A low cost Pulsar Machine

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A pulsar machine (or pulsar detection system) is used at many of the large radio observatories around the world. Some of these pulsar machines are well known for the work that has been done such as the Penn State Pulsar Machine at Arecibo. Others are just coming on line, such as PuMa, located in the Netherlands. This paper presents a low cost Pulsar Machine for use at smaller observatories just entering the field of pulsar research.

Why Study Pulsars?

Why would any one want to study pulsars? They are for the most part very distant objects that can be seen only with large telescopes (radio or optical). What effect could these possibly have on us? Questions I am often asked.   A pulsar, for it's size, around 10 to 20 km in diameter (6 to 12 miles) is one of the most energetic objects in the universe. It is literally a physics laboratory in space. Reference 1 has additional information pulsars.

Now let's apply this to one of our most pressing problems today - clean, efficient, low cost energy. The study of these objects could lead us to a much more efficient source of power. Maybe a tiny pulsar in a shoe box that can power you car and never needs refueling that is so strong that, when your car wears out, you just unplug it and put it in you new car. Speculation? Yes it is, but we will never find these new sources unless we look, and I believe that pulsars may be the right place to look.

What is a Pulsar Machine?

A radio telescope has several parts. The antenna, which collects the signal, a low noise amplifier (LNA) that amplifies the signal, the receiver (or converter) that converts the signal to a lower (or intermediate frequency), and finally, the backend which converts the intermediate frequency to some type of audio signal. A pulsar machine (or pulsar backend) is an additional piece of equipment that attaches to the radio telescope and provides additional processing to allow the detection of pulsars. A pulsar machine may generally be defined as hardware and/or software that allows the detection of pulsars.

Past Pulsar Machines

Pulsar machines have been developed at Pennsylvania Statue University as well as Berkeley Caltech for almost 30 years. They are deployed at the major observatories around the world. Reference 3 has additional information on some of early pulsar machines.

Current Pulsar Machines

One of newest is the PuMa Westerbrok Synthesis Radio Telescope in the Netherlands. There are also major Pulsar Machine at Green Bank and Arecibo.

Pulsar Machines for the Amateur Radio Astronomer:
There have been several efforts by amateur radio astronomers to build such machines. For some of us, the detection of pulsars is the "Quest for the Holy Grail" of amateur radio astronomy. There are a number of notable efforts:
- James C. Carroll (A Post Detector Pulsar Extractor – SARA Paper)
- Robert M. Sickels (Pulse Catcher – SARA Paper)

Current Amateur Radio Astronomy Pulsars efforts (including the author):
- P. Ibelings and M. Wheatley at the PARI Observatory.
- Jim Van Prooyen and Rich Nagel at the Grand Rapids Radio Observatory.

The low cost Pulsar Machine
The design of the pulsar machine involved a number of design trade-offs to arrive at a system that was low cost and usable with a small radio telescope. The parameters that were studied in the design included:
- Observation frequency
- Analog vs. Digital electronics
- Band width
- Dispersion issues
- Algorithms for processing the data
- Filter design
- Search methods
- Low Cost Processing Technologies

Observation Frequency
The selection of an observation frequency presents a unique set of problems for the amateur radio astronomers. The issues include:
1. More signal to work with at the lower frequencies.
2. Less distortion of the signal at higher frequencies.
3. Equipment costs are less at the lower frequencies.
4. Much more gain for a given size dish antenna at higher frequencies.

There is no one good choice, pulsars have been observed at frequencies from a few megahertz to the high gigahertz.

Analog vs. Digital
The first pulsar machines had a large number of analog signal processing elements. Today most of this is done using digital technology. In general a digital system will have a lower cost of acquisition then analog systems.

Wide Band vs. Narrow Band
Many pulsar machines use wide bands, and it makes sense from a systems view. The more signal you can put into the system, the greater the sensitivity. Some are as wide as 100 MHz. But there are problems here, such as how you are going to digitize a wide signal band and keep the cost under control. The other problem is interference from other sources, when you are not observing in a radio quite zone. We use a narrow band approach to the problem. This allows us to keep the cost very low and it keeps out the

local radio and TV stations. However, this has a cost in that it we need to observe for a long period of time before we see a detection. Generally, one hour of observation is used to make sure we have the data needed for a detection.

The Dispersion Issue

The narrow band approach means that dispersion is not an issue. We use a bandwidth of 75 kHz. We are currently studying bandwidths of only 30 kHz for the next generation receiver. This receiver front end will be build by Radio Astronomy Supplies some time in the winter of 2008/2009.

Fast Folding Algorithm (FFA)

This is a computer algorithm that is the heart of the system. It allows for the detection of periodic events within time series data. The algorithm was developed by David H. Staelin in 1969. References 4 and 5 have additional information on the development of the FFA.

Filter Design

The pulsar machine has a filter that processes data after the FFA. The filter is unique to this pulsar engine. It is called a Jakeway filter, named to honor Jarry Jakeway, who was my mentor during its design in 2002/2003. This is an efficient recursive filter for use with noisy data sets.

Search Methods

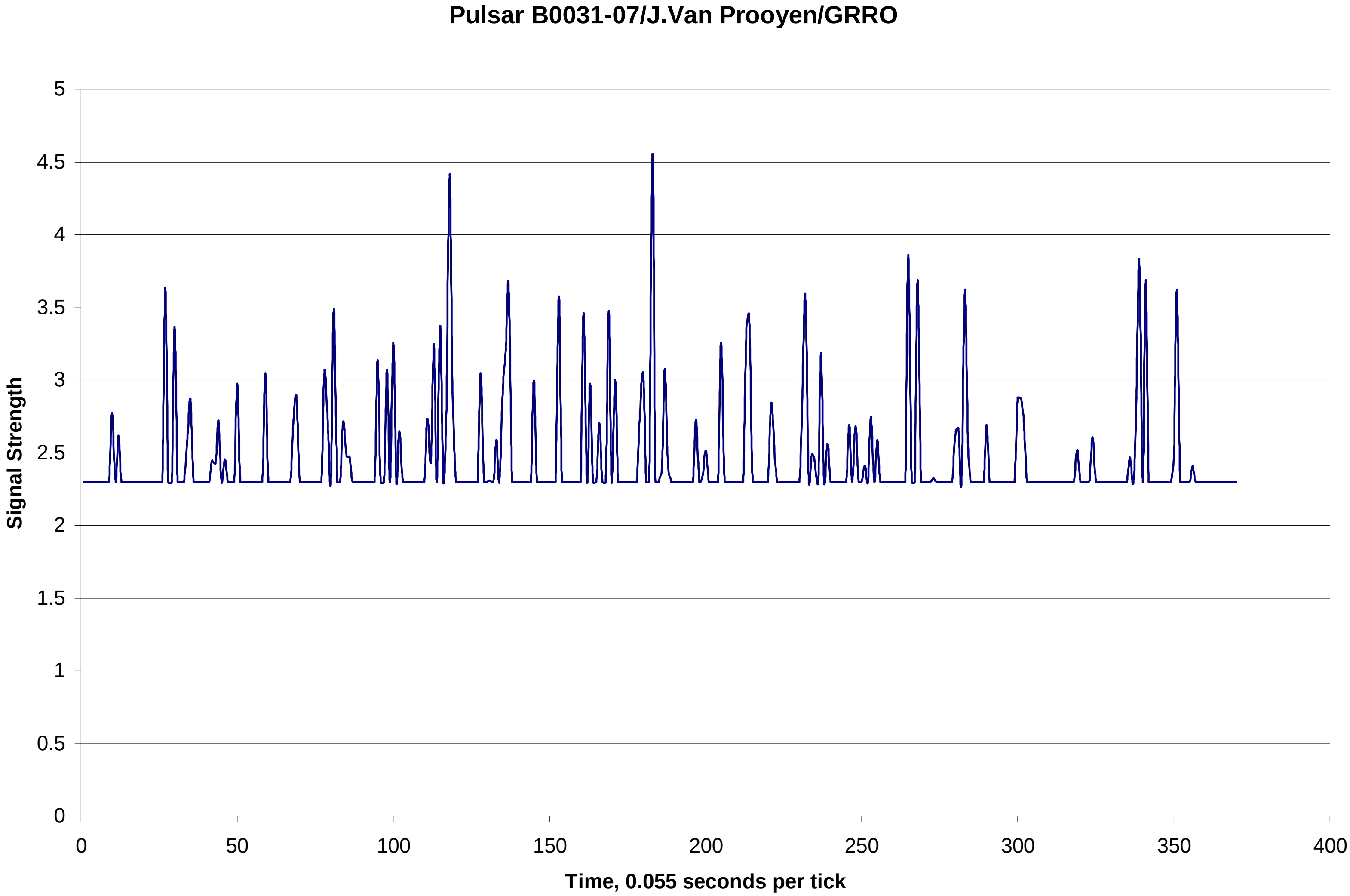
The pulsar machine supports two search methods, targeted and non-targeted. The targeted search has been fully developed and is optional. The non-targeted processing of the pulsar machine will be the subject of future papers. It will use a Parameter Space Search Algorithm (PSSA) that is still under development. This version of the Pulsar engine will require the use of advanced computer technologies that are now available, such as Beowulf, GPU's, and other Parallel Processor technologies.

Deployment of the Pulsar Engine

One of the major issues has been how to deploy the Pulsar Engine (i.e. put it in to use by other members of SARA). Due to the fact that it is still under almost continuous development and the regulations on use of such technology (ITAR), we have arrived at the following model for it use:

- Members of SARA may send observations to an FTP server for processing by the Pulsar Engine. Data sent to the FTP server must be in one of the supported data formats. There will be more information on this in the SARA Journal some time this Fall.
- Processing produces histograms, using of MS Excel or JPG files and will be posted to the FTP server for downloading. This processing may take anywhere from 24 to 48 hours for turnaround.

The following is a example of the output from the Pulsar Engine:



Summary of the observation histogram of pulsar B0031-07 pictured above:
This is a pulsar with a period of 0.9429509945998 seconds. This pulsar has three modes of drifting sub pulses. This can be seen between index 95, and 103, (on the x-axis) and again between 161, and 172. It also produces giant pulses approximately once in 800 periods (~ 754.3608 seconds). Due to the folding of the data over an observation period of 3600 seconds there should be several giant pulses visible in the plot, this is supported by the data at index 118 and 183 (on the x-axis).

Conclusion

The study of pulsars is fascinating and do-able for the amateur astronomer. And, being incredible energy-producers for their size, they may have implications for energy production on our own planet in the future. In this paper, the reader has been brought up-to-date with current work and given a glimpse of the future in the study of Pulsars. If you have a radio telescope and would like to be part of the project please send an e-mail to me at grro1@dnx.net.

References

1- Neutron Star Description, this is what a pulsar is.
http://en.wikipedia.org/wiki/Neutron_star

2 - Handbook of Pulsar Astronomy, this is hand down the best book on pulsar astronomy I have ever seen, it also talk about many of the detection methods.
ISBN0-521-82823-6
http://www.jb.man.ac.uk/pulsarhandbook

3 - Back-Ends - J. R. Fisher, a good paper on pulsar back end at several of the major observatories around the world.
http://articles.adsabs.harvard.edu/full/2002ASPC..278..113F

4 - David H. Staelin. Fast Folding Algorithm for Detection of Periodic Pulse Trains. *Proceedings of the IEEE*, 57 (1969).

5 - R. V. E. Lovelace, J. M. Sutton and E. E. Salpeter. Digital Search Methods for Pulsars. *Nature* 222, 231-233 (1969).

Web Pages related to Amateur Pulsar work:

Amateur Pulsar Observation of P. Ibelings and M. Wheatley
http://www.moetronix.com/pulsar/index.htm