British Astronomical Association

Radio Astronomy Group

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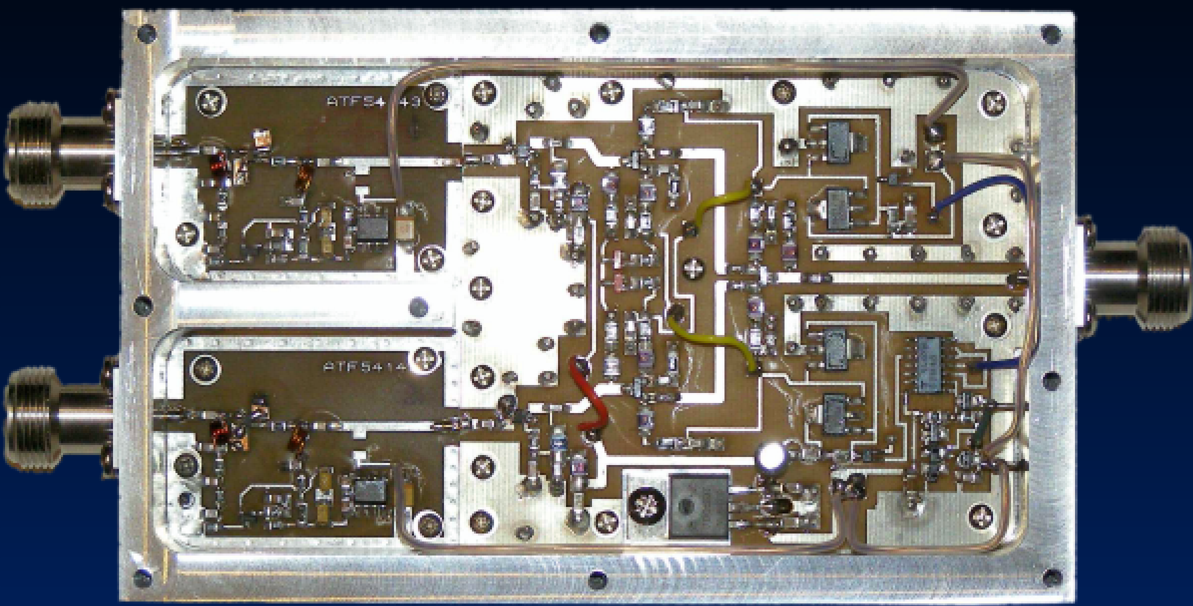


Amateur Radio Astronomy in the Southern Okanagan

Starbase Dual-Axis Magnetometer

National Space Centre Project

2.695Ghz and 1.420Ghz Progress Reports

The Maplin 1.8m Dish

www.britastro.org/radio

GROUP NEWS

Group Meeting Institute of Astronomy
2006 September 23 10:30

Dr Jim Cohen, Jodrell Bank
The Methanol Multibeam Project

The Methanol Multibeam (MMB) Project is a joint UK and Australian project to survey the Milky Way for methanol masers, which signal the birth of massive new stars. A purpose-built 7-beam receiver was jointly constructed by Jodrell Bank Observatory and the Australia Telescope National Facility. It was commissioned in January 2006 and in its first science run on the Parkes Telescope it detected 94 new methanol masers. Jim will describe the scientific rationale for the project, the multibeam receiver, and present some of the latest results.

Dominic Ford, Cambridge University
The Square Kilometre Array

Dr Laurence Newell
The *Starbase* Project

David Farn
Starbase Hydrogen Line Receiver

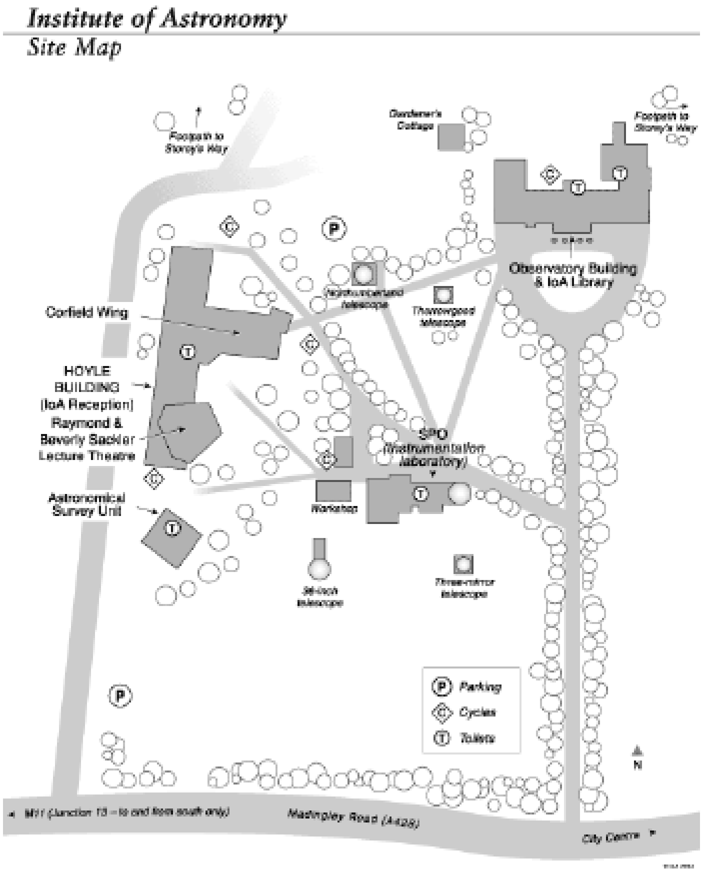
Martyn Kinder
Starbase 2.695GHz Receiver

Jeff Lashley
Beginner's Astrophysics

Mark Byrne
Starbase Controller Progress

John Cook
Starbase Magnetometer and VLF Receiver

Members' Presentations and Raffle



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Lat: 52:12:52N (52.2145) Lon: 0:05:43E (0.0954)

Cover Photograph

The cover photograph shows David Farn's Low Noise Amplifier (LNA) front-end for the *Starbase* Hydrogen Line Receiver. To the left are two identical LNAs, one to be connected to the antenna, the other to a reference source. The right hand board is a switch which alternately connects the source signal or reference output to the main amplifier. This arrangement is known as a Dicke switch, and when combined with a synchronous detector, allows a significant improvement in detection sensitivity and receiver stability. Alan Morgan's LNA units will be used in the final *Starbase* module, which will be cooled to about -40C using a Peltier device, to further reduce receiver noise.

Java Developers Required

The *Starbase* Java software is a complex development which has far outgrown my original vision of its purpose; I would be very grateful for any assistance in its further development!

If you have the following (ideal) skills, or would like to learn, and are interested in the Plug and Play Observatory concept, please get in touch:

- Java 5
- Swing (UI interaction design)
- XML, XSD schema
- Xml Beans, Xpath
- Class loaders
- JDBC with e.g. MySQL
- RxTx serial communications
- Distributed systems development

Baseline

2006 April Vol. 1 No. 4

The Circular of the Radio Astronomy Group

Editor Dr Laurence Newell

Secretary Mrs Karen Holland

The *Circular* is published four times per year. The BAA is not responsible for individual opinions expressed in articles, letters, reviews or reports of any kind. Material published in the *Circular* does not necessarily express the views of the BAA Council or of the RAG Officers.

Contributions

Please send all contributions to Karen Holland, either in paper form, or electronically.

karen.holland@xcam.co.uk

It is our policy to use Système Internationale (SI) units wherever possible.

www.simetric.co.uk

Advertisements

Advertisements are invited from both commercial vendors and from individual members. Please make sure that any images are supplied with at least 100dpi resolution, preferably not compressed (by JPEG etc.). There is no charge for this service.

Deadline

All material submitted for publication in the *Circular* must be received by the Editor no later than one month before the next publication date.

Membership of the RAG

There is currently no subscription for membership of the Radio Astronomy Group or for the PDF form of the Circular. If you wish to make use of the *Starbase* Plug and Play Observatory, please contact Karen Holland for a client configuration form.

radiogroup@britastro.com

www.britastro.org/radio

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Radio Astronomy Group Meeting

University of Cambridge

Institute of Astronomy

2006 September 23

From the Coordinator

Laurence Newell
Radiogroup@btinternet.com

Group News

The last issue of our first volume! I can hardly believe that we have now been active for two years. As you will see, we have been very productive in this time, and I am very thankful to all members who have given so freely of their efforts and expertise to achieve so much for the Group.

Officers

Once again there have been a few changes in the administrative and development teams. We now have a new Assistant Coordinator, Mr Jeff Lashley. I am very grateful for Jeff for stepping forward to fill this important role: Jeff introduces himself in the next section. Jeff brings with him a wealth of experience which will be very useful to us. In particular, he is leading the development of a radiotelescope system at his place of work, the National Space Centre in Leicester, which he describes in an article in this Circular. This is an exciting opportunity for the Group, complementing our other activities with other organisations.

For various operational reasons, our work with the MRAO at Cambridge is now project managed by Trevor Sutton, who previously was involved with the Controller and *Starbase* developments. The work on the 2.695Ghz receiver has been temporarily suspended, to allow Martyn Kinder to concentrate on some design changes in the VLF receiver, to clear the backlog of potential orders.

Membership

We now have 157 members on our email and postal mailing lists. The full list of members is again given at the end of the *Circular,* excluding those people who wish to remain private. If your information is incorrect, please don't hesitate to contact us with any corrections.

Cambridge Meeting 2006 September 23

Our next public meeting is at the University of Cambridge Institute of Astronomy, on Saturday September 23, starting at 10:30. The meeting details are given on the inside of the front cover. The Institute of Astronomy is easy to get to, and there is ample car parking. We are aware that this event does clash with other astronomy-related events, but unfortunately it proved impossible to find a weekend where this did not occur. You may be interested to know that the weekend is also the Cambridge University Alumni Weekend.

Technical Team Meetings

The last technical team meeting was on May 13, and is written up towards the end of the Circular. Amongst other things, we decided to change the design of the VLF Receiver slightly following beta testing, and we settled on a design for the controller module. We also decided to go ahead with John Cook's dual-axis magnetometer, which is described in this Circular. The production unit will be fully *Starbase* compatible, and will be produced using Surface Mount Devices to reduce size and costs.

Variable Star Section Database

I have been approached by Andy Wilson of the BAA Variable Star Section (VSS) concerning the planned redesign of the VSS database. Andy had learned of the *Starbase* Repository development, and has suggested that we try to coordinate our design efforts, to see if we could use a common database schema, or at least to re-use each other's work. Let me know if you'd like to be involved.

VLF Observation Programme

John Cook continues to issue VLF monthly reports (as PDF) to those on his mailing list. If you would like to receive the reports, please contact John.

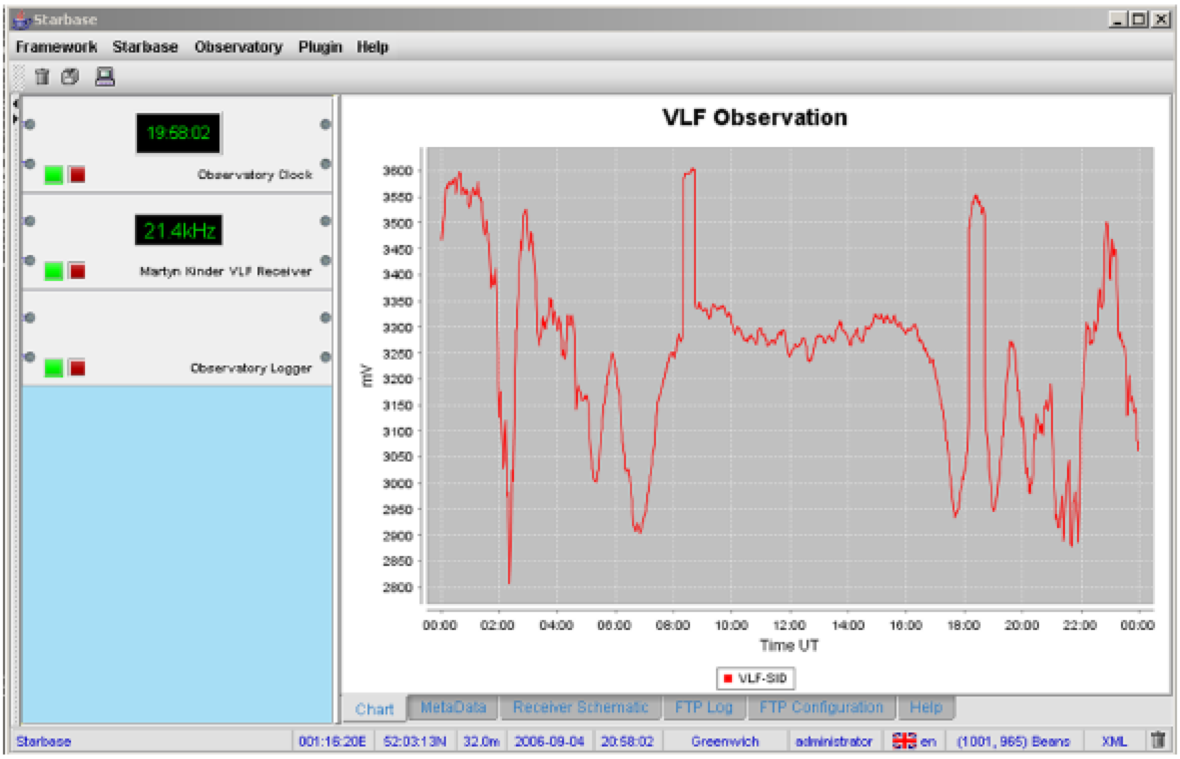
Erratum

We have been informed by Mike Scott (via Colin Clements) that Colin's HF Radiometer article contained a reference to an incorrect diode type. The diodes are marked as A119; this should have read AA119. My apologies - this one was my fault, the debounce circuit in the third finger of my left hand was too effective on this occasion.

Starbase Development

The development of our Plug and Play Observatory, *Starbase*, has been the main focus of our work over the last quarter. In this Circular you will find progress reports on the hardware developments for the 2.695Ghz receiver, the 1.420Ghz Hydrogen Line receiver, and the new Magnetometer.

The *Starbase* Java software is progressing well, but unfortunately there is no room in this issue for a full report, so I have chosen to show a screenshot of the prototype Observatory plugin, in 'ordinary observer' mode. The left-hand rack units are data sources, the right-hand panel shows the information known about the selected source. I currently have a working system which can retrieve data from Martyn Kinder's FTP server, and continuously display his VLF receiver output as a chart in the *Starbase* UI, as shown. The data format used is Radio Sky-Pipe, but in principle it could be anything. The



Framework is now fully XML-driven, with a basic XML persistence layer for testing purposes. The embedded MySQL database has been 'parked' for the time being, in order to make faster progress with the UI. There will be a live demonstration of the progress so far at the Meeting on September 23, with, I hope, more data sources.

A preliminary data schema has been designed which structurally links the configuration of each receiver via its controller directly to the *Starbase* software. It has taken a huge amount of effort to get this far, but things should now start to get easier!

Group Officers

Group Coordinator	Laurence Newell
Assistant Coordinator	Jeff Lashley
Group Secretary	Karen Holland

Technical Teams

The members of the development teams and Observing Programmes are listed below. Email addresses are available in the List of Members at the end of the Circular.

2.695GHz Receiver

Martyn Kinder
Terry Ashton

1.420GHZ Receiver

David Farn
Alan Morgan

VLF Receiver and Magnetometer

John Cook
Karen Holland

Controller Module

Mark Byrne

Starbase Java Software

Laurence Newell
Trevor Sutton

Database, FTP and Website

Database	James Wilhelm
FTP server	Martyn Kinder
Website	*vacancy*

National Space Centre Liaison

Jeff Lashley

MRAO 151Mhz Liaison

Trevor Sutton

Laurence Newell
Group Coordinator
2006 April

Assistant Coordinator's Report

Jeff Lashley
engineer@classicengineer.co.uk

As some of you may already know, I joined the organising team of the BAA RAG recently as the assistant coordinator. Although radio astronomy is a fairly recent interest of mine, I have been involved with amateur astronomy since I was at school in the 1970's.

I was born in Yorkshire, but my family took me to their native region of Sunderland when I was 7 years old. I grew up and worked in the Sunderland area for many years.

I bought my first real telescope, an 8 inch f/6 Newtonian reflector, in 1980, previously I had been an active variable star observer using binoculars. I carried on the variable star work with the reflector for a while.

In the early 1980's I was unemployed for a time, when I began studying for an Open University degree. The final modules were completed while I was working for a BT customer service department. The topics I covered were all science and mathematics, such as physics, astronomy, optics and mathematics. In all I worked for BT about 11 years, however the job had changed out of all proportions so I felt I needed a change. I secured some short term IT support work through agencies, which lead to a permanent placement with IBM servicing desktop computers, printers and EPOS equipment.

In my heart I really wanted to work in the astronomy field. I had contacts in the planetarium industry, so I got to hear about a vacancy at the Mills Observatory in Dundee. The Mills Observatory claimed at the time it was the only full time public observatory in the UK. I was successful in my application, which meant I moved up to Fife, living near St. Andrews where the night sky was very dark and superb for optical astronomy. For two years I ran the public astronomy programme at the observatory. This meant odd work shifts, 6 months daytime working around summer time, and six months working 2 till 10 over the winter season. During this 'winter' season, each clear night the telescope would be opened up for use. Needless to say visitors were mostly interested in looking at the bright planets. Jupiter and Saturn were particularly well placed for winter evening viewing during my stay there.

There is of course a limit as to how far you can progress in one place, especially a small site like The Mills Observatory. Fortunately it was a boom time for UK planetaria around the new millennium, with major projects in development in Glasgow, Leicester, Bristol and the South Downs. In 2001 I was due to visit the National Space Centre in Leicester to get inspiration to develop the visitor experience at the Mills, however, completely coincidently, there was a vacancy for technical support open at the time. I could not miss the chance to apply. I got the job, and have been working there ever since. My role is quite varied, and includes building and repairing exhibits, IT support and much more.

I'm involved with a radio society, (and astronomical society) based the Space Centre, which encouraged me to work towards my amateur radio licence. A spark was laid by the society chairman who wanted someone to talk about radio astronomy, I volunteered, after all I had been working in the science communication industry. This suggestion has encouraged me to put together some form of radio telescope, so my association with the BAA RAG came at the right moment. In another article in this Circular I begin to describe a new project based here at Leicester.

My immediate role in the BAA RAG is to coordinate the public meeting at the Institute of Astronomy in Cambridge on September 23rd.

Secretary's Report

Karen Holland
karen.holland@xcam.co.uk

Financial Report

Radio Astronomy Bank Account – for the Period 2006 April 1 to 2006 August 31

As reported in the last Circular, following discussions with the BAA it was agreed that whilst all items that are clearly connected to, or funded by the BAA will come out of our BAA budget, we might operate a separate bank account (the Radio Astronomy Bank Account) for the purpose of the Plug and Play *Starbase* project development and production. You will find a report on this account presented in Circular number 3, which includes all transactions up to 31st March, 2006.

This Radio Astronomy bank account is currently looking healthy, due to the Harold Ridley Grant, which has not yet been used (£250), and the generosity of the BAA in offering not to reclaim back the VLF PCB cost which had been claimed from them, before the financial situation regarding VLF production had been agreed. These two items, together with the generous donations we have received, mean that we have a good balance available to support future development of the project when required. It is our intention that the project should be non profit-making.

Previous balance (on 31st March, reported in circular 3) was £291.45

Income	
Interest on the account	£0.12
VLF receiver payments for prototypes	£541.75
VLF deposit for next build	£25
Donations from technical meeting	£38
Total Income	£604.87
Expenditure	
Remaining VLF build bill	£264.33
Total Expenditure	£264.33
Current Balance	£631.99

Please remember that if you are paying the group for Circulars, CDs, meeting attendance etc., or anything that has the BAA's name or logo associated with it, then any cheques should be made out to the *British Astronomical Association*. If you are paying us for a VLF module, or in the future, other *Starbase* modules, or if you wish to donate money to the group's *Starbase* project, then cheques should be made out to *Radio Astronomy Group*.

Membership Enquiries

Membership of the section is currently free, and simply involves giving us your details to store in our database, so that we can add you to our email (or postal, if necessary) distribution list to keep you informed of activities and news about the group. If you would like to join, please send me your details; the minimum I require is your name and email address (for email only contact), but I would be very happy to receive additional information such as your address, telephone numbers, and information regarding your level of experience, or specific interests in radio astronomy, especially if you feel able to help us with one of our projects.

Circular Subscriptions

Although the circulars are downloadable from the website in PDF format, some people prefer a paper copy of the circular. If you would like to take out a subscription, you can send me a cheque, made out to the British Astronomical Association, for £3.50 per issue. Please do not send money for more than 4 issues at a time. The circulars will be posted out each time, and a subscription reminder will be sent out when you receive your last issue.

Speaker List

I have been producing a speakers list that will be made available on our web pages. The aim of this list is to provide a useful resource for schools and local societies, that will also help to promote radio astronomy. The list will include anyone who is willing to give talks on any area of radio astronomy. The list is not intended to be a list of speakers who will promote the BAA radio astronomy group, although we would, of course, be happy to provide publicity material to anyone who is happy to distribute it.

If you feel that you would like to be included on the list, please let me have your name, contact details and any other information that is relevant such as the specific talk title or area that you are happy to talk about, together with any geographical restrictions that you might apply. If in doubt, leave information out, as you can always opt to reject an offer to speak if you feel that an invitation is not suitable, and you might be in a position to recommend one of the other speakers.

Current speakers on the list are:
Brian Coleman: Radio Astronomy – a beginners view
Martyn Kinder: The 2.7GHz Receiver
Karen Holland: A Beginner's Story of Building and Operating a VLF Receiver
Jeff Lashley: The Astrophysics of Radio Astronomy
Bob Marriott: The History of Radio Astronomy in the BAA
Laurence Newell: Introduction to RA in the BAA
James Wilhelm: TBA

VLF Receiver Production

Since my last report, I completed the testing of each VLF transmitter as well as I could, and sent them off to the respective 'guinea pigs'!

Figure 1 shows the receivers prior to despatch with test sheets.

My receiver seems to be working fine, and I have been successfully collecting data. See Figure 2 for a spectacular series of flares monitored on 26th and 27th April.

Figure 2: A series of flares seen on 26th and 27th April with my receiver, that correlate well with the GOES solar flare data plotted on the same scale.

The Next Build of VLF receivers

At the last technical meeting, it was proposed that several changes be made to the format of the VLF receivers. These changes are currently being implemented by Martyn Kinder, and once finalised, it is expected that more VLF receivers will be available. It is not currently proposed to make another VLF build of the current type, as these would not ultimately work with the controller.

A reminder of the final article!

Due to increased work commitments, I am hoping that another member of the team will be able to produce and supply future VLF receivers, but I will be happy to continue to flag members in the database, as being interested; please let me know if you think you might want a VLF receiver. All those people who have expressed an interest in buying a VLF receiver will be contacted before the next build is started to establish the numbers required.

Figure 1 Assembled and tested VLF Receivers

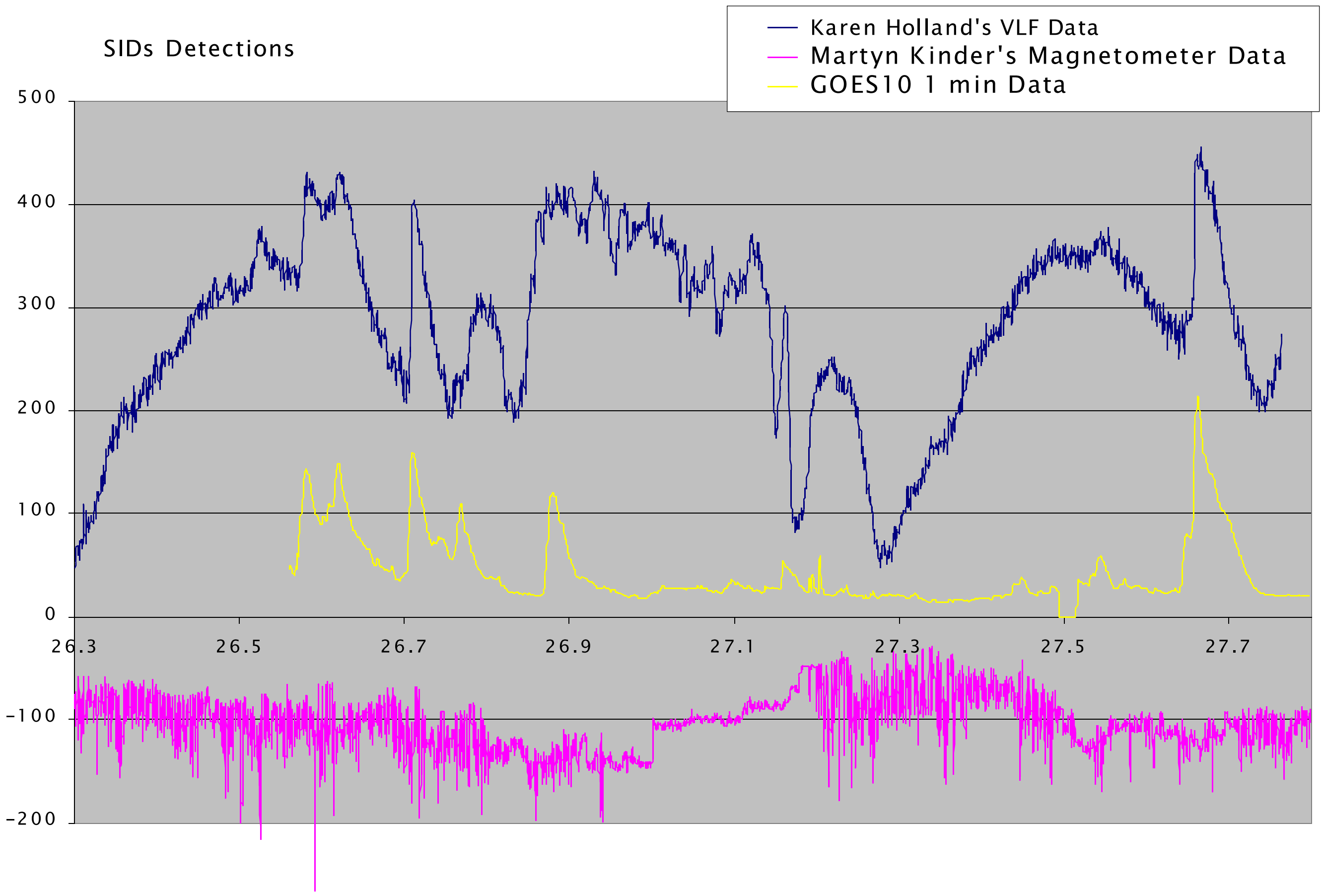


Figure 2 SID Detection by Karen Holland and Martyn Kinder, confirmation from GOES

Amateur Radio Astronomy in the Southern Okanagan

Ken Tapping
ken.tapping@nrc-cnrc.gc.ca

Introduction

My introduction to the BAA Radio Astronomy Section was in the late 1960's. At that time the Director was John Smith, and the leading UK amateur radio astronomers were John Smith and Michael Hale, I was a beginner. Interestingly, Michael Hale is also now in Canada, doing amateur radio astronomy on Gabriola Island, between the West Coast and Vancouver Island. At that time, the standard workhorse radio telescope design was the phase-switched interferometer. Experiments with single antenna instruments were somewhat frustrating, even the 9m (30ft) radio telescope John and I built was an altogether harder machine to get usable data out of. This difficulty in getting single-antenna radio telescopes to work to their potential marks the start in the line of development leading to the experiments described here. For a detailed description of the instruments please look at the articles on the UKARANET website.

The Okanagan Valley is located in the rain shadow of the Rocky Mountains. we live just outside Penticton, on the shores of Lake Okanagan (Lat 50 Degrees North, Long 120 Degrees West). For the first time we have enough land for gardening and radio astronomy experiments, and the local population density is low enough for the spectrum not to be loaded with interference. Summers are like those on the north coast of the Mediterranean, and the winters are much milder than they are in the rest of Canada. When we lived in Ottawa, we had to live with winter temperatures as low as minus 32C, during which coaxial cables did not bend, they broke, and unheated electronics stopped working.

We walled off a section of the garage to make an electronics lab, which provides the room for multiple experiments. At the moment there are operating two correlation interferometers, a radio meteor counter, and since we live close to a subduction zone, a seismometer. That last experiment does not qualify for discussion here, but if you would like to find out a bit more about that one, send me an e-mail.

Ken Tapping's Control Room

Correlation Interferometers

In amateur radio astronomy sensitivity is not just a matter of low noise receivers and antennas that are as large as possible; it is a matter of stability. For example, using low-noise GaAsFET or HEMT amplifiers, we can have receiver noise temperatures as low as 15K without resorting to cooling. Assuming a 3m dish with an aperture efficiency of 60%, a bandwidth of 100MHz and an integration time of 1s, it should be possible to detect sources as weak as a few Janskys with a signal to noise ratio of a few times the RMS noise level. In practice, unless one is observing special sources like pulsars, this is rarely achieved. Instead, what we see from people using such systems are observations of the Sun and Moon with huge signal to noise ratios, but with baseline stability that is so bad that it limits the amount to which the gain can be increased, and thence the recognizablity of weak sources. This comes from two problems: firstly there is a lot of noise from the ground entering the antenna sidelobes, and this varies with antenna declination and with time, and more seriously, since the gain-bandwidth product of the receiver is extremely sensitive to temperature and supply voltage, it is almost impossible to keep a receiver adequately stable. In addition, any losses between the antenna and receiver will also yield temperature-dependent noise contributions.

The simplest design of radio telescope is an antenna, amplifier, detector and recording system. Since the output comprises noise contributions from the source, background sky, ground and receiver, this type of radio telescope is known as a total power radiometer. When making radio telescopes out of communications or satellite receiving equipment, it is often difficult to configure the radio telescope into any other kind. This type of radio telescope can be used for solar studies, because the emissions are strong, pulsar observations, since one can exploit the unique time-variations of the pulsar signal to separate the desired signal, or spectral line observations, where the emissions on the desired frequency can be compared with those observed on neighbouring frequencies. Taking into account the ground and other unwanted emissions, a receiver with a 15K noise temperature will probably end up as part of a radio telescope with a noise temperature of 30K or worse. If one is recording the receiver output using a 12-bit analogue-digital converter with a range -10 to +10V, observing at the sensitivity limit would mean the RMS noise fluctuations would have to be sampleable. If we assume the RMS fluctuations in the receiver output cover the least significant 2 bits of the A/D converter dynamic range (with averaging and dithering to increase the resolution), about 0.5mV will be equivalent to about a few milliKelvin. Assuming the noise temperature of the receiver is say 30K, then these fluctuations will be riding on the top of a few Volts. This voltage is proportional to the mean system noise level in the receiver. A small change in receiver temperature or power-supply voltage operating on all those undesired noise power contributions will produce a change in the receiver output bigger than that encountered when observing a weak source. Using a DC voltage to back off that background will help put the A/D converter in the desired part of its operating range, but it won't make the system more stable. Early experiments with a 4 GHz satellite receiver on a 3m dish showed exactly this problem, with satellite interference making it worse.

The Dicke Receiver was developed to reduce the problem of receiver gain variations in single-antenna radiometers. Back when it was developed, centimetre-wavelength receivers had mixers as their input stages and noise temperatures of thousands of degrees. In its original form, the Dicke Receiver consisted of a receiver with a switch at its input, so that it could be switched rapidly between the antenna and a temperature-stabilized, matched load. The signal processing system used a synchronous detector to subtract the signal seen when at the load from that seen when looking at the antenna. The output was (Source + Sky + Ground + Receiver) - (Load + Receiver) = (Source + Sky + Ground - Load). This was very good when the largest contributor to the receiver noise output was the receiver, but these days it isn't, so this particular piece of arithmetic is no longer as effective at stabilizing the receiver. Moreover, the load is usually a lot hotter than the sky, so the result of the subtraction calculation may be bigger than the noise temperature of the receiver. Under these conditions making the receiver a Dicke type will well make the stability worse. Cooling the termination in liquid nitrogen or helium makes it better, because it makes the difference smaller, and when the output is balanced, we have the system at its most stable. If the load is cooler than the antenna, we can balance the receiver completely by adding a little noise to the load channel from a noise source via an adjustable attenuator. I did try a little experiment of using the receiver output to control a PIN diode attenuator to keep the receiver balanced, and then recorded the drive signal to the attenuator. This is a sort of centimetre wavelength Ryle Vonberg Radiometer. I used it at 10GHz. However, it was not really practicable in that having a Thermos flask of liquid nitrogen on a receiver box that had to be tilted was a problem, and carrying "borrowed" liquid nitrogen home in the car was not pleasant either.

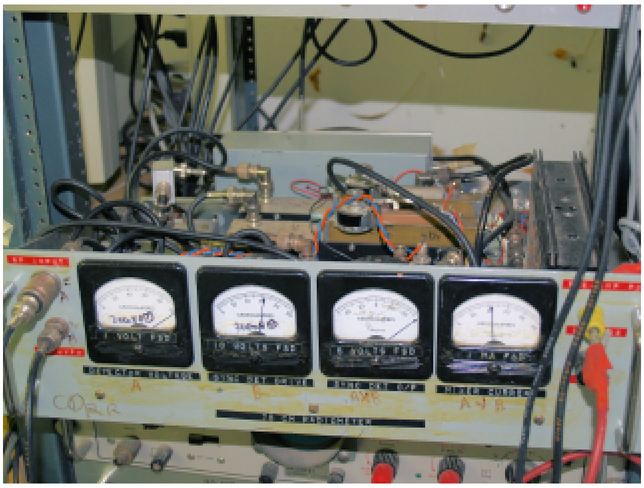
The variant of the Dicke Receiver used most often these days employs a second feed horn as a substitute for the termination. This horn is offset from the focus of the dish (where the feed horn used for making observations is located). If the horns are close enough together, the mean and "reference" beams are located close together in the sky, and see more or less the same piece of ground and pass through the same chunks of atmosphere. This works very well for large antennas, reasonably well for antennas in the 3-4 m range, and usably for smaller ones. Two difficulties are getting hold of low-noise ferrite switches for the Dicke Switch and the amount of clutter one ends up with at the focus of small dishes. I found these instruments great for monitoring solar variability at 10GHz and measuring the temperature changes of the Moon over a Lunation. However, getting anything fainter with dishes ranging from 40 - 100cm was problematic. Another problem is sometimes the design of the low-noise amplifier feed assembly makes the addition of extra components very difficult, particularly since the waveguides and feeds are made of metallized plastic or zinc die-cast material, in which it is easy to file or drill extra holes, but since one cannot solder such materials, these parts are hard to modify without adding serious losses and mismatches.

After giving up on a 4GHz total power system on a 3m dish, I tried noise adding as a means of stabilizing the receiver. A small horn was mounted at the vertex of the dish, facing the feed at the focus. A noise source was attached to the horn and attenuation added until the noise source increased the receiver output voltage by a factor of about five. The noise source was then pulsed at about 100 pulses per second with a mark-space ratio of 1:1. The mathematical analysis of the signals carried out in the signal processor will need an article of its own. However in effect one is doing two things: one is using the noise pulses as a gain scaling standard to keep the total sensitivity constant, and also to obtain a backing off voltage that since it has passed through the receiver, also follows the gain variations. This worked really well on the 3.3GHz, 46m radio telescope we first tried it on, but was not as effective on the 4GHz receiver on a 3m dish. I think this was because the smaller dish saw more ground radiation, which varies with time, affecting the baseline, and there was a lot of satellite interference. What was needed was an instrument that was not as sensitive to ground radiation and labelled sources in such a way that they would be easy to identify. In other words, an interferometer.

The logical choice was a phase-switched interferometer. These are "tried and true" instruments that have been used very successfully by amateurs over decades. That is why I wanted to try something else. The phase switched interferometer usually consists of two antennas separated in the east west direction. Each antenna has its own low-noise amplifier, and the signals are fed to a common receiver. In this mode the system would act as a simple interferometer, with sources making fringes, which uniquely identifies them,. but still with all the baseline instability problems associated with total power receivers. However a device is added to the feed cable from one of the antennas that can switch a phase shift of 180 degrees in and out many tens of times a second. This has the effect of turning all the maxima in the interference pattern into minima and vice versa. If we use a synchronous detector to subtract the receiver output when the system is in one state from that when it is in the other, one is in essence subtracting one interference pattern from the other, and also subtracting all the non-switching components of the receiver output. By playing with the mathematics a bit one gets an output pattern that is proportional to the geometric mean gains of the antennas multiplied by the cosine of the phase difference between the signals they each receive.

There is another way to get that same result. Once again one has two antennas separated in an east-west line, each with a low-noise preamplifier. The signal from each antenna is then fed to its own mixer and intermediate frequency (IF) amplifier. The two mixers are necessarily fed from a common local oscillator. The outputs from the two IF amplifiers are then multiplied, using a simple double-balanced mixed. What comes out is exactly the same thing as one gets from the synchronous detector in a phase switched interferometer. One advantage of the multiplying (more correctly correlation, since one is dealing with amplitudes and phases) interferometer over the phase switched interferometer is that in the latter, all the signals are modulated by the switching frequency, which makes audio monitoring less convenient. The correlation interferometer yields undistorted audio, so it is easier to identify interference. Of course it requires more or less identical mixers and IF amplifiers, and for everything to be hooked up with (more or less) equal lengths of cable, to keep the phase shifts imposed by the receivers the same for both channels.

408Mhz Correlation Interferometer



The 408Mhz Backend

The first correlation interferometer to be made was at 408MHz, using a bunch of old broad-band Yagi antennas I had acquired years before. An article discussing this instrument in detail is available on the UKARANET website. One day I was going through the junk boxes and found enough debris from old experiments to make a 408MHz phase switched interferometer too. The signals coming in from the antennas were split between the two receivers, so that the performances could be compared. The computer data logger had several analogue input channels, so it was easy to make parallel observations using both. It was unfortunately not possible to make the two systems as identical as I would have liked. The correlation interferometer has an IF of 10MHz and a bandwidth of 250kHz, and the phase switched interferometer an IF of 30MHz and a bandwidth of 1MHz. The different IFs meant the chance of local oscillator and IF crosstalk between the receivers was reduced.

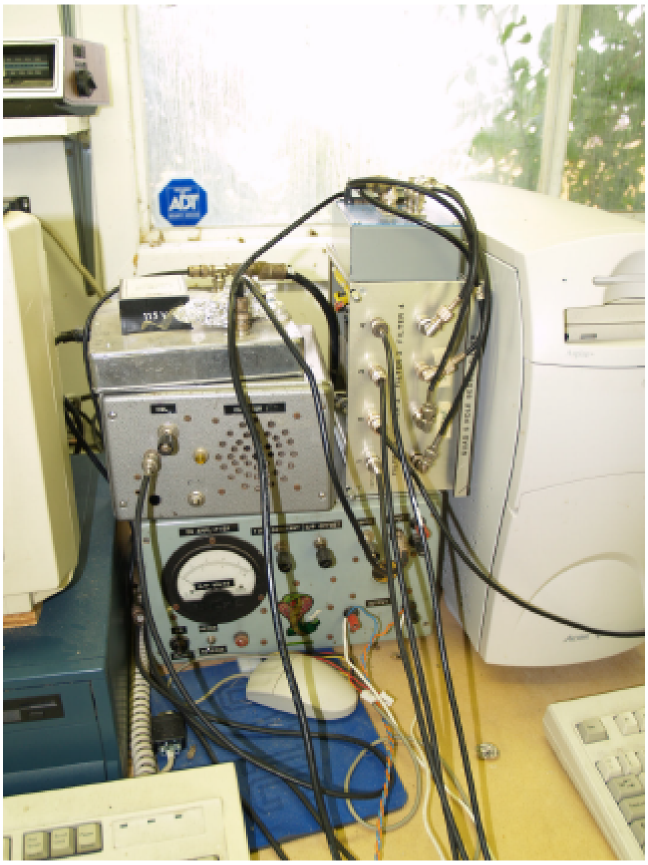
Both systems performed at the level achieved by amateurs for decades. They both picked up Cassiopeia A, Cygnus A and Taurus A, with maybe a suspicion of Virgo A. The Sun produced enormous fringes and for want of better ideas, the systems were set up to make daily solar observations. A few months ago observations were stopped in order to deal with some interference difficulties and have not yet been restarted. In conclusion this experiment was interesting, proved the correlation interferometer concept for back garden radio astronomy, but did not break any new ground in sensitivity. The 4GHz correlation interferometer was another matter entirely. This has certainly proved to be the most sensitive back garden radio telescope I have ever made.

4Ghz Correlation Interferometer

In many countries, TV companies move signals around using satellites operating in C-Band (3.7 - 4.2GHz). In Canada and the US, the rules about what you can receive in your own garden are rather blurry. It seems to be that if the signals fall on your property, providing that you do not get into any deals with third parties, such as selling what you receive or what can be derived from them, those signals are yours to enjoy. As receiver technology got better, someone discovered that a small 3-4m dish plus a cheap GaAsFET amplifier, with an appropriate receiver, would give you free satellite television. This led to an explosion of people selling cheap home satellite TV systems, and dishes sprouted up almost overnight, pretty well everywhere. Considering the standard of North American TV, it is hard to imagine why anyone would want more of it! However, the market got so big that the TV companies got unhappy and started to scramble the signals. However, other companies in the Far East and in the USA started making descramblers. Canada is more like the UK from the regulatory point of view, and declared that any attempts to unscramble these signals would be illegal. However, the descramblers were so small and cheap that people simply bought them in the USA and drove back with them. Finally, the TV companies started selling satellite TV in the Ku band (11 - 12 GHz), which meant a 60cm dish rather than a 3m one, and sold the receivers at rock bottom prices. The home market for C-Band equipment collapsed. This meant that dishes and low noise amplifiers with noise temperatures as low as 15K were being junked. When starting in this frequency range, I asked a local Satellite TV salesman for some amplifiers. He said sure, and produced a cardboard box containing a dozen low noise amplifiers (all old and removed from homes who had bought new ones). I asked how much, he asked would $2 be too much? I started counting the amplifiers. He stopped me and said he meant $2 for the lot! The amplifiers all had a WR229 waveguide input and an N-Type socket for output. The had gains of about 55dB and noise temperatures ranging from about 30K to 50K. Similar scrounging produced two 3m dishes, one free and the other the price of the petrol used to deliver it, a 1.8m dish and a 1.5m dish, again for the price of the petrol.

The power is fed through the centre of the output cable. This was inconvenient but was easy to fix. Removing the lid from the amplifier showed the power being separated by a printed choke on the circuit board, and the power blocked from the output of the last amplifier stage by a chip capacitor. It was easy to scrape the choke away with a sharpened screwdriver, drill a hole through the box for a feed-through capacitor and wire it so that power was applied on a separate terminal.

In his book on radio astronomy projects, Bill Lonc made a waveguide to coax adaptor by simply cutting a piece of double-sided printed circuit board to cover the open end of the waveguide input to the amplifiers, drilling holes for the screws to secure it, and mounting a Type N or SMA connector in the middle, and soldering on a small wire loop parallel with the shorter wall of the waveguide. I hate to think of the quality of the match, but making them took 30 minutes or so. Moreover these adaptors would only be used on the "second stage" amplifiers, with a lot of gain in front. Bill tried making TRF receivers by simply connecting two amplifers together, with the second unit using one of the waveguide-coax adaptors. I thought that it would be interesting to make a correlation interferometer using two pairs of these amplifiers, one on each antenna.



The 4Ghz Backend

It turns out that the open end of a WR229 waveguide is not an unusably bad a match to free space, so the waveguide inputs to the low noise amplifiers might be all the antenna needed for at least some experiments. If we assume that the open end of the waveguide would act as an antenna with a beamwidth of (say) 60 degrees, the quiet Sun would increase the antenna temperature by about 3K. The RMS fluctuations in the receiver output would be much smaller than that, so in principle it would be possible to make an interferometer using the open-ended waveguides as antennas. Two preamplifiers were clamped to sawhorses so that they pointed to roughly the elevation at which the Sun would cross the meridian, with a baseline of about 4m. The outputs from each these amplifiers were passed through 20dB attenuators to another amplifier, fitted with one of the homemade coax-to-waveguide adaptors. The outputs from these amplifiers were fed to a double-balanced mixer used as an analogue correlator. The output of the correlator was passed to a DC amplifier/integrator and thence to a chart recorder. Nice clean fringes were obtained from the Sun. Such an interferometer would be very inconspicuous, would take up little space, and be useful for solar activity monitoring.

We had been carrying around for some years a nice piece of aluminium tube that was too good to leave. It is about 7 metres long, has an outside diameter of about 8cm, and a wall thickness of about 8mm. We had on one occasion used it to lever tree stumps out of the ground. Despite this abuse it was still perfectly straight. I mounted it more or less east-west and clamped a small dish to each end, with a 4GHz horn and amplifier on each dish. The rest of the receiver was as used in the sawhorse experiment. The sensitivity was excellent, and it picked up Cygnus A and Cassiopeia A with no difficulty, and overloaded on the Sun. However, there was a lot of interference from satellites and aircraft radar altimeters; the bandwidth had to be reduced. This is not very easy at 4GHz, so the receiver was converted to a superhet, using an old 2-4GHz Gunn diode as a local oscillator. The IF chosen was 750MHz, with a bandwidth of 50MHz.

The 4Ghz Correlation Interferometer

The signals from the geosynchronous broadcasting satellites were still a nuisance. Since these satellites do not move with respect to the inteferometer baseline they do not make fringes, they merely make the output from the receiver wander around as the satellite signals scintillate due to the atmosphere. A high-pass filter with a cutoff below the lowest fringe rate (a few milli-Hertz) smoothed the baseline beautifully. So far all the sources in the 5GHz Greenbank GB6 Survey stronger than 20 Janskys and above the celestial equator have been detected (some requiring averaging of multiple scans and additional signal processing). The compact source at the Galactic Centre and some of the HII regions nearby have been detected, but M42 has been beyond reach because it lies at the same declination as the geosynchronous satellite belt as viewed from Penticton. The faintest source recorded so far is 3C295 (10 Janskys), which required averaging seven observations and some additional filtering. I would not hesitate to recommend this instrument design to those wanting a small but sensitive back garden radio telescope. Maybe the next experiment will be increase the dish diameter to 3 metres and improve the digital signal processing. A detailed writeup on these experiments is posted on the UKARANet website.

Counting Meteors

Before I came to Canada I spent a fair amount of time visiting Ron Ham, an amateur radio experimenter living on the north face of the South Downs, not far from Pulborough. One of his experiments that really impressed me was his meteor counter. It was tuned to a VHF broadcast station in Gdansk, Poland, and receiver bursts of signal reflected from meteor trails. After a few years and some degrees of longitude, I finally got round to trying this for myself. I got an old FM radio receiver with a synthesized local oscillator, made a 3-element Yagi which I mounted pointing easterly at an elevation of 45 degrees, and tried tuning the radio to frequencies where there were no strong local signals. Eventually, after a lot of trial and error, I found 102.3MHz. This one yielded at least one meteor a minute during an ordinary evening, with echo durations ranging from a fraction of a second to 30 seconds. For a long time I had no idea where the transmitter was located. Finally, one day a long echo at the right time caught the announcement that the station was "Sunny 102.3 FM". A search on the web revealed that "Sunny 102.3 FM" is located in Modesto, California!

Finding a good method of automatically counting the meteor echoes was a long process. With FM receivers having wide range AGC and severe amplitude limiting, just looking for high-amplitude audio was useless. I tried using filters to distinguish music from noise but that didn't work very well. Most of the receiver was on one integrated circuit with no recognizable number. Finally I got a level from the "local oscillator lock light" on the front panel. That has worked nicely and the equipment has been left along with a computer doing the data logging for some years. A plot of the latest Perseid shower is included here. In comparing with your observations remember these were made at longitude 120 degrees West of Greenwich.

New Data Logging System

Until now an experiment has consisted of the radio telescope hardware, an analogue digital converter and a computer with some sort of signal processing software, usually home-grown because (a) it is more interesting to do that oneself, and (b) software written by others is a more unknown quantity, unless one has the source code, and it never does exactly what one wants it to do. Each experiment is connected to a local Ethernet hub, and thence via a coaxial cable from the "shack" to my den, to my desktop machine, so the data can be grabbed, further analysed, incorporated in reports and e-mailed to friends. The network depends upon coaxial cable, because running a wireless network next to a collection of high-sensitivity experiments is running the risk of additional interference problems. Cheap digital wireless components are not guaranteed not to make interference levels high enough to be a problem to radio telescopes.

However the shack was getting filled up with computers, and there was always the problem of getting hold of another A/D card, and getting the data to be recorded was a significant part of each project. The solution was to have a standard data handling system. Developing one is a joint project between Chip Wiest and me.

Unless one is doing some clever digital signal processing, the digital sampling rate for most experiments rarely exceeds 100 samples/sec. In fact at the moment we are finding 20 samples per second easily enough for two interferometers, a meteor counter and a seismograph. The full system comprises four computers: the Logger, the Server, the Viewer and the Experiment Machine

The Logger has an A/D card and 8-channel sampling filter and inverter/offsetter unit. The Logger samples the input channels and writes the output to a single file on a ramdrive. The file contains one-minute worth of data as a table with time and eight data columns. When the next minute starts, that file is over-written. In this way the Logger can be started and basically never touched again. Hook up a data stream to one of the input channels, and it will be logged.

The Server interrogates the Logger over the network to make sure the file is closed and it is not close to the end of the minute, and if it is safe, copies that file from the Logger's ramdrive to its own. We use ramdrives because they are fast and have no moving parts, so there is no need to worry about how many read-write operatings they are subjected to. Once the Server has it on its own ramdisc it is copied to another file also on the ramdisc for the Viewer to grab, and separates the data channels.

A configuration file tells the Server what sort of output files are needed (per minute, per hour and/or per day), and what time resolution is needed. The data are then averaged down to that resolution. The time column in each file can be local time, Universal Time or Local Sidereal Time. It is possible to specify new channels without stopping the logging process. The Viewer runs in my den, and shows a minute-by-minute display of all the data channels being logged.

The Experiment machine takes data from the Server and does the required analysis, saving the results. In many cases this analysis process needs only to be done once a day, in other cases once an hour. System demands on the Experiment machine are not heavy. The biggest problem encountered so far in setting up this system is avoiding collisions in file access. One outcome of this new system will be to release a lot of bench space.

Not all projects can be accommodated in this system, but almost all general purpose radio astronomy experiments can.

What Next

The dangers of making predictions like this is that the listed projects might never get done. Ideas that sound inviting at the moment are: a directional meteor echo detector, using multiple antennas correlated in pairs, meteor Doppler analysis, Doppler analysis of auroral backscatter (aurorae are quite common here because of the high magnetic latitude), and experiments with post-demodulation correlation.

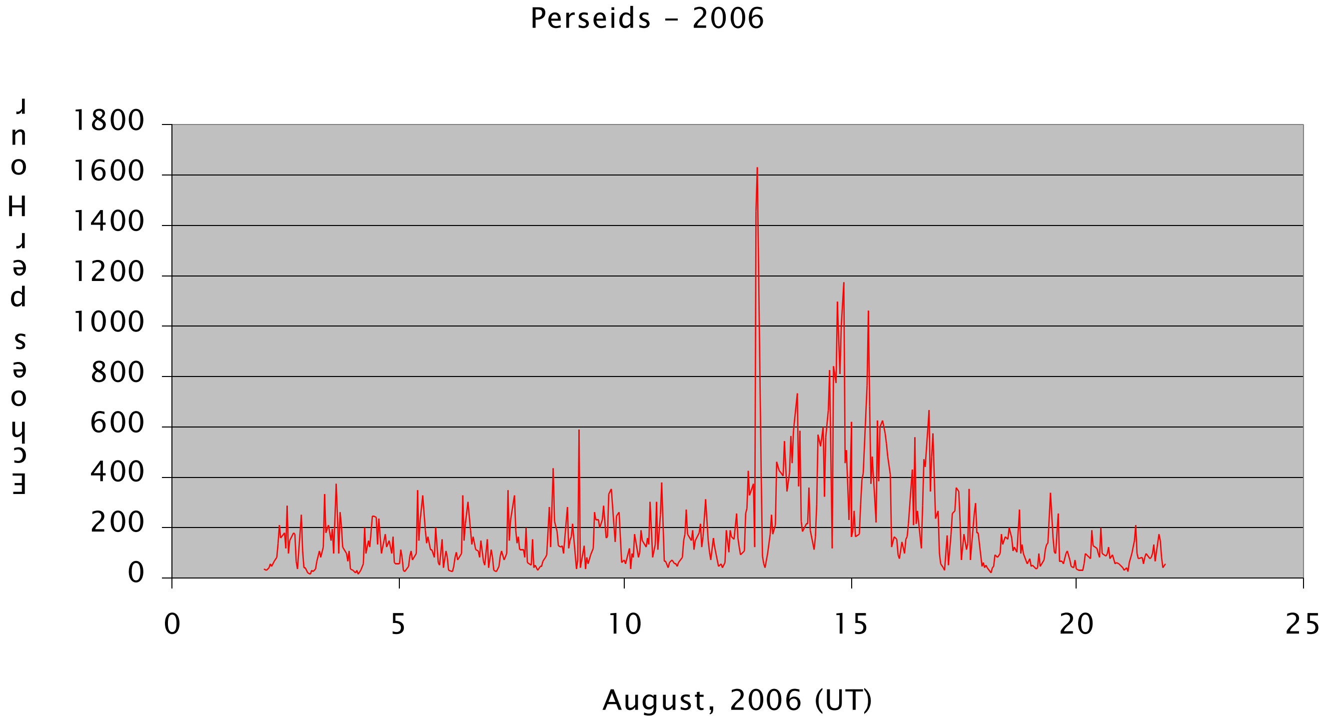
To do meteor echo position measurements needs multi-element interferometers and correlation of the signals from all antenna pairs. This could be a long-term project. A radio amateur a bit to the north of us has done very interesting work on Doppler analysis of meteor and auroral backscatter, so it certainly is doable. The post-detection correlation issue is something more complicated.

The problem with interferometers is that to preserve phase coherence the same local oscillator has to be used for all receiver channels. Some of the low-noise centimetre wavelength receivers used for satellite broadcasting or communications are not engineered in a way that makes this easy or maybe even possible, and if the two receivers are a hundred meters apart, synchronizing the local oscillators could be difficult or out of the question. Hanbury-Brown and Twiss experimented with putting two antennas and receivers a long way apart. Each receiver had its own detector and the demodulated output fed back to the base station. From a normal interferometry point of view this is useless, since all the phase information has been lost – or has it?

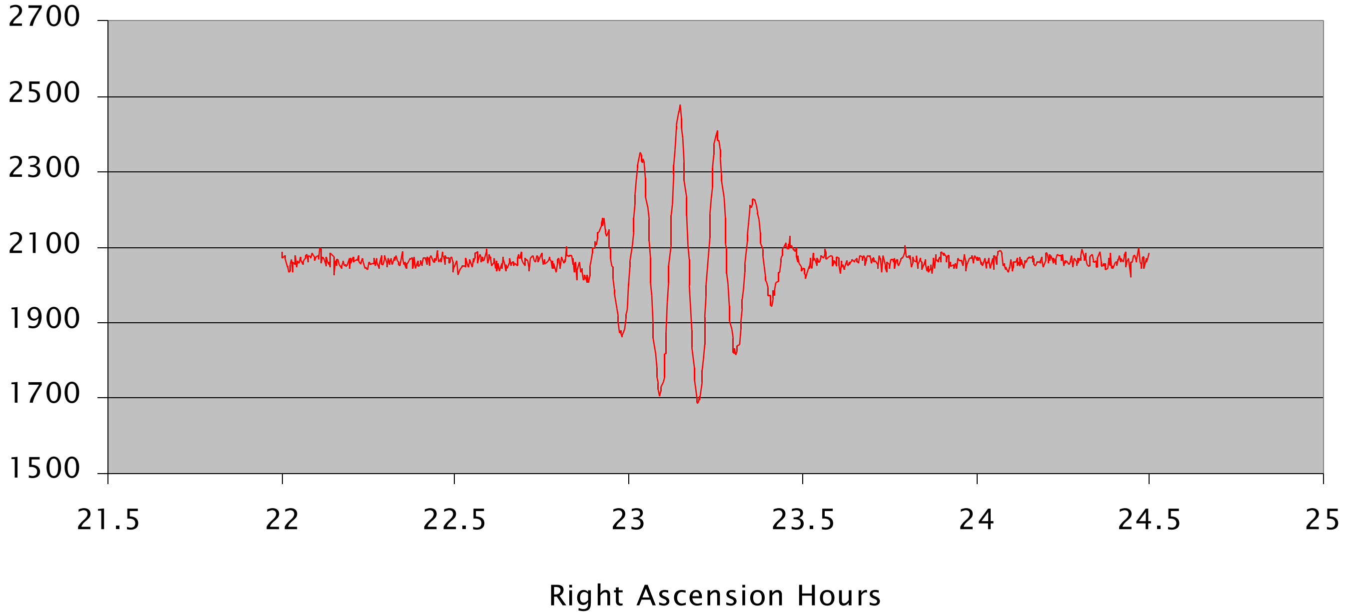
The detector in a radio telescope multiplies all the frequency components of the noise together, producing a noise output that is a complex spectrum of beat frequencies. If the noise components observed by the two receivers have common beat elements due to interaction of frequency components observed at both receivers (from the source for example), it should be possible to see similar beats in the outputs from both receivers. One can filter out a slice of detected output, say 5 – 10kHz from the two receiver outputs and correlate them. One will not get fringes since too much phase information has been lost. What one should get is an antenna profile that is the geometric mean between the receivers, with an amplitude related to what would have been the amplitude of the fringes, so one can estimate source sizes. The downside is that this technique is not efficient, and yields a sensitivity between one and two orders of magnitude lower than one would obtain with more conventional interferometer designs. However, it would be an interesting experiment using the two Ku band receivers I have. With the excellent electronics possible now, and the almost unlimited computer power available, there is more potential for experimentation in amateur radio astronomy than ever before, despite the rising level of interference.

Results

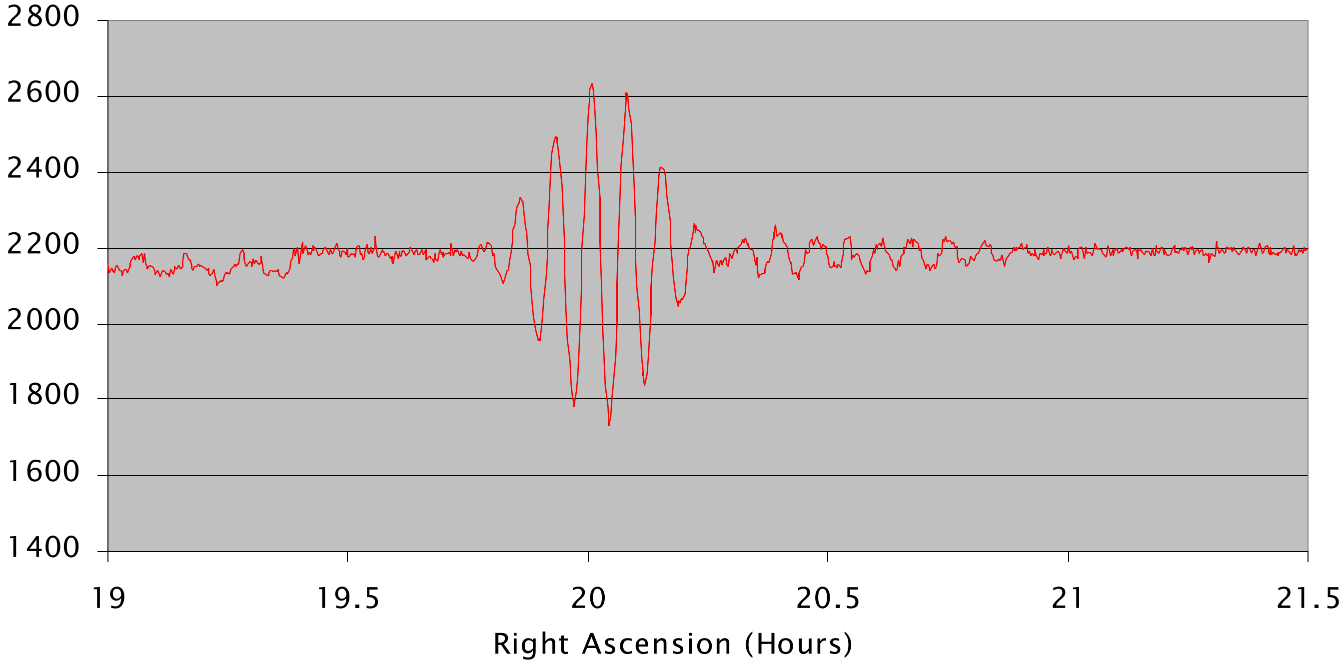
The various charts below show the Perseid meteor echoes and interferograms of Cassiopeia, Cygnus, Taurus and Virgo.

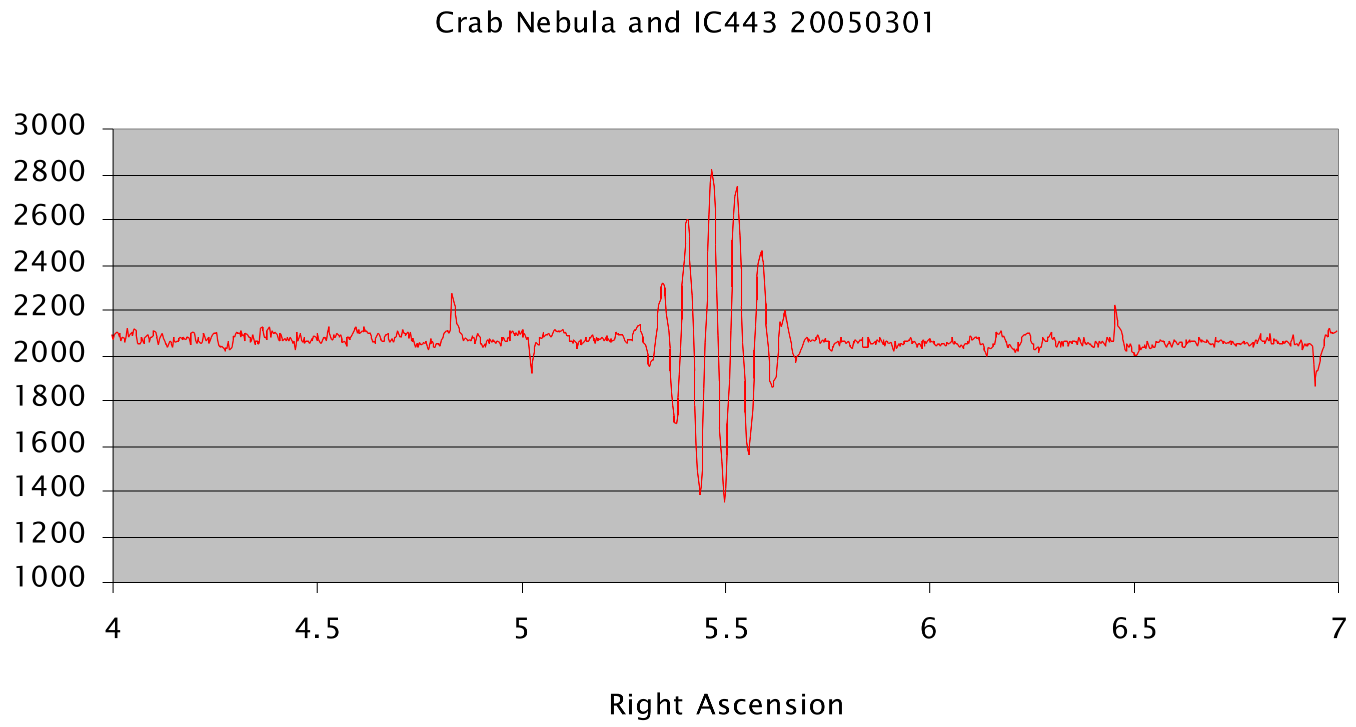


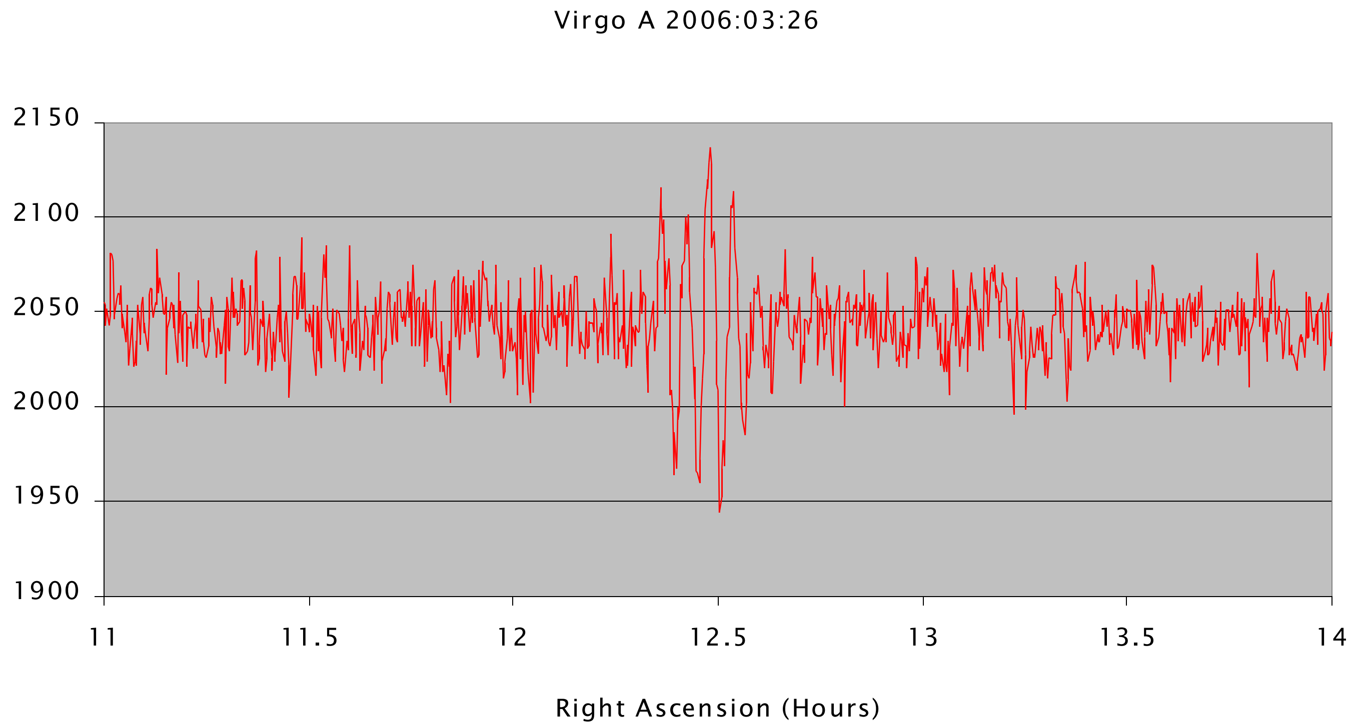
Cass_A_20051226



Cygnus A and Cygnus X




Crab Nebula and IC443 20050301
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
4
4.5
5
5.5
6
6.5
7
Right Ascension


Virgo A 2006:03:26
2150
2100
2050
2000
1950
1900
11
11.5
12
12.5
13
13.5
14
Right Ascension (Hours)

2.695GHz Receiver

Martyn Kinder
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Due to changes in project volunteers, there has been a delay getting this project off the ground. In the interim, I have the dubious honour of running with this and trying to develop the spectrometer.

What are we trying to achieve?

e-mail correspondence from Terry Ashton describes in far more detail the effect that we are trying to capture:

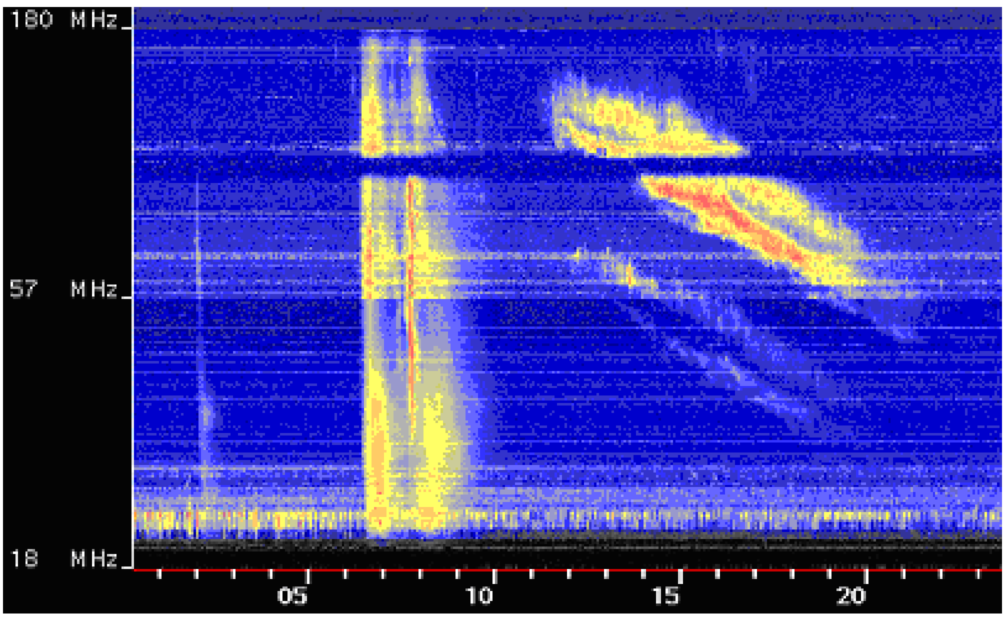
"At decimetre wavelengths, i.e. a frequency range of 0.3 - 3 GHz, flare-associated bursts are the most complex and least understood. Bursts above 1 GHz are rare (that's one of the reasons why we're interested - little or no work being done here) and most activity occurs between 300 - 500 MHz. Generally the bursts drift downward in frequency (but there are exceptions), so you'll detect one at 3GHz before its presence is detected at the lower frequencies, and as such so the rate of drift reduces. Depending on what type of event that's occurring, drift rates of the order of 500 MHz s-1 can be typical for frequencies near 3 GHz, reducing to ~100 MHz s-1 at 300 MHz, but rates as high as 950 MHz s-1 have been observed. Of course in saying all this it must be realised that the bandwidth of the burst is seldom more than 100 MHz and more often only a few tens of MHz. I'll have to think of a better way to describe this but it should be possible to identify such features as: "inverted-U" bursts; "J" bursts; "herring-bone" bursts; "spaghetti" bursts; "fibre" bursts; "microwave-spike" bursts; "zebra" bursts; "tadpole" bursts; "pulsating" bursts; "flare-continuum" bursts; "moving-Type-IV" bursts, and, of course, harmonics of the above. (That's all of the menagerie I can think of at the moment but somewhere in that lot is, I believe, the signature that announces a pending auroral display and I think it will be associated with the impulsive phase of a type III burst.)

The image below shows a radiospectrograph image (the x-axis is time in minutes, intensity in colour). This is a fast type III event (albeit at longer wavelengths) followed by a slower Type II with its fainter 2nd harmonic at the lower frequencies. I can't recall (but I can look it up later) details of the scan but I think for the 57 - 180MHz section there were 123 bins of 1MHz bandwidth sampled in 0.5 seconds. So it's fast! There's an additional, but even more complicated, problem to address and that is the sensitivity of the antenna changes with frequency. Hence the integration time has to change with the sample to maintain constant sensitivity across the band."

And following a clarification question:

"I am not sure about how strong the flare can be. The flux of the quiet sun is about 60 s.f.u. at solar minimum rising to about 200 - 300 s.f.u. at solar maximum. Flares can appear at any time and whilst most peak at under 10,000 s.f.u., I am aware of some being greater that 50,000 s.f.u. but I'm not sure whether an upper limit exists. See pages 17-18 of the first Circular for some of my (theoretical) calculations on how this relates to signal voltages for the proposed receiving antenna."

The objective of the 2.7GHz work steam is to build a spectrometer to capture these events.



Radiospectrograph of a Type III event

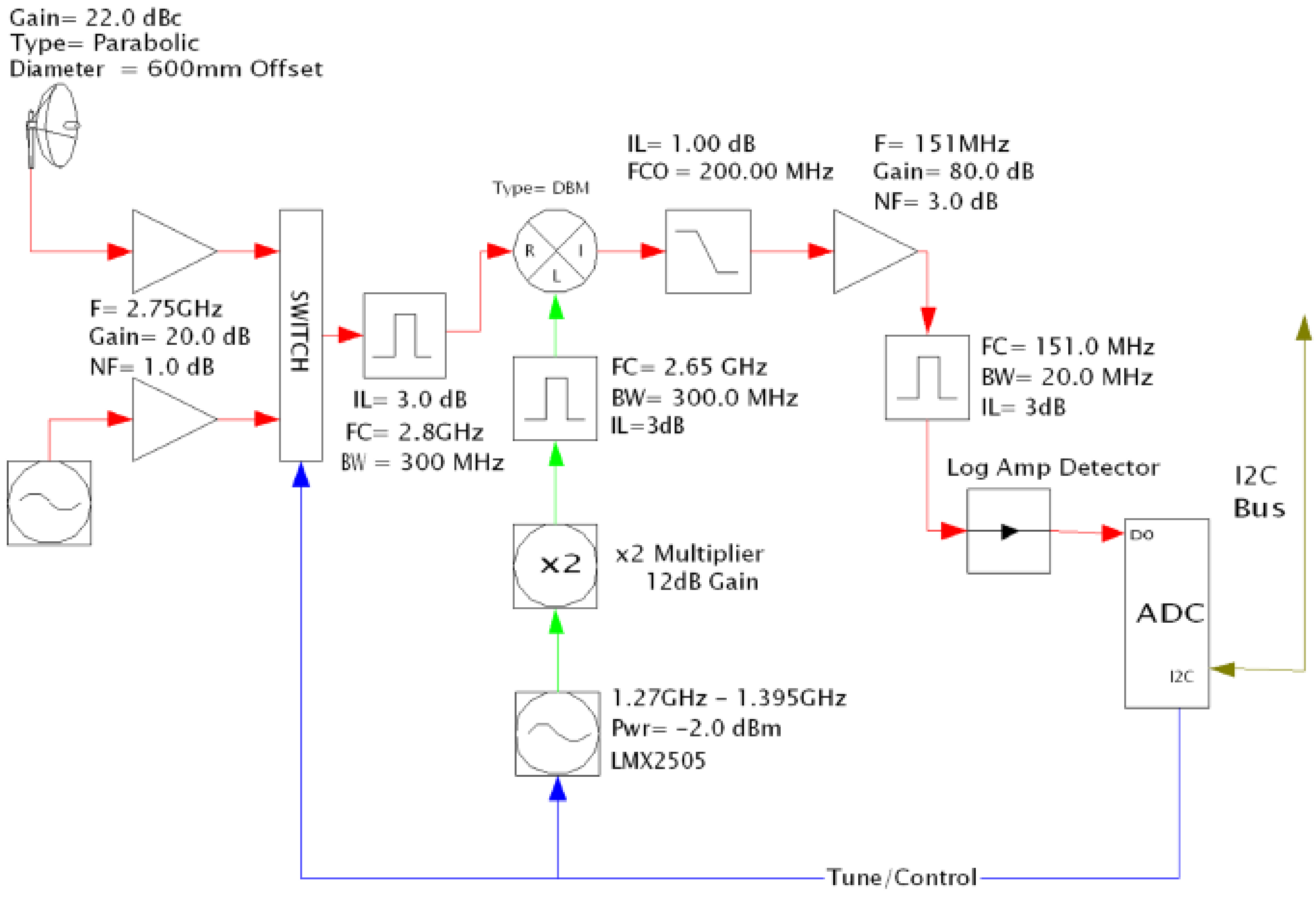
It should also be noted that these natural phenomena do not comply with the Radio Astronomy allocation is 2.690GHz-2.700GHz! Therefore, to be able to detect and monitor these events, it will be necessary to listen outside the RA allocation.

Terry's original plan was that a network of receivers would be established, each monitoring a (say) 20MHz single channel bandwidth. The data from each of these receivers would be uploaded, synchronised and a spectrograph produced from the correlated data. However, restrictions on development and sale of these receivers mean that it is unlikely that the vast numbers originally envisaged may not actually be realised.

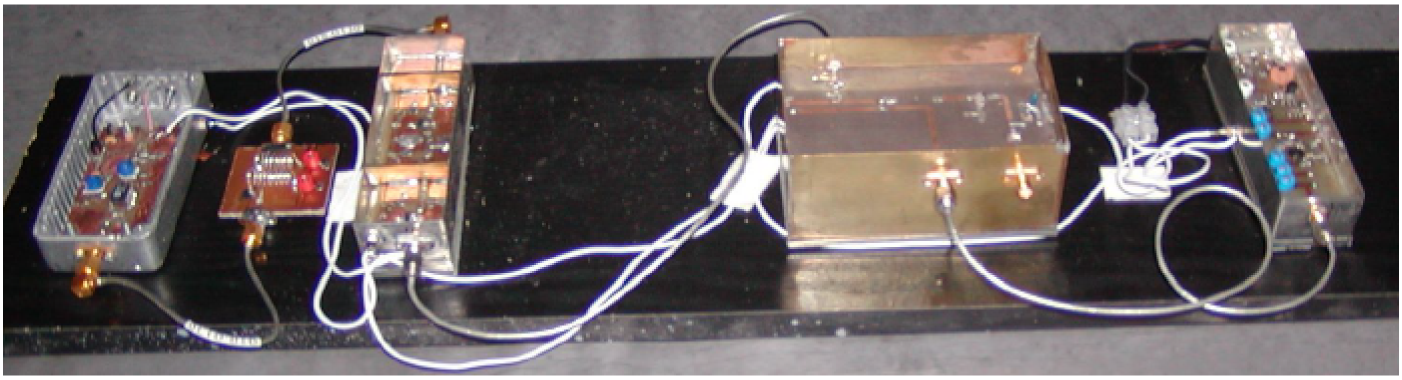
My initial thoughts on the project have produced a system architecture that looks something like the following diagram. In this form, the receiver is configured as a scanner, constantly tuning from about 2.65Ghz to 2.95Ghz in 20MHz steps (10MHz at the Local Oscillator). Careful filter design will be required, but almost certainly there will be some ripple in the filter pass-band. Therefore it will be necessary to take frequent samples from the inbuilt calibrated noise source and the signal compared against this in the PIC controller. Note that the input amplifier is actually two matching amplifiers on the same board. The switching is carried out after this initial phase of amplification.

Use of low cost devices designed for the mobile phone industry will help ensure that the component cost remains low, however, this will probably be offset by the complexity of the filters required to achieve a realistic performance. Clearly much more is yet to be done.

However, all is not quite so straightforward! From Terry's note reproduced above, a flare develops very quickly.



2.695GHz Receiver Block Diagram


The 2.7GHz Receiver Test Bed

Now making some very basic calculations,

If at each synthesizer step, we perform the following:

1. Tune VFO (20mS)
2. Stabilize (100mS)
3. Sample Noise source signal (500mS integrated)
4. Output to ADC (20mS)
5. Switch to aerial (100mS)
6. Stabilize (100mS)
7. Sample aerial signal (500mS integrated)
8. Output to ADC (20mS)
9. Compare/Differentiate by onboard PIC
   - write to I2C (20mS)
10. Switch to noise (100mS)
11. Go to step 1

Say a total of 2 seconds per sample x 15 samples at 20MHz steps (in a full 300MHz scan) = 30 seconds which to me seems to be way too slow.. However, assume that there are 20 of these receivers working away collecting data and each is offset from each other by a few MHz. Assuming that we are not attempting to keep them in synchronization with each other, then each will collect a reasonable number of samples during the period of the burst. Data will be uploaded to the *Starbase* repository where the sum of the data collected will be analysed and hopefully a useful Spectrogram can be produced.

The Test Bed

From the last but one Circular, you may remember that I have been developing a 2.7GHz total power receiver. Progress has been steady rather than startling, but I have at least detected some solar noise and output it to SkyPipe. What has become rapidly obvious is that its much more difficult to set up a system to measure noise as against a crystal clear narrow band sine wave carrier. Other lessons learned include the challenges of developing bandpass filters that actually work, quite important when you are extracting natural noise from man made and system noise.

The photo above shows the test bed system on its err.. test bed.

From right to left the modules are:

Detector

My initial detector circuit was based upon the Analogue Devices AD8307 Log Amplifier. This device has a huge dynamic range, but is based upon a stepped output of 0.5dB steps. Considering the large beam-width and consequently poor resolution of the proposed antenna system, a more sensitive detector is required. Mark 2 is currently under development and hopefully will comprise the final system complete with Analogue to Digital Converter.

151MHz Bandpass filter

I think that this is about the 5th iteration of a bandpass filter. I initially used filter modelling using Ansoft designer software. After failing to realise some of the unfeasible component values suggested by the software, I settled for a pair of closely coupled series resonant LC circuits tapped at the 50 Ohm point to get a good match. A second filter produced a similar response and insertion loss. Sometimes, cut and try can be the way forward.

75dB 151MHz Amplifier

This comprises of four Mini Circuits GALi-3 (low(ish) noise) in series. The initial design was famous for instability and only became stable when each stage was separated by a 6dB attenuator. The circuit and PCB layout will appear on my web site in due course..

2.7Ghz - 151MHz converter

This is loosely based on Charlie Suckling's 2.4GHz Amateur Satellite converter, but with a pipe-cap image rejection filter. The front end device is a MGF1494. It seems to work OK.

1.26GHz Oscillator

The last unit is a crystal controlled 1.26GHz Oscillator. The converter uses a sub harmonic mixer which effectively doubles the LO signal frequency at the point of mixing. This unit was built from one of Charles Suckling's excellent kits.

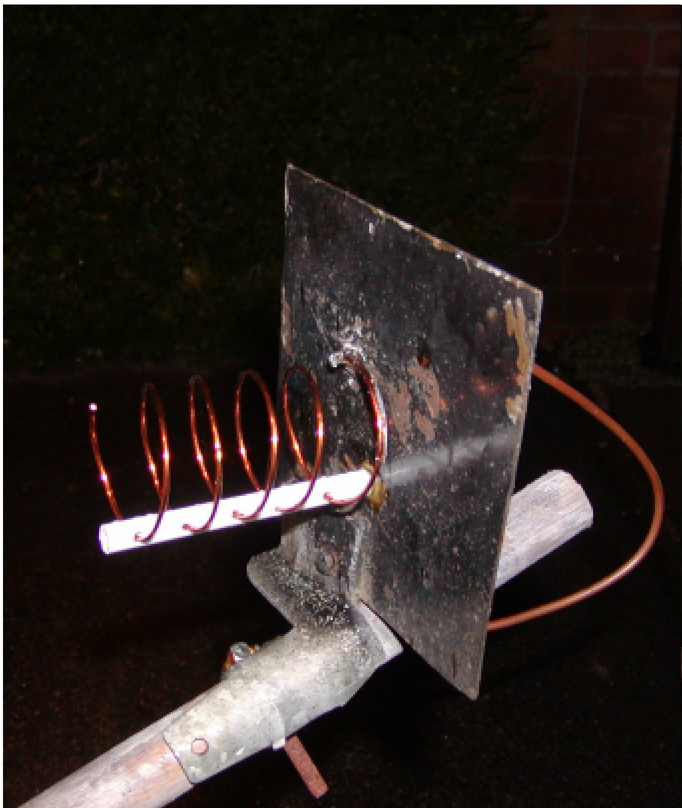
I am currently experimenting with an ex Satellite TV small parabolic antenna as the collector. This was particularly successful for 2.4GHz amateur satellite signal reception. The gain is a function of the diameter of the reflecting surface, the surface accuracy, and the quality of the illumination from the radiator. Despite these factors it is possible to estimate the gain of the antenna which can be deduced from the following formula:

$$G = 10 \log10\ k (\pi D)^2 / \lambda^2$$

where
G is the gain over an isotropic source
k is the efficiency factor which is generally about 50%
D is the diameter of the parabolic reflector in meters
lambda λ is the wavelength of the signal in meters
Therefore for a 600mm antenna, the gain at 2.7GHz will be in the order of 21dB, which is useful. For a typical parabolic reflector antenna the beamwidth is $65D/\lambda$, so at 2.7GHz, the beamwidth is about 13 degrees. The sun subtends an angle of about 0.5 degrees, so although the antenna is capturing a hot sun, it is also capturing lots more cold sky and even worse, at sun rise and sunset and for a good time after/before, it will also capture a significant amount of ground noise. One other problem that has to be considered is that the antenna feed (the helix) is not perfect and will not illuminate the parabola perfectly and any overspill will also collect further ground noise which will add to the overall system temperature. This isn't going to be easy. Fun, but not easy.

A helix feed normally has an input impedance of about 120 ohms. To bring this down to 50 ohms a 3mm wide piece of brass strip is solder around the first quarter turn. Again, more detail to appear on my web site in due course.

Finally, a plea for help. I am the very first to admit that I am not an RF designer. I can build systems from other peoples' designs and generally get them working well, but I do need some help developing this system. If you have the skills and would like to contribute or have a better idea, please get in touch. I won't be in the slightest bit offended!



The helical feed and the satellite TV dish

1.4GHz Hydrogen Line Receiver

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Alan Morgan
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The technical team for 21cm remains unchanged with Alan Morgan concentrating on development of the low noise amplifier stage and myself on most everything else. A development system is gradually taking shape and it is hoped that a total power radiometer will be operating in the near future. It would be nice to shift the emphasis towards observational radio astronomy. So far we only seem to be updating our skills in radio frequency engineering. A little input from the astronomers would be useful to make sure we are building a practical observational tool.

The original concept for the 21cm spectrometer as seen in previous circulars remains more or less intact. The system is a double conversion superhet with IFs at 151MHz and 38MHz. Using protected frequency bands for the IFs allows the possibility of building 151 and 38MHz systems with reduced effort. By this stage it was hoped that the 38MHz IF and detector modules would be available for use with the 21cm system but this has not transpired, so development has expanded to include these two modules.

The principal advance in planning since the last report is the early adoption of a switched radiometer design, know as a Dicke radiometer after the inventor, Robert Dicke. It was always recognized as a "must have" feature, but it does add to the complexity of the system. Providing Dicke capability affects the low noise amplifier, IF and detector modules, so it makes sense to build in the capability now rather than do rework later.

The main advantage of a Dicke noise switching arrangement is improved system stability. Stability is a limiting factor when looking for very small peak output level changes, which may be in the order of 0.03dB. Variations in system gain due to temperature changes could easily degrade measurement accuracy.

The Dicke system introduces a switch at the receiver input. The switch is used to connect either a reference load or the antenna to the receiver. At the output of the receiver, the same signal used to drive the input switch is also used to drive circuits so that the noise signal from the reference load is subtracted from the antenna noise signal. If the two signals are made equal in level with the antenna pointing at a cold sky, the output of the receiver will be zero. Any system gain changes will affect both reference and antenna signals and the output will remain at zero. However, when noise from a astronomical source is added to the antenna, this will appear as the output of the receiver.

Because antenna temperature is only being measured for half the time, the relative accuracy of the measurement is degraded by a factor of Root 2. Also, the difference between two uncorrelated random variables is being taken, which degrades accuracy by a further factor of Root 2. The corresponding loss of accuracy by a factor of 2 is still worthwhile.

This sounds great in principle but the real world makes implementation a challenge. Ideally you'd like to have the switch as between the antenna and the Low Noise Amplifier, but the losses of any practical switch would have a huge effect on the noise figure of the front end, reducing the sensitivity of the system. The switch also has to operate 24/7 at frequencies up to hundreds of times per second, so mechanical designs are very difficult to produce. The second best option would be to have the switch after the first stage, but tests of a prototype switch show that this may still impair the noise figure too much. Therefore, the current plan is to build two identical two-stage amplifiers, one connected to the antenna and the other the reference load. A fast PIN diode switch will follow the amplifiers (Figure 1). The disadvantage of this idea is that the preamps are outside the gain compensation loop. However, the preamps are identical and are housed to match them thermally, so it is hoped that the degradation in performance of the Dicke arrangement will be minimal.

Antenna

As can be seen from my more detailed description elsewhere, a 1.8m dish has been purchased from Maplin Electronics. The Maplin dish may be small for radio astronomy purposes, but it is an off-the-shelf item that is quite easily deployed. To collect the energy from the dish a suitable feed for 21cm is required and once again an off-the-shelf solution is being sought. We hope to have an Astronomy Supplies feed available to test soon. Using these components, implementing a basic antenna should only require simple mechanical operations to mount the feed on the dish. All being well, instructions and maybe parts can be prepared for this purpose. Larger dish kits are available on the Ham Radio market, or else a dish can be built from scratch with minimal tools but lots of persistence. The implementation of a pyramidal horn design has not yet been investigated.

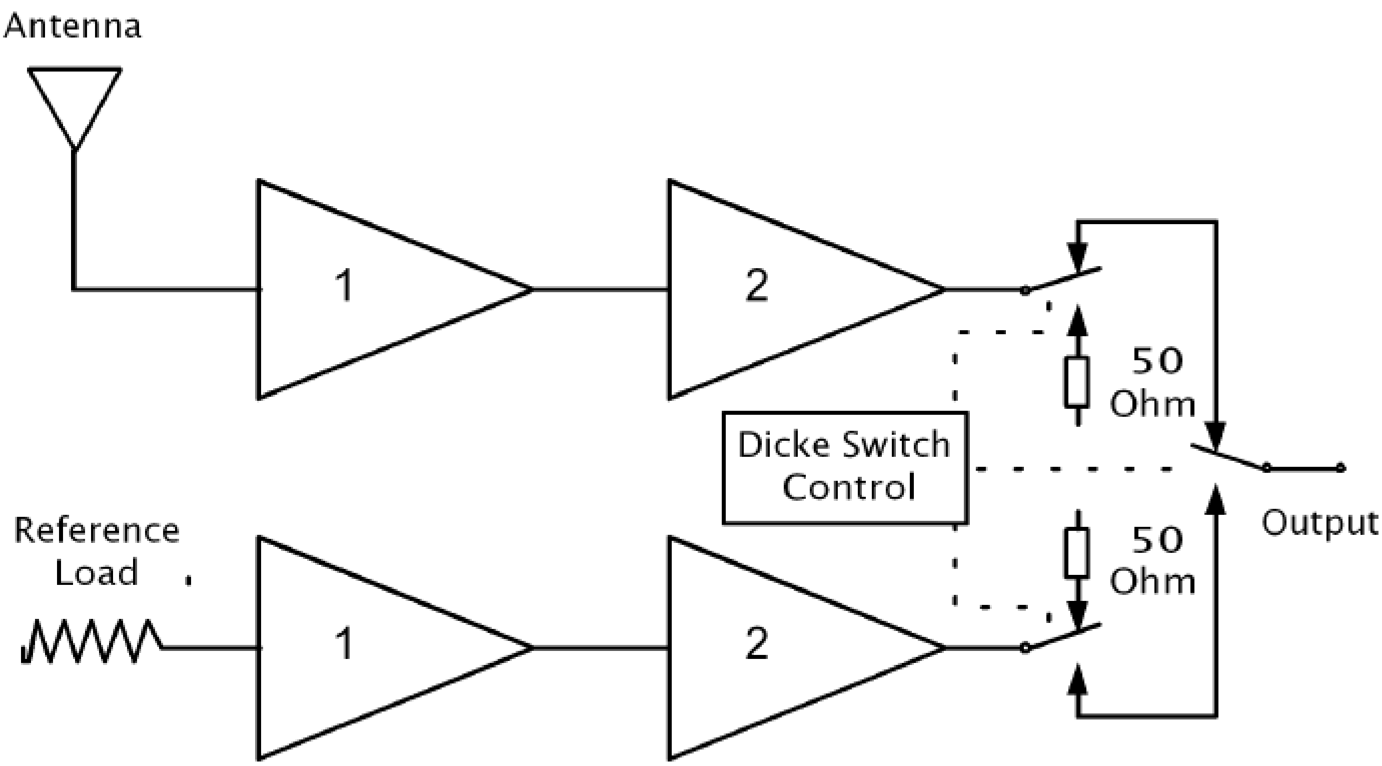

Figure 1 Dicke Switch

Low Noise Amplifier

The prototype low noise amplifier board produced by Alan Morgan has now been boxed up with N type coaxial connectors (Figure 2). It is producing about 30dB gain at 1420MHz. The design has a low noise HEMPT first stage followed by a microwave integrated circuit second stage that adds more gain buffering the system to some extent to subsequent cable losses. The noise figure of the completed LNA has not yet been measured but should be about 0.35dB.

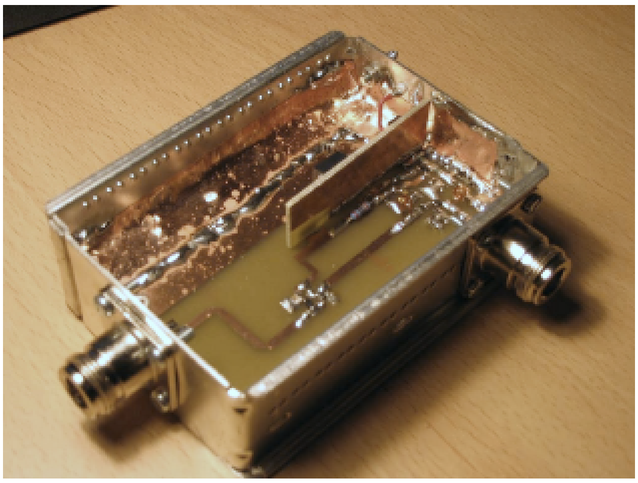

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Figure 2 Preamplifier

Alan's has only built one amplifier in this prototype, the second would be a mirror image of the first. The Dicke switch is not installed although some space has been left on the pcb design for this. Alan experimented by putting the 5v regulator on a piece of double sided pcb down the middle of the two amplifiers in an attempt to shield one amp from the other. He also thought he would try putting the two RF input connectors on opposite sides of the box (only one is shown in the picture) with the output on a third side. This was to try and make the two inputs as physically far apart from each other as practical. If the first input is connected close to the antenna feed point, then this would leave more space for connecting the temperature controlled reference load to the second input. While building the prototype, Alan has concluded that it would be best to keep a screen between the two amplifiers, but move the regulator back onto the main board. Our experiments with the PIN diode Dicke switch have shown that it will take up a bit more space than previously thought, requiring a larger box for the next iteration.

Making measurements of very low noise amplifiers at microwave frequencies is not easy. A manual approach can be taken using loads of with a known temperature, but this is very tedious. I am pleased to say that Alan Morgan has invested in a professional Precision Automatic Noise Figure Indicator (PANFI) test set, an HP8970A, to simplify the process. The test set is not yet operational because it lacks a noise source. If you have a calibrated 28V noise source tucked away somewhere, we would be very happy to hear about it. This system should allow the performance of our low noise amplifier to be optimised and will greatly assist when we enter a production phase.

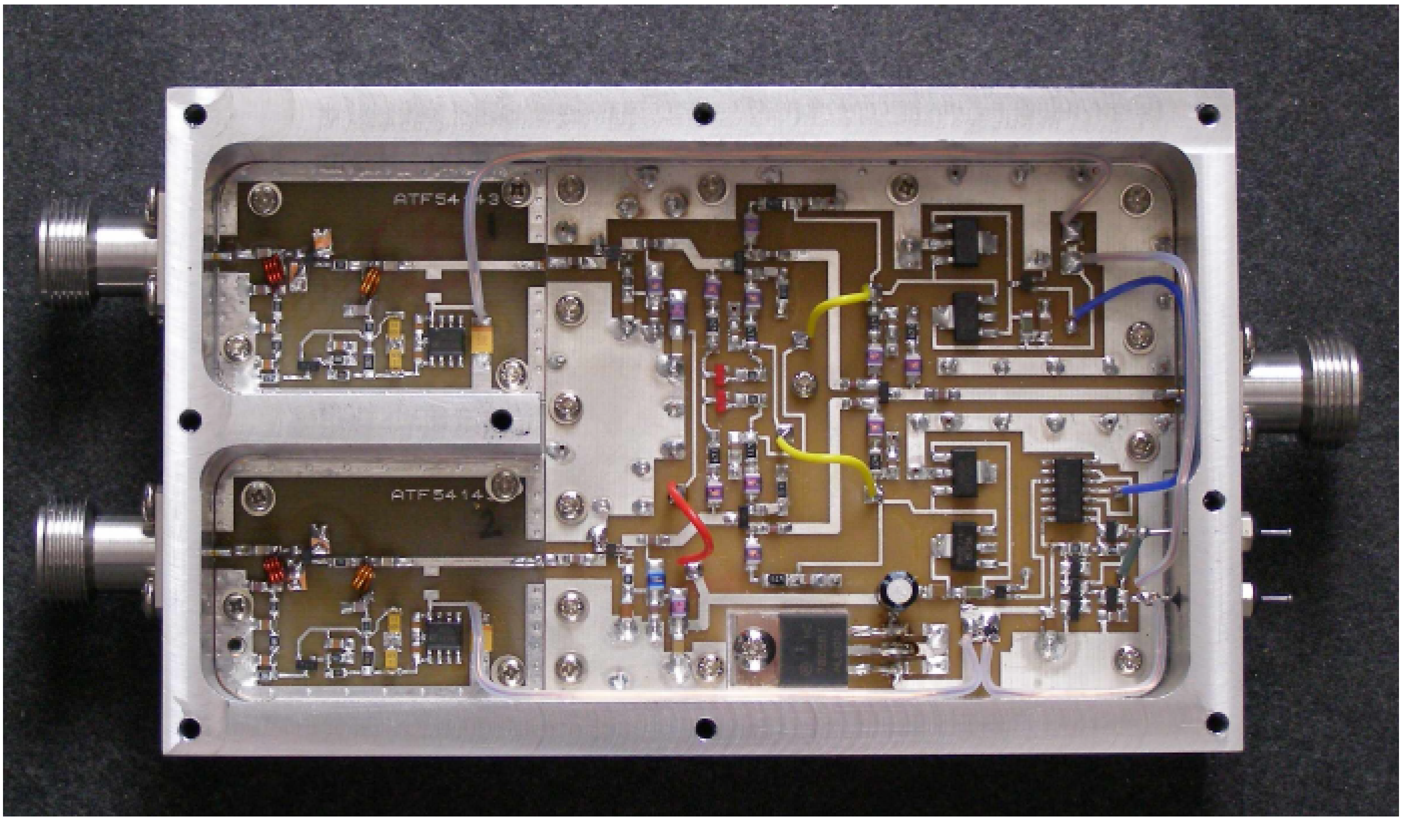

Figure 3 Dicke Switched Low Noise Amplifier

At the risk on treading on Alan's toes, I got interested in the design of a PIN switch and built a Mark 1 version to see if I could make it work. The design has been simplified and a Mark II version built that will be included in my own prototype dual channel low noise amplifier (Figure 3). I have cheated as far as the amplifiers are concerned by buying some ready made PCBs . These are not optimised for 21cm but should provide enough performance to test the total power radiometer. They can be replaced at a later date when something better comes along. My amplifier is being housed in a professional style, milled aluminium box that should provide excellent screening. The milling machine to produce the box is another recent investment and involves yet another learning curve. This low noise amplifier is still a work in progress at this stage but should be finished for the September meeting.

1420 to 151MHz Downconverter

The prototype 1420 to 151MHz downconverter and associated 1570MHz local oscillator has been completed and was demonstrated at the May technical meeting. Using a 23cm amateur radio low noise amplifier and a Racal RA1772 communications receiver as the IF amplifier, it was possible to measure cold sky, warm ground, and glowing development team noise temperatures. The downconverter features a good filter at 1420MHz to help reject radar, mobile phone and satellite signals that are close to the protected radio astronomy band. Various discussions from interested parties has resulted in a bandwidth for the receiver at this point of about 20MHz. The local oscillator design also came in for further scrutiny, but for the moment this will remain as a fairly conventional multiplied crystal oscillator unit. Keeping the local oscillator separate from the downconvertor will enable further developments to be implemented in this area if necessary.

151 to 38MHz Downconverter

A prototype of this stage has been completed (Figure 4). It has a local oscillator at 189MHz and a mixer to take 189 – 151MHz = 38MHz. It may be possible to integrate this stage into another module at some point, but for flexibility and ease of measurement it has been kept as a separate unit at the moment.

38MHz Main IF Amplifier

The original 38MHz main IF amplifier was part of a separate development and it was hoped to benefit from this work. Unfortunately this has not happened and a new design is being developed to suit the 21cm receiver. The unit will have more than 80dB gain and this requires it to be well designed mechanically. We need to ensure that the input is sufficiently screened from the output to avoid unwanted feedback and instability. The design goal is to produce a filtered 38MHz signal with a bandwidth of about 17MHz and -20dBm noise output to feed the following detector stage. The prototype has been designed and all parts obtained. All that is missing is time and energy.

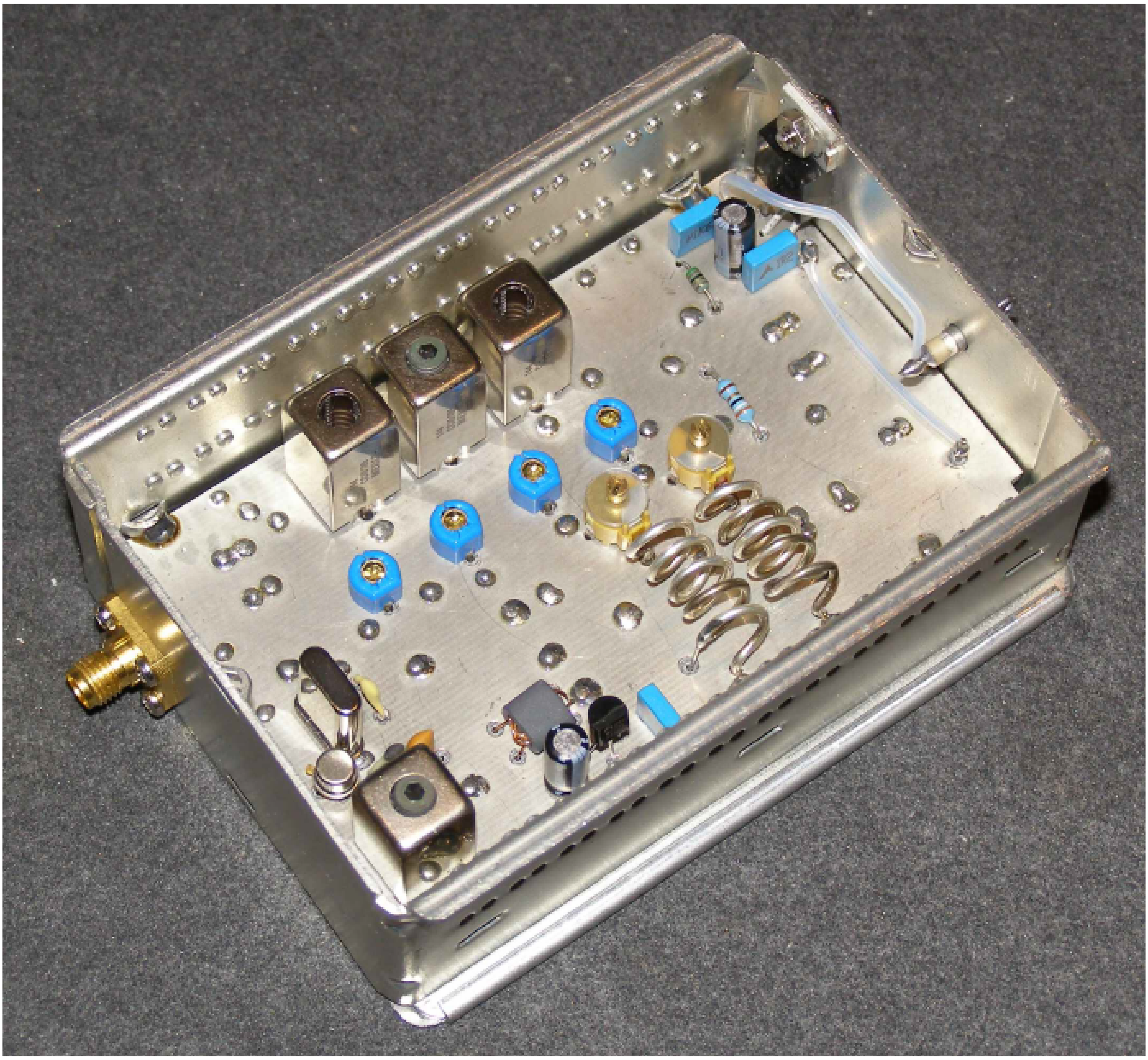

Figure 4 151Mhz to 38Mhz Downconverter

It may be possible to integrate some gain control into the amplifier. This will allow the system to be calibrated for variations in feeder loss and module gains. It will also be possible to balance out the level differences for the Dicke arrangement when switching between reference and antenna inputs. Some digitally controlled attenuator chips have been obtained for this purpose. They are super bits of technology, but are only 4mm square with five connections on each side. Making printed circuit boards and mounting the chips will present another challenge.

Detector

The development of the detector stage has also been unable to keep up with the 21cm system. Therefore a prototype detector system is being designed around a zero bias Schottky diode square law detector (Figure 5). The detector will provide square law voltage, logarithmic voltage and pulse rate outputs. The integrator period will be programmable in 6 decades steps from 1ms to 100s. It is hoped to include the "Lock in Amplifier" or equivalent for the Dicke arrangement in this module.

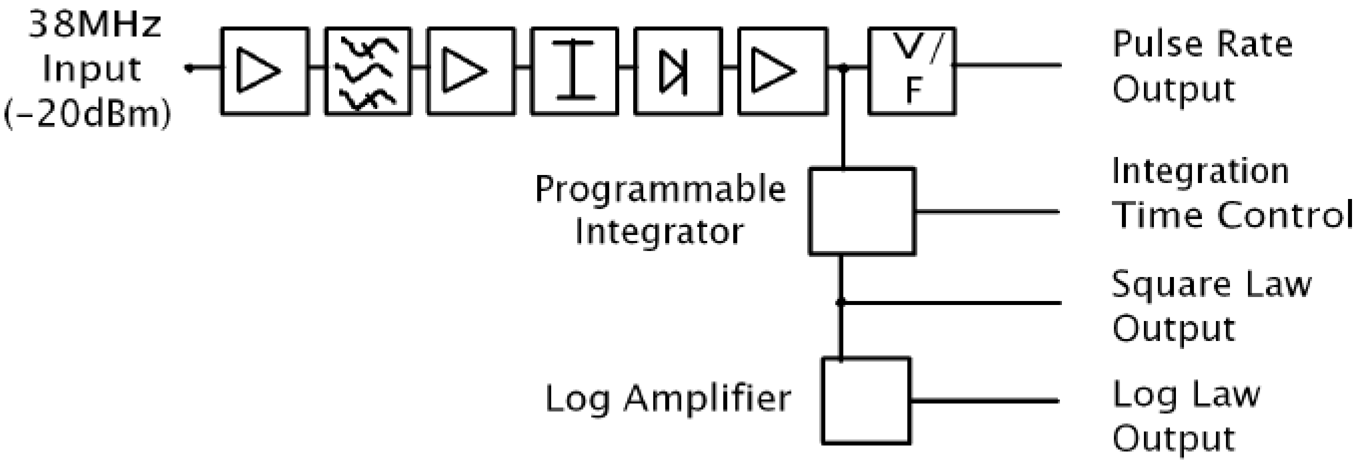

Figure 5 Detector Module

Enclosure

A 19 inch rack case has been purchased to house the various modules (Figure 6). This will allow the units to be securely mounted, protect the interconnecting cables and enclose a power supply. To aid the stability of the system, it is intended that the temperature inside the enclosure will be controlled electronically using a fan or fans.

Spectrometer

No work has been done on the spectrometer module. A hardware system can be built but this would be decade old technology and I still hope that we can obtain some support from within our membership to develop a DSP based system. A simple solution that will allow measurements in 20KHz chunks of the approximately 3MHz wide band of interest would be to use a PC sound card. However, it would be much better to use a high speed A to D converter on a stand-alone board to process the data. There are many *Software Defined Radio* projects being developed at the moment and this may yield a source of ideas and usefully priced hardware. Meanwhile a DSP book has been obtained for self-instruction purposes, but it needs translation into English!

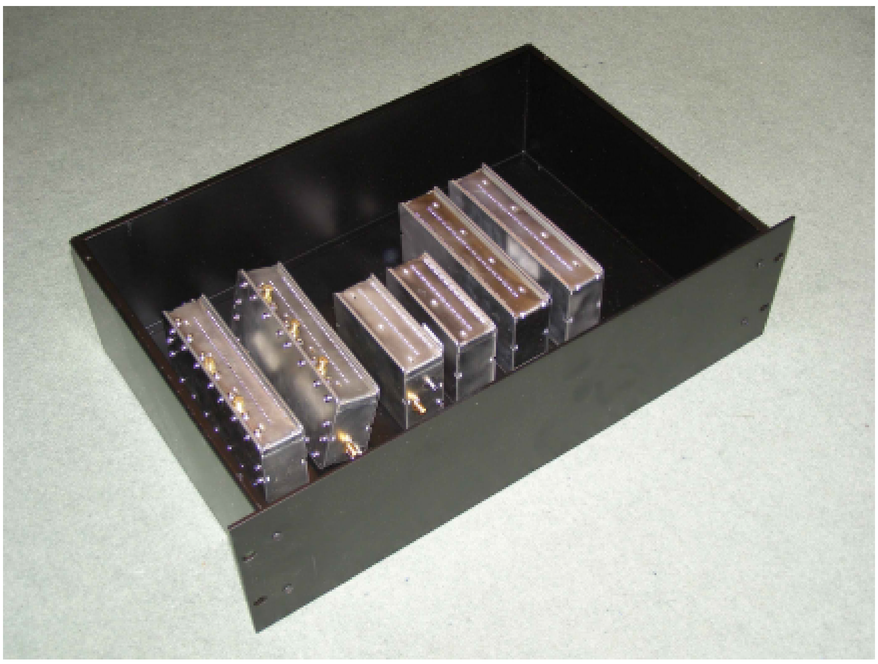

Figure 6 19inch Rack Case

Editor's note

We have not yet decided how the final Starbase Hydrogen Line Receiver will be packaged. David's prototype shows one possible solution. Other suggestions gratefully received!

A Dual-Axis Magnetometer

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Following on from my article in the previous Circular, here is a description of the magnetometer design for our *Starbase* project. The most important item is the magnetic sensor itself, and here I have used an Anisotropic Magneto-Resistive (AMR) sensor by Honeywell. The HM1022 consists of a pair of bridge circuits arranged at right-angles to each other. The bridge supply is obtained with a pair of precision shunt regulators arranged to give +/-2.5 Volts. The total bridge supply is thus 5 Volts, with the zero-field output at 0V.

As with most electronic circuits, the bridge has a temperature sensitivity, as well as DC offsets. The HM1022 has an answer to these problems, as it includes a set/reset strap for each bridge. These are low resistance elements that can be pulsed periodically with a high current (about 0.5A). The high local magnetic field generated by these straps pushes the bridge sensitivity to its maximum; a positive pulse renders maximum sensitivity in the normal direction, whilst a negative pulse reverses the direction of sensitivity (i.e., north & south are swapped). The temperature sensitivity & offsets remain fixed by the characteristics of the bridge, and so appear to reverse relative to the magnetic sensitivity each time the set/reset strap is pulsed. This design alternates positive and negative pulses at 500us intervals in each strap.

The differential output from each bridge is boosted by a factor of 1000 by an instrumentation amplifier, the single ended output of which is fed to a pair of analogue switches. The switches are operated in phase with the set/reset strap pulses, so that one switch routes the positive signal while the other routes the negative signal. Each switch is loaded with a 0.1uF capacitor, so that a charge is stored according to the magnitude of each signal. These two signals form the inputs to a second instrumentation amplifier, such that the positive and negative contributions are summed to give an output twice that of the input. As the temperature and offset effects are nearly the same for each phase, the summation will cancel them out, leaving just the wanted magnetic component. The overall gain of this stage can be adjusted according to the required magnetometer sensitivity. At this point, the signal will vary about 0 volts as the field moves either side of the sensor. In order to provide a unipolar voltage suitable for an analogue to digital converter (ADC), a 2.5 Volt offset is applied by a final buffer stage such that the output range is now 0..5 Volts. With the sensor axis at right-angles to magnetic north, the output voltage will be 2.5V. Shifts in the field one way will reduce the voltage, while a shift in the opposite direction will increase it. Because this is a rotational field shift, the voltage change will be proportional to Sin(shift angle). If the field were to shift a complete 90 degrees, the field would then be parallel to the sensitive axis and the output would be a maximum. In practise the sensor saturates long before that happens. LEDs have been included to show this null position. Thus by correctly orientating the two axes, all LEDs will be off, and both outputs will be at 2.5V. As the diurnal variation pushes the field from side to side, the outputs will rise and fall about this mid-rail position, and the LEDs will brighten accordingly.

Sensitivity

The magneto-resistive effect in this device has a sensitivity of 1mV/V/Gauss (10V/V/Tesla) relative to the bridge voltage. With expected variations up to 500nT, the sensitivity is better expressed as 10nV/V/nT. The total bridge supply is 5V, the first stage gain is 1000, and the chopper circuit has a gain of 2. Therefore the basic sensitivity becomes 10nV x 5 x 1000 x 2 = 100uV/nT. The subsequent stages have a minimum gain of 20, giving 2mV/nT at the analogue to digital converter input. A 5 Volt range thus covers a magnetic field strength variation of about 2500nT at the sensor. The overall gain can adjusted as described above, within limits yet to be determined.

Calibration

The chopper-stabilisation described above reduces the temperature sensitivity considerably, and also removes DC offsets inherent in the sensor bridge and high-gain amplifier. It is therefore possible, if rather tricky, to calibrate the completed magnetometer in terms of mV/nT. A known magnetic field is easily generated by a solenoid carrying a fixed current (i.e., a known number of ampere-turns is present within the solenoid). Two such coils suitably spaced can produce a volume within the coils of constant ampere-turns. If the coil diameter is large enough, the magnetometer can be fitted inside and the output observed as the current is adjusted. In reality, the actual field present will be the vector sum of the solenoid's field and the local magnetic field due to the earth and other magnetic objects. As described above this can be nulled out, so that a good guide to the magnetometers sensitivity can be obtained. In practise, if the daily diurnal curve is visible then adequate sensitivity is available to detect and record magnetic disturbances and storms caused by solar flares and coronal mass ejections.

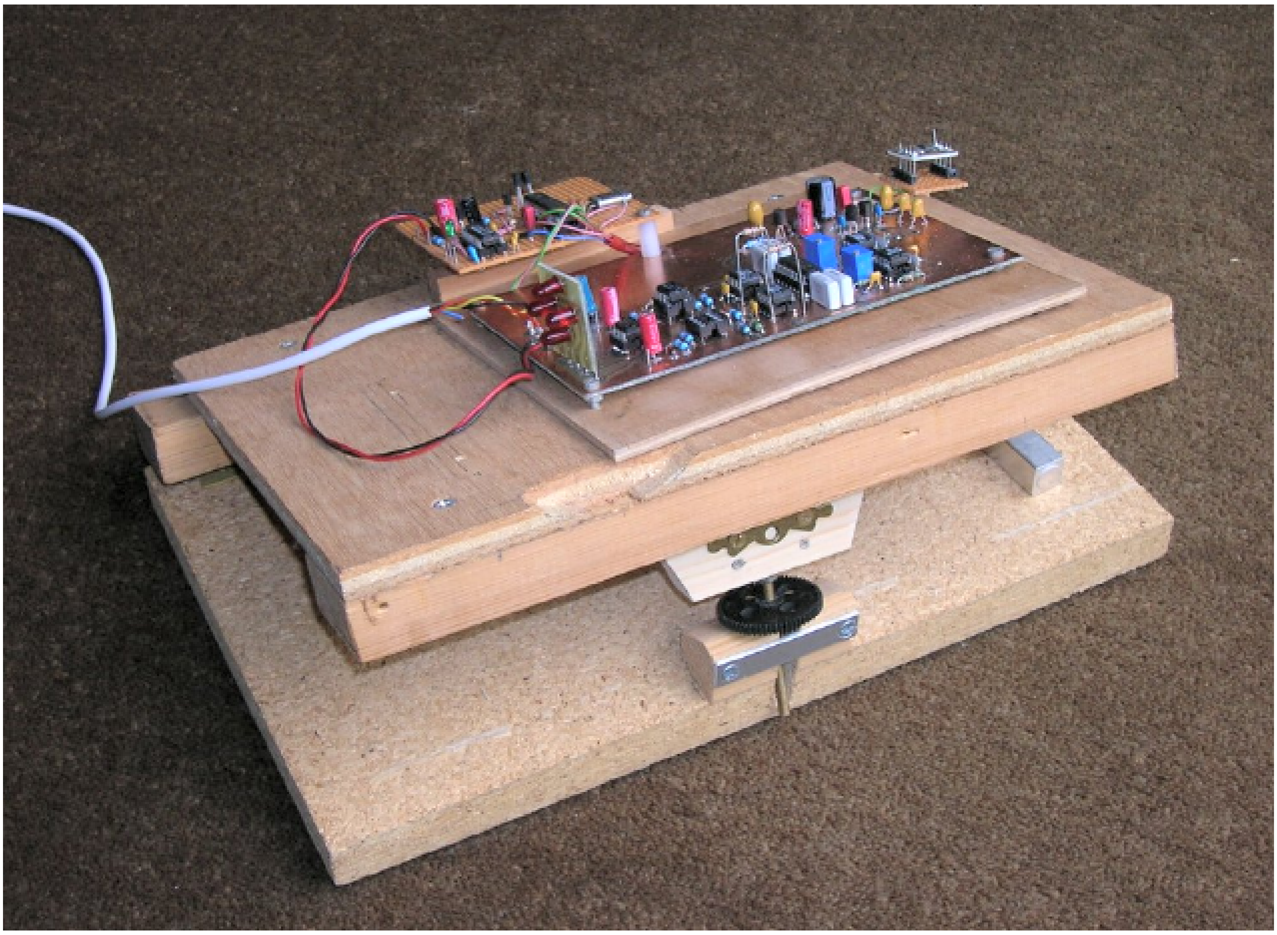

Figure 1 Magnetometer prototype on its "magneto-equatorial" mount

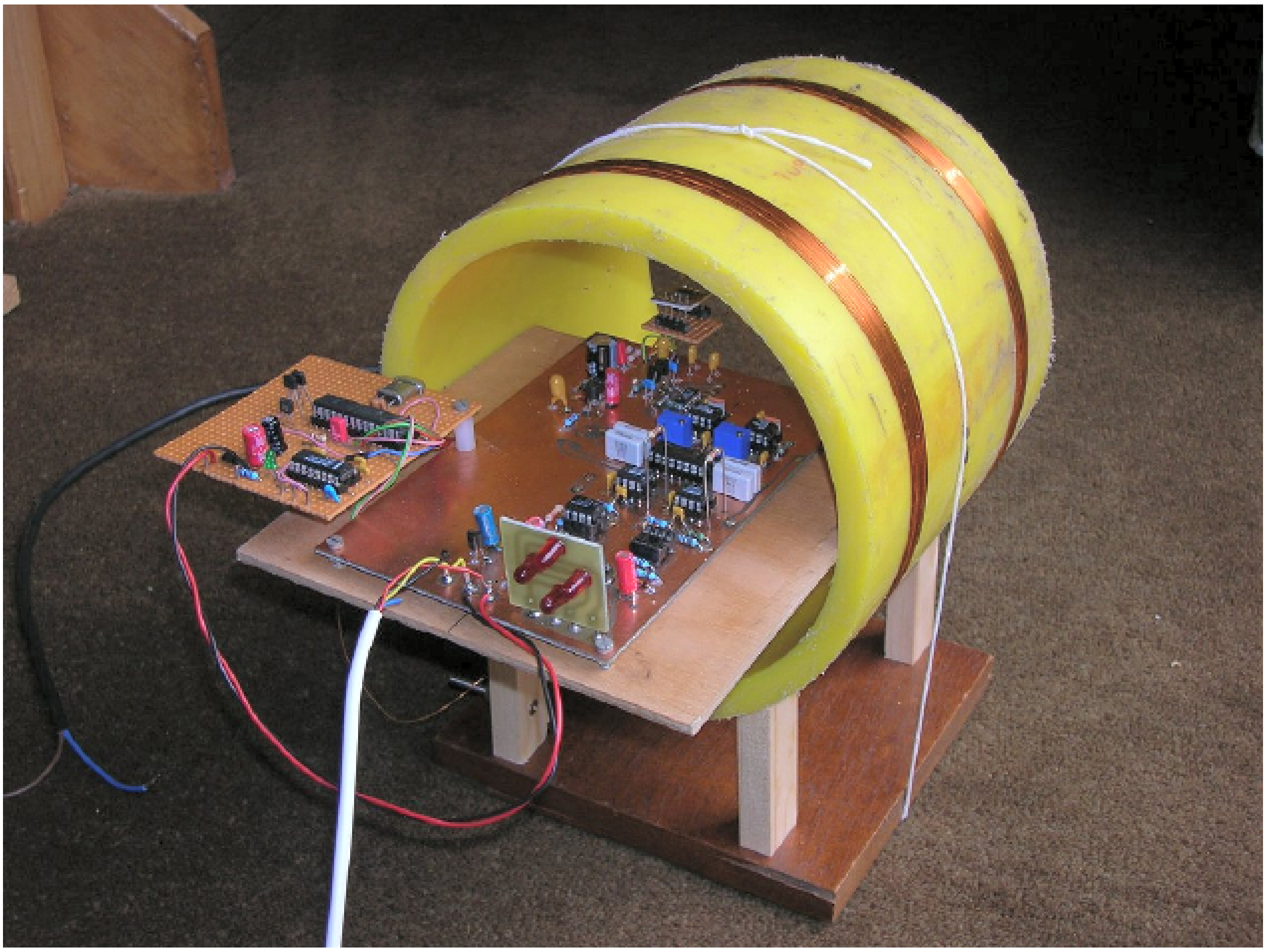

Figure 2 Helmholtz coil arrangement for sensitivity checking

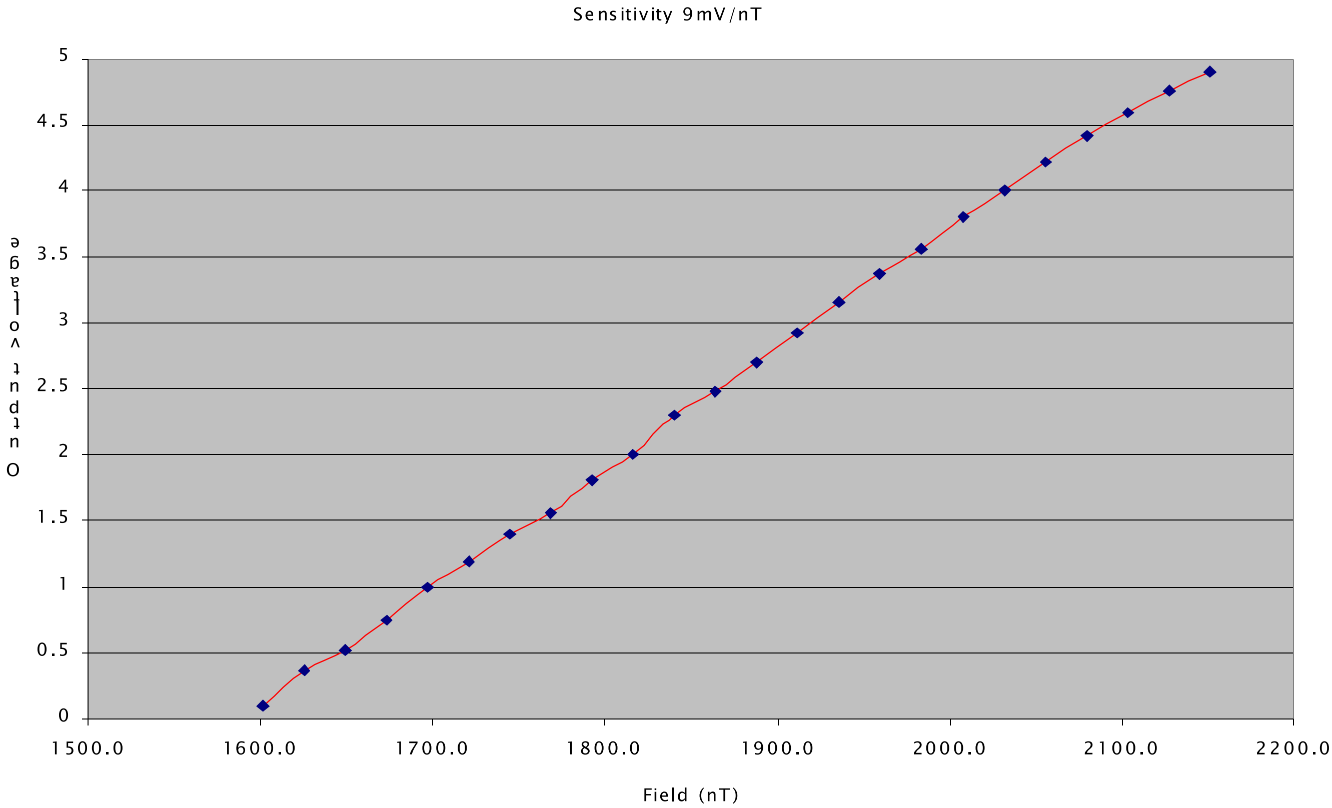

Figure 3 Preliminary calibration chart from the magnetometer prototype

VLF RECEIVER

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The following article describes my experiences with one of the RAG development prototype VLF receiver modules designed by John Cook and Peter King.

The Receiver

I've mounted the receiver module in a 2U 19" box (see Image 1) along with a power supply providing +/-15 Volts and 5 Volts. The antenna input socket comes out at the rear of the case. On the front of the case I have provided a socket for the receiver DC output – this is currently being fed into a digital multimeter. The meter has a serial data link to a PC so, in conjunction with some logging software, the meter reading in volts DC is logged once a minute. I'd like to replace this meter at some stage with some alternative logging arrangements and so have provided a DC meter on the front of the box which reads from 0 to 4 Volts (the output range of the receiver) as an indicator of signal strength. I have also added a switch and socket on to the front panel which feeds into the antenna input via a 100k resistor. This is to allow an audio lead to be easily connected up to a PC soundcard output so a test/line-up signal can be introduced when required. One final addition to the system is an RF output taken from a point just before the detector. This is a useful point in the circuit to monitor on an oscilloscope while tuning so I've brought this out of the receiver module via some coax and onto a BNC socket on the front of the case.

The Antenna

The antenna consists of approximately 80 turns of 22swg enamel covered wire forming a square loop with sides approximately 550mm long (see Image 3). The inductance of the loop is about 45mH. Despite the system working very well the quality of my woodworking is appalling and needs to be sorted out ASAP. The structure has fallen over several times – once onto my head – and so the system needs to be taken offline and the antenna base rebuilt before any further damage occurs (to my head or otherwise).

The Tuning Capacitor

Following the antenna comes the capacitor switchbox which sits in parallel with the loop (see Image 2). It contains a 250pF variable capacitor and five fixed capacitors (100, 200, 400, 800, 1600pF) which can be switched in parallel with the variable capacitor. This gives a wide tuning range with fine tuning once you get into the correct area with the switches. For example, in the picture of the capacitor switchbox it is tuned to 18.3 kHz with switches 3, 4, and 5 switched in. Four other frequencies are marked on the dial (the number beside the frequency indicates which switches need to be switched in to get to that frequency).

Tuning procedure

This is the procedure I now follow to tune up the antenna and receiver. I did have some initial problems tuning up the system and it took a while to get this procedure sorted out. However, I now find it relatively easy to tune providing I follow these instructions.

1 Connect aerial (via capacitor switchbox) to VLF receiver input. Monitor VLF receiver RF output using 'scope connected to RF monitoring point.

2 Connect PC soundcard output to antenna input (via socket on front of box). Use Cool Edit Pro audio program on PC to generate test tone (e.g. 18.3kHz). Use level of approx -20dBFS (higher levels overload RF input of receiver & much lower levels than this get mixed up with real signals). Note: need soundcard capable of over 48kHz sampling rate to be able to generate the higher frequencies in the VLF band such as 23.4kHz (the one I use is a 96kHz sample rate capable MAudio 2496).

3 Adjust switches and variable capacitor on capacitor switchbox until you get maximum RF output on 'scope. Make a note on capacitor switchbox indicating position of knob and which switches are required for that frequency. (Note: this only needs to be done first time – subsequently when re-tuning all you need to do is set the knob & switches to marked positions.)

4 Adjust RF frequency control on VLF RX to get maximum RF output on 'scope.

5 (Adjust Q – increase until output oscillates then back off a bit to point before this happens. I found that once this was set I didn't need to readjust it again.)

6 (Adjust RF gain – I tried experimenting with this but now just leave it at max level.)

7 Disconnect PC test tone from VLF receiver and stop PC generating tone. Increase gain on 'scope Y axis to see RF signal from transmitter. Adjust antenna position to get maximum RF output. (If this is first time then make note of antenna orientation so you can easily return antenna to this position.) Adjust variable capacitor to confirm that you are indeed tuned to that transmitter – i.e. RF level should drop when you move knob in either direction away from current position.

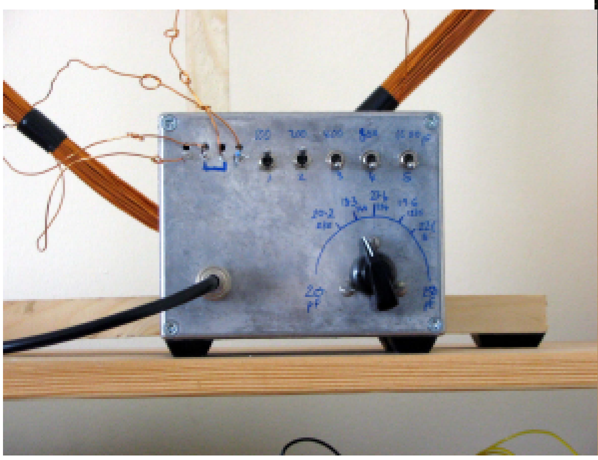
Signals

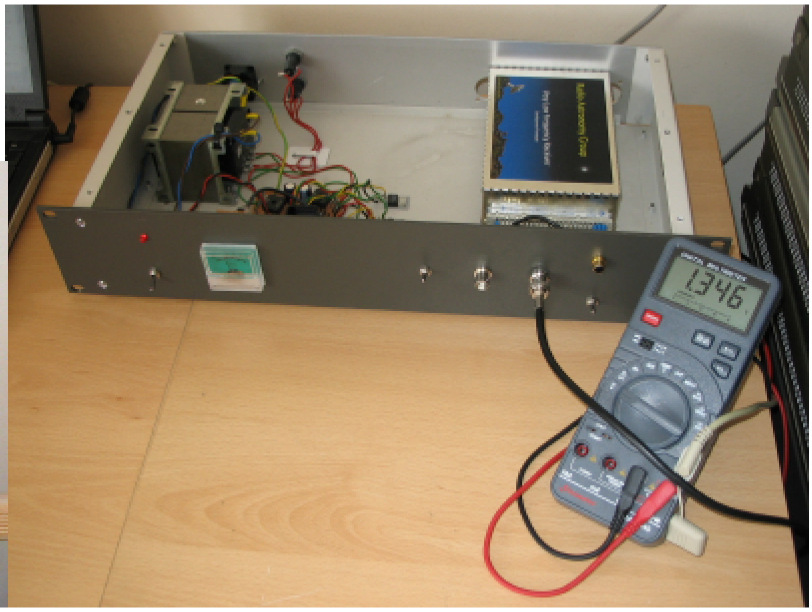
Here are some signals (and their strengths) that I picked up across the VLF band at around midday one day in early July (the x1 or x10 refer to the DC gain setting on the receiver board):

Freq (kHz)	RF (mV pk-pk)	DC o/p (V)
18.3	300	2.4 (x10)
19.6	700	3.7 (x10), 0.84 (x1)
20.2	1500	1.6 (x1)
22.1	500	3.3 (x10), 0.64 (x1)
23.4	1500	1.6 (x1)

For the past few weeks I have had the system tuned to the transmitter on 18.3kHz which is located in LeBlanc in France (my location is Cambridge in the UK). A typical output on a quiet solar day (which is all I've seen!) is shown in Image 4. This shows a whole day from midnight on the left to approx. 10.30pm on the right, showing clearly the rapid drop in signal around dawn, the gradual rise to the peak at midday, the gradual decline in the afternoon, and then the rapid rise again at dusk. Also clearly seen are the small post-dawn and pre-dusk peaks. The vertical scale is in mV. All I need to do now is wait for the sun to get active…

Image 1 Rack-mounted VLF receiver
Image 2 tuning unit (below)





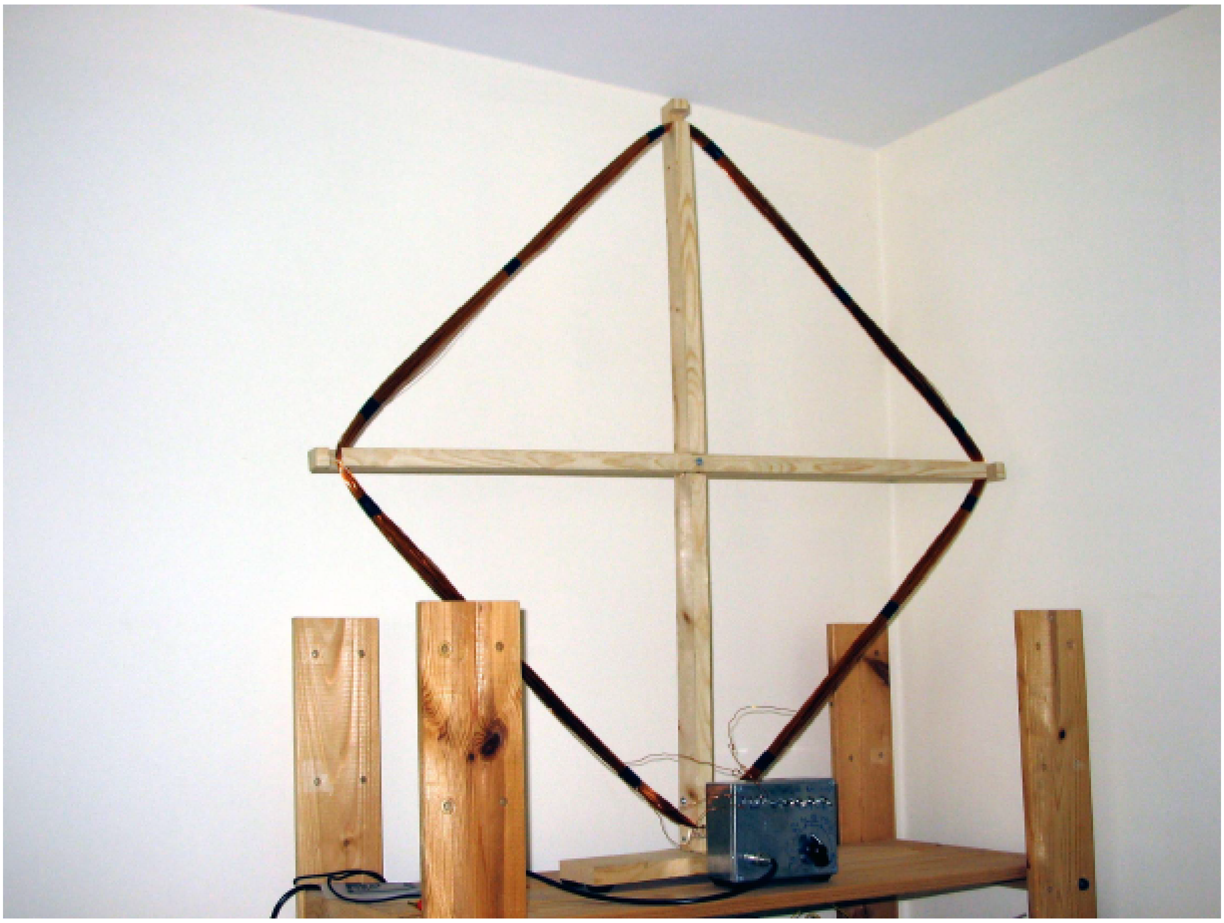


Image 3 VLF Loop Antenna

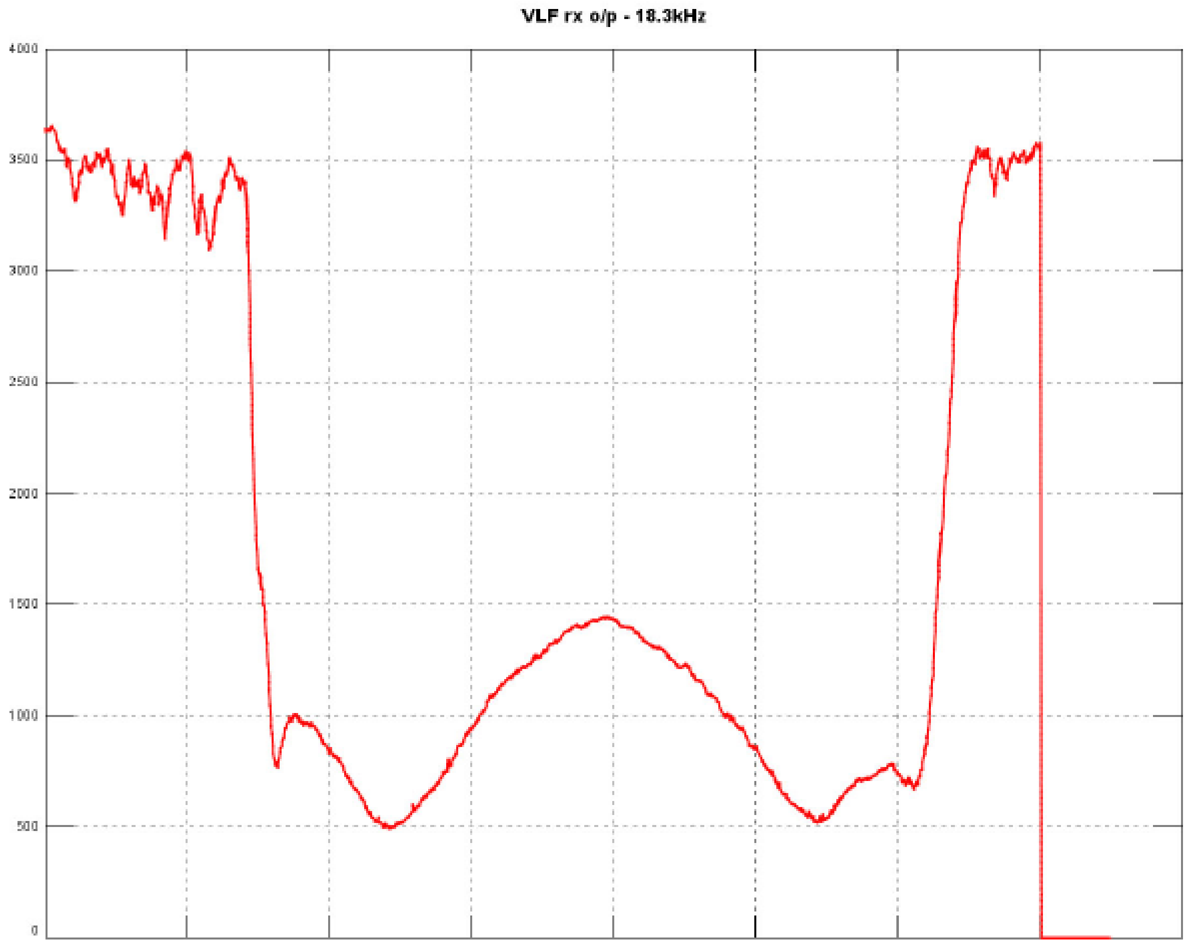


Image 4 VLF Receiver Output

TELESCOPE PROJECT AT SPACE CENTRE

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Before I became assistant coordinator of BAA RAG, I had already been planning to use a spare 2.4m dish on the roof of the National Space Centre in Leicester. This dish was installed when the building was constructed in 2000/2001. The Space Centre was in partnership with Leicester University. The University Space Research Centre had secured funding for the dish and a satellite transceiver for a project called CATSAT. CATSAT was to be a small scientific satellite developed jointly by the University of New Hampshire and the University of Leicester, England, through the USRA (Universities Space Research Association)/NASA STEDI (Student Explorer Demonstration Initiative) programme. It was to have studied the origin of gamma-ray bursters from a 550-km circular polar orbit and had been scheduled for launch in December 2001 aboard a Delta 7310 alongside ICESat. However, the mission was cancelled before launch. The transceiver equipment was never installed, the order was cancelled with the project, however the dish had already been constructed, and fitted. To date this dish has never been used.

My idea was to seek permission from the University to use it for radio astronomy. Over the last few weeks I have been assessing the condition of the unit with a view to converting it into a radio telescope. The first stage was to power it up and see what happens! It turns out not to be as simple as that!

Problem 1

The control computer will not start! Ok replacing the power supply does get it started. Oh dear Windows 98!. The control software was written and supplied with the dish which was aimed at the weather satellite reception industry. However it will track any satellite you want to enter, and has built in tracking for Sun and Moon too, and I think any other manually entered celestial source.

Problem 2

The control software has a routine to power up the motors. (The dish is on a full Azimuth/Altitude motorised mount.) When asked to power up it kept returning an error message ‘Failed to power UP’. Bearing in mind at this time

I had no manuals, or knowledge of the system. I followed the cables to the first control box which was obvious, and mounted next to the PC, this was turned on. The next box was not so obvious; the cables disappeared through the roof to the upper level. This second interface was quite large and contained most of the control hardware; this was turned off – Bingo! Oh dear, it still would not power up!

By this time I was getting frustrated. Analysing the circuit it was clear that a critical relay was not being energised to power up the motors. I took the details of the hardware and tried to track down the manufacturer. This was not as easy as it sounds. Dundee Satellite Systems was the company, an Internet search did not pull up much info, Yell.com did not list it. As you will know if you have read my biography in another part of the circular, I worked for 2 years in Dundee, so …. no never heard of them! However I did know that Dundee University had a big satellite weather image receiving station, they must know the company, and it's probably the same people? I was right. The university put me in touch with the makers who gave me some info and a PDF of the manual.

One of the first things they said was, have I released the E-stop switch on the pedestal of the dish. What E-stop? I had not seen one. It turns out the hand control paddle with the E-stop was wedged under the pedestal base. I retrieved it, and released the switch.

Yippee the dish powered up!

Problem 3

You didn't think it was going to be that easy did you? I set the dish to track the Sun. It appeared to be doing so, the dish had moved, but the software said 'tracking error 12 degrees'. It was not immediately clear why. Later in the afternoon the tracking error had reached 45 degrees! The reason was the azimuth had not moved at all. Oh dear, here we go again. The azimuth amplifier was quite warm, where the elevation unit was cool. The suspicion is the azimuth motor unit is seized, since it has been standing for 5 or 6 years unused.

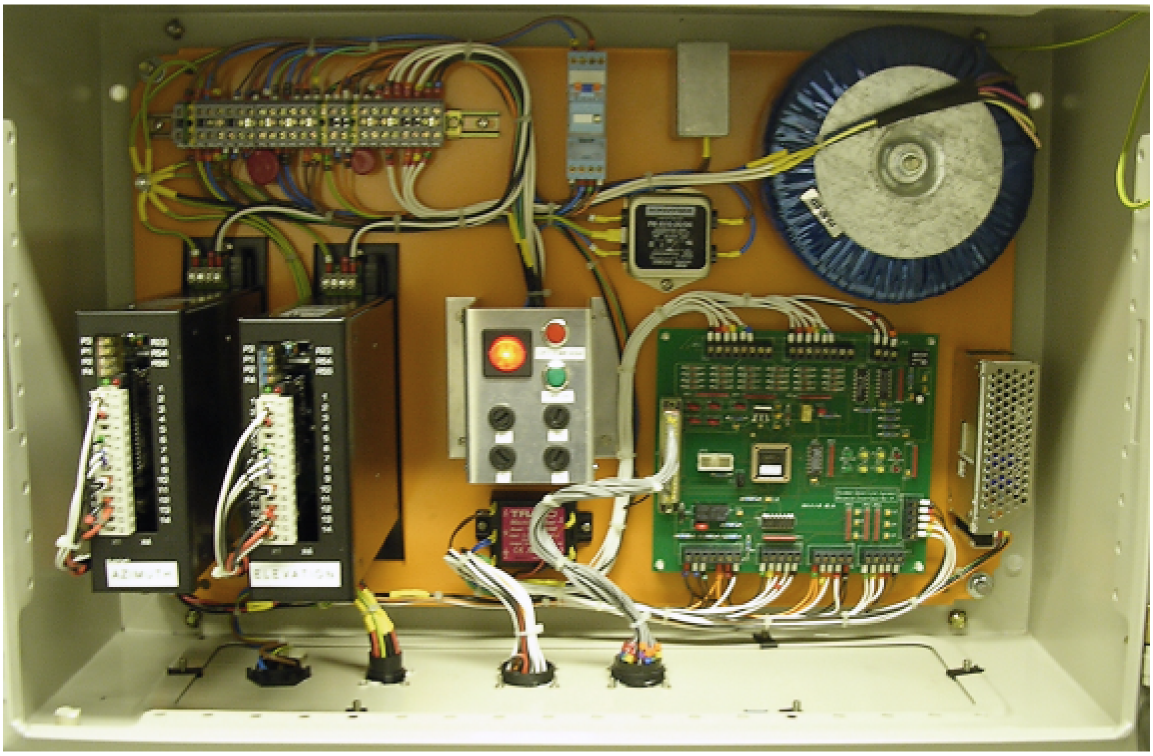
Problem 4

In trying to diagnose the fault in azimuth I pulled out two control cables to check for damp or corrosion, forgetting the system was powered up. On reconnecting the cables the computer had lost info on where the dish was pointing, and it is currently reporting the secondary limits have been reached which disables the dish altogether. The manual explains how to recover from this but it does not appear to acting as is should. It does not help that the PC, control box and dish are spread over 3 locations, and there is only one of me!

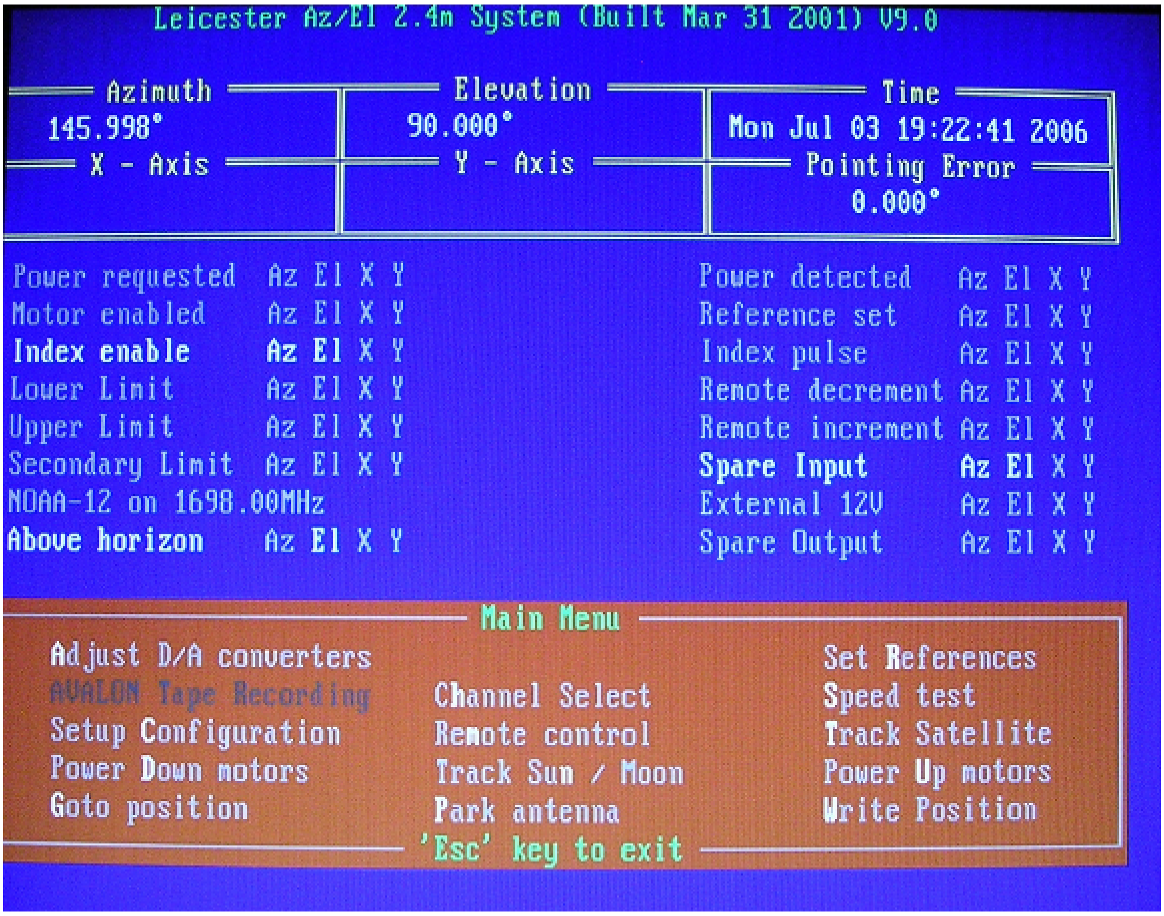
That's where I am now with the dish. I will contact the makers again to ask for advice.

This dish would make an excellent 2.7GHz solar telescope, and the group has access to a 6.6GHz methanol line receiver, but 2.4m is rather small for the kind of sources emitting the methanol line. At the time of writing the instrumentation has not been finalised.

Antenna Controller Interface



The Motor Controller



The Telescope Control Software

The Maplin Electronics 1.8m Dish

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The problem of finding suitable antennas has been an occasional topic of discussion in the RAG. Antennas can be obtained on the second-hand market, as kits for amateur radio, or built from plans, but the only obvious source for an off-the-shelf antenna is a satellite dish. Large domestic satellite dishes are not a commonplace sight these days. You can probably buy a large dish from a specialist satellite TV supplier, but as far as I know Maplin Electronics are the only high street name stores to offer one for sale.

The Maplin part number A12FB, is a 180cm prime focus parabolic reflector made by Fortec of Canada. It has a theoretical gain of about 26dB at 1420Mhz and about 32dB at 2.7GHz. The dish surface is solid and the manufacturer claims over 45dB gain at 12GHz. Although the size of the dish is marginal at 1420MHz, it still seems big in a confined space (Figure 1). I bought one to see if it is possible for the first time radio astronomer to get some results.

The dish comes packed in a surprisingly small, odd shaped box. It is quite heavy as the construction is almost entirely steel. The polystyrene packaging inside is just about adequate. My dish had only a few minor knocks despite some items coming loose in transit. The only instructions supplied are an exploded diagram on one side of an A4 sheet. If you are good with flatpack furniture you should cope. There are about 147 parts in the box so it is best to lay them out so you can check the numbers and locate them on the drawing.

I started by joining three panels together using M6 nuts and bolts. The panels are all the same except for the one with the Fortec logo on it. I built the dish on a lawn with the fronts of the panels facing down. If you do not have a patch of lawn handy, I would suggest laying out some old curtains or similar to stop the paint being damaged on edges of the steel panels. The second bolt hole from the centre will have a bracket fitted for mounting a ring that supports the mount so a longer bolt is used in this position and can be left finger tight until the bracket and ring are mounted. A flat spanner is provided in the kit but a real 10mm combination spanner would be worth the expense.

I then assembled the other three panels. The two halves of the dish will support themselves and can be offered up ready for joining together. When the panels are all in place the mounting ring can be fitted (Figure 2).

The dish is supplied with a floor mount that provides for elevation adjustment. The mount is made from three square section tubes, one telescopic and three circular cross members. This could be bewildering at first, but I found it best to assemble the parts onto the base ring and then attach it to the dish while it is still lying face down on the ground. When the stand is attached the dish can be pulled upright to sit on the base ring. The central plate can be fitted at this point with a coach bolt from the front, through a bracket at the rear.

The dish is stable on the base but it does offer a lot of wind resistance and it is likely that any strong wind would blow it over. The kit includes some clips and fixings so the base can be secured to the ground. Mounting on concrete or onto large concrete blocks would be best, however my temporary arrangement has just survived a very strong squall that snapped my bird table off. All I have are two large bags of sand sitting on the base ring (Figure 3) just like many signs in road works.

The dish has a diameter of 1800mm and the drawing shows best focus at 684mm from the centre. This gives the dish an F/D ratio of about 0.4, which makes a suitable feed fairly easy to engineer. I am hoping to get a feed horn from Astronomy Supplies so that a complete antenna for 1420MHz can be built with the minimum of mechanical effort. A normal horn or "coffee-can" feed has a beamwidth that is suited to a dish with an F/D of about 0.5 and would under illuminate a 0.4 F/D dish. This may be an advantage for radio astronomy, as it would limit the spillover around the dish and the ground noise that this introduces. Meanwhile I have a VE4MA feed that I am modifying for 1420Mhz (Figure 4). This feed has a choke ring to control the radiation pattern and is a good feed for dishes with F/D of around 0.35. I hope to be able to compare the noise temperatures of at least two types of feed in the future.

Conclusions - At £100 the Maplin dish represents reasonable value for money. If part of a permanent installation I would consider replacing the hardware with stainless steel parts or at least giving the plated parts a thick coat of Waxoil. Waxoil is a available in spray cans from car parts shops and can be sprayed on thickly to cover any exposed metal to stop corrosion. Use a finger to get an even coat. If left untreated the nuts and bolts would probably be rusted solid after one winter.

As part of a transit instrument the supplied mount is quite good. It has a wide range and is very easy to adjust between the horizon and the zenith. A suitable elevation scale could be easily devised. For any purpose other than a transit instrument a suitable Alt/Az mount would be needed. The dish is quite heavy and the mount would need to be suitably engineered.

The accuracy of the dish surface should be good up to at least 12GHz making the dish suitable for many types of observation when provided with a suitable feed. A matching LNB is available for the dish and the hardware to mount this is included in the kit. The LNB is slightly expensive at £70, but could represent an easy way to make solar observations at 11GHz.

David Farn with the assembled Maplin Dish

The dish mounting assembly

David's feedhorn, and some bags of sand!

REPORT TO BAA COUNCIL

Laurence Newell
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This short report about the last year's activities of the RAG was recently submitted to Council for publication in the BAA Journal.

The Radio Astronomy Group is now in its second year of revival, and continues to make very good progress. We now have over 160 members on our mailing list, which means we have collected two per week over the last year!

The RAG's main publication is the quarterly *Circular*, with three issues produced in the last year, and the latest in preparation. Each issue contains about 50 pages of articles from both professional and amateur astronomers, together with project reports of the Group's activities. The *Circular* has proved very popular, and we have sold several hundred copies. Each issue is sent to the BAA Library. There is also a CD ROM of the full proceedings of our first public meeting, held 2005 October, in Northampton, which has also sold in large quantities. A full report of the meeting (by Karen Holland) may be found in the Journal (116(2), 99).

Group members have given presentations on Radio Astronomy to various local astronomy societies. We have also attended the Back to Basics Workshop in Milton Keynes, with a Radio Astronomy presentation and demonstration of the Group's projects. Demonstrations were also given at the Winchester Weekend and at the Exhibition Meeting, where several Very Low Frequency (VLF) receivers attracted a lot of attention. In particular, a 'retro' styled antenna mount was so popular that it will become another product in our range!

The Group's technical team of 11 members is actively involved in developing various receivers, modules and software for the project we have named *Starbase*. This is a fully integrated, modular observatory, with a *Plug and Play* architecture for both the software and hardware, which should ultimately allow users to enjoy radio astronomy without detailed technical knowledge.

Ten beta testers are now evaluating the first *Starbase* receiver, the VLF module (designed by John Cook and Peter King). As a result of their feedback, we will be redesigning the interface and using a surface mount assembly. John Cook has also designed a prototype magnetometer, which will soon be in production, again in surface mount. David Farn and Alan Morgan have produced a prototype Hydrogen Line receiver (1.4GHz), which is nearing completion. The initial version is 'total power', but it is intended to produce a spectrometer to allow velocity resolution of the spiral arms of the Galaxy. Martyn Kinder (with Terry Ashton) is working on a 2.695GHz receiver, again initially as total power, but ultimately as a spectrometer. An end-to-end test bed has been completed, and was demonstrated at the Exhibition Meeting. Mark Byrne is working on a prototype controller module, to which the receivers will be attached. Laurence Newell is developing the Java software *Starbase* 'client', which will control the receivers, log their output, and provide networking services to other observatories. Laurence Newell is also liasing with Andy Wilson of the Variable Star Section, to see if we can rationalise the designs of our various databases, since there is a lot of overlap in our respective requirements.

The RAG now has a new Assistant Coordinator, Jeff Lashley, who works at the National Space Centre in Leicester. Jeff has taken on the task of commissioning an 'unwanted' radiotelescope dish, on the roof of the Space Centre, with the intention of having a networked observatory as another *Starbase* component. We hope to use this for methanol line measurements, in the 6GHz region.

Our work at the Mullard Radio Astronomy Observatory (MRAO) is now under the supervision of a new Director at the MRAO. Eventually it is hoped that we will be able to view the telescope output on a web page, produced via the *Starbase* network. The MRAO RAG team are Trevor Sutton, Peter King, Karen Holland and Terry Ashton. We are very grateful to Peter King for his efforts in renovating the telescope for BAA use.

The Group continue to receive donations of equipment from British Telecommunications, for which we are very grateful. We now have an assortment of oscilloscopes and logic analysers, for the use of Group members.

TECHNICAL MEETING 2006 MAY

Karen Holland
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Present: Mark Byrne, David Farn, Karen Holland, Martyn Kinder, Alan Morgan, Laurence Newell, Trevor Sutton

Apologies for Absence were received from: Terry Ashton, John Cook, Paul Edwards, Peter King

General Issues

The current state of the group was outlined, and the notable points were as follows:

Terry had stepped down as leader of the 2.7GHz project due to personal commitments, but had signed up to help Peter at Cambridge on the 151MHz project. There was therefore currently a vacancy for an assistant coordinator; this was an administrative role rather than a technical one. As no one volunteered to take this on, it was agreed that the vacancy would be advertised in the next Circular, but the position would be abolished if no one offered to fill this role.

The current number of members stood at more than 140. Martyn offered to produce a FAQ guide that could be issued to new and prospective members. About 40% of members were BAA members.

Since the financial discussions at the Milton Keynes meeting, the BAA pseudo account was now being managed by Laurence, who intended to ask the BAA for an increase in the budget next year in order to fund the redevelopment of the website (MB knows someone who he may be able to persuade to help). The Radio Astronomy Group Project account was being managed by Karen.

The new Circular was presented. CDROM sales totalled around 50 now, and it was agreed that we might investigate the possibility of producing mouse-mats or other items for sale at meetings (DF to investigate the cost of doing this) .

Regarding the possible conversion from group to section, whilst everyone in the group had voted for conversion to a section, it was agreed that the decision needed to be made by Laurence, as he was the one who would need to spend additional time attending council meetings, and absorbing the additional responsibility and duties that this role might involve. Laurence felt that he would prefer not to take this on at the current time, particularly as the group were not yet producing any observations, and it was agreed that the decision would be reconsidered annually. Karen noted that we could, in the future, ask if section status might be possible, without the need for the director to assume a position on council.

Company Formation

The group then moved on to consider if a company should be set up, to handle the supply of the Starbase units. It was unanimously agreed that we should not set up a company at the current time due to the significant overheads that would need to be spread over a small number of units, and the investment in time that would be required to produce and keep the necessary records required for a Limited Company. We would continue to trade as a closed group, and would review this decision annually.

Controller module

Mark's system - key points
Mark's chosen microcontroller was a PIC18F2520, with 1536 bytes of RAM and 16384 words of program memory. The extra memory added externally would be I2C or SPI for data storage purposes. Mark planned on taking a USB to serial cable from the PC (which would be programmed as a serial interface by the PC). USB would be converted to RS232, then RS232 to RS485, with opto-isolation (MB would do this). This would run at 19.2Kbaud. He had chosen a 28 pin microcontroller IC, which had I2C, serial, a2d and 1.5Kb memory (extra memory to be added externally as required). It didn't have a real time clock, but could count time from an arbitrary start date, and could timestamp to the nearest 4ms.

Although it was possible for SPI and I2C to co-exist, they used the same pins on this microcontroller. More suitable 68 pin microcontrollers would be more expensive (current 28 pin chip costs £3.00), and Mark felt that I2C would be used for the hardware block, and SPI would be done in the software.

Mark had tested the VLF receiver on-board EEPROM and was able to read and write to it.

Laurence expressed some concern at the time that might be required for the development of the software protocols, but Mark felt that it was achievable on a sensible timescale, even given work commitments. Mark planned on building around 10 prototypes to be tested with the current prototype VLF receivers.

(Mark's communication protocols are available on request from the Secretary or from Mark.)

Trevor's System

Trevor described the basic operation of this system, and a proposal for the polling algorithm to address the plugged in instruments, and present all 8 d/d and 8/a/d to each instrument, so that each could have up to 8 measurable parameters and 8 control outputs.

An alternative payment structure had been offered, which allowed for the payment of the full development cost separately rather than spread over the units. In this case, the one-off payment for development was be £10000, and the cost per board was be £100 each for a minimum batch of 15. All prices were excluding VAT. If this route were chosen, then because the development would be fixed at the outset, then a full specification would be required, whereas using the previously-discussed payment scheme would have permitted the development to progress interactively.

A discussion followed regarding which system should be progressed. It was clear that Trevor's option was a very well-produced product, manufactured to a high standard, and would do the job well; the only point of concern was the cost of this option. It was felt that the price of £350 would be too high for many potential customers, and even if we could obtain funding to assist towards covering the development costs separately, we would still be required to find the other 50% funding which would be very difficult and take time. Mark's option appeared to meet our needs at a much reduced cost.

It was agreed that, whilst we are still in a development phase, and we therefore cannot, be absolutely certain about the choice, we would progress for the time being with Mark's option, but keeping open the possibility of using Trevor's option at a later date.

It was clear in the following discussion, that we still needed to consider data rates, and how power was to be supplied to the modules. This required a proper architectural diagram (marked for Mark's benefit with I2C where appropriate). LN was to create this from DF's Powerpoint drawings.

It was agreed that we would change the interface details of the controller to include RS485, single a2d (coax), I2C (shielded cable), with all other requirements being on individual boards. This would mean that some changes were required to the future VLF receiver, and old ones would need to use a specially modified cable.

VLF Receiver Project Report

All 10 VLF Rx prototypes had now been dispatched, and feedback was awaited. At this meeting it became clear that there were already a number of changes that may need to be implemented to the boards, and so another prototype batch to the current design would only be made if there were sufficient numbers of people willing to take these, knowing that the design would be changed in the future.

Changes which were considered were:
Make the board smaller to reduce the cost, with surface mount components.
Add SPI on to the board.
Add the controller design gerber plot to the pcb.
Consider using software-tunable pots for software tuning in future.
What about power? Could it come down the RS485 cable?
It was agreed that going Pb-free was acceptable, as soon as we could source all Pb-free components.
Mark was concerned about using the box with a hole and plastic connector on it (from an EMC point of view) but the controller changes that were made above removed this concern, as the 64w connector would be changed on future units.

It was agreed that Trevor would ask his carpenter friend whether he might consider making a nice aerial to donate for demonstration at meetings.

Magnetometer Project Report

John had provided a document detailing the magnetometer head that he had developed in the past, and detailing the outstanding questions that he had before he felt he could proceed with designing a pcb for prototype receivers.

Martyn described his magnetometer system explaining how he had had to bury the magnetometer head (only the sensors) 1m below ground level to keep them thermally stable, and away from moving pieces of metal (like garage doors). The remainder of the magnetometer head circuitry was above ground. Even buried, the sensor was still extremely temperature sensitive, but he felt that this would be best dealt with by attaching a temperature sensor, and calibrating out this in software. He confirmed that he had obtained fantastic results with his system.

It was agreed that we should proceed with the development of a prototype, with an I2C interface built in, with the magnetic sensor and the head separate.

1.4GHz and 2.7GHz Project Reports

(David presented some Powerpoint slides)

David gave a demonstration of the system working from the boot of his car. Metalwork quotation came in at £350 for set-up and £56 per box and makes the system easy to assemble. He thinks this includes the copper resonators. The prototypes pcbs had been made on FR4 material and did not appear to suffer badly from radiation losses. This was often a cause of instability when circuits were housed inside a metal box. It was planned to obtain the prototype boards for the machined boxes from a pcb prototyping company and to use plated through holes for grounding. The boxes accommodate the filter in one corner, with the pcb fitted in the rest of the space.

He is mixing down to 151, and intends to stick with this frequency because of the mechanical design differences that would be created if the change were made to 408, increasing the cost (as the two boxes would need to be different). He agreed with Steve Cripps comment about using a single chip LO, but doesn't have the kit necessary to measure the phase noise that this might generate. Next he intended to work on the 151 to 38 down-conversion (with a 20MHz passband)

For the spectrometer, the 38MHz would be taken down to 10.7MHz or similar, and a tunable frequency would be used to tune across the centre of the band. The band would be around 2 MHz +/- 2MHz. In practice the system would be designed to step to each frequency and remain at that frequency for the necessary integration period, which could be from a few seconds up to 100s of seconds. This would use an I2C programmed synthesizer which should be straightforward to design. A gas velocity of 1km/s produced a Doppler shift of 4.74KHz. Therefore, to obtain resolution to about 5km/s a receiver bandwidth of 10-15Khz was required. A practical step size for the synthesizer frequency would be 5KHz.

Martyn intended to discuss with Paul, changing to mixing down to 408MHz now (as opposed to 151), and then on to 38, consistent with David's work. Martyn would now work on the 38MHz unit. Alan would look at producing a front end with a Dicke switch.

Modules that now exist are the 1.4 front end and local oscillator, and the 2695 front end. Martin may use a synthesized LO to scan between 2690 to 2790. So it seemed likely that by September we would have an end to end system. There was a brief discussion about aerials; Martyn agreed to write up how to make a dish out of wire mesh.

Test Equipment

LN reported that he might get another 1.5GHz spectrum analyzer from BT. DF had used a borrowed a 2GHz scalar analyzer (sweep generator and display) for development, but he would need to consider purchasing this equipment at a cost of about £1000 when we started production of the 21cm receiver.

The Group IT Infrastructure

MK was now running a group server, and James Wilhelm was still maintaining the group database. We would endeavour to obtain funding for the development of the Website.

MRAO Liaison

Peter was quite unwell at the moment, but continued to work on this project. The RAG PC was now in the hut and working. Some high level work still to be done on the aerials. Dave Titterington had a PC in the Ryle building, which we would be able to connect to via another PC, so that we could FTP. The cable needed to be put in from the Ryle building to the RAG hut, but we needed to sort out the cable first. Peter had painted the hut and had had a name plate made for it. he observatory had a new manager who was keen on what we were doing, and would like us to make posters for display there.

Group Events

Exhibition Meeting June 24th: volunteers were needed even if only for an hour or two. It was agreed that we might be able to borrow David's 1.4 GHz kit for the exhibition meeting; Karen would be passing on June 17th and could pick this up if convenient. Terry had permission to use a big printer at work, and so would make some posters.

September Meeting IoA: Current speakers were, Jim Cohen talking about A Methanol Multi-beam project, David, talking about the Hydrogen line receiver, Martyn/Paul to decide if they say anything about the 2.7GHz system, John to talk about the VLF receiver. MB to contact Ann Davies about Alan Chapman speaking.

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All current members' primary email addresses appear on the next three pages, unless a member has specifically requested that we keep their address private. If your details are incorrect, please let us know!

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This section is a list of guidelines which we ask you to follow if you are considering submitting an article for publication in the Circular. It will be much easier for us to import your article into the *PagePlus* publishing software if you follow these rules. This means a more accurate, more efficiently produced document, which means happier members! We are committed to delivering a quality publication, making the best use of your material.

- Please supply ALL text in a plain, unformatted file, which preserves newline (carriage-return, line-feed) characters. For Windows users, Wordpad is ideal. Please DO NOT USE Microsoft Word! It requires a lot of effort to undo Word's 'features' and stylesheets. Also, Notepad treats newlines differently, and so requires a lot of manual intervention to put things right...
- Please use standard British English spellings, and avoid unnecessary abbreviations wherever possible (although we accept that common abbreviations such as JPG, USB, RF are inevitable).
- Please use the correctly punctuated forms of: etc. e.g. i.e. et al. ibid. and so on, to avoid our having to reformat.
- All images should be supplied individually, and NOT embedded within another document. Please use high colour-depth *uncompressed* formats wherever possible, such as PNG or TIFF. The images should be of the highest resolution available, at least 100dpi, and preferably 300dpi. Monochrome (black and white) images are acceptable, and of course JPGs if that is all you have.
- Please DO NOT USE Word for creating images - the resulting objects are awkward to import, and do not reproduce well. It is better to use a vector drawing tool like Visio, or create a 300dpi bitmap in PaintShop. The difference in quality is well worth the extra effort!

It is useful if you can supply a separate document showing how the images relate to the text, either electronically or on paper.

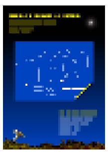
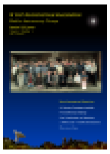
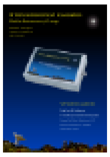
- Please DO NOT combine several images in to one image file - they will have to be manually separated and/or cropped for inclusion on the page.
- Photographs of small objects should be taken with a plain white background if possible. This makes it much easier to cut out the image and blend it into the page. Similarly, please crop all images to remove unwanted areas; this helps to keep the file size down (the overall document for each Circular is about 80Mb before PDF conversion).
- Wherever possible, please supply any graphs or charts in their original numerical form either as Excel spreadsheets or as comma-delimited (x,y) files. This will ensure that all graphs have the same appearance, and can be produced to the same high quality output as the photographs. However, if (for example) your data logger can produce only JPGs, then please select the highest possible resolution output. It would be very useful to have a document showing how the graphs should appear, with legends etc. as required.
- Remember that the paper copy of the Circular is printed using a professional colour printer, capable of very high quality output. For instance, if an image chart has to fill the width of the page at 300dpi, then an image of at least 2000 pixels width is required.
- Please supply a caption or legend for each image, and for each chart or graph, again in a plain text form, in a separate file. The Circular style is to place the caption underneath each image, centred, and in italics. Remember to include the correct credits for any public domain images used.
- It is our policy to use Système Internationale (SI) units wherever possible. See www.simetric.co.uk if you are unfamiliar with the SI System. Please DO NOT USE feet, inches or Fahrenheit (or even Angstroms)!
- For simplicity, we will assume that copyright in all text and images shall remain with the original author, unless explicitly stated otherwise at the time of submission.
- We will assume that you are willing for us to publish your email address unless you let us know at the time of submission.
- All material should preferably be sent by email to Karen Holland at karen.holland@Xcam.co.uk.
- If all else fails, please send in your article typed double-spaced on plain paper!

RAG Mart

VLF Receiver

The *Starbase* VLF Receiver is currently being redesigned following feedback from our beta testers. The main changes involve the replacement of the 64 way connector with an I²C link, and the use of surface mount devices to reduce the size of the unit. Please contact John Cook for technical details, and Karen Holland for supply information.

Circular Back Issues

Circulars Volume 1 Numbers 1, 2 and 3 are still available. These cost £3.50 by post from Karen, or £3.00 from any exhibition stand near you!

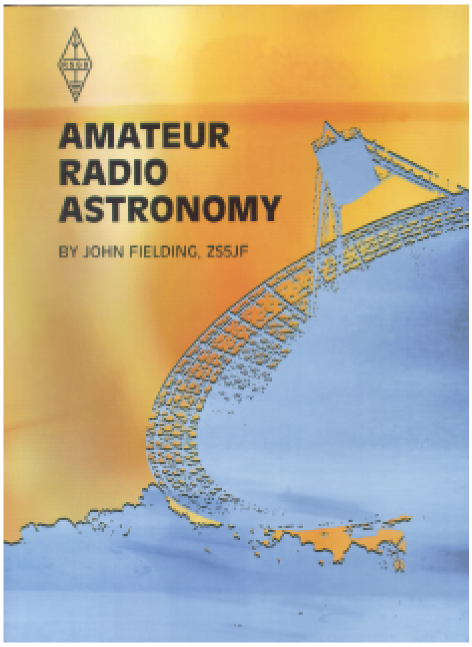
Northampton Meeting CD ROM

All of the presentations given at the Northampton 2005 October meeting are available on this CD ROM, £3.00 by post from Karen, or £2.50 at an exhibition. A very useful introduction to the work of the Group.

RAG Greetings Card

Copies of the RAG Greetings Card (with envelope) may be purchased for 50p each, from Karen. Please note that these cards are blank inside, and may be used for any occasion.

Radio Astronomy Book



By John Fielding, ZS5JF
© Radio Society of Great Britain
Size 240x174mm, 320 pages, ISBN 1-905086-16-4

For anyone with a passing interest in radio astronomy this book is a revelation. Amateur Radio Astronomy shows how much radio amateurs have contributed to the science of radio astronomy and how the average amateur can make and set up equipment to study the signals coming from space.

Amateur Radio Astronomy covers in depth the subject of receiving radio signals from outer space. Starting with a historical perspective of Radio Astronomy this book covers all that is needed to become active in this area. The book covers what parameters are required for the antenna and receiver through practical low noise amplifiers. The reader is also provided with straight-forward advice on assembling a receiving station along with practical information to put together your own station. A practical design for a "hydrogen line receiver" aimed at 1420MHz is also included.

This book has no equivalent published elsewhere and the author has achieved a great balance between historical narrative and technical information. Amateur Radio Astronomy is not only 'a great read' but a practical reference for this fascinating topic.

The above text courtesy of The Radio Society of Great Britain, Lambda House, Cranborne Road, Potters Bar, Herts. EN6 3JE

We hope to have a review of this book in the next issue of the Circular. We have negotiated a Group member's discount with the RSGB, and the offer may be found at www.britastro.org/radio/offer. The BAA offer price is £15.29. The book is also available directly from Laurence Newell (please enquire about postage costs), or at BAA RAG exhibition stands.

OUT OF THE NOISE

Milky Way arms pinned down

physicsweb.org/article/news/10/6/3
Astronomers have made the most detailed map ever of our galaxy's overall shape, showing that its spiral arms extend much further than expected. Evan Levine, Leo Blitz and Carl Heiles of the University of California at Berkeley analysed the distribution of atomic hydrogen in the Milky Way at radio wavelengths to reveal hitherto unseen features of our galactic backyard. The map shows that our galaxy's spiral structure is not symmetrical around its centre but contains more arms in some areas than others. Contrary to theoretical predictions, the arms also continue well beyond the distance at which stars should be found (Sciencexpress 1128455).

Ships shed light on geomagnetic field

physicsweb.org/article/news/10/5/7
Geophysicists in the UK have used a mathematical model based on old ships' logbooks to show that the observed decline in the strength of the Earth's magnetic field may only be a recent phenomenon -- and not a fixed trend as commonly thought. David Gubbins and colleagues at Leeds University say that our planet's magnetic field was stable until the mid-1800s and has been weakening steadily only since then. The decline is caused by magnetic flux reversals in the Southern Hemisphere and could point to a geomagnetic flip of the Earth's poles sometime this millennium (Science 312 900).

New names for Pluto's moons

physicsweb.org/article/news/10/6/11
Two new small moons of Pluto, which were discovered by the Hubble Space Telescope last year, have been officially christened Hydra and Nix. Previously they were known rather boringly as P1 and P2. The new names were approved this week by the International Astronomical Union (IUA) the official body that assigns names to celestial objects.

Amateur astronomers prove their mettle

physicsweb.org/article/news/10/5/14
An international team of professional and amateur astronomers, employing a budget telescope atop a Hawaiian volcano have discovered their first extra-solar planet. This discovery demonstrates how effective amateurs can be in contributing to serious research. However, amateurs without $60,000 or a volcano need not apply.

IoP News items from the Institute of Physics website.

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We hope that you have enjoyed reading the *Circular*. Please let us have your feedback; any comments, be they positive or negative, are most valued. All your suggestions will be carefully considered. Please send any articles and photographs to Karen Holland.

Baseline is set in 9pt. Lucida Sans Unicode, using Serif's PagePlus 10. It is intended for distribution in PDF format, or for printing at A4 size at 300dpi.

The Group blue is R000, G067, B191.
The Group yellow is R234, G225, B014.

Radio Astronomy Group Gallery

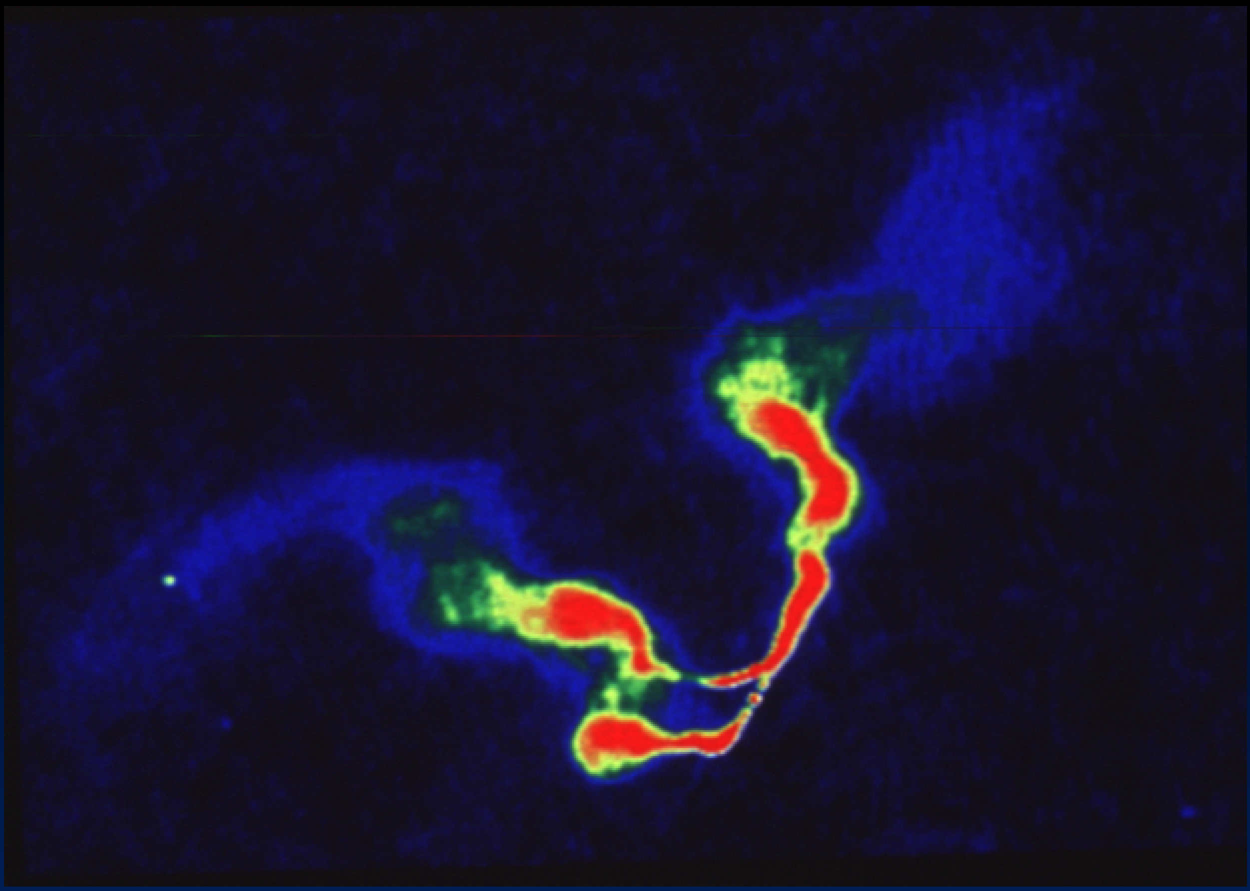
David Farn demonstrating his prototype Hydrogen Line Receiver at the RAG Technical Meeting at Xcam Northampton on 2006 May 13.
This must be worth a caption competition!

Laurence Newell feeling rather uncomfortable in this arrangement of Section Directors at the BAA Exhibition Meeting!

Karen Holland and her daughter at the BAA Exhibition Meeting, Cavendish Laboratory, University of Cambridge.
The VLF and 2.7Ghz demonstrations are in the background.

Ken Tapping's 408Mhz correlation interferometer in Penticton, British Columbia. Would anyone like to design an Ethernet interface for the sundial?

The prototype Hydrogen Line Receiver. From the left, Alan Morgan, Laurence Newell, David Farn and Martyn Kinder. We received signals from the Sun.



20 cm pseudo-colour VLA image of the radio source 3C 75 in the cluster of galaxies Abell 400. Red shows regions of intense radio emission, while blue shows regions of fainter emission The image consists of two twin jet radio sources associated with the binary nucleus of the central galaxy in Abell 400. The jets bend and appear to be interacting.

Image courtesy of NRAO/AUI and F.N. Owen, C.P. O'Dea, M. Inoue, & J. Eilek

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