Okanagan Observatory
Radio Astronomy

RAdius

October 2012

Many Steps, mostly forward!

by Hugh Pett

Finally, more word on the radio astronomy project at the Okanagan Observatory - sorry for the long hiatus.

After some considerable excitement last January, with what looked like real radio signals from the Sun, further observing did not confirm the observations. In terms of the science, the experiment did not replicate very well. The apparent Gaussian distribution disappeared, never to return, and the slow noise bumps as the Sun transited the antenna could have been due to changes in the low-noise amplifier as the Sun's heat changed its temperature.

For no particular reason, I have still not made the double-helix antenna, for use in an interferometer. I expect it may be early next year before that happens, since I will not have much time to devote to it now before the Christmas season.

Okay, there is the sort of negative stuff out of the way. On to the piles of positive happenings!

One of the most important aspects of any science endeavour is to get the overall concept straight, so that there is a reasonably clear idea where it is all heading. After having some more fun with the theory of radio interferometers, Chris Purton again came up with an expanded treatise this year. This is still pretty heavy going for me, but more parts of it are clicking into place in this gap between my ears.

With this issue, I am adding another information dimension to the newsletter, in the form of Web references to additional details. The first item in this process is Chris' latest effort, which is a .PDF you can download by simply accessing it here:

http://mypage.uniserve.com/~hipett/radio_interferometer-Purton-120729.pdf

One of my character flaws (noted as early as High School by at least one teacher who would continually ask me "Are you still spreading yourself too thinly!?") is exactly that, I tend to operate like a shotgun, not a rifle. That is abundantly true in the past 8 months, as numerous issues, problems, opportunities and just plain fun things caught my attention.

What follows for the rest of this newsletter is some detail on various shotgun pellets. As always, your comments are welcome on any or all of them.

Enjoy!

Pointing a 10-foot dish antenna accurately

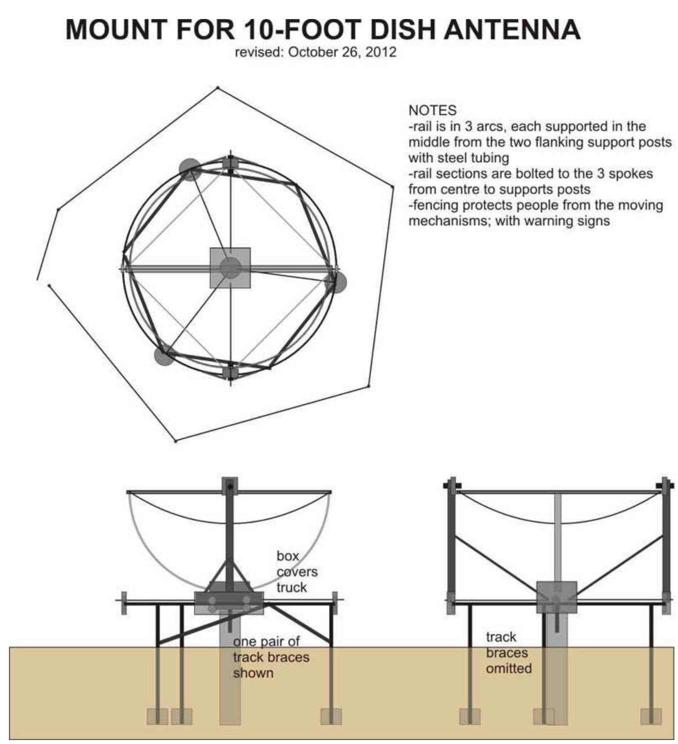
An early discussion with Ken Tapping pointed out to me that to make sure observations are accurate enough, an antenna must be pointed at least as accurately (in degrees) as 1/10th of a "beam width". Radio is not exactly comparable to optical astronomy in this respect, but it is a little bit like how well you can resolve a close binary pair - the bigger the telescope, the better you can distinguish two objects. In the case of a radio telescope, a very narrow beam means that you can distinguish two radio sources better; and of course the bigger the radio telescope, the more separate objects you can locate.

A 10-foot dish receiving a hydrogen-line signal at 1.421GHz has a beam width of about 5 degrees. 1/10th of that is half a degree, which I interpret as + or - 0.25degree. It does not take much advanced math to see that there are 1420 quarter-degrees in a circle; a 10-foot diameter circle is about 380 inches, so the pointing has to be +/- 380/1420 or 0.25 inch. Since I look forward some day to employing higher observing frequencies, I chose a design criterion of +/- 0.1inch for pointing, in both Azimuth (Az) and Elevation (El). The antennas are Az-El rather than polar aligned, since in general it is easier to build. There are good reasons why large optical telescopes use polar alignment, especially for photography, but they don't apply the same way to simple radio telescopes.

I started talking to people about how to achieve the desired pointing accuracy, at a reasonable cost. At one point the name "Jodrell Bank" popped into my head, and a quick Internet check confirmed my recollections - it has a basically simple Az-El design, using a horizontal circular track as a base, and a swivel mount for the elevation (http://www.jb.man.ac.uk/). I figured this could be scaled down fairly easily to something suitable for this project.

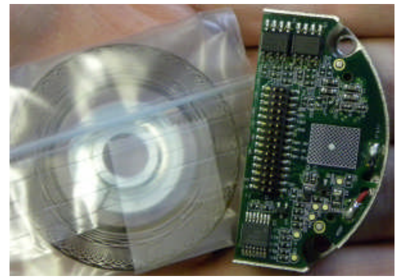
Advantages to this design are several, but a key one is that there is no super-strength point needed, where a great deal of weight would be concentrated in a small area. That means much lighter supports are possible, and much smaller drive motors with simpler gearing - all ways to reduce costs. It also has the attractive feature of being able to use off-the-shelf components such as the 12VDC automobile seat motor I found at Princess Auto for $10 (plus $50 for motor control hardware)! An inexpensive highly-reliable geared motor with control hardware costs more than $400, and range very much higher than that. I decided that being able to easily (and inexpensively) replace components like motors was more important than having them last for 20 years.

If you have ever installed or taken down one of the 10-foot dish antennas for TV reception (such as I am using), you know that 80% of the weight is in heavy steel frames etc., attached at the centre of the dish. This is required because that is the weight concentration point, and things need to withstand tons of torque.



I drew up my Jodrell Bank ideas (ref: http://mypage.uniserve.com/~hipett/mount-for-10ft-dish.jpg) to show around, first to my mechanical engineering friend at UBCO, and then to others. Roland Oliynyk took an especial interest, and offered to work on the mount design with me. He has since enlisted an Okanagan College colleague to work on it as well. Roland figures that the shops at the College should have no trouble producing the mount components; I sure hope so, that would be a wonderful boost for the project!

Just measuring angles to a small fraction of a degree is a challenge, and doing so repeatably by remote control (another design feature) is a greater one. Fortunately, the component for such measurements, an "absolute shaft encoder", can be assembled from a couple of $50 pieces (ref: http://mypage.uniserve.com/~hipett/Avago-absolute-shaft-encoder.pdf electronics, and an encoder wheel), and connected to a control computer.



absolute shaft encoder

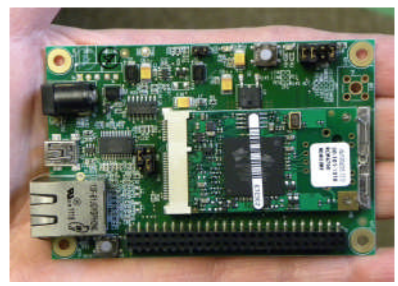
The overall cost of using the (more-)familiar servo motors was going to be about $1500 per antenna; using the components I can buy off the shelf will cost about $400 per antenna.

As a final "plus", a recent Lee Valley Tools catalogue had a device that measures angles from the vertical (or horizontal) to within 0.2degree (ref: http://www.leevalley.com/en/wood/page.aspx?p=67350&cat=1,43513), which will make it easier to align in the vertical direction.

Tracking an object in the sky

It is all very well to be able to point a dish at the sky, to some precise point, but the observations will be slow and tedious, as a radio source slowly moves past the beam of the antenna. For the most return on the hardware, the antenna must follow a source just as optical telescopes do. This requires a means of continuously adjusting the pointing of the antenna.

The tricky part is that both azimuth and elevation are changing all the time, unlike a polar-aligned telescope which uses Right Ascension (RA) and Declination (Dec) to pinpoint any object. I need a way to take the fixed numbers for RA and Dec, and convert them into varying Az-El numbers to point the antenna.



microcontroller

Fortunately, there are very inexpensive (about $100) microcontrollers that can sense their environment, read the position of the shaft encoders, compute Az-El, and then drive (using a motor controller: http://mypage.uniserve.com/~hipett/28820_Pololu-Dual-MC33926-Motor-Driver.pdf.) the simple DC motors to move the dish. These microcontrollers are programmed in an extended version of a well-known language, C, which comes with the hardware. I have a nodding familiarity with C, and in fact have programmed an earlier version of the microcontrollers available today. More fun stuff!

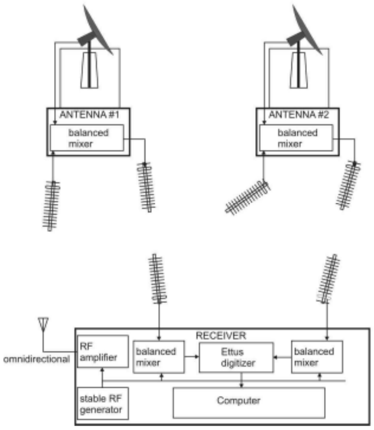
A BIG Shock - and a Solution!

This summer after discussing possible antenna locations with the Observatory Working Group, I costed out the running of cables underground to the antenna site nearest the electronics in the SuB. Yowch! It could cost more than $2000 to run cables the 40 meters from the South end of the SuB, more or less straight North to the edge of the parking lot. That includes the installation, which would need at least one conduit, power, radio coaxial cables for two antennas (one for extension at a later time to another location) and various cables to control the mount. The cost for the more distant antennas would be even greater.

The Group was most helpful and cooperative, and pointed out that no long-term plans for the Observatory had ever materialized - once work actually began the ideas had changed! They cited the extreme case of the SkyTheatre moving from the upper bowl to its present location beside the first permanent structure on the site, the PUP. They were cautioning me that at some future point, the parking lot might have to be extended and that could move right into where I had hoped to site an antenna.

I was not at all happy with the cabling cost, which might have to be re-done if overall plans for the Observatory changed, as the history strongly suggest they would.

What to DO?!



Enter my previous work in amateur radio - at least one part of the cabling might be replaced with radio links. Some work with the various amateur radio band frequencies showed that the planned observing frequency of 1.421GHz could be easily translated into the 2.3GHz amateur band, by adding a signal from a lower band (0.904GHz). Keeping radio signals very precisely on the same frequencies is tricky at best, if the signals are generated at different points as they would be from the individual antenna sites. By sending a common signal on 903.98MHz by radio to all the antennas, and using the same signal in the receivers in the SuB, it is possible to very accurately reproduce the original signals from the Heavens. If you want to look at a larger version of the diagram of the idea try this: http://mypage.uniserve.com/~hipett/wireless-signal-transmission.jpg

And Power!

Fifteen years ago, I bought some inexpensive (at the time) solar panels, which are still in the basement awaiting a purpose. It appears that they can easily supply enough power to operate at least the first mount and antenna electronics. That means I don't have to worry about getting power cabled to the first antenna site. The cost of solar-electric panels drops each year, so by the time I am looking at a second antenna the cost will be less than that for laying a power cable.

AND! the biggest benefit in terms of the overall Observatory planning for this approach is that the antennas can go absolutely anywhere on the property that can see the roof of the SuB! More than that, if plans change and an existing antenna absolutely has to move, the cost will not be all that great - future planners will not have to include a bunch of extra money as moving expenses. All the components of the mount and dish are readily moved, and site preparation consists of building a new centre column and moving the fence and 3 track support posts.

Fortunately, Chris Purton's interferometer work shows that as long as there is lots of computing power available, there is no need to have antennas in a straight line, nor on one level. Computing power for a given cost increases inexorably each year, so that is not an issue.

Now, all that is needed is building some radio transmitters, receivers and associated components, at frequencies never before attempted (by me, anyway!) **Any microwave designers out there that want to lend a hand??**

There's Lots of Information Flying Around in a Radio Telescope

Because the work of radio astronomy today is carried out in the digital world, vast amounts of data flow constantly in various streams. Even the modest telescope at the Okanagan Observatory will require the assembly of many information sources, paths and sinks (in computer info-speak, a "sink" is a user of data.)

The chart at (http://mypage.uniserve.com/~hipett/RT-info-flows.jpg) highlights most of the pieces that will eventually be found in the information puzzle at the Radio Telescope. They come down to 3 broad categories: links to the outside world; controlling the actions of the antennas; and "number-crunching" the vast quantities of readings from the antennas. The texts in italics show the information content, while regular text shows the kind of connection; for example, ZigBee is a slow text-based communication protocol, sort of like the radio equivalent of RS-232.

This information flow drawing highlighted one of the fun aspects of doing something for the first time - routine matters can suddenly become roadblocks! In this case, I had (as I thought) almost finished the drawing, when suddenly out of the black came a blockage - it would be impossible to communicate between the Master Controller and the outside world! Kind of an important function, right? Back to scratching my head, and investigating several alternatives.

What finally emerged from the re-working of the information flow diagram was a much better design, using components sitting in boxes within arm's reach of my desk! I would not have to buy a whole new kind of microcontroller after all, just use what I have now with a tiny radio module (XBee-PRO-802.15.4).

And so it goes, round and round like a big balky wheel, as more ideas filter through the grey matter, firing off more random neurons to generate wild ideas, some of which actual should work.

The Computers of the Radio Telescope

There are three kinds of computer required for the radio telescope: a "master controller" scheduling activities and connecting to the outside world; a heavy-duty number-cruncher gobbling up tens of millions of pieces of data each second, and reducing that to something us mortals can comprehend; and specialized microcontrollers to point the antennas in the right directions.

PROGRAMMERS! You are welcome to join in the fun, and help program these computers.

Safety Mechanisms and Procedures

You will notice in the first diagram of the overall mount, a six-sided outer line with a gap. The line represents a fence, the gap the opening for the gate. This would be an ordinary chain-link fence 6 feet high, not to protect the antenna, but rather warn people that there is danger inside. As with all remotely operated telescopes, they are apt to move unexpectedly, as they point to new locations in the sky. Also, even the tracking involves moving 0.3inch/minute along the track.

Because of the possibility of sudden movement, it is important to try and prevent injury to people who may be there at the time. The most basic safety measure is blocking easy access, and having warning signs on all sides of the fence. There will always be someone intent on getting closer, so the design of the tracking mechanisms is such that moving parts are as enclosed as possible, to avoid cutting off fingers as wheels roll along the track and such like.

There will also be motion sensing, with possible use of a siren to warn away someone getting too close. Contacts on the gate will alert the Telescope Supervisor that someone is inside the fence.

It may be necessary to have an automatic shutdown of the antenna if people are too close.

In Summary

I said right at the beginning of this project that it would require me to use all of my knowledge and experience from amateur radio, to computers, electronics, mechanical design, science and astronomy. I was right about that, and it is still a blast learning more and more along the road.

Thank you to all of you that are helping me have so much fun!

The steps ahead - the (now!) four-year roadmap

Some things still to come

Construction projects:

-second helical antenna, to record interference patterns from the Sun, and possibly other sources (Winter 2012/13)

-single dish, fixed azimuth, local control of elevation (Spring 2013)

-single dish, Az-El mount with .2deg pointing accuracy (Summer 2014)

-dual dish, Az-El mount with .2deg pointing accuracy (Summer 2015)

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