Okanagan Observatory
Radio Astronomy

RAdius

January 2012

FIRST LIGHT!

by Hugh Pett

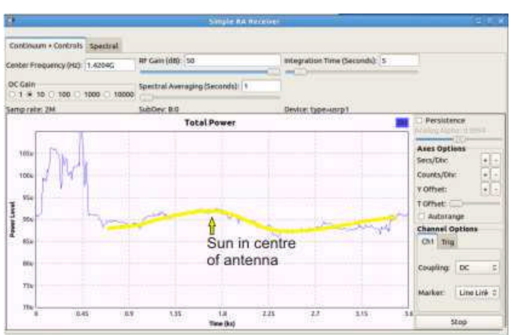
In some ways, it seems so far from August last year, when the first issue of RAdius appeared. In months, it has been nothing exceptional; in results it is middling distance. But in variety of effort it has been a long and torturous journey. Not only did I have to learn a completely new (for me) computer environment (Linux), complete with rules vastly different from any I had used before, but I had to dredge up knowledge and skills from more than 50 years ago (such as how to tap holes for bolts.)

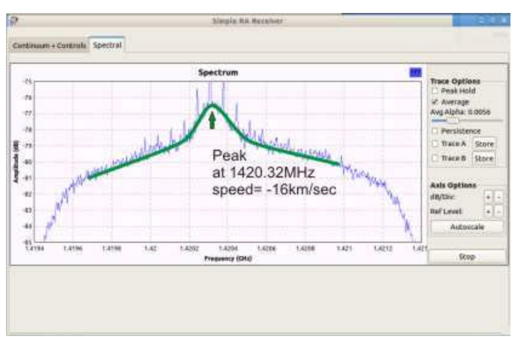
There were many willing to encourage me along this path, and offer assistance, advice and tools. One in particular (recommended to me by Ken Tapping) requires special mention: Marcus Leech. It turns out that Marcus earns some pocket money developing and selling software for amateur radio astronomers, and helps many people around the world learn about the intricacies of SDR - Software Defined Radio. Most professional radio astronomy today requires extensive use of digital techniques for processing the incredibly weak signals from the heavens.

Marcus has been willing to bear with me as I stumble along the path (and regularly fall into the swamps at the side of the road) to learning about SDR, FFT, GNURadio, Ubuntu, and numerous other tools of the radio astronomer today.

Months of sporadic work, frustration, fascination, and fun culminated on January 5, 2012, with my first observations of radio signals that may be from beyond Earth: one from the Sun, another from an unknown source.

This issue of RAdius will detail the steps and equipment used to receive those first signals. Here, in two simple images, is the face of my "First Light" experience:



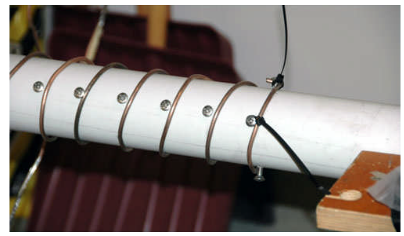


Not so impressive at first glance, but the result of much work and not a little fear that results might have been a long time coming.
These images are described in detail later in this issue.

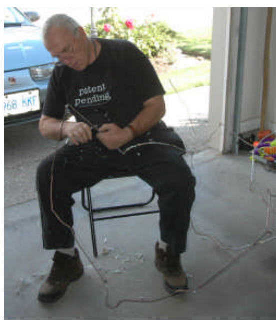
Some of the Steps and Activities

Having begun the process of learning the computer system and software game, it was time to build an actual telescope. For a variety of reasons, but mostly because it seemed within my cluster of capabilities, a helical antenna took shape over the Fall of 2011.

Helical antennas have one huge redeeming quality: they are very forgiving of construction inaccuracies. For me, not particularly good at precision work, this made a BIG difference. The tradeoff is, as so often, that you end up looking at quite a bit of the sky, which means that a signal of interest has to compete with a bunch of crud that has no redeeming value. The term used is "half-power beam width", which in very rough terms means you are looking through a cone from the point, at a patch of sky. The angle of the apex of the cone is the half-power beam width. Antennas have a similar effect to the "fuzziness" around a point object like a star - the light is spread out by various processes, falling off from the centre in a sort of series of waves. An antenna has the same thing, called "side lobes", which mean you may "see" a signal you are not pointing anywhere near to.



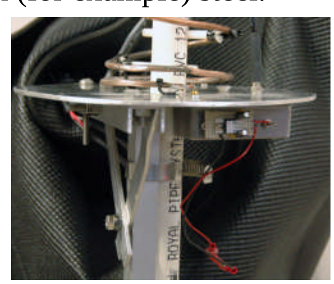
Still, helical antenna it was to be. A number of steps were needed, including making jigs and templates to wind the helix. The material for the helix has to be more than a thin wire, and Mervin provided some copper pipe out of a refrigerator cooling coil. This proved to be very difficult to straighten out, but it was quite good for winding.



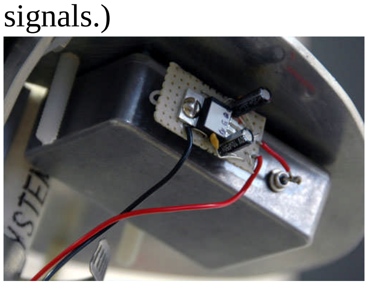
Suggestions from Ken and Marcus made me use plastic cable ties, rather than the copper wire in my prototype antenna, to hold the helix in place. Even though the geometry is forgiving, there are a few requirements on the dimensions and placement.

The helix by itself is bi-directional, it literally does not know which end is "up". To tell it, you must put a flat "ground" at one end - the other end is then "up". You could do it as easily as sticking one end in the (moist) ground, but then you could observe only straight up - rather limited. The solution is to place a metal plate (the "ground plane") at one end, and make sure that it is connected to whatever passes for an electrical ground in the system.

Making the ground plane was fairly straightforward, once I confirmed that my ancient jig saw with a metal-cutting blade would do nicely on the 1/8" aluminum sheet I found at Knox Mountain Metals. I already had a hole saw for the centre hole, and aluminum is a lot easier to work than (for example) steel.

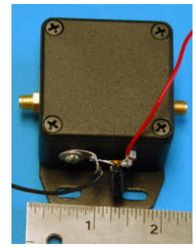


The trick was to make the mechanical connection between the helix and its central support, and the ground plane, and also provide a means of attaching the assembled pieces to a heavy-duty tripod I have had lying around for many years (obviously just waiting for this project!) This took the most think-time, but in the end it has worked out very well, being both rigid and easily altered or disassembled when needed (such as adding the radio amplifiers that select the desired band of signals.)



Along the way, I built a tiny power supply for the LNA (Low Noise Amplifier) Marcus supplied (he builds them for people like me that are afraid of trying it on their own, and sells them at a very reasonable price. He has a day-job as well. Check out his website: http://www.science-radio-labs.com/, and his passion: http://www.sbrac.org/) As Eric mentioned in his talk to the Okanagan Centre Annual Meeting last November, the total power received by every radio telescope ever made is not enough to light even a tiny light bulb for a tiny fraction of a second - these signals are WEAK!

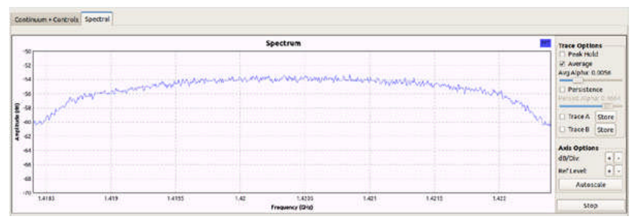
And there are lots of things that make a lot more noise than the signals we are looking for; one of the worst is the electronics in a typical radio receiver, which although it may SEEM quiet actually has a lot of noise coming out the end. In order to hear the weak signals, they must be boosted (amplified) WITHOUT adding a lot more noise - a "Low-Noise" amplifier.



If the antenna is a long way from the receiver, a further boost is needed, and Rod Stuart built me two such amplifiers. He used to do that sort of thing at D.R.A.O. before he retired.

Finally, we get to the receiver, a not-very-impressive box about 8" x 7" x 2", with no knobs, no lights, and not much inside except a fan and a couple of small electronic circuit boards.(http://www.ettus.com/products)

But the box does magic, taking the weak signals from the antenna, and changing them into millions of numbers every second. The numbers give the details about the strength of the signal at thousands of very-nearly-the-same frequencies, covering in my case 2MegaHertz of the radio spectrum. The 2MHz is centred on 1420.4MHz, the frequency of a hyperfine transition in neutral hydrogen (the H1 radio line), which happens to be the most common element in the universe. So there are LOTs of places to point the antennas of radio telescopes - almost anywhere in the sky, in fact. Of course, most of those directions have very weak signals, far weaker than I will ever detect with this helical antenna.



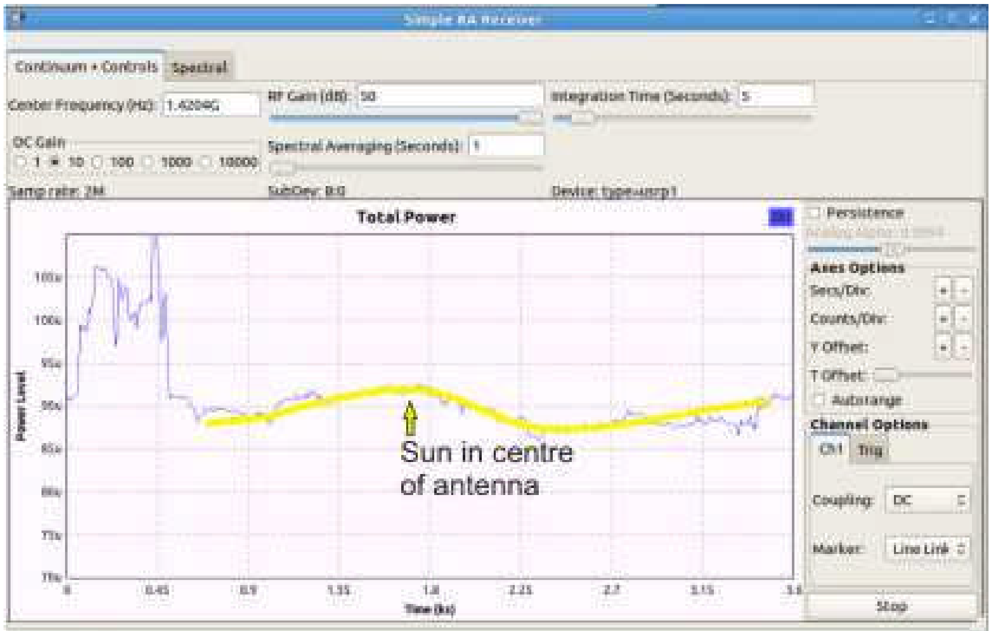
The final stage is processing by the most powerful desktop computer I could afford, a 3.3GHz, 6-core, 8GB RAM beast. (Also note the nice tidy work area!) The above display shows the result of pointing where there is NO signal at 1420MHz, at least that I can detect.

Once a signal appears on the displays (power, and frequency), it is time to compute other numbers, such as how strong the signal is in terms other astronomers can relate to. This system will not allow that, for a while at least. The signals are just barely stronger than the all-pervasive noise from the circuitry, and going beyond the fact of observation into measuring a precise amount will take more equipment, more computer processing, and a LOT more learning on my part!

Accomplished to date

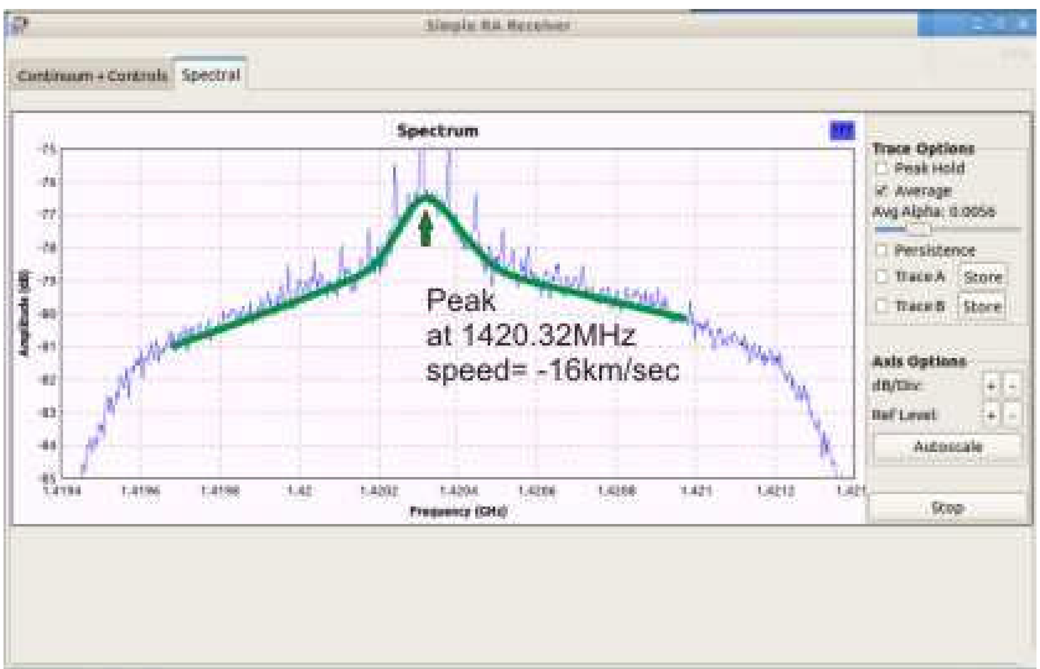
June/July:	acceptance by the Observatory Working Group of the concept of a radio telescope at the Okanagan Observatory
ultimate goal established:	a dual-dish radio interferometer, operating at H1 frequency (1420MHz), fully tracking in azimuth and elevation
initial hardware acquired:	a super-microcomputer, 6-core AMD 3.33GHz processor, 8GB RAM; USRP1 radio receiver from Ettus Research (www.ettus.com)
software acquired:	radio astronomy computation and display; authoring tools for software-defined radios
first antenna:	20-turn helix, on the simple mount (December 2011)
hardware:	two Low-Noise Amplifiers (LNAs) (July 2011) two additional amplifiers for long cable runs (December 2011)
simple mount:	for helical antennas, allowing pointing in azimuth and elevation (January 2012)
first real signal:	January 5, 2012 - a clear "bump" as the Sun moved through the reception pattern of the helix antenna; a possible "spectrum" from an unknown Galactic source

The First Signals



I was using the antenna in "drift" mode, in which it is pointed in one direction, and the Earth rotates it across the sky. This graph resulted (I have added the yellow line to show more clearly an approximate average of the strength of the signal), and the slight mound occurred when the antenna was pointed at the Sun. While I watched the end of that hump, the signal suddenly spiked much higher (stronger), looking like a butte in the Arizona desert. (NOTE: left is most-recent)

It took me a minute or two to realize this was not normal, and I flipped to the other display, showing the strength of a thousand "channels" (frequencies) centred around that for the hydrogen H1 emissions.



This is what greeted me; actually, the first view had a peak about half as high, and the size increased for about 3 or 4 minutes to this size. (green line added to show approximate average) Those of you with some mathematics in your background will notice this peak looks a lot like a curve called "standard deviation" in statistics, and more specifically a "Gaussian" for the mathematician that described it.

This is the sort of curve that comes from neutral hydrogen along the Galactic plane, and from "hot spots" elsewhere; it was what I had hoped to find eventually.

The simple fact of seeing a Gaussian near the expected frequency is not enough to prove it came from a Galactic source - the possibility of radio interference from an Earthly source is always there. The fact it grew slowly, over minutes, then faded, is interesting, but again not conclusive.

I computed the Doppler shift of the peak, assuming it was an H1 emission, and it turned out to be what would happen if (say) a cloud of hydrogen were moving away from the Earth at 16km/second. This speed is common in the Galactic plane. Although tentative, this observation is an intriguing glimpse into what may lie ahead.

What Comes Next?

I have a lot to learn about the computer end of things, from basic Digital Signal Processing, to more Linux operating system, to software that will plot more-complex curves, as well as more equipment such as noise calibration circuits.

In terms of major steps, the original five-year plan is still a pretty good guideline. The next step could either be a second helix antenna, allowing an interferometer antenna system; or a very simple helix to put at the focus of the 10-foot dish (sitting beside the helix in my garage right now.) Since moving the 10-foot dish in and out of the garage is a half-hour job, and for the double-helix about 5 minutes, I'll try the double-helix first!

The steps ahead - the five-year roadmap

Some things are still to come

Construction projects:

- second helical antenna, to record interference patterns from the Sun, and possibly other sources (Spring 2012)
- single dish, fixed azimuth, local control of elevation (Summer 2012)
- dual dish, fixed azimuth, local control of elevation (Summer 2013)
- single dish, Az-El mount with .2deg pointing accuracy (Summer 2014)
- dual dish, Az-El mount with .2deg pointing accuracy (Summer 2015)
- Internet access to telescope operation (Summer 2012 through Summer 2016)

Presentations:

- noise from the Sun (Summer 2012)
- interferometer patterns from the Sun (Fall 2012)
- interferometer patterns from a few strong non-Solar sources (Winter 2012)
- Internet presentations (remote operation) (Winter 2012)

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If you are seeing RAdius for the first time, and would like to receive future issues, please email me and let me know where to send them.