 (1991)

Additional information on AIP Conf. Proc.

Journal Homepage: <http://proceedings.aip.org/>

Journal Information: http://proceedings.aip.org/about/about_the_proceedings

Top downloads: http://proceedings.aip.org/dbt/most_downloaded.jsp?KEY=APCPCS

Information for Authors: http://proceedings.aip.org/authors/information_for_authors

ADVERTISEMENT

Submit Now

Explore AIP's new open-access journal

- **Article-level metrics
now available**
- **Join the conversation!
Rate & comment on articles**

FRATs: a search for Fast Radio Transients with LOFAR

S. ter Veen^{*}, H. Falcke^{*,†}, R. Fender^{**}, J.R. Hörandel^{*}, C.W. James^{*}, S. Rawlings[‡], P. Schellart^{*}, B. Stappers[§], R. Wijers[¶], M. Wise[†] and P. Zarka^{||}

^{*}*Department of Astrophysics/IMAPP Radboud University Nijmegen, P.O. Box 9010 6500 GL Nijmegen The Netherlands*

[†]*ASTRON, Dwingeloo, The Netherlands*

^{**}*University of Southampton (School of Physics & Astronomy)*

[‡]*Oxford University*

[§]*University of Manchester (School of Physics & Astronomy)*

[¶]*University of Amsterdam*

^{||}*Observatoire de Paris (LESIA)*

Abstract. The FRATs project aims to detect single dispersed pulses from Fast Radio Transients with LOFAR in real-time. These pulses can originate from pulsars, RRATS and other classes of known or unknown objects. To detect these pulses a detection algorithm is being run on an incoherent beam from the different LOFAR stations. This incoherent beam has a wide field of view and can be formed parallel to other observations, such that both can run at the same time. A precise localisation is done by storing the data from each dipole. This gives an all-sky coverage with a spatial resolution of order arc seconds. The source is identified by making high time-resolution images. This is explained in more detail with preliminary results illustrating the methods.

Keywords: Single pulse, Pulsar, RRATS, LOFAR, Radio Astronomy

PACS: 95.55.Jz, 97.60.Gb, 97.60.Jd

INTRODUCTION

There are two ways to search for pulsars. One is to use Fourier techniques to search for a repeating signal, the other is to look for single pulses. In the pioneering years, pulsars were found by looking for single pulses, but after that usually Fourier techniques were used, due to the higher sensitivity. In recent years also single pulse searches were performed again, which lead to the discovery of Rotating Radio Transients (RRATS) [1], pulses that repeat only occasionally. This leads to the question of what RRATS are and how many more of these objects are out there. Two possibilities connected with pulsars are that they are the giant pulses from far away normal pulsars, or almost dead nearby pulsars that only emit rarely. To detect these and other kinds of single pulses we develop a new real-time detection mode for LOFAR (the LOW Frequency Array) [2].

METHOD

The difficulty in detecting strong single pulses is that they only happen occasionally. Therefore a large instantaneous sky coverage and observing time are required. Also, when only a single pulse is found, one wants to be absolutely sure that it is from an

Radio Pulsars: An Astrophysical Key to Unlock the Secrets of the Universe
AIP Conf. Proc. 1357, 331-334 (2011); doi: 10.1063/1.3615150
© 2011 American Institute of Physics 978-0-7354-0915-6/\$30.00

astrophysical source and not of terrestrial origin. See for example the discussion [3] that followed the Lorimer burst [4]. Dispersion has to be corrected for as well.

LOFAR is a next generation telescope with a large scalability factor. Instead of using large dishes, it uses stations with fields of simple dipoles. The core of these stations is in the Netherlands, but there are also international stations in Germany, France, the United Kingdom and plans for stations in other countries. There are two types of dipoles, the Low Band Antennas (LBAs) that operate from 10–90 MHz and the High Band Antennas (HBAs) that operate from 110–240 MHz. The stations are placed on baselines from 100 m to 1000 km. There are three observation modes: imaging, beamforming and storing the data per dipole. The latter are stored in the ringbuffers in the Transient Buffer Boards (TBBs). With the current amount of memory 1.3 seconds at full resolution can be stored. Buffertime can be traded for bandwidth or sensitivity by storing data from fewer dipoles. If an interesting event is found, these buffers can be stopped and read out partially or completely. For this project we use both the beamforming mode and the TBB data.

The beamforming mode consists of two stages. To form a beam, the different elements (dipoles or station beams) are added with a time delay corresponding to the observing direction. This results in high time-resolution data. First a beam is formed at the station level by adding the dipoles in each station. Then from different stations these station beams can be combined in a coherent (added in phase, small FoV, high sensitivity) or incoherent (added in power, large FoV, lower sensitivity) way. We use the incoherent mode, for a large field of view (10.3/sq. deg. at 150 MHz), and do this in parallel to running observations, to obtain a maximum observing time. For the incoherent mode, the sensitivity is described as

$$\Delta S = \frac{S_{sys}}{\sqrt{2N_{st}\Delta\nu\Delta t}}, \quad (1)$$

in which ΔS is the beam sensitivity (1σ level), S_{sys} is the System Equivalent Flux Density N_{st} is the number of stations, $\Delta\nu$ is the bandwidth and Δt the time integration. The factor of 2 is due to summing both polarizations. For a Dutch LOFAR station at 150 MHz is $S_{sys} = 1.4$ kJy. Using 36 stations with a bandwidth $\Delta\nu$ of 1 MHz, and an integration time of 1.3 ms, ΔS becomes 5 Jy. At a trigger threshold of 5σ pulses above 25 Jy can be detected. However, note that the peak flux density is averaged over the time integration. If the actual signal is shorter, the relative noise level increases. More information about the sensitivity can be found in [2].

The beamformed data consists of a dynamic spectrum with a high frequency resolution (700 Hz–12 kHz). The current trigger algorithm works on several frequency bands ($\sim$ MHz bandwidth). It incoherently dedisperses the data in each band for several dispersion measures (DM) and checks for peaks, using a simple $P > S_{sys} + N * \Delta S$ algorithm, where P is the power of the signal, S_{sys} is calculated by taking the mean and ΔS by taking the standard deviation of the dedispersed dynamic spectrum data. Then it checks for a coincidence between peaks found in the different bands that corresponds to a delay for the given DM (Fig. 1). If such an event is found, a signal is sent to obtain the TBB data. There are currently two ways to distinguish a real signal from Radio Frequency Interference (RFI). A real signal should appear in more than one band simultaneously and it should not trigger the DM = 0 signal.

FIGURE 1. A pulse from the Crab pulsar, dedispersed in each of 4 frequency bands. The signal arrives later in the lower frequency bands. This time delay between the different pulses is caused by dispersion. The ordering in the legend from top to bottom is the same as in the figure.

The TBB data is the lowest data form, the raw time-domain voltages from each dipole. It contains all the information that LOFAR has about any signal, with which new beams can be formed in any direction and also in the near-field. Near-field beamforming is used to study cosmic ray air showers and lightning and is also used to discriminate against terrestrial signals for this project. To analyse where the pulse came from, first incoherent beams are formed in all directions to check whether the pulse originated from the pointing direction or a sidelobe. Then in the actual direction of the pulse coherent beams are formed to find the precise location.

PRELIMINARY RESULTS

In October 2009 the first real-time trigger on the Crab Pulsar was performed and 4 giant pulses were detected. In the next year single pulses from several other pulsars were found. Fig. 2 shows a pulse imaged using TBB data from 4 November 2010. The current delay is around 2 seconds. At full spectral resolution and sensitivity the buffer length is 1.3 seconds. Therefore the signal that was triggered on is not in the buffers anymore. However because the pulses are dispersed, if the DM value is not too low, the pulse can still be found in the buffer at a lower frequency. It is possible to increase the bufferlength

FIGURE 2. A dedispersed image in the direction of the Crab pulsar, before, during and after the pulse, made from the Transient Buffer Board data. This is with only one LOFAR station, hence the low resolution.

by storing fewer dipoles or less bandwidth or by increasing the memory in the TBBs.

CONCLUSION

With LOFAR a real-time search for Fast Radio Transients is feasible. By using an incoherent beam, parallel to other observations, a large sky and time coverage is obtained. To detect a more accurate direction and discriminate against RFI the raw data from each simple dipole is obtained and analyzed. A prototype of this pipeline ran successfully, proving the concept, and resulting in a movie from one giant pulse from the Crab Pulsar. The next step is to implement this in the LOFAR framework to have it run automatically.

REFERENCES

1. M. A. McLaughlin, A. G. Lyne, D. R. Lorimer, M. Kramer, A. J. Faulkner, R. N. Manchester, J. M. Cordes, F. Camilo, A. Possenti, I. H. Stairs, G. Hobbs, N. D'Amico, M. Burgay, and J. T. O'Brien, *Nature* **439**, 817–820 (2006).
2. M. de Vos, A. Gunst, and R. Nijboer, *Proceedings of the IEEE, Special Issue Advances in Radio Telescopes* **97**, 1431–1437 (2009).
3. S. Burke-Spolaor, M. Bailes, R. Ekers, J. Macquart, and F. Crawford, III, *ApJ Letters* **727**, 18 (2011).
4. D. R. Lorimer, M. Bailes, M. A. McLaughlin, D. J. Narkevic, and F. Crawford, *Science* **318**, 777 (2007).