British Astronomical Association

Radio Astronomy Group

Baseline 2006 January
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John McKay, 3peaks

Colin Clements, Lisburn

Rev John Wardle, Bridlington

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Baseline

2006 January Vol. 1 No. 2

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.

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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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Institute of Astronomy
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From the Coordinator

Laurence Newell
Radiogroup@btinternet.com

Introduction

A very Happy New Year to you all! My apologies for this issue of the *Circular* being delayed far beyond the intended publication date, but as I am sure you realise, getting the material together always takes longer than you anticipate... Anyway, we have done it, and we hope that you enjoy this *Circular* as much as the previous issue. There have been a few minor changes of presentation, but the format remains largely the same.

It has been a very successful year for the Group, with appearances in Cambridge at the Exhibition Meeting, and our first public meeting in Northampton. We have formed development teams of formidable combined experience, and are making good progress in our stated goal of developing a *Plug and Play Observatory.* Our Group now has an entry in the Report to Council, which appeared in the BAA *Journal*. All in all, we are beginning to make an impression!

We have an article this time by Dr Ken Tapping, on the always difficult issue of Interference. Ken works at the Dominion Observatory near Penticton, British Columbia, and is involved with the John Smith 408MHZ survey team mentioned in the last Circular. There's also a lot more Observatory News items, showing just how much work is going on in the UK.

Group News

Membership

We now have more than 110 members on our email and postal mailing lists! This is very good progress, from a 'standing start' little more than a year ago. The full list of members is given at the end of the *Circular*, to help you contact old friends!

RAG Response to Ofcom Consultation

Readers of the last Circular will remember that the Group produced a document to respond to Ofcom's consultation *Recognised Spectrum Access as applied to Radio Astronomy.* The Group's document together with those from many other organisations may be found on the Ofcom website www.ofcom.org.uk. As you will see, we are mentioned several times in the final statement! See:

consult/condocs/astronomy/responses/?a=87101

Lift Required

One of our members who lives in Bewdley, Worcestershire, suffers from ME and cannot drive at the moment. He would like to ask if there is anyone in his area who could offer him a lift to our next public meeting? Perhaps if you can help you could let myself or Karen know, and we will pass on your details.

Cambridge Meeting 2006 September 23

The date of our next public meeting has been set. We are fortunate to have booked the lecture theatre at the University of Cambridge Institute of Astronomy, for Saturday September 23rd. It may be possible to arrange for a tour of the MRAO on the Sunday, if there is sufficient interest from people willing to stay overnight. Please let myself or Karen Holland know.

Northampton Meeting 2005 October 8

We had intended to be able to provide a CD-ROM of the presentations given at the Northampton Meeting. Unfortunately it has not been possible to collect all of the material together in time for this issue, but we are continuing to try to extract the presentations from the speakers! The group photograph of the meeting attendees is given inside the back cover. If there is sufficient interest, we would like to produce some professionally framed copies for sale. The 'finder chart' will be included on the back. Please let myself or Karen know. Also, let us know if you can identify any of those marked as 'unknown'!

Team Meetings

There has not been an admin team meeting since the last *Circular*. However, we are holding a development team meeting in Northampton at Xcam on January 14th, where we hope to progress many of the technical details of the development projects. We will report on this meeting in the next *Circular*.

Circular Contributions

There has been a very pleasing response to my requests for content for the *Circular*. So pleasing, in fact, that I have had to hold over some items until the next issue. Having decided to limit each issue to no more than 52 pages (it has to be divisible by 4!) has meant that some planned items are deferred. In particular, there is no discussion of the *Starbase* software or database, or of the Controller and Detector Modules. These are all complex developments, and have been slow to get started. If your article hasn't appeared this time, never fear, it will be in the next issue. There is a short article later in the *Circular* giving guidance for potential authors.

VLF Reports

For similar reasons I have decided not to include John Cook's VLF monthly reports. John now produces these in PDF Format, and sends them by email to interested members. If you would like to receive the reports, please contact John. They will shortly be available as downloads from our website. We are also planning to add these results to the embryonic *Starbase* Repository.

ISSN Allocation

As you will see from the cover, we have now been assigned an International Standard Serial Number (ISSN) by the British Library. These numbers are:

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They are for the *Circular* only, and must not be used on other RAG publications. We are now obliged to send a copy of each issue to the BL!

PPARC PUS Grant

In the last issue I mentioned that we are planning to apply for a PPARC Public Understanding of Science Small Award. Unfortunately, it has not been possible to progress this application owing to the amount of other work we have had to deal with. The next PPARC closing date is in March, and we hope to prepare something in good time.

The award scheme is described at:

www.pparc.ac.uk/rs/fs/pu/SmallAwards.asp

Aims and Objectives

I have once again restated our Aims and Objectives here. You are encouraged to distribute the *Circular* to anyone you feel may be interested in our activities.

Aims and Objectives

- To give assistance to new amateur radio astronomers
- Set up a panel of Technical Advisors
- Co-ordinate Group Observing Programmes
- Encourage information exchange
- Provide design information, hardware and software

Development Project

- To produce a modular *Plug and Play Observatory*
- No radio or electronics expertise required by users
- Multiple receivers with programmable controllers
- Integrated software and database of observations

Group Officers

The Group officers are currently:

Laurence Newell	Group Coordinator
Terry Ashton	Assistant Coordinator
John Cook	VLF:SID Programme Leader
Peter King	MRAO 151Mhz Liaison
Karen Holland	Group Secretary

Development Teams

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

2.695Ghz Receiver

Terry Ashton
Paul Edwards
Martyn Kinder
Stuart Withnall

1.420GHZ Receiver

David Farn
Alan Morgan

VLF Receiver

John Cook
Karen Holland (tester)

Controller Module

Mark Byrne
Laurence Newell
Trevor Sutton

Detector Module

TBA

Database and Website

James Wilhelm (Database)
TBA (Website)

Remember that the admin team thrive on your feedback - please let us know what you think about this issue. Also, please do not stop sending in material - it is much easier if I have it available well in advance of actually needing it...

Best wishes for 2006.

Laurence Newell
Group Coordinator
2006 January

Secretary's Report

Karen Holland
karen.holland@xcam.co.uk

Let me Introduce Myself…

I guess I should start this column by introducing myself. I come from a background of working in science and electronics; my degree was in Physics, specialising in electronics in my final year, and, for a good number of years, I worked to develop fibre-optic transmitter and receiver modules (both analogue and digital), for military and commercial applications, with bandwidths of up to 1 GHz. Over the last 10 years or so, I have combined looking after my three children with astronomy and running a business making digital cameras primarily for science experiments. The astronomy rapidly progressed from grinding a 6" mirror to doing CCD photometry of Variable stars, and I have now been editing the quarterly circulars of the Variable Star Section of the BAA for the last 10 years, in addition to other duties within this section. During this time, I made contact with the University of Leicester Astronomy group, and amongst other projects in collaboration with them, I conducted a research project (all FORTRAN programming rather than observational work) which resulted in a controversial paper (MNRAS 319, 956-962, 2000) and considerable media interest, in addition to other papers. Following on from this, came a Royal Society Industry Fellowship, which allowed me to combine my work for the business, with the research aims of the theoretical astrophysics group at Leicester. My day-to-day business work involves a wide variety of technical duties concerned with the design and manufacture of CCD cameras, in addition to the less exciting administrative duties that are necessary to keep a business running.

Somehow, I have now become involved in the Radio Astronomy Group! I say somehow, because, although I have an interest, I have very little knowledge of this area currently, and the only promise that I can make at the moment, is that I will try to reduce the administrative burden on Laurence, although I hope to contribute more to the technical side as I learn more. I particularly enjoy explaining complicated subjects in a simple way, and I hope that I might be able to do more of this in the future for the group.

I have to say that I have enjoyed being involved a great deal so far, largely because I know so little about radio astronomy, that each day I'm learning lots of new things! My learning plan, for the moment, is to try to set up one of John Cook's VLF systems, in addition to managing the day-to-day secretarial duties. I hope that as I become more knowledgeable about each area, I may be able to begin a series of talks and circular articles, along the lines of 'Noddy's Guide to XXX '!

I will aim to provide a summary in each circular of news relating to the work that I have been doing for the group, and will begin this format now.

The First RAG meeting

We had our first RAG meeting at the Humfrey Rooms in Northampton on October 8th, to which 55 people attended. See my full report on this meeting, later in the *Circular*. We had a full programme of speakers including:

- Dr Tim O'Brien: *Jodrell Bank's 6.4m Robotic Radio Telescope*
- Murray Niman: *Challenges to the Radio Astronomy Spectrum*
- Richard Lines: *Monitoring of the Schumaker-Levy - Jupiter Impact at 21MHz, and Solar Observations at 600MHz*
- Dr Laurence Newell: *BAA Radio Astronomy Group Co-ordinator The Activities and Work of the Radio Astronomy Group*
- John Cook: A *Simple VLF Receiver for Solar Flare Monitoring*
- Peter King: *The 151MHz Steerable Array at the Mullard Radio Astronomy Observatory*
- James Wilhelm: *The John Smith 408MHz All Sky Survey*
- Bob Marriott: *The History of Radio Astronomy in the BAA*
- Members Section*: Andy Thomas talked about his work*

The meeting was a great success, with many more people attending than we had expected; posters and demonstrations were brought along, a raffle was held for the prizes of a low noise amplifier (donated by Jeff Lichtman of Radio Supplies) and several radio astronomy books donated by Cambridge University Press. We invited attendees to fill in a questionnaire that would provide us with useful information regarding what people want from our group, together with their interests and level of knowledge, and we received 28 replies, of which more information later in this report. Thank you to all those people who have emailed since the meeting congratulating us on the event.

The 2006 RAG meeting

I have now agreed that the 2006 meeting of the Radio Astronomy group will be held on Saturday 23rd September at the Institute of Astronomy in Cambridge. Dominic Ford, who is a postgraduate student at the University of Cambridge has kindly agreed to be a co-organiser for this meeting. If you have any suggestions for good speakers, please let me know.

Membership enquiries

Laurence has set up an excellent membership database for the group; 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.

Speaker List

I am starting to create 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.

Group Poster Collection

We are starting to build up a collection of posters that we can display at meetings. These include both our own group posters, which advertise the work of the Group, but we also have some members' posters. If you feel that you could produce a poster describing your work, and would be happy for us to add it to our collection, then please let us have a copy, so that we can display it. Make sure you have your contact details on the poster, in case anyone wants to discuss your work further or ask questions later. It may be possible to arrange printing of posters, if you find this difficult and can send us an electronic version. Additionally, you should indicate if you are happy for us to display your poster on the Group web pages.

Winchester Weekend

We are planning on having a display board in the foyer area at the BAA Winchester weekend, and would be very grateful for any assistance that members might give in manning the stall during the weekend. The aim is simply to inform the Winchester delegates about the work of the group, and encourage any interested parties to add their names to the members' database. No special knowledge is required, just a willingness to agree to do a slot or two on the stand over the weekend. Please contact me if you are willing to offer assistance.

VLF Receiver Production

Now that John Cook has designed the PCB for these receivers, and has made and tested one receiver, he plans to make another couple before we try to productionise this process in order to be able to easily supply quantities of made-up boards at cost price to members who want them. As I regularly design and procure assembled PCBs for Xcam, it seems likely that we will adopt the same procedure as I use for manufacturing these boards, subcontracting out both the PCB manufacture and assembly to a local company. I hope to work together with John, over the coming months, to establish a test plan, that will enable us to supply finished, tested boards to members at a low cost.

With a view to starting to learn more about the VLF receiver, I have started to build an aerial to use with one of the completed boards. This should be a good learning process for me, and whilst I am doing this, I am trying to write a 'Noddy's guide to constructing and using a VLF receiver', that will include full instructions on how to use the prototype boards in advance of the controller becoming available.

In addition to the planning of supply, there is also a regulatory nightmare that we have to negotiate, including CE testing, WEEE and RoHS regulations. As radio astronomers, the CE testing of the boards should hopefully be relatively straightforward, but RoHS and WEEE regulations may require a little more work to ensure compliance. Even though, in some RoHS cases it is possible to claim exemption from the rulings, it is estimated that 40-60% of components may become obsolete as a result of these new laws, and so any new design work that is attempted needs to take this into consideration. I attended a conference covering WEEE and RoHS in November, to enable me to further the action plans of my own business, and we hope to soon finalise the arrangements that we need to make, in order to sell the boards. Anyone who feels that they may have knowledge specific to our area, please do pass information on.

Documentation Numbering System

Since we will be producing many PCBs, shielded boxes and other components, as part of our work, I have modified my company's documentation numbering system so that it is appropriate for the RAG. This will enable us to keep track of different versions of circuits as we develop them, and to number all our drawings, parts lists and circuits uniquely, avoiding confusion and mistakes in production.

Personal Collaboration with Peter King

I have, for some time now, been talking to Peter King about trying to correlate visual observations with radio observations. Peter is the man to whom we must be grateful for setting up the links between RAG and the MRAO (Mullard Radio Astronomy Observatory), and for arranging for us to have access to the 151 MHz array. He has, for a long time, had an interest in variable star observations, and I have recently agreed to become his mentor, through the variable star mentoring scheme that I set up for that section. This means that we will observe the same stars together, initially just using binoculars, to compare our visual estimations. However, far more interesting than this, is the project that we hope to run, in which we will make coincident radio and visual observations of flare stars, to see if we can learn anything from this project. This will be one of the very few collaborations between different groups within the BAA! I visited the MRAO later in November to visit the 151 array with Peter, to plan this project further. A short report of this visit follows in the next section.

A Tour of the MRAO

Our first stop enabled us to peer through the gate at The Ryle Telescope, which was formerly the 5km Telescope, and is also known as the arcminute microKelvin imager. The Ryle Telescope is an 8-element interferometer which operates at 15 GHz. The radio dishes are equatorially mounted 13 m Cassegrain antennas, on an E-W baseline. Four of the aerials are mounted on a 1.2 km rail track, and the others are fixed at 1.2 km intervals, and this provides baselines which range from 18m to 4.8Km.

The MRAO Ryle Telescope

The Ryle Telescope has three main scientific programmes: its main use currently is to survey for radio sources that would contaminate the degree-scale microwave background observations with the Very Small Array . It is also used for exploration of the the Sunyaev-Zel'dovich effect in galaxy clusters, particularly in determining the Hubble Constant, and flux monitoring of galactic variable sources. The Sunyaev-Zel'dovich effect is the Compton scattering of cosmic microwave background photons by hot, ionized gas in clusters of galaxies, and this produces both a "hotspot" in the CMB and a change in the shape of the radiation's spectrum.

On our drive to the One Mile array, we passed by the great Merlin dish (Multi-Element Radio-Linked Interferometer Network), which consists of an array of up to seven radio telescopes that are positioned at various locations across the country, including the Lovell telescope, the Cambridge telescope, and others located at Defford, Knockin, Darnhall and Pickmere. The array is controlled from the Jodrell Bank observatory.

The longest baseline is 217km and Merlin operates at frequencies between 151MHz and 24GHz, with a resolution of up to 40 milliarcseconds at 5 GHz. Microwave links are currently used to send data back for analysis, but as these links have a limited bandwidth, they are currently being upgraded to fibre optic links, which will provide the much greater bandwidth of 4GHz, compared to the current 30MHz. The increase in data will increase the sensitivity of the array by a factor of around 30, but also means that a new correlator has to be built, in order to be able to process the 200Gbit/s data that will be generated.

The MRAO Merlin Telescope,
Controlled from Jodrell Bank in Cheshire

Finally, we visited both the One Mile and the Half Mile telescopes, which share the same rail track.

The Half Mile telescope was constructed in 1968 and consisted of two aerials at the beginning, although two more aerials were added later. Two of these dishes were fixed, and two were moveable, and shared the rail track of the one mile array, to allow a range of baselines. This telescope was used for Hydrogen Line studies of nearby galaxies, and produced the first good radio maps of hydrogen distribution at 1.4GHz for the Andromeda galaxy (M31) and the Triangulum galaxy M33. It is now decomissioned.

The One Mile telescope, also decomissioned, was built just before the Half Mile telescope, and was completed in 1964. This has three 60ft diameter paraboloid telescopes which are steerable; one can be moved along the rail track, and two are fixed. These dishes operated at 1420MHz and 408MHz to perform aperture synthesis interferometry producing the 5C catalogue of radio sources. This was the first radio telescope ever to use the technique of aperture synthesis, and the resolution was 20 arcsec at 1.4GHz, and 80arcsec at 408MHz, which was unprecedented at the time. The three dishes are 18m in diameter, and the moveable dish could be positioned at many different intervals along a half mile length of track. This system has been used to map objects, to produce deep field surveys, and to develop the technique of aperture synthesis.

The MRAO One Mile Telescope

MRAO CAMBRIDGE

Our grateful thanks to the staff of MRAO for their collaboration in working with the BAA on this project

One dish of the One Mile Array, and the control hut

The dish at the other end of the rail track;
the other dishes are just visible in the background

The Interference Challenge

Dr Ken Tapping
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Ken works at the Dominion Radio Astrophysical Observatory, Penticton, British Columbia. A photograph of their interferometer is give at the end of the article.

Background to the Problem

Radio astronomy is probably the most demanding thing one can do with radio technology. It involves digging for weak signals at the limit of sensitivity, and integration times that make severe demands upon the stability of the receiver. That is why the many millions spent on building large radio observatories are invested in carefully chosen remote locations. A major consideration in siting these observatories is to get as far as possible from the cacophony of interference our civilisation makes. Unfortunately amateur radio astronomers have neither the millions or much choice over the location of their radio telescopes. Therefore, dealing with interference is an issue of primary importance, probably more so than the usual goal of achieving the maximum sensitivity.

Through international agreements, the UN's International Telecommunication Union has allocated specific bands for radio astronomical use. However, for amateurs, this is more a curiosity than something of value, because the additional considerations raised in protecting those bands allocated to radio astronomy is that the operators of radio observatories make an effort to get well away from interference sources. Interference can be, and is radiated into those bands, with the proviso that they are not causing interference problems at radio observatories. Amateurs cannot do this, so interference in the radio astronomy bands is very likely. There is a possibility that clear spaces exist in the bands, but even under the best circumstances, it is unlikely that all of a band will be usable; it could be that none is. For example, the band 406.1 – 410 MHz is allocated for radio astronomical use, (although it is shared with other users on a non-interference basis). At the Dominion Radio Astrophysical Observatory, located about 25km from the town of Penticton, British Columbia, the other side of some low mountains, all the band is usable, with occasional interference problems. At our house, in the hills on the north-western edge of Penticton, I found my 408 MHz interferometer had to be limited to a bandwidth of 250 kHz, and over the last few months, even that bandwidth has become unusable, and will have to be reduced.

Interference comes about in four different ways:

- Interference intentionally transmitted into the band being used for radio astronomy. This can happen if the band is shared, or if has given up on the official bands and are trying to find some space, somewhere, to do some observations.

- Harmonic and other stray emissions being produced by a transmitter operating at some other frequency. This can happen because of bad design, or a lack of maintenance. Many of the unlicensed home devices, such as the hardware for wireless commercial and home computer networks change their behaviour after being kicked over, bathed with coffee or tea, or other accidents. Sometimes the interference source is not even an intentional transmitter. We had a mail franking machine that proved to be a major source of interference at 408 MHz, and now lives in a screened room. Computers are terrible sources of interference.

- Harmonic emissions being produced outside the transmitter, perhaps from corroded joints on the antenna, or corrosion on some metal structure nearby, like the antenna tower, gutters, drain pipes etc. These interference problems come and go with changing weather, season and other conditions, and are very hard to track down.

- Too much sensitivity by the receiver to signals in adjacent or harmonically-related frequencies. Strong signals can overload the front-end amplifiers, or lack of selectivity may allow unwanted signals to get to the mixer, at which point anything can happen.

Dealing With It

Following the tradition that prevention is better than cure, it pays to make sensible choices about the project to be attempted. The criteria to consider are not only the scientific desires underlying the project, but also the environment that one is forced to live with, and the options available for dealing with interference problems when they are encountered. For example, in a city or large town, frequencies below about 400 MHz will probably be loaded with interference much or most of the time. Centimetre wavelengths are a better option. However, commercial, unlicensed radio devices are now using bands up to several GHz. Using modern technology, one can achieve remarkable results at GHz frequencies.

The figure below shows a small 4 GHz correlation inteferometer, using one 1.5m and one 2m diameter dish on opposite ends of a 7.3m aluminium pole.

Figure 1: 4 GHz Correlation Interferometer

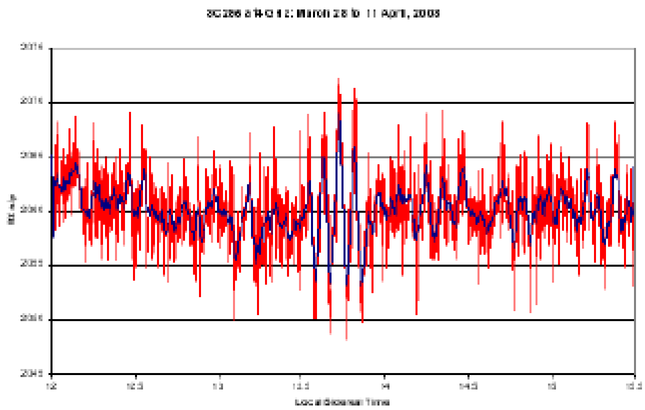

Figure 2: The radio galaxy 3C286 using the 4 GHz interferometer in Figure 1. The poor baseline is due to interference from satellites.

The *RMS* noise in the above record is around 10 Janskys. If the interference issue is addressed, small, back garden radio telescopes can yield impressive results, even when some interference is present.

General Design Points

The rule here is very much like something John Smith, a previous Director of the BAA Radio Astronomy Section said regarding dealing with water problems. One uses gaskets and sealants to keep out the water, and then make a small hole at the lowest point to let out the water. One designs the radio telescope system with keeping out interference in mind, and then incorporates into the design features to help deal with interference problems.

- The front-end amplifiers in the radio telescope usually have a larger bandwidth than components further down the receiver chain. Because there are fewer tuned circuits, the sensitivity to out-of-band signals is higher than would be the case in the intermediate frequency amplifier for example. Tricks to get better noise figures, such as having the first tuned circuit be heavily loaded by the first transistor, GaAsFET, HEMT or whatever means almost anything can get to the first amplifier, which is bad. Even if the first amplifier has phenomenal dynamic range, what gets through it could get to the mixer. This device is inherently a non-linear producer of intermodulation products, so the bandwidth of signals reaching the mixer should be limited to the desired bandwidth. A really selective multipole filter would be a good idea. However, one needs then to consider what the out-of-band impedance components of the filter do to mixer performance and to the output of the front-end amplifiers. Some padding using 3dB or other attenuators would be a good move. The insertion loss of the filter will require more gain in the preamplifier, which increases interference susceptibility, so be careful. A sensible move is to put a filter *before* the preamplifier. A quarter or half-wave trough-line filter is easy to make and has a low loss. It will help stop undesired signals reaching the amplifier, and permit the use of a little more gain to deal with the loss of the pre-mixer filter.

- Make sure the local oscillator produces only the desired frequency. In practice, all local oscillators produce harmonics etc. However, make the oscillator as clean as possible. Don't hang a filter directly on the oscillator output. Put in an attenuator. You might need to add an amplifier so that you can run the oscillator at a low level, and take a very small output.

- If you are using a phase switch, with diodes as the driven elements, drive the diodes hard and make sure the line bringing the switching signal is well filtered. Interference can get picked up by that wire, which feeds it into the diodes, which then modulate the signals going through with the interference. This happened to me.

- Make sure the input tuned circuit of the IF amplifier accepts only the desired band. If you need to add a filter, do so. Now that small, broadband amplifiers are cheap, an IF amplifier can be built using 6-8 stages with gains of about 10dB, coupled through selective filters. If possible, it is always best to distribute the gain and the filtering processes.

- Dealing with interference problems might need redesigning part of the receiver or adding additional components. Building all the system on one board might look nice but it is not wise. Make the system out of single-function units, all in their own metal boxes, with filtered power lines and with the inputs and outputs being through coaxial cable. In that way major design changes are possible in way that is easy, and even fun. How easy would it be to adapt your design to

- reduce the bandwidth of the intermediate frequency amplifier from say 4 MHz to 250 kHz?

- You might need to retune the receiver to get away from an interference issue. If the local oscillator is a fixed frequency device, a new local oscillator will be needed. Paradoxically, the best local oscillator for a radio telescope would be one that is stable but tuneable.

Impulsive Interference

This sort of interference comes from electrical switching devices, bad commutators on DC electric motors, car ignition systems and so on. It comes in spikes covering a wide range of frequencies. One cannot tune away from them. If you're lucky, it might be possible to exploit the directional properties of the antenna to minimise the interference. However, in general this is not the case.

If the interference spikes don't turn up too often, then they are more of an annoyance than a problem. On a paper chart recorder they might look awful. However, if you are, as is usually the case these days, using a computer as a data logger, drawing dots for each value and not joining the dots with lines works wonders, and the averaging process can make the problem less difficult to live with. Otherwise, one can simply throw out readings bigger than a multiple of some running estimate of standard deviation and not incorporate them into the averages at all.

If the impulsive interference is too bad for that, try breaking the IF amplifier into two sections, a larger-bandwidth, very linear section with a large dynamic range, and then a second section with a much smaller bandwidth. Put a diode or other type of limiter between the sections so that they cut off the tops of the interference spikes before they get to the second half of the IF amplifier, where they would get smeared over the data you want to receive.

Continuous Interference

If this is coming in on an identifiable frequency then the solution is to retune the radio telescope away from it, reducing the bandwidth as required. If it is not possible to retune the receiver or the interference is too weak to identify, but bad enough to be a problem, then there are still things to try. The key point is to have the desired data have some identifiable property the interference does not. For example, in an interferometer, a source being carried through the antenna beam by the rotation of the Earth will produce fringes with a known frequency. Things moving at other than the rotation rate of the Earth will produce fringes at other rates. A ground-based interference source will not produce fringes, but merely a baseline offset. However, fluctuations in the strength of the interference signal due to propagation conditions or some properties of the transmitter modulation can still make the record messy. The recovery technique here is essentially to filter out components of the receiver output that are not fringes coming through at the sidereal rate. This can be done using analogue filtering; modern operational amplifiers with high input impedances can be used to make high-pass or band-pass filters at milli-Hertz frequencies. An alternative is to use digital signal processing. Modern personal computers have enough capability to do this, in fact they could replace all the post-demodulation signal processing other than the DC amplifier and sampling filter needed to precede the digitizer.

Personal Communication Devices

Mobile (or cellular) phones, Blackberries and other personal communication devices all use small, almost non-directional antennas. If these devices are to work in buildings, cars, trains and pockets, the transmitter has to squirt out a lot of power, particularly with the cheap receiver front-end electronics used in personal communication devices. The radio telescope receiver will be orders of magnitude more sensitive than these devices. Since the sensitivity of a directional antenna to signals coming in from well away from the direction the antenna is pointed is only a little bit less than the gain of the antenna of the hand-held radio device, interference is a real possibility. Find out what frequencies are used for these devices, and stay away from them.

Final Comments

The radio spectrum is now under more pressure than ever before to find space for accommodating new radio services. This puts radio astronomy under pressure to share, coordinate and so on with other users. It is also making the interference environment worse and worse. It is interesting to consider that the observations made by Jansky and Reber would now be impossible at the sites at which they were originally made; the interference would be too bad.

Interference can be the bane of the amateur radio astronomer, and dealing with this is necessary, even if the sensitivity to cosmic signals is reduced by several dB; some data is better than none. The key points are to design the receiver with interference in mind, and make the resulting instrument adaptable as required to deal with problems.

Building the radio telescope as single-function modules all in metal boxes and standardised power and signal connectors is a good move. After an experiment or two one accumulates a collection of modules that makes constructing new experiments even easier.

Figure 3: The 7-element Synthesis Radio Telescope at the Dominion Radio Astrophysical Observatory, near Penticton, British Columbia, Canada.

Radio Astronomy Frequency Allocations

Interference problems at particular frequencies and/or locations might be unaddressable. However, there are always other frequencies. The current UK allocations for Radio Astronomy frequencies are given here as a useful reference:

37.5 - 38.25 MHz	Continuum
73 - 74.6 MHz	
150.05 - 153 MHz	Solar/Continuum/Pulsar (VHF)
322 - 328.6 MHz	
406.1 - 410 MHz	
608 - 614 MHz	
1400 - 1427 MHz	21cm Hydrogen Line (L band)
1660 - 1660.5 MHz	
1660.5 - 1668.4 MHz	
1668.4 - 1670 MHz	
1718.8 - 1722.2 MHz	
2655 - 2690 MHz	
2690 - 2700 Mhz	Solar/Continuum (S band)
3260 - 3267 MHz	
3332 - 3339 MHz	
3345.8 - 3352.5 MHz	
4800 - 4990 MHz	
4990 - 5000 MHz	
5000 - 5030 MHz	
6650 - 6675.2 MHz	
10.6 - 10.68 GHz	
10.68 - 10.7 Ghz	

Flare Classification and Reporting

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Flares are classified on a rather curious scale, running A, B, C, M and X. It is logarithmic, and is calibrated as follows:

Class	Energy
X	$10^{-4}...10^{-3}$ W/m^2 (measured at 0.1...0.8nm wavelength)
M	$10^{-5}...10^{-4}$ W/m^2
C	$10^{-6}...10^{-5}$ W/m^2
B	$10^{-7}...10^{-6}$ W/m^2
A	$10^{-8}...10^{-7}$ W/m^2

As it is logarithmic, each category can be subdivided into 10 with a resolution of 0.1, leading to a flare being quoted as C5.6 or M1.2. The background level from a 'quiet' sun is often within A or B-class, with most flares being of B or C-class. More energetic active regions produce M-class or X-class flares. At the extreme, a flare can exceed X9.9, and produce X17 or X20 flares. Flares of X-class pose a threat to orbiting satellites, as well as human space travellers. C-class flares are easily detected as sudden ionospheric disturbances, while some larger B-class events can also be recorded. X-class events produce spectacular SIDs, as the ionosphere slowly recovers.

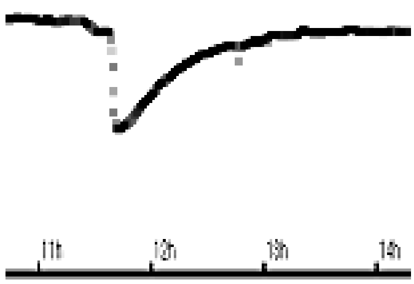
When recording SIDs, start, peak and end times are required. 'Start' is the time at which the event is first recorded, 'Peak' is the time at which maximum or minimum signal strength is recorded, and 'End' is the time at which the signal strength returns to its previous diurnal trend. Start and peak times are easily read, while the end time often requires a little guesswork to identify.

The amplitude of the disturbance usually correlates with the flare class, but will depend on the state of the ionosphere at the time. Since it is an indirect observation of solar activity, the amplitude is not recorded in VLF reports. The length (duration) of the SID recorded does not always correlate with flare class, but can be recorded as the ‘importance’ of the event on the Earth. This has traditionally been recorded as follows:

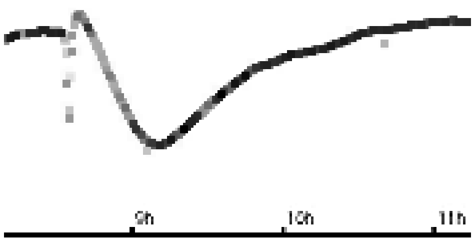
Duration	*Importance*
<18min	1-
19..25min	1
26..32min	1+
33..45min	2
46..85min	2+
86..125min	3
>126min	3+

The shape of recorded flares will vary from one observer to another, but a little experience while the sun is active will allow most events to be isolated from other interference. The text-book SID has a sharp rise to a definite peak, followed by a longer recovery period. In practise, many SIDs do not look that simple, and may have multiple peaks. SIDs may also appear inverted. This variation in shape is due to a combination of the path from transmitter to receiver and the varying state of the ionosphere. The sun often produces multiple flares over a short period, leading to superimposed SIDs that can create confusion.

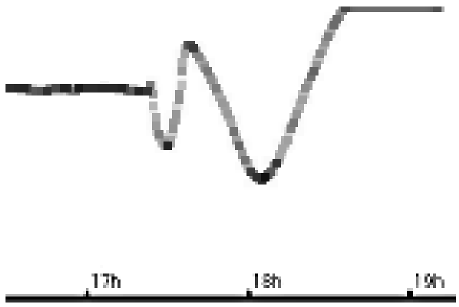
The following illustrations show some recent events:



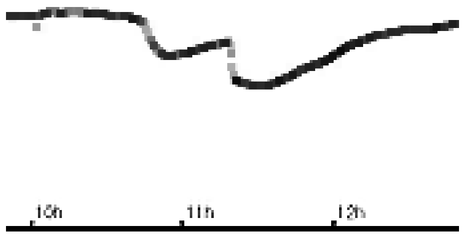
This is typical of an ordinary SID that I record. Measurement is fairly easy. It is inverted relative to ‘normal’, but is clearly the correct shape.



This is typical of a much more energetic solar flare, producing a SID that has a double peaked structure. The start and end times can be measured as usual; the peak time I measure at the maximum point, in this case at 08:37UT.



This is much more difficult, as the flare occurred during the sunset dip in signal strength. The result is a combination of the two effects. The start is easily measured, and the peak is also clear (as above). The end time cannot be measured, and would be left blank.



This recording shows 2 flares in rapid succession, such that the SID’s overlap. An end time for the first event cannot be measured.

These sudden ionospheric disturbances might be recorded thus:

Date	*Start*	*Peak*	*End*	*Importance*
2005-03-10	11:39	11:42	12:42	2+
2005-09-15	08:33	08:37	10:33	3
2005-09-07	17:23	17:28	?	-
2005-09-13	10:45	10:55	?	-
2005-09-13	11:!8	11:32	12:05	2+

Note that all times are recorded in Universal Time (equivalent to GMT).

Project Development Reports

2.695Ghz Receiver Development

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These are my design notes for the development and construction of a dual band radio telescope. It should be noted that this is not the “official” BAA RAG 2.695GHz telescope which is developing under the guidance of Terry Ashton. This telescope is a total power receiver and will be used to monitor the RF noise produced by the Sun.

The telescope is entirely modular. I have chosen this approach so that units can be swapped out as the design progresses. The medium term objective is to integrate the RF sections with the *Starbase* system. In the sort term, I want to get a system in place so that I can prove that the S band and VHF modules work to a satisfactory level. It can also be used to baseline performance against the RAG Radio Telescope. It is intended to make circuits and layouts publicly available for reproduction by competent engineers, however, it will not be made available as discrete assembled modules.

The two bands that I am currently focussing on are centred on the Radio Astronomy dedicated frequencies of 2.695GHz and 151MHz. Both these frequencies are fairly close to the Amateur Radio allocations of 2.4GHz and 144Mhz and to accelerate the development time, existing proven published circuits from these bands will be reused. Full credit to the original designer will be acknowledged.

Phase 1

This phase comprises of the production of two modules. A 2.695GHz to 151MHz down-converter and a 151MHz to 28MHz down-converter.

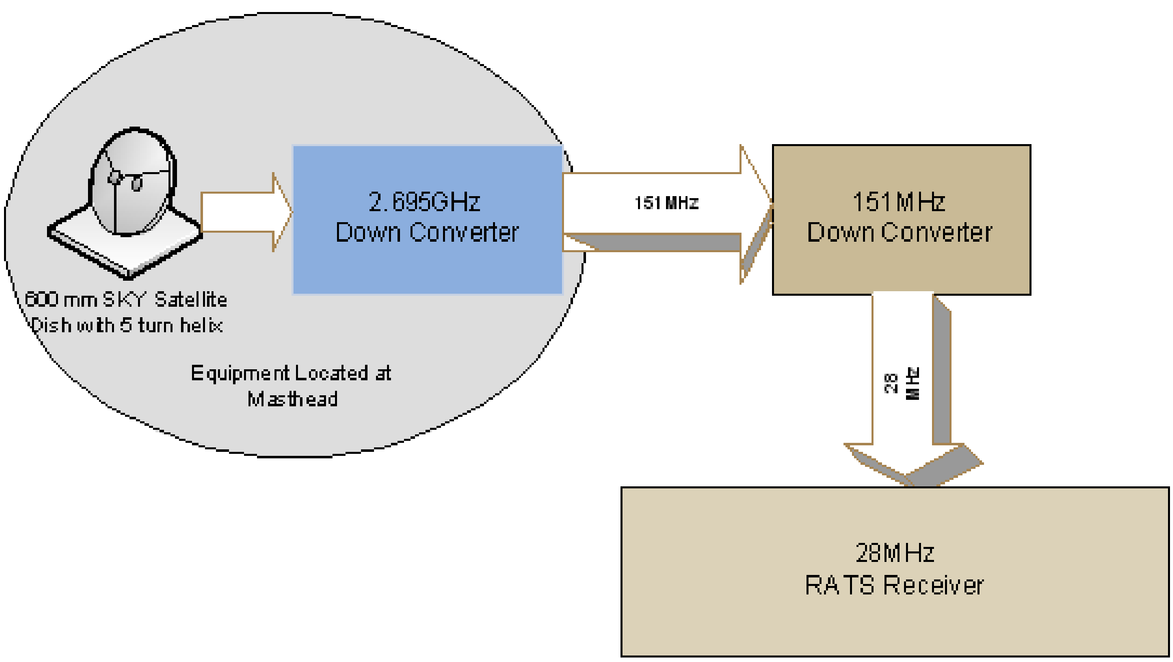
The *Starbase* system utilises a 38MHz IF, so it is likely that the 151Mhz converter will (hopefully) become redundant in a short period of time. However, I have a *very* sensitive 28MHz receiver (RATS [Receiver Alignment Test System]) designed by Roger Blackwell G4PMK and published in RadCOM, (Journal of the RSGB) in July and August 1995. This will be ideal to setup and prove the higher frequency RF stages.

The 2.695GHz Converter & Local Oscillator

For the prototype, I have decided to use a receiver that incorporates a sub-harmonic mixer with external oscillator. The benefit of a this type of mixer is that the local oscillator frequency is doubled at the point of mixing, therefore for a 151MHz intermediate frequency:

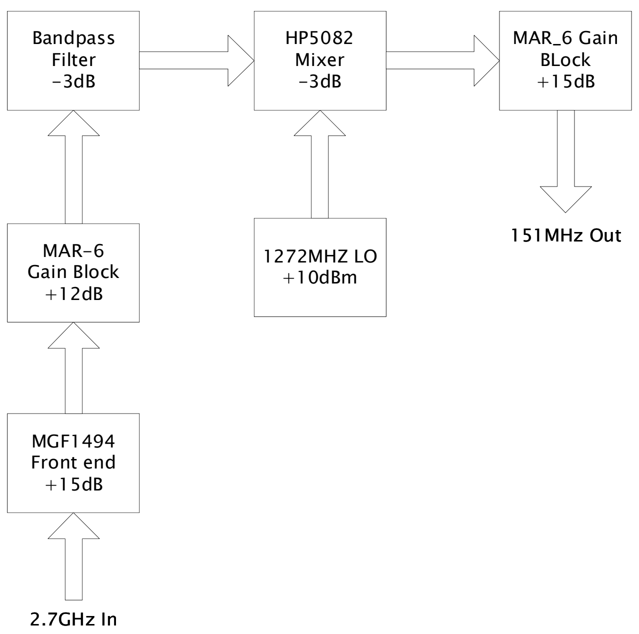
2695MHz-151MHz = 2544MHz (local oscillator)

Because it's a sub-harmonic mixer the LO needs to be half of the wanted 2544MHz = 1272MHz. About 10dBW of RF is required. This is much easier to produce than at 2544MHz. And as a modular approach has been adopted, different oscillator designs and configurations can be utilised without having to redesign the artwork for the amplifier and mixer stages.



Initially, I am using a WDG016 kit (available from Charles Suckling G3WDG) for the Local Oscillator. This uses a x12 multiplier to achieve the desired output frequency, so 1272/12 = 106. A 106MHz 5th overtone crystal is required and this has been sourced from Quartslab. This oscillator provides a very stable and clean output. This type of oscillator is perfect where spatial resolution of the received signal is required, for example, in a H line receiver. However it is overkill where the requirement is for a total power receiver. So I am investigating other less critical, lower cost alternatives, possibly based on DRO (Dielectric Resonator Oscillator) technology. These provide a clean output and are used in the LNB's of many domestic satellite TV systems.

The RF and LO stages will be contained in a waterproof box and located directly behind the dish. I expect that the Noise Figure will be < 1dB with about 36dB of system gain. The 2.695Ghz receiver layout and gain distribution is estimated to be as follows:



Receiver Gain Allocation

The 2.695GHz down converter will use a pipe-cap filter as an image rejection filter. I have documented my experiments with this type of filter on my web site at http://www.czd.org.uk/astro. If required, additional gain blocks will be added between the 2.695GHz and 151MHz converters.

The prototype converter is constructed on 0.8mm PTFE based PCB material with an Er of 2.5. The layout and circuit diagram will be available following system testing. The 151Mhz signal will be brought down to the radio room using RG213 coaxial cable to connect to the 151 to 28 MHz down converter.

151MHz to 28MHz Converter and Local Oscillator

The design of the 151MHz module is more demanding. The allocation at 151MHz is very small and there is a great deal of adjacent noisy users, such as the BT radio paging service. Propagation from VHF sources tends to more omni-directional than microwave sources and there is far more scope for interference. Additionally, because the wavelength at 151MHz is about 18 times longer than at 2.695GHz, there is less scope to build a more directional antenna (unless you have the space for a 12 metre diameter dish!) and the gain capability of the average aerial will be about 12dB less. Therefore a receiver with more selectivity is required to suppress interference from other sources. But a higher gain with lower noise front end is also required.

Amplifiers by their nature are fairly broadband so will amplify the local unwanted signals as much as the wanted signals. And to compound the problem a total power receiver is inherently broadband as we are measuring the received power across as wide a spectrum as we can get away with! Additionally, the effects of mixing from the image frequency should not be underestimated. To achieve a 28MHz output from a 151 MHz input requires a Local Oscillator of 123MHz. But 123MHz - 28MHz = 95MHz which is right in the middle of the medium power VHF FM local radio broadcast band! Unless these are totally suppressed at the receiver front end, they will simply add to the total power received and passed to the detector. They will comprise a far bigger component of the signal than the signal received from the sun. With a 38MHz IF, the problem is not quite as bad. A local oscillator of 151MHz - 38MHz = 113MHz will be required. The image will be at 113MHz - 38MHz = 75MHz. I think this allocation is currently used for commercial VHF vehicle communications, but this is much easier to filter out. Ideally, a dual conversion receiver may be a better option and this may be considered for the future.

You can see why the design of the 151MHz converter is tricky! In hindsight, I think using the RA allocation of 408MHz as the IF may have been a better strategy. Usually, the selectivity (the ability to resolve the wanted from the unwanted signals) of a receiver is carried out in the detector stages, however careful design and filtering at the higher frequency stages will clearly help.

I have identified an existing and proven (144MHz to 28MHz) converter design that is no longer available in print. I have modified the circuit to use SMD technology as many of the original discrete active components are no longer available. The artwork and the circuit diagram have been produced and the design is currently being built. This module will be enclosed in a fully screened case and fastened to a standard sized Eurocard PCB to locate in the Starbase chassis. These two modules will be aligned using the RATS and a standard amateur band 28MHz receiver. If this is successful, the VHF converter will be redesigned at Phase 3 to provide a 38MHz IF output.

Alignment

Alignment of the 2.695GHz system will be by the use of a comb generator. A Crystal controlled oscillator running at 96.25MHz will have its 28th harmonic exactly on 2.695GHz. A narrow band receiver should hear this is a warble free whistle. The stability of the oscillators can also be tested using this method.

151MHz Low Noise Preamplifier

The prolific German designer, Rainer Bertelsmeier DJ9BV has produced a number of very low noise preamplifiers over the last few years. In Dubus Technik IV he detailed a MGF1302 based amplifier designed for 144MHz. I plan to build this and locate it at the 151MHz antenna. This will be followed by a 20dB gain block using MAR-6 devices and then fed to the 151 to 28 MHz down converter using RG213 coaxial cable.

Thus ends Phase 1.

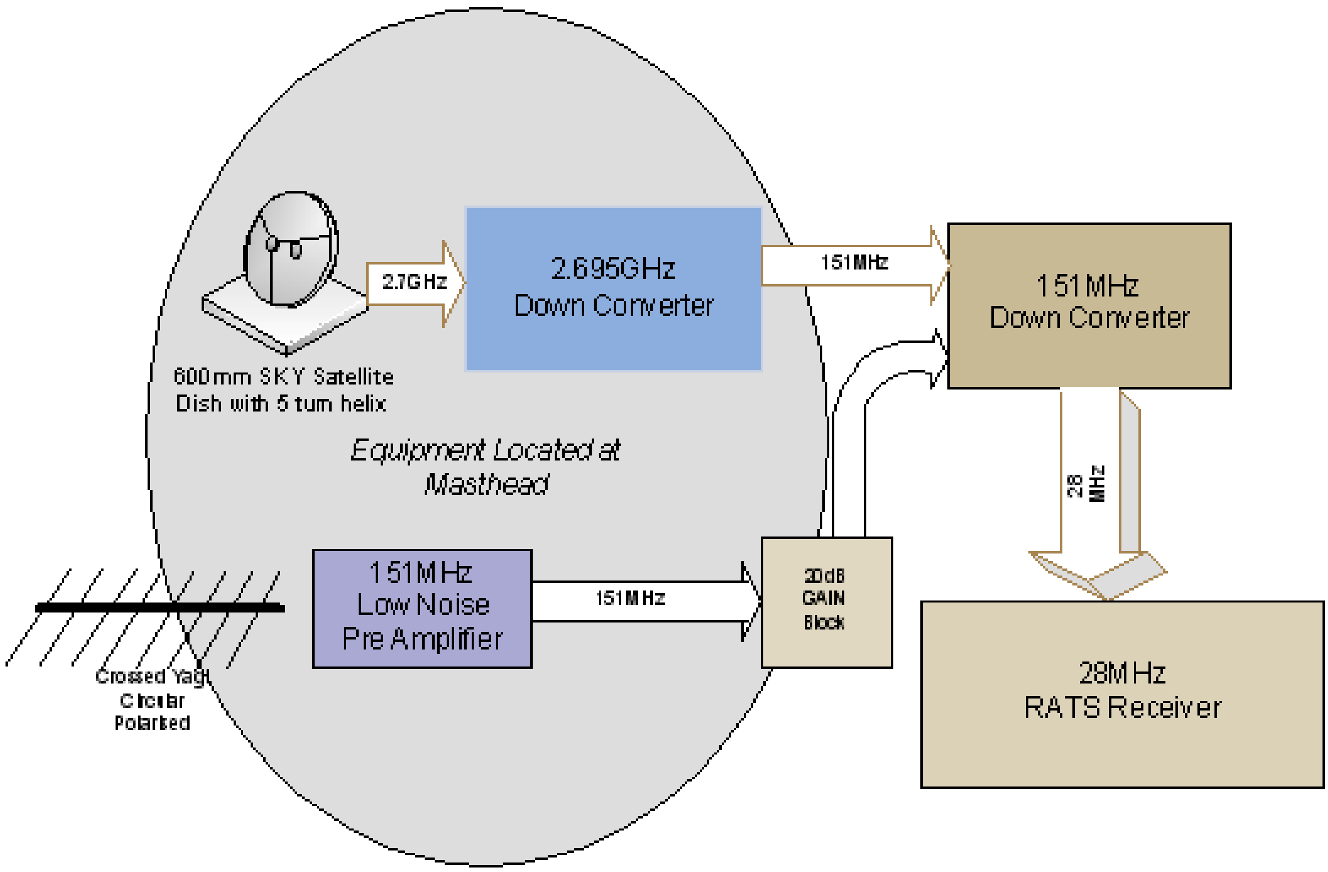
Phase 2

This details the introduction of a switched noise source and calibration system. I also need to devise a method of getting the aerials to follow the sun. More on this and the effect of temperature in the next circular.

Phase 3

Integration into the *Starbase* system.

Progress on this project along with circuits and PCB layouts will be made available on my website as they become available. An update will also follow in the next circular.



1.4Ghz Hydrogen Line Spectrometer

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Alan Morgan and myself decided by mutual consent to look first at the system components between 1420MHz and 151MHz. Alan has taken on the Low Noise Amplifier (LNA), I am looking at the down-converter. We have yet to meet or even talk to each other directly, something we must put right soon.

Down Converter

A lot of time was spent thinking about system design. Alan had provided a block diagram of the envisioned system, but I was concerned about a single conversion design from 1420MHz to 151MHz. The priority in the design is spectral purity and it was thought that with simple filtering, image rejection would be a problem.

A double conversion design using 405MHz commercial IF filters was studied and quite a bit of time spent going up a blind alley. It turned out that the filters were difficult to source and then further analysis proved that actually, a single conversion design would be best due to spurious.

Filtering and in particular image rejection remains practical problem. A figure of >100dB rejection was set as a design target. More time was spent looking at image rejection mixers in detail (I was designing these at 1.9GHz for GEC in 1980 but that's another story), but it was decided that the complexity and cost were a problem. Practically, the achievable rejection ratio was also limited.

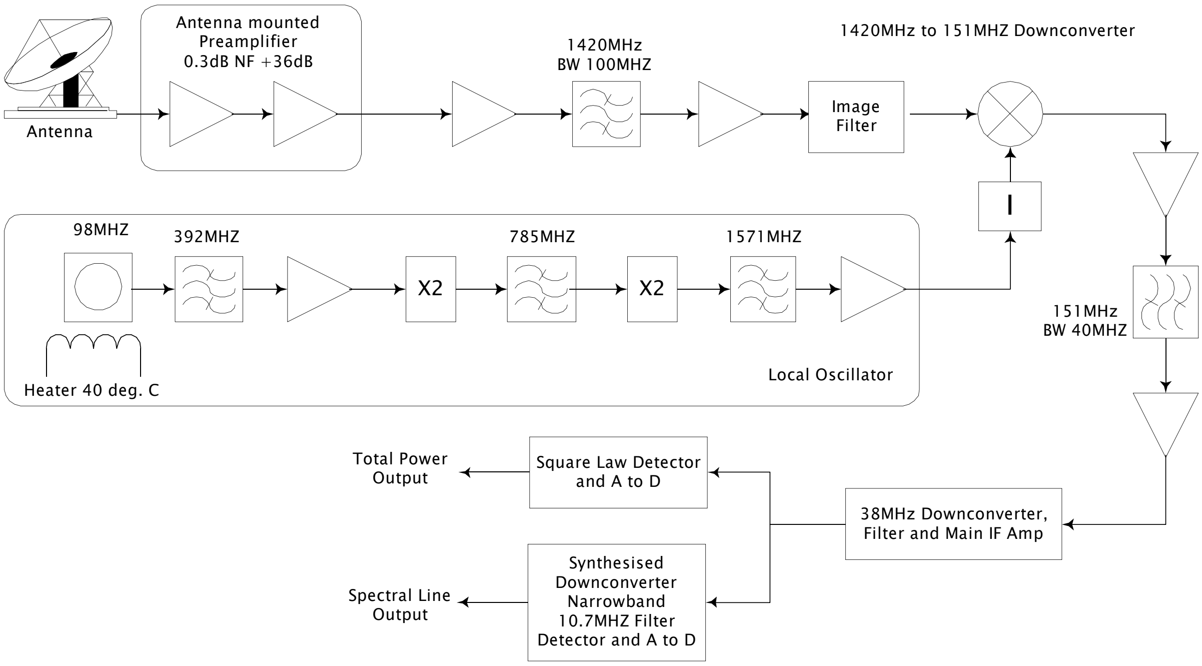
It was time to try a few ideas out, so a hunting began for some test equipment. A Wiltron 6409 Scalar Analyser has been borrowed with an eye to eventual purchase. This box allows frequency response and return loss (a measure of impedance match) to be swept between 10 and 2000MHz.

A channel filter was designed and fabricated in microstrip. This is built on 1.6mm FR4 because it was to hand. The response of that filter is very encouraging with acceptable through loss and rejection at 1722 MHz better than the current test set can measure, about 50dB. A commercial filter has been purchased from Astronomy Supplies to use as a reference, delivery is still awaited.

It was decided to put the LO on high side at 1571MHz as this reduces spurious responses and avoids some possible interference from high power radar down at 1150MHz. By placing a notch filter tuned to 1722MHz before the mixer the image rejection ratio of >100dB should be achievable. At these of levels, layout becomes very important.

A 1733MHz notch filter was designed and fabricated. See picture. The design worked with very low through loss at 1420MHz but with only about 40dB rejection in the notch. This appears to be due to coupling between the open circuit stubs used. With better layout it is hoped this can be improved, although the rejection is probably already adequate.

It was clear that impedance matching to the test pieces was not perfect. BNC PCB connectors had been used and there are mismatches at the transitions. Some 1.0mm FR4 board has been ordered and the next iteration of design will use SMA launchers.

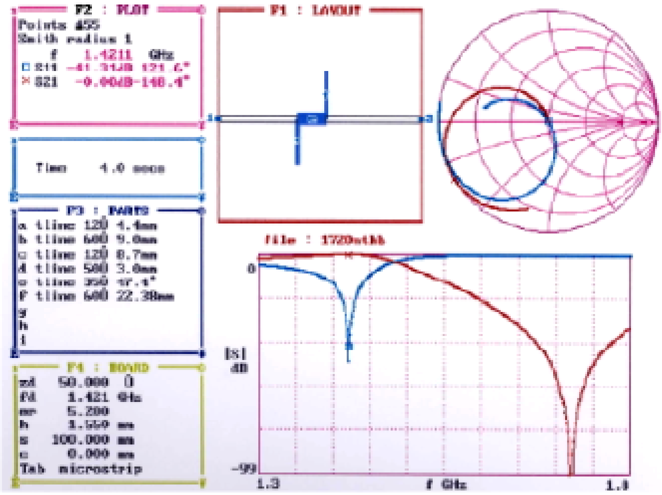


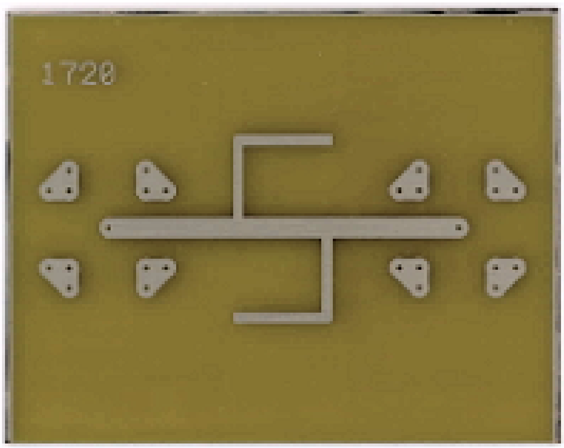
Following the mixer to 151MHz it was decided that some form of band limiting filter would be desirable. A 30MHz wide filter was designed, centered on 151MHz. See picture. This has been built and tested. The response is as predicted but the return loss could be better. The design will be revisited, but isolated as it will be by buffer amplifiers, moderate matching would not be a problem. It is only a three element filter with limited rejection but serves to clean up any RF/LO leakage.

Design interest now turns to the local oscillator chain. Many favourite semiconductors seem to have gone obsolete recently so a little extra work has gone on to identify replacements. Crystals have been ordered for the oscillator, which will probably use a Butler circuit. Filtering of the LO chain is important to minimise spurious. A final output filter has been designed at 1571MHz but has not been built. Experience with the 1420MHz filter has shown that this should not be a problem. To combat frequency stability problems if used for precision spectrometer work, it was decided that provision would be made to optionally add thermal regulation for the LO crystal. Crystal heaters from Kuhne Electronics have been obtained that should hold the temperature at 40°C. These are very nice little units and not too expensive.

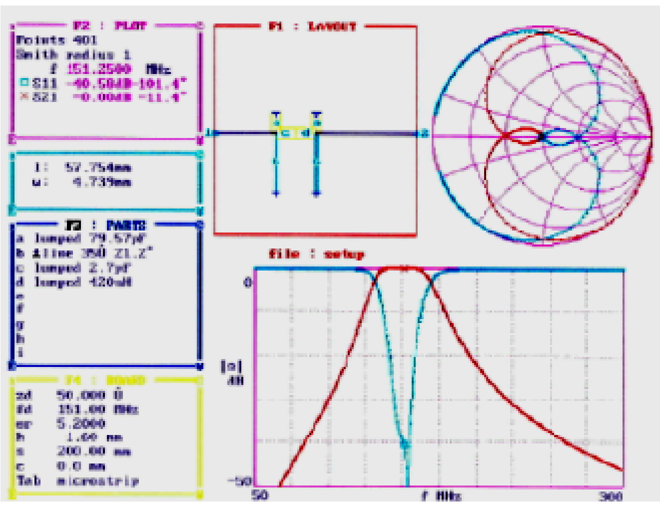
Looking forward to system testing. An old 144/28MHz converter has been modified for 151MHz. The necessary 123MHz crystal had been in the spares box for 30 years, justifying at last my “come in handy” store. I have broadened the IF bandwidth of this unit which will be used at 28MHz +/- 2MHz IF for test purposes. Crystals for the eventual 151MHz to 38MHz stage (189MHz) have also been ordered. It is realised that this may overlap with other P&PO modules.

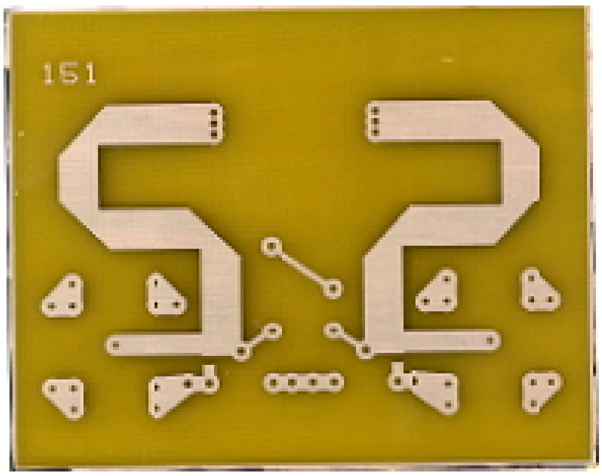
Current plans are to build some more down-converter filter test pieces on 1mm FR4 with options to add buffer amplifiers using MMICs and then procuring LO parts so that a PCB for a complete unit can be designed and built. Work holidays and Christmas may temper the pace of development a little.





The prototype 1722Mhz microstrip filter



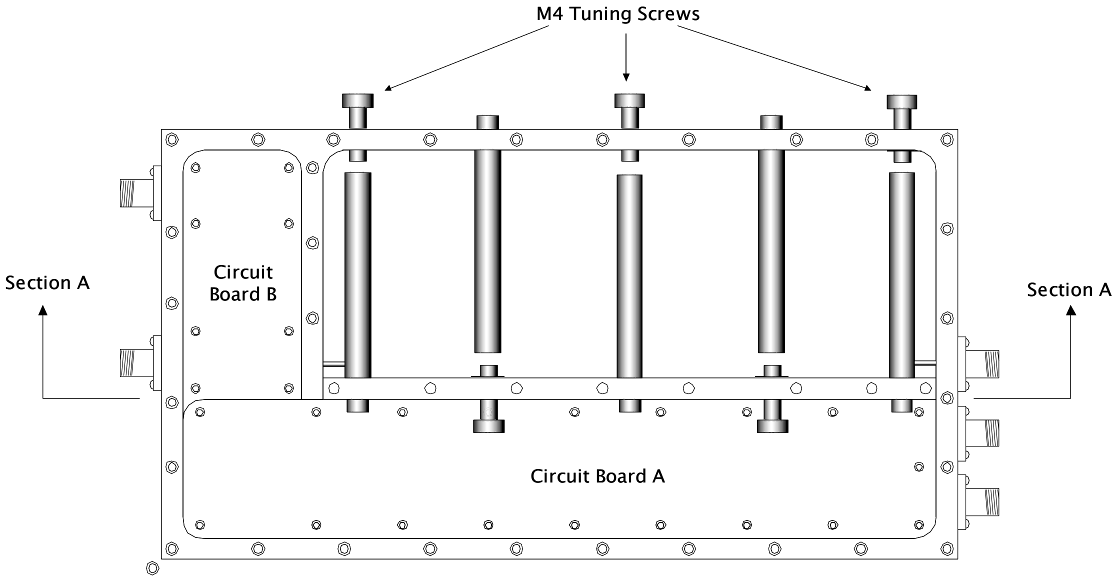


The prototype 151Mhz microstrip filter, Δf 30MHZ

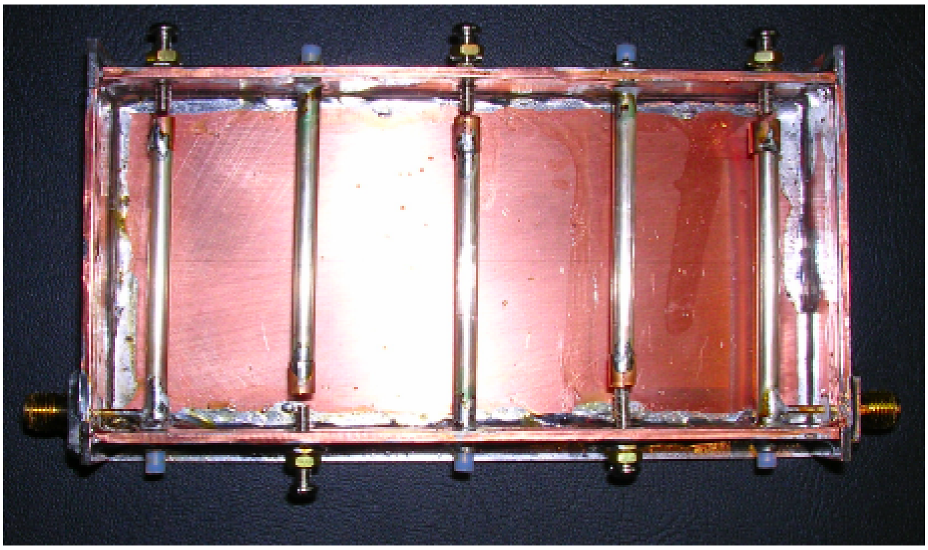
There are some serious interference sources around 1.4GHz orbiting above our heads. GPS, Galileo, GLONASS, Iridium and Meteosat satellites just to mention a few. Terrestrial mobile phone systems and radar put out even bigger signals. Adequate filtering in the receiver is therefore essential to limit the effects of interference. Having built some printed filters for 1.4GHz, the passband ripple and roll-off rate proved disappointing. Roll-off could be improved by providing more filter elements or by cascading filters, but at the expense of more passband ripple.

As an alternative, more conventional mechanical designs using high Q air-spaced resonators have been explored. A five section interdigital filter was selected as a good compromise between performance and size. A prototype has been built and with careful tuning this provided the design bandwidth of 20MHz at 1420MHz. Passband ripple was 0.5dB rather than the 0.1dB design aim, but this is thought to be due to poor impedance matching at the filter input/output connections and can be improved.

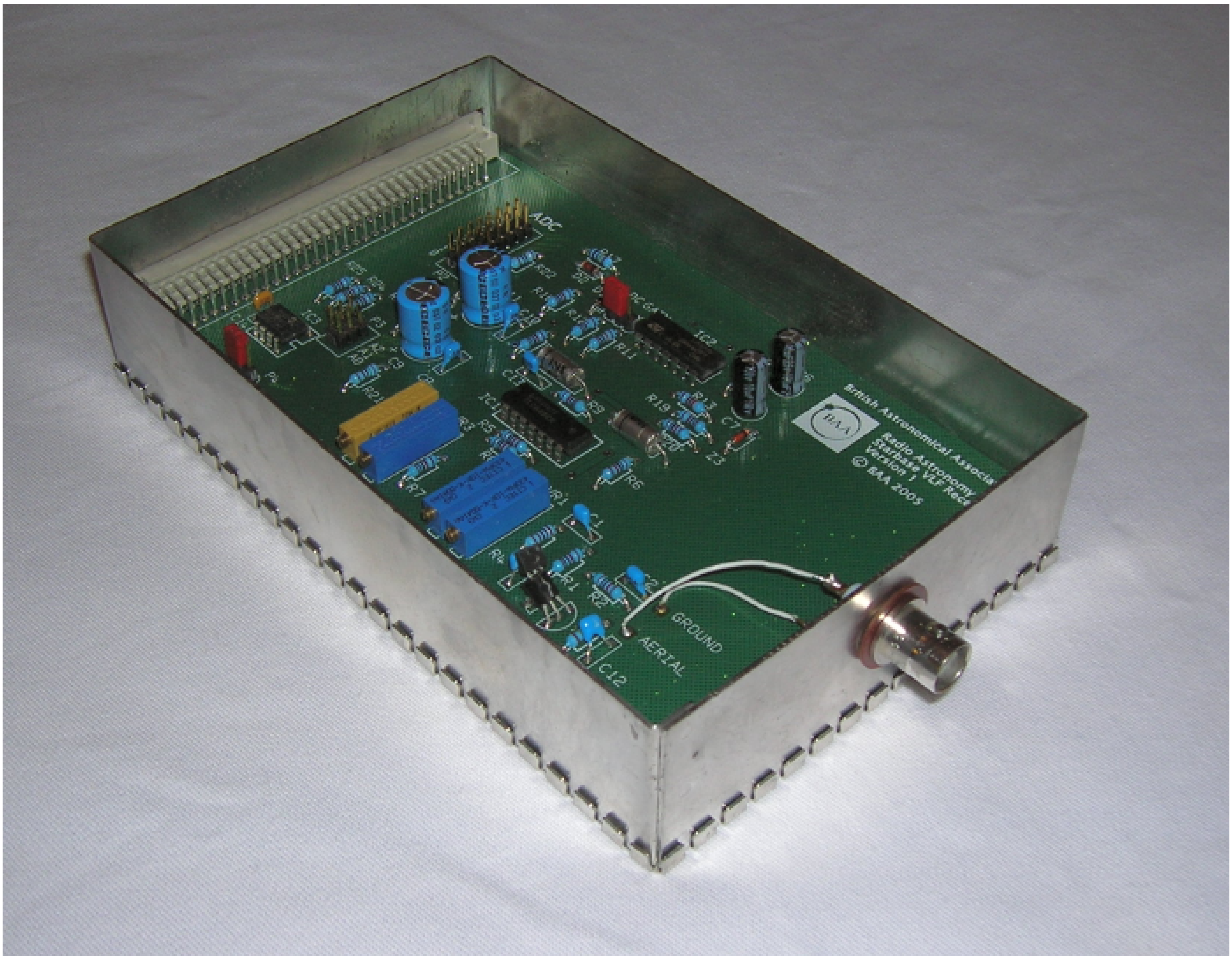
Conventional filtering brings complexity in the mechanical design of the unit, which must be more robust than the tin box approach advocated for other modules. Fully dimensioned drawings of a suitable housing have been produced and a quote is currently being obtained for NC machining. If anybody has access to NC machining at an advantageous price this would be helpful.



The proposed 1420Mhz interdigital filter, Δf 20MHz



The prototype interdigital filter



VLF Receiver

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We are developing a Very Low Frequency (VLF) Receiver, the prototype for which is shown above. This is a simple design for a VLF receiver, suitable for recording solar flare induced sudden ionospheric disturbances (SIDs). It has a tuning range of about 12kHz to 35kHz, requires a supply of +/- 15V DC at 15mA, and provides a 0-5 Volt output signal. It is designed to work with a small tuned frame aerial. A number of these modules have been built, recording signals from various European transmitters.

A cascode input stage buffers the tuned aerial, providing a small gain. Its primary function is to isolate the aerial from the filter. The filter circuit uses a quad-opamp, and is based on a circuit used in analogue computing. While it is greedy on opamps, it provides nearly independent control of gain, frequency and Q, a feature that greatly speeds up initial tuning. Just two close-tolerance capacitors are required. To eliminate the build-up of offset voltages in such a circuit, the filter output is AC coupled into a selectable x1 or x10 gain stage. In conjunction with the filter gain control, this can be set to fit the diurnal change in signal strength within the 5 Volt range of the output.

The amplified and filtered signal is rectified to provide a simple DC output with a fairly long time constant of about 1 second. This will remove all of the original modulation, and produce a smoothly changing voltage free of too much noise. A final x2 amplifier drives the output to the recording device. Further filtering can be provided by the recording system, if required. No calibration of signal strength is required, as this is an indirect recording of the sun. The timing of the events it what is required.

For use within the *Starbase* system, a small serial memory is included. This can be used to store identification details for the module, which might be just one of a number of VLF / HF / UHF receivers.

We have produced a batch of ten circuit boards, which we are currently assembling and testing. The screening cans will be manufactured with cutouts for the connectors, as shown. The fully tested modules will be available for sale shortly. Please contact either myself or Karen Holland if you are interested.

MRAO 151MHz Liaison

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A few weeks ago, I (Karen Holland) was fortunate to be able to visit Peter King at the MRAO, to visit the 151 MHz array and the Mullard Radio Astronomy Observatory for the first time. On arrival at the Observatory, Peter first took me to see the 151MHz radio-telescope, to see the progress that he had been making in preparing this for BAA use.

When I last enquired about the status of this project, one of the key operations that needed to be completed was the installation of the cables into the stanchions. Unfortunately, Peter explained, when the equipment was installed for the Ryle 5GHz array (see later image), the stanchions of the 151 array had to be lowered, and this operation had broken the cables that were inside. I guess as the 151 array was no longer in use by the professionals at that time, this was not thought to be of great concern, but it was obviously one of the key things that Peter had to organise next, to get us one step nearer to being able to use the array. The cables needed to be cut to a precise length, making the task a non-trivial one, and this had meant that we had had to wait until there were MRAO staff available to complete this task for us. So I was pleased to hear that Peter had been able to arrange that this work had now been completed. Peter explained that he was hoping to use two aerials on each side of the hut, which will give us a longer baseline than that originally intended, and he hoped that more of the aerials might be able to be used in the longer term, giving an even longer baseline. We will initially use aerials 1 and 2 on the Ryle Array side of the 151 MHz array hut, and aerials 5 and 6, slightly further away.

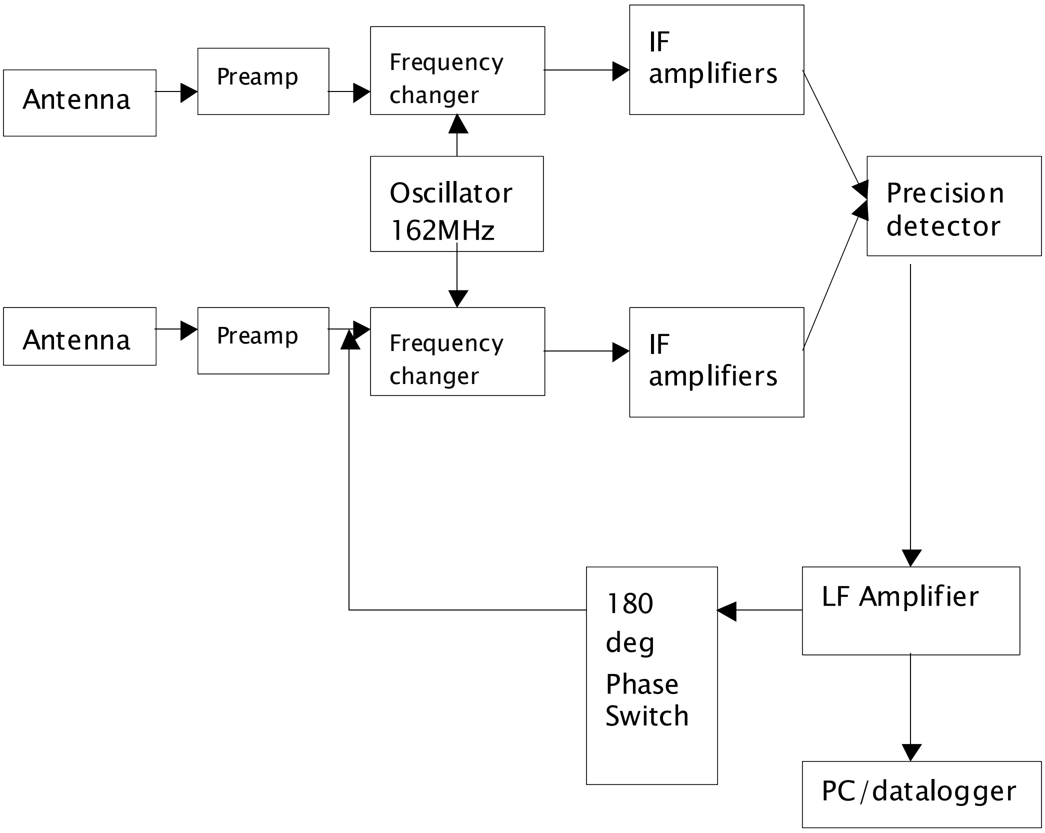
Staff at MRAO had also installed four new aerial preamplifiers; this work had to be done by MRAO staff for insurance reasons, since it was necessary to work at height.

Peter had been busy trying out the data logger that he intends to make use of, having tried various versions, and this is now working well. He has more investigations to make regarding the software that he might use; he reports that it is currently possible to log data for up to 12 hours.

Negotiations are currently underway with Dr Guy Pooley of Cambridge University concerning the installation of an Internet link; we are now more confident that we have identified the people concerned whose permission is required for this work to proceed.

Aerial arrays 4, 5 and 6,
and the receiver cabin, just in front of the BAA Hut

Peter King inside the receiver cabin



A simplified block diagram of the MRAO radio telescope

More detail of the MRAO receiver equipment

THE RAG WEBSITE

Laurence Newell
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We do apologise, but... the redevelopment of the RAG website has been taking *much* longer than anticipated. We would very much like a volunteer to become the RAG webmaster. Experience of HTML and graphic design is essential, with preferably MySQL and possibly PHP. There is an existing template which could be expanded.

If you have any projects details or photographs you would like to share, please send them to Laurence Newell. We will endeavour to include everything in good time.

The website currently has various download PDF documents which may be of interest (including the *Circulars*).

www.britastro.org/radio

Observatory News

Motorised Polar mount Drive Controller

Alan Morgan

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This is very much a 'work in progress' article and describes the design and construction of a control system for a motorised polar mount drive. Although the drive in this project consists of one motor which can move a dish over an hour angle of 18h through 0h to 6h, the ultimate plan for this system is that it could control two motors and these could be in a polar mount or in an azimuth/elevation system, or just one motor in the declination axis of a transit telescope.

The project began when I acquired a fairly elderly and rusty satellite TV horizon-to-horizon drive (see below) and a 1m diameter prime focus dish and realised that they would be ideal for a small radio telescope project. The drive consists of a 36V DC motor which is connected to a small gearbox and then to a worm drive which rotates a shaft over +/-90 degrees. The dish is attached to this shaft. There are microswitches inside the drive which cut the power to the motor when you attempt to drive past the limits. Thanks to a cunning arrangement of diodes you are allowed to reverse out.

Photo 1 Satellite TV drive

You can preset the angle of the polar axis based on your latitude and you can also adjust the declination over a limited range (in the satellite TV world this is to allow you to drop the dish declination a few degrees down from the celestial equator (approximately -6 degrees from the UK) to point at the geostationary satellites). I haven't worked out how to motorise the declination axis yet – I suspect it may not be possible at all with this particular mount. But, as I said at the start, I hope this project will at least be a starting point for a more general control system for hour angle/declination drives, and with some small changes to the software for an azimuth/elevation system. A final point to note about this drive is that there is an additional microswitch inside the gearbox which opens and closes as the motor rotates. This is used to provide an indication of dish position. The switch changes state approximately eight times per degree of dish movement, so it should be possible to point the dish to a fairly high level of accuracy.

Having acquired the mount, I decided that I wanted to design a system which would allow me to do the following:

Mode 1: Drive the dish manually with a speed control and an east/west direction switch.
Mode 2: Set the desired hour angle with a numeric keypad.
Mode 3: Provide a simple preset store and recall system.
Mode 4: Provide a computer interface (serial, USB or Ethernet) so that the dish can be positioned by an external computer.

At the moment I've only got as far as Mode 1! But that's mainly because I've not implemented the feedback system from the positional microswitch to allow the control system to work out where the dish is pointing. However, I have got it to count switch closures and display that as a 16 bit hex value. There is a small amount of backlash in the gearbox and I have a second (8 bit) counter which keeps track of that. Next step is to work out how to convert the 16 bit counter value into hours and minutes (or degrees).

The control system is built around an 18F452 PIC microcontroller. I won't provide a circuit diagram at the moment (as it's still changing) but here's what I've got working so far: there is a toggle switch which determines the east or west direction and this feeds into one of the input pins on the PIC, a 10k linear pot is used as a speed control which feeds 0 to +5 volts into the PIC's A-D converter, the PIC's pulse width modulation circuit takes this value and produces a pulse train (the duty cycle of which is proportional to the A-D value), and finally some external logic routes the pulses to an H configuration of power transistors, the route depending on the east/west direction switch. Photo 2 shows a picture of the prototype – the display is mostly static characters at the moment (and the declination display is not connected to any hardware at all). In Modes 2 to 4 the bottom two lines will show the next source which the drive will move to. Finally, there is an external EEPROM which is used to store calibration data (including backlash and soft limits) so that if the power is removed from the circuit it won't need to go through the calibration procedure every time it's repowered.

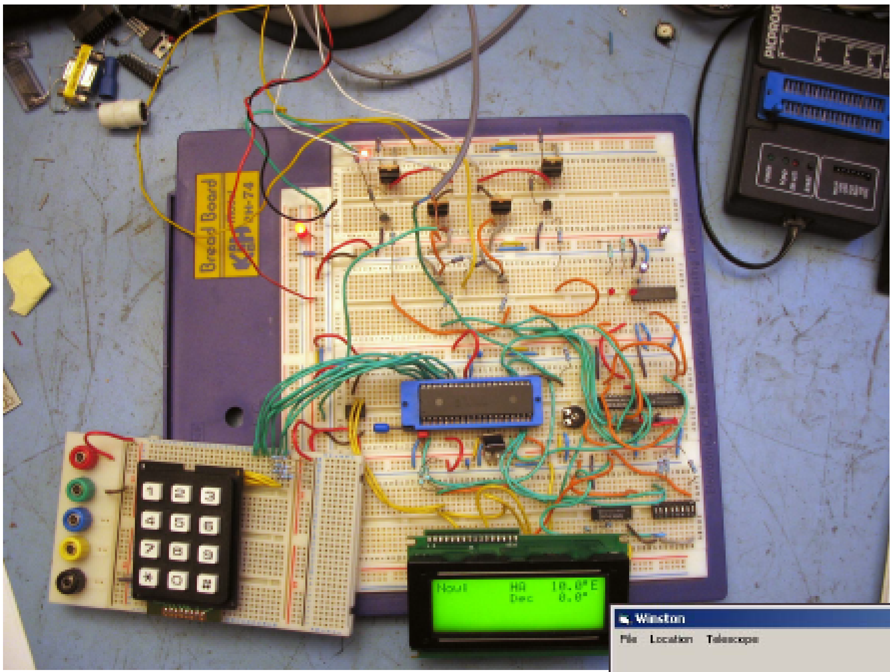

Photo 2 Controller Electronics

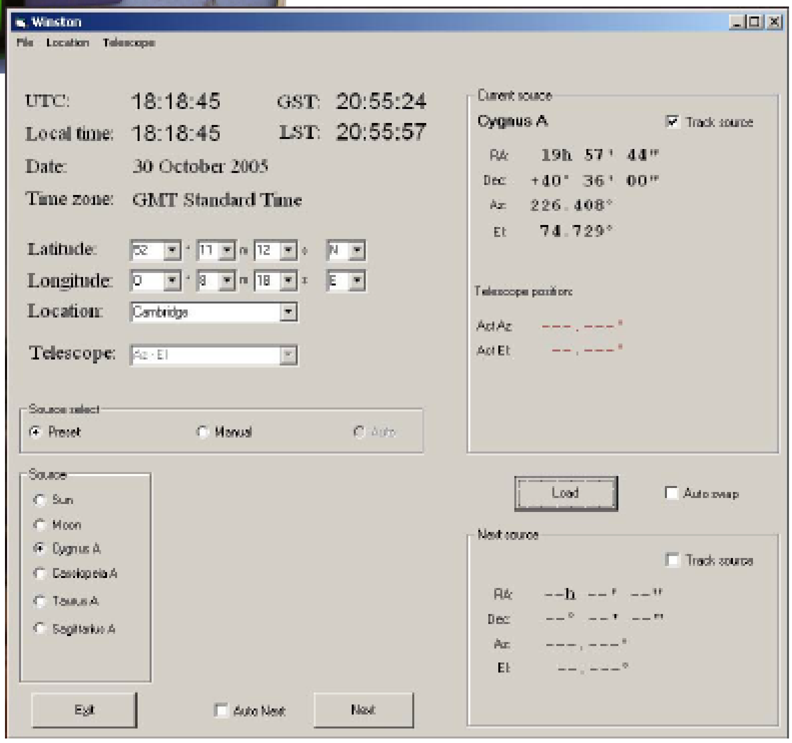

Photo 3 Controller Software

The next part of the project is to work out how to convert the switch count into an indication of hour angle. It's looking like some floating point calculations will need to be done and so I may have to use a bit of C to do this. Other features that are going into the software are: adjustable backlash so this system can be used with other drives, adjustable soft limits, and a power output stage which is physically separate from the PIC hardware, so that if the controller is used on a different drive with larger motors then a different output stage can easily be fitted.

At the moment I have no plans to make the controller do anything clever like sidereal tracking – I think of the controller as merely the interface between a computer and a motor. However, it's something that I may think about in the future. As for the software which will run in the computer… well, I do have something that I wrote a couple of years ago when I was trying to learn Visual Basic.

It's not ideal and it's far from finished but it may be useful for testing the controller once I've got it working properly. The program is called Winston and is shown in Photo 3. It reads local time, date, and time zone from the PC's clock, uses the observer's location to work out the local sidereal time, and then you select your source (choose from a list of presets or manually enter the RA & Dec) and it works out the azimuth and elevation of the source. As I said, it needs to be finished before it can be of any use – in particular I need to make it produce an hour angle output for this particular mount rather than Az/El.

Anyway, that's it for now. Any comments, suggestions, and criticisms will be gratefully received!

Some Radio Astronomy Experiments

Andy Thomas G0SFJ

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This article demonstrates some of my early experiments in radio astronomy. They use simple equipment that is well within he reach or the average radio amateur – some of can even be found as junk!

The Sun at 11GHz

It's very easy to detect the radio emission from the Sun at various frequencies from VHF upwards, although you have to check that the sudden burst of "noise" you've recorded actually did come from the Sun and not a passing taxi!

My first experiment followed an observation with Satellite TV dish (80cms) and a TV band (11 GHz) LNB (the thing you plug the cable into) connected to a "Scientific Atlanta" satellite TV receiver. This receiver, unusually, took the Automatic Gain control (AGC) out to a separate socket, so I put a multimeter across it and swung the dish across the Clarke belt of geostationary satellites. As the dish transited across these satellites the AGC voltage rose and fell, so I realized that it might detect the Sun in the same way.

By carefully aligning the dish with the Sun – do not look at the Sun in any circumstances! – and allowing for a 45 degree offset in the angle of elevation of the dish, the passage of the Sun could be verified by a fall in the voltage. If it didn't fall in about 10 minutes, then the dish was pointed at a TV satellite! But once the Sun was found, it could be followed across the sky quite easily.

This was 1999, and the solar eclipse was due, so I drove to relatives in Cornwall and set up the dish outside their house.

First of all, on the day before the eclipse I set up the dish to point to its maximum output at 10:35 am. At this time on the eclipse day, at the height of the transit the sun would be approximately half covered by the moon. This is position 1 on the graph in Figure 1 below.

On the day of the eclipse itself, I started monitoring at 09:57. At 10:35, (position 2 on the graph) I recorded a voltage approximately 50% of that recorded the previous day. Finally at position 3 (10:47 local time on eclipse day) I adjusted the dish to get the maximum voltage and indeed could not get it as high as it had been the previous day. I concluded that the 11 GHz TV receiver showed a 50% reduction in output when the Sun was covered by 50%.

Nancay

The following summer my family went for a holiday in France, and by a strange coincidence (as I had to explain!) we stopped for two nights at a campsite called Pierrefitte, which happened to be 12 km from the French radio-astronomy station in Nancay. So I hired a bike and after an hour or so pedalling through the pine forest I arrived at the Observatory, where there is a small public area demonstrating astronomy. It happened that the attendant was an astronomy student and he listened to my account of my first venture into radio astronomy with some interest. (I had come prepared with a copy of my observations). He picked up the 'phone and spoke to an astronomer in the main complex, Bertrand Flouret, who invited me to ride the 1km track way of dishes up to the operations building where he would meet me.

Inside the operations room – which was shielded by a Faraday cage – Flouret listened to my account with great interest. He said that at Nancay they had used their dishes in the 1km interferometer to monitor the eclipse. When I said that I wasn't sure if I had really picked up the radio emission from the Sun, and not its heat, he stabbed the chart at point 3 with a "*Non!*" explaining that the rapid rise was indicative of radio output. He then said that he had written a project for a local festival, in Haute Maurienne, on amateur radio astronomy, and he gave me a copy of his paper. This describes radio astronomy in simple but technical terms and proposes two main projects: using a TV dish to observe the Sun; and a simple solar interferometer (using TV band Yagi antennae).

Almost in passing Flouret proposed using a Satellite signal strength meter *SATFINDER* to record power level output from the Sun. This effectively made the dish and LNB into a total power radiometer, rather than the output I had previously recorded on the receiver AGC, which was based on 1 channel. He had modified the *SATFINDER* by connecting a digital voltmeter (DVM) across the analogue signal strength meter and recording the output.

Figure 1 AGC voltage on satellite TV receiver measured on chart recorder

Blackbody temperature of Sun at 11 GHz

This idea reminded me of a book by a Canadian lecturer, William Lonc (1996). Both he and Flouret (2000) proposed comparing Voltage from Sun (Vsun) with Voltage from the ground emission (Vcal) to get blackbody temperature of the Sun.

Back home, first I pointed the dish at the ground, recorded the output on the DVM and assumed that to be 300 degrees Kelvin. Then I took the maximum reading on a solar transit.

Equation 1 below works out at a blackbody temperature at 11 GHz of about 6,000 degrees Kelvin for the Sun.

Equation 1

$$TempSun = Y^{*}\ TempCal^{*}Vsun\ /\ Vcal\ \ ^{\circ}K$$

$$TempCal = 300\ ^{\circ}\ Kelvin$$

$$Y = (\text{diameter field of view of antenna/angular diameter of sun})^2$$

Which gives a TempSun of about 6000° K.

So I concluded that with simple equipment it was possible to measure a physical characteristic of the Sun.

The effect of X Ray Flares

My next investigation looked at the effect of the Sun on the Earth's atmosphere. Specifically, I was looking for an effect on the ionosphere, which refracts radio waves at HF (3 to 30 MHz) in daytime.

By monitoring the space weather environment on the NOAA website I noticed that a large sunspot was passing across the sun and large flares were being emitted. Realising this might give an opportunity to see the effect, I looked for a trans-equatorial signal. I set the chart recorder to observe the signal strength (audio power output from a short-wave radio) from the BBC relay in South Africa on 6190 kHz.

On 31 March 2001 region 9393 of the sun produced a large X ray flare between 1100 and 1131 UTC to magnitude M2.1 Figure 2 shows (reading from right to left) the sudden drop in signal as the flare reached the Earth and changed the ionisation level of the ionosphere. Another strong flare was recorded on April 2nd 2001 (Figure 3).

This experiment can run automatically whenever there is a period of sunspot activity.

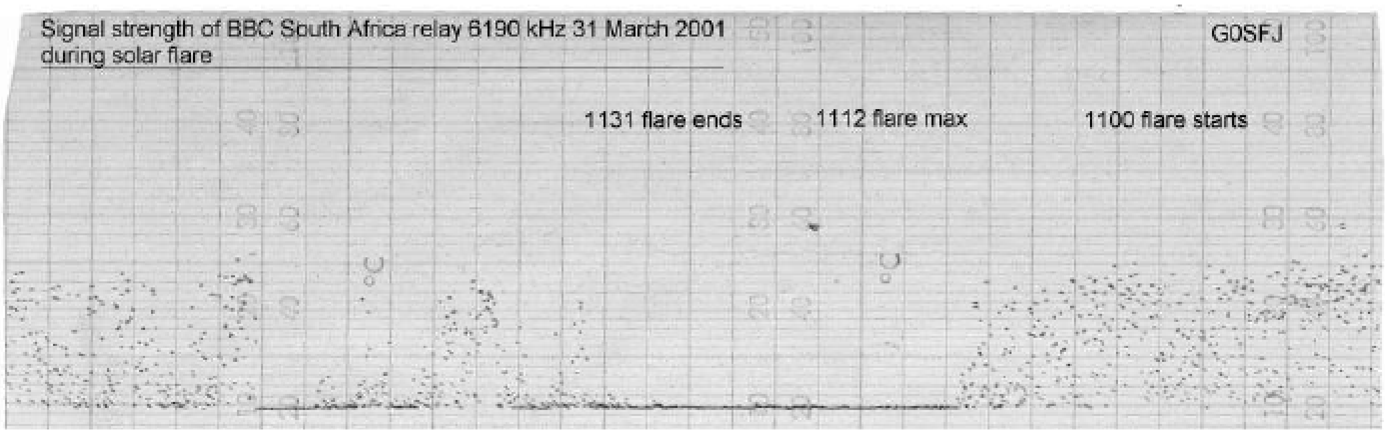

Figure 2 Signal drop and recovery due to large X-Ray flare on 31 March

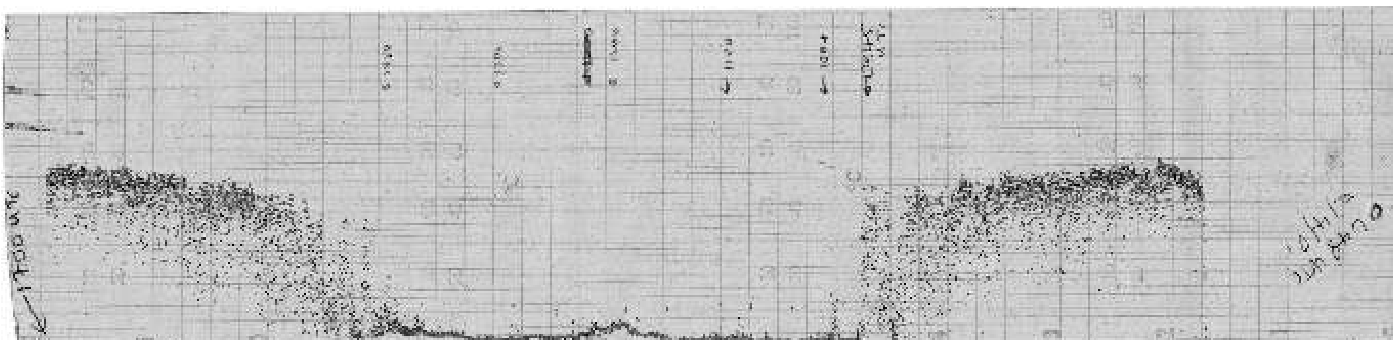

Figure 3 Flare on April 2nd 2001

Observing Meteors

I have tried observing meteors by using radio waves from distant places to reflect off the meteor as it ionised in the atmosphere. However I am concerned that automatic counts of "pings" might be artificially increased if the reflection takes longer that the time it takes the equipment to reset.

I found a program from the website of COAA Portugal that uses a computer soundcard. It takes the audio from a short wave receiver to monitor reflections of a distant carrier wave from spiralling gas cloud due to a meteor disintegrating in the atmosphere and its ion trail being blown by high altitude winds.

I used the short wave signal from BBC Carlisle, because at my location in the Midlands, I was beyond the ground wave but underneath the sky wave, so I could only receive the signal if it was reflected from above. Figure 4 shows a result. You can also monitor airliners; it is in effect passive radar!

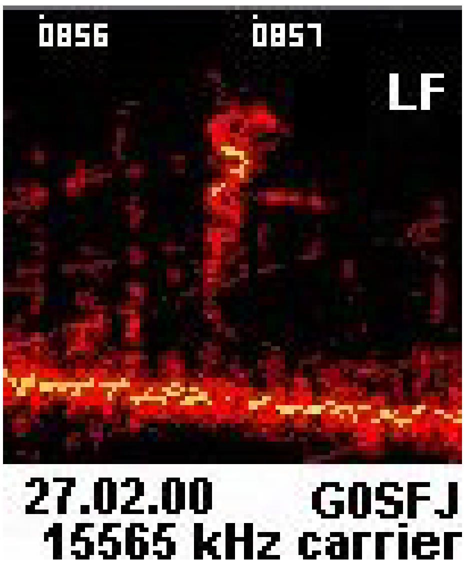

Figure 4 Reflection from spiralling gas cloud caused by disintegrating meteor

False positives

I get very excited when I get a result in radio astronomy but, as I mentioned earlier, you have to be sure that your radio telescope is really recording what you think it is. There are many false positives.

To give an example of what I mean I would like to turn to my other great passion, which is monitoring satellites. Figure 5 is a screen dump of the display from a computer program called SPECTRAN. The central area is in effect a graph, with the vertical axis being time (here 22 seconds) and the horizontal axis frequency (in this case audio frequencies in kilohertz), low frequency to the left.

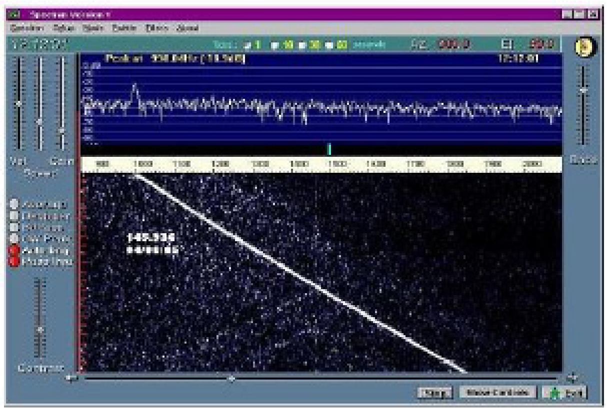

Figure 5 Genuine satellite HAMSAT: Doppler shift

Figure 5 shows as a gradient the Doppler shift of the satellite's beacon as it approached my receiver. The signal (audio tone) is dropping in frequency. This is a genuine observation of the Indian amateur satellite HAMSAT, which was launched from India with a mapping satellite called CARTOSAT. With two consecutive passes observed, you can calculate the period of the orbit, and from Kepler's laws the height of the satellite above the earth's surface. From this and the gradient or rate of Doppler shift, you can calculate the horizontal "slant" range of the satellite at the time you observed it, therefore its Sub-satellite point, useful for earth mapping images.

In the best Kettering Grammar School tradition I used the same equipment to look for a satellite of the Planetary Society called Cosmos-1. This satellite was launched from a Russian nuclear submarine, and initially ground monitoring stations reported strange signals at the times when they were expecting to receive signals from a successful orbit of Cosmos-1. I, too, received signals a few minutes earlier than I expected to receive them and although weaker they looked like those in Figure 5. But as I continued to observe, the trace then went UP in frequency not down! So I had to conclude that the observation was a false positive, it's not Doppler and so it's not a satellite. It's interference from my computer. That's why I prefer to use surplus chart recorders rather than computer logging. It's also why at Nancay a Farady cage, which stopped the computers interfering with the signals being received, covered the observation room. This is a real problem at the signal levels we use in radio astronomy, and in conclusion I would urge any users of Ethernet networks (as proposed by BAA RAG) to use Shielded Twisted Pair (STP) cable not Unshielded, and earthed metal cased routers, not plastic ones.

References

Lonc, William: Radio Astronomy projects (Radio-Sky publishing, 1996)

Flouret, Bertrand: La Radio-astronomie d'Amateurs - Festival de haute Mauriennce 2000 (Unpublished paper, Station de Radioastronomie, Nancay, France)

Observatory Report from Redenham

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The 3.7M telescope at Redenham started life as A TVRO system with a Cassegrain feed. It turned out that this feed system worked very well on the 10GHz amateur band (10,368 MHz) so that seemed like a good place to start.

The telescope with its original Cassegrain feed suitable for frequencies of 10GHz and above

In common with most Radio amateurs I have a desire to make my signals go as far as possible and at microwave frequencies the possibilities are somewhat limited unless you resort to satellite communication. And what better satellite than the Moon. Although it can only act as a passive reflector it is reliable, predictable, free and has given rise to the somewhat arcane method of communications known as Earth-Moon-Earth or EME.

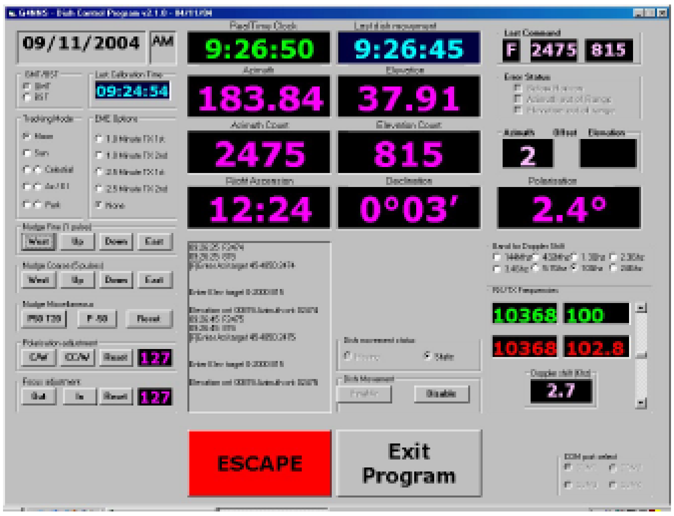
This and some other phenomena that anyone seriously using the radio spectrum cannot fail to notice leads inevitably to an interest in Radio Astronomy. EME acts as a good test bed for a radio telescope. The very weak signals reflected (scattered is perhaps a better description) by the moon are very weak by the time they return to earth which means that the radio telescope has to be very sensitive. My transmit power at 10GHz is only 9W. Another challenge is that, particularly at the higher microwave frequencies, the beam width of a 3.7m antenna is quite narrow (circa 0.5 degrees) and unlike an optical telescope with it's finder scope, the only way to know where it's pointing is to have an accurate system to measure azimuth and elevation and preferably to control these automatically.

All this means a fair amount of engineering work before we can get started on serious astronomical observations. The last couple of years have been devoted to this engineering and to making some radio contacts by EME on a number of bands. To date, some 23 different stations have been contacted on 10GHz, the furthest being on the west coast of the USA. One station has been heard on 24GHZ and I hope to do some more work on this very challenging frequency as the opportunity arises.

Last year's project was to construct an Azimuth and elevation mount to replace the original "Clarke Belt" mount.

Final assembly of the Azimuth and Elevation mount. Last year's major project

A circularly polarised feed system for 3.4GHz together with the transmit and receive system in the new focus box



A screen shot of the tracking software developed by Robin Lucas G8APZ

This year a focus box has been constructed to accommodate feeds for lower frequencies for which the Cassegrain sub reflector is too small. EME contacts have been made on 5.7GHz and on 3.4GHz using feeds and equipment located in the focus box.

The next steps towards proper radio astronomy are to make feed systems for the frequencies of interest, starting with the Hydrogen line at 1420MHz and 2.69GHz for solar observations. I also want to pursue some ideas to make proper radiometer systems for each of the frequencies of interest. At present, my only "observations" have been of thermal noise of the Sun and Moon referenced to cold sky. These relative measurements have been used to check system performance rather than make quantitative observations. It has been quite satisfying that the system sensitivity on all the bands so far tested is sufficient to detect thermal noise from the moon at circa 160K.

One of the problems with a project of this type is that it is rather too big for one person to make progress at anything but a snail's pace. I have been fortunate in receiving a great deal of help from Ian Lever G8CPJ (with mechanical engineering) and Robin Lucas G8APZ (on making my very crude tracking software into a reliable and versatile package). So progress to date has been a team effort. If there is anyone out there who would like to join in, their contribution would be very welcome.

Ian Lever G8CPJ (front) attends a trial assembly of the elevation mount at the fabricators

3peaks Amateur Radio Telescope

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The major problem to overcome when building a 12 foot radio telescope was to ensure that my neighbours continued to have an un-interrupted view of the quarry. My initial enquiries with neighbours showed much sympathy and enthusiasm with my project as the original 6 foot telescope had not caused any problems over the 7 years during which it had been in regular use and although the 12 foot telescope would be a little more conspicuous it would be designed and placed so that it would be as inconspicuous as possible.

This introduced some problems as the telescope could not be designed with the standard altitude/azimuth axis rotation although the azimuth axis was thought to pause no problem, the altitude axis would have to be re-designed.

Eventually the off-set altitude axis was agreed upon and there was much long and hard pondering on the advantages and disadvantages of this method. Most of the problems have been solved during construction, especially my misgivings regarding the efficiency of windscreen wiper motors being able to lift the radio telescope on a 5 foot arm but there were still misgivings regarding the movement of the plane of the antenna whilst observing in tracking mode.

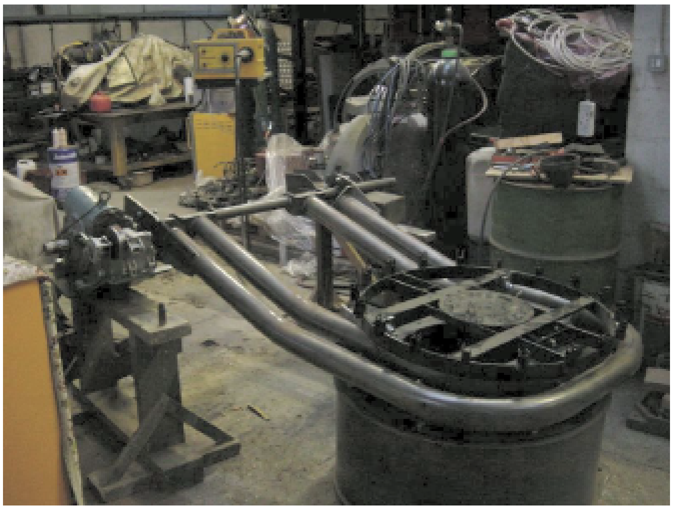


Figure 1

Fig.1 shows the elevation arm nearing completion in the workshop. The method of raising and lowering the radio telescope is more or less self explanatory especially if the view of the gearbox, Fig. 2, is considered.

The ribs of the radio telescope are mounted on the base ring which is attached to the inner elevating arm visible on Fig. 1 and in total, there are about 150 pounds sitting on the end of an arm of five feet length, a lot of work for the tiny motor to do.

Figure 2

The gearboxes, there are two of them visible in Fig. 2, are forty to one ratio, the grey box to which the motor is attached and fifty to one ratio, the green box, to which the elevation pivoting arm is attached. Both gearboxes are very heavy duty, the forty to one is a drum rotation box from a cement mixer and the former use of the fifty to one is unknown and was just 'kicking around' the workshop.

My skepticism, although ridiculed, increased with progress of construction and the fateful day arrived when testing of the elevation arm could be performed. Typically, no ammeter was available for the testing and again typically, the on off switch was constructed with bare wires and a thumb and forefinger. It was generally agreed that the current was fairly low due to the size and sound of the spark on connection and the ridiculing of my skepticism proved correct. Later, on site testing, whilst better prepared, showed that the current was approximately 1.3 amps on raising the radio telescope and 0.8 amps when lowering, this at 28 volts DC.

The azimuth motor and gearboxes are mounted in the cylindrical base shown in Figure 3. The gear chain consists of a forty to one ratio as in the elevation and a sixty to one ratio gearbox giving a total ratio of two thousand four hundred to one, the only reason for deciding which gearbox went where was convenience of fitting. The azimuth motor is a 12 Volt Ford Escort windscreen wiper motor which draws about 4 amps whilst moving at full slew rate.

Figure 3

The altitude gear ratio of two thousand to one will ensure a 10.8 minute of arc per revolution whilst the azimuth gear ratio of 2400 to one will give a 9 minute of arc per revolution accuracy of the altitude and azimuth motors respectively. Both motors have a full speed rotation rate of approximately one revolution per second, therefore to target any position in an adjacent quadrant will take approximately ten minutes with both motors running simultaneously.

Fifteen bit shaft encoders are fitted to the final drive of both the azimuth gearbox and the altitude gearbox which, theoretically, will give a pointing accuracy of approximately forty seconds of arc. This is a far greater accuracy than will be needed for the theoretical 3.5 degree beam width of the radio telescope while operating at 21 cm., the beam width decreases with increase in frequency. This arrangement also ensures that any backlash will be taken up before a shaft encoder reading changes and accuracy will be preserved.

Although difficult, the slew ring can just be seen in Fig.4. this arrangement allows the elevation arms to rotate about the axis of the cylinder. Similar devices are used on gun turret mounts. Two grooved rings are pressed together with the groove filled with ball bearings and grease ensuring a smooth rotation.

Figure 4

The whole base is fixed to about 4 tons of concrete by three 30 cm. resin bonded bolts, enabling easy levelling whilst ensuring stability.

Fig.5 shows the elevation gearboxes and the base in brand new steaming colours, black and slurry tank green. This method of construction ensures that most of the radio telescope is below ground level and only the parabolic reflector and horn are visible whilst operating within ten to fifteen degrees of 'bird bath' mode.

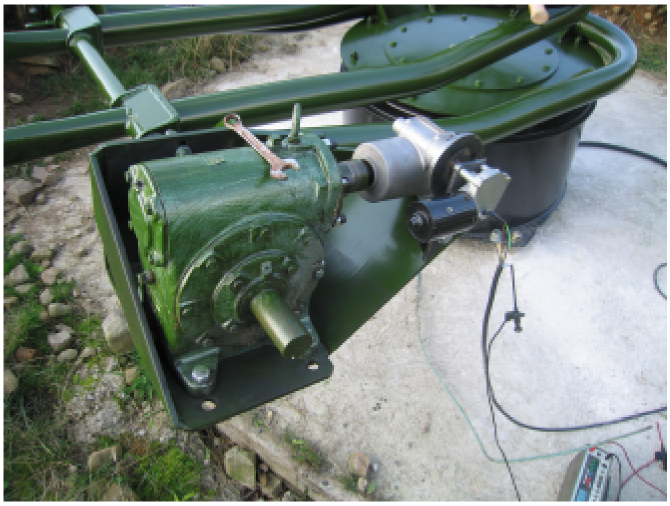


Figure 5

Fig. 6 (on the next page). A rare picture of the author, hard at work, with the telescope ribs in place. The construction of the telescope went smoothly. Help was solicited on many occasions to ensure that undue stress was not imposed on the structure thereby reducing sensitivity to the telescope.

Figure 6

Figure 7

Fitting the outer ring to the telescope ribs was one of the more difficult tasks and, with hindsight, I should have enlisted more help to mount the horn stays and the horn. This latter showed up a weak point in the construction, namely that the horn stays are too easily bent at the ends and accurate positioning of the horn was achieved only with great difficulty. A modification to the horn stays will greatly improve the ease and accuracy of positioning. See fig. 7.

Preliminary Results

Initial results are very promising and in drift mode, the Moon shows up well Fig. 8 below, taken on the 13th of November, 2005, at an elevation of 45.75 degrees. The small peak just before the Moon begins transit is probably a side lobe. This result shows great promise for future moon bounce experiments and the prospect of receiving the Seti League beacon from America on 1269 MHz via our Moon appear to be well within the telescope's capabilities. Figure 9.

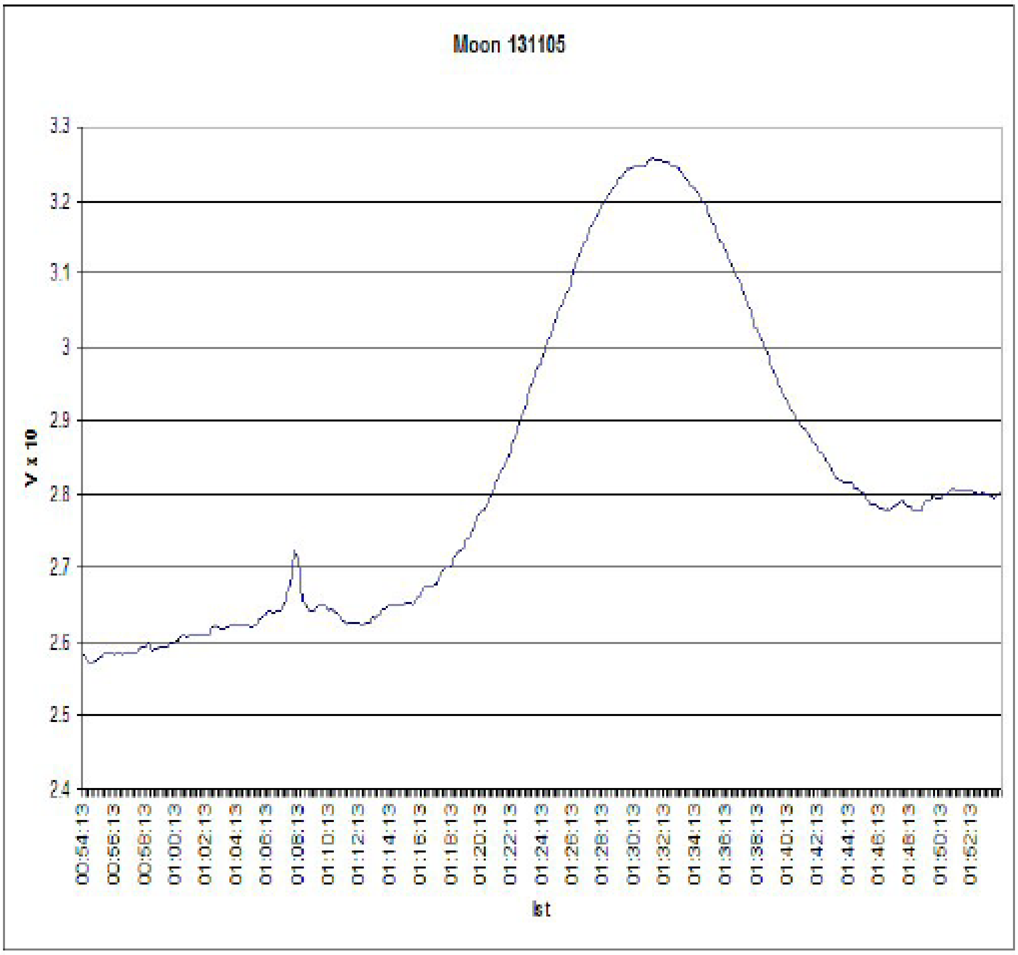
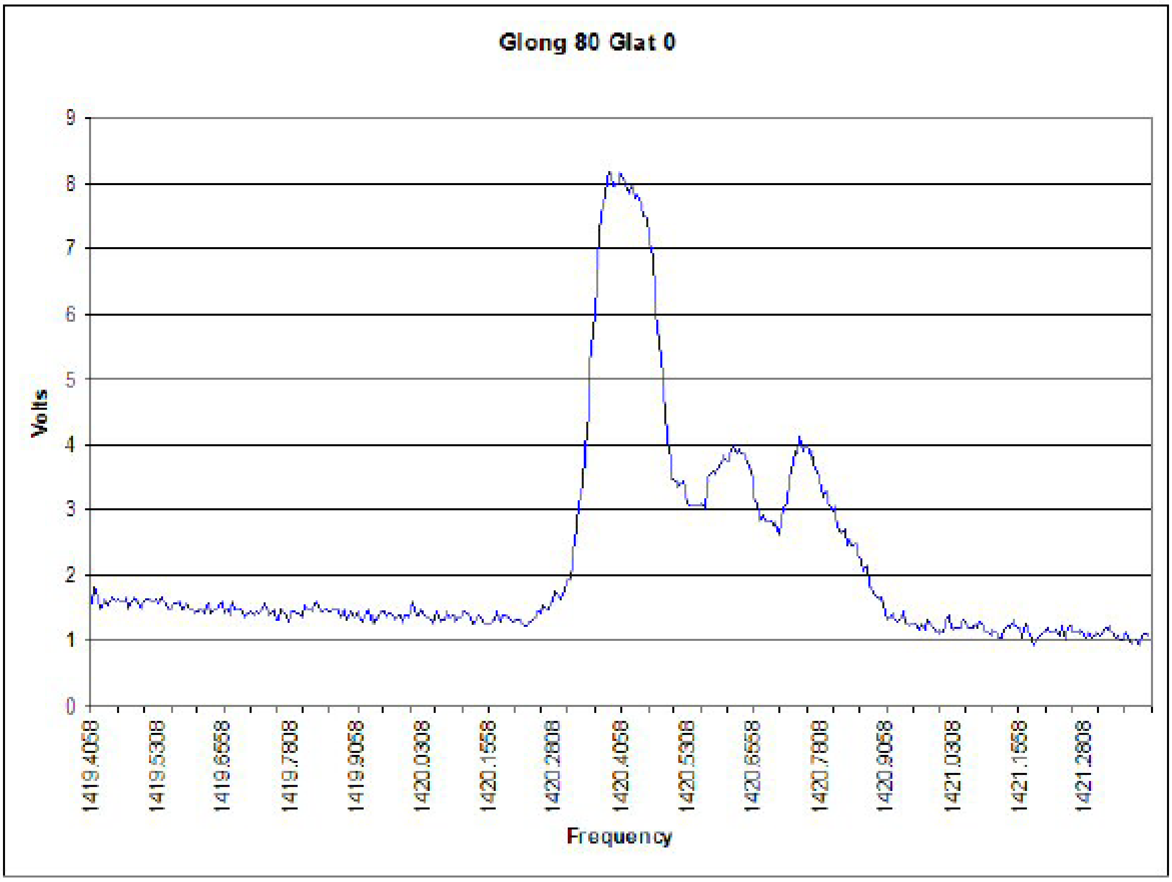


Figure 8



The most abundant element in our universe is hydrogen. Early radio astronomy predicted (Van de Hulst, 1944) the twenty-one centimetre neutral Hydrogen emission line and this was subsequently confirmed by observations by Ewen and Purcell in 1951.

Fig. 9 demonstrates the sensitivity of the radio telescope at the hydrogen line frequency of 1420.405751 MHz, the most accurately measured frequency known to mankind. This is even more surprising when it is realised that the total number of photons from Hydrogen falling on the whole of the Earth at any instant generate less than one watt.

The vertical axis is volts whilst the horizontal axis is four hundred, five kHz wide contiguous channels, spread across the hydrogen line frequency. Looking along the frequency axis there is a peak at the approximate rest frequency of hydrogen, this is caused by hydrogen in the home arm, also known as the Orion arm, the spiral arm of the Galaxy in which our Solar system resides. Moving further to the right, the peak at approximately 1420.6mHz we encounter the Perseus arm of the Galaxy and that the frequency is increased by approximately 0.2 MHz signifies that the Perseus arm of our Galaxy is moving towards us at a relative velocity of approximately 40 kilo-meters per second. Further to the right the Cygnus arm is found to be moving at a rate of approximately 70 kilo-meters per second towards us.

It is proposed that a hydrogen line survey, along Galactic longitudes of approximately thirty to two hundred and thirty degrees, encompassing the Galactic anti-centre and approximately ten degrees north and south of the Galactic equator, with a high theoretical definition, will be well within the capabilities of the radio telescope. The ensuing data will be mapped in such a way as to show the structure of our Galaxy. This would probably be a 'First' for amateur radio astronomy in Britain.

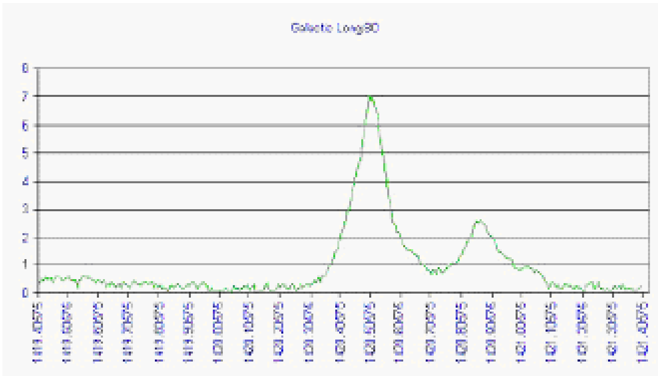


Figure 10

Hydrogen line scans Figs 9 and 10 show the difference that the narrower beam width of the new telescope makes. Fig 9 shows the completely resolved Perseus and Cygnus arms of the Galaxy whilst the unresolved state is evident in Fig.10 taken with a much wider beam width using the old telescope.

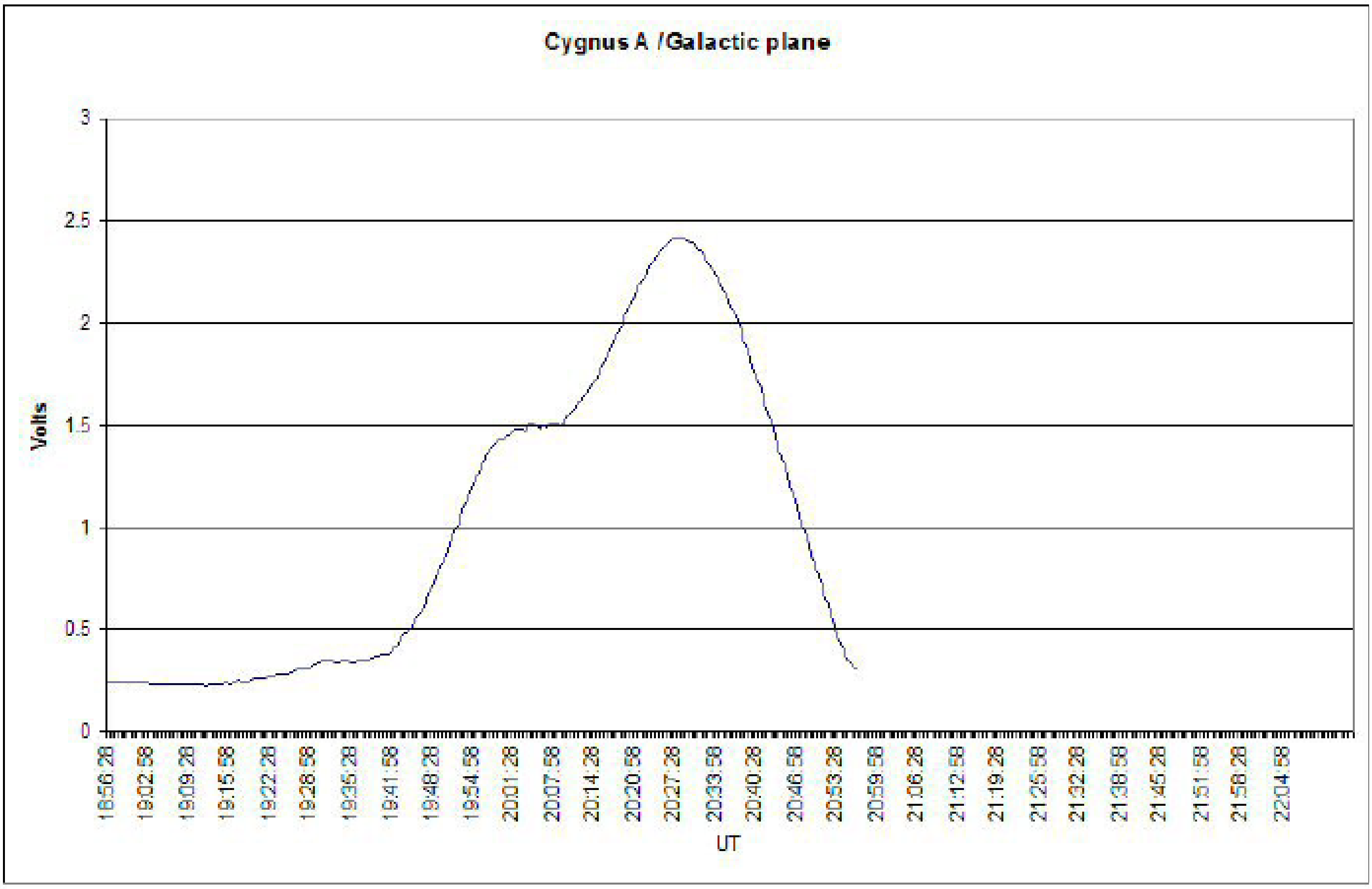


Figure 11

It has also been proposed that, using sufficient integration, the accuracy of pointing could be sufficient to ensure detection of hydrogen in the Andromeda galaxy (M31). Using data collected by the radio telescope detailed characteristics of the Andromeda galaxy will enable approximate calculation of rotational velocity, radial velocity and mass. Once again, another first for amateur radio astronomy.

When used as a radio telescope in drift scan mode, pointing at the correct declination along the meridian and using a wide band width, radiation from Galactic and extra Galactic sources can be observed.

Cygnus A Fig.11 at six hundred million light years distance shows up well, the first hump, followed by the Galactic plane at probably less than thirty thousand light years. This, again, was unresolved with the wider beam width of the old telescope.

It is hoped that the radio telescope, with suitable supervision, will be available to anyone who is interested in understanding how our Universe works. Certainly, there are not many communities where a scientific workshop is available on the doorstep, nor where astronomy is actively encouraged.

One last point, for the experts. Has anyone any thoughts on the efficiency of this offset altitude axis radio telescope, for instance, as the elevation rises or lowers the plane of the radio telescope reflects different points along the wavelength. I can imagine this causing concern with interferometers but what about spectrometers etc?

If anyone has any questions or requires any further information you may contact me at 3peaks@daelnet.co.uk

RAG Loan Items

Don't forget that the RAG has three industrial-quality PCs available for loan to BAA members! Each machine is fitted with a dual motherboard, with *twin* 500Mhz Pentium processor cards and SCSI RAID drivers. Each processor has one fixed and one hot-swappable 18Gb SCSI drive. The power supplies may be 24V DC or 240V AC.

Following further donations from BT, we now have various items of test equipment, including a 1GHz sampling oscilloscope, logic analysers, networking items and power supplies. If you have a particular development need, please let us know, we may be able to help.

VLF Observations in Bridlington

Rev John Wardle

jawardle@fish.co.uk

With the help of John Cook, I have recently started making VLF recordings in order to identify SIDs, particularly solar flares. I already had two receiver combinations which covered the VLF band but decided to build a dedicated receiver. The Gyrator design intrigued me as it uses an op-amp circuit to simulate an inductor. I followed the Gyrator II design which can be found at www.aavso.org The receiver works well, tuning about 15 - 25kHz, and I have calibrated it using a combination of live signals and my audio generator.

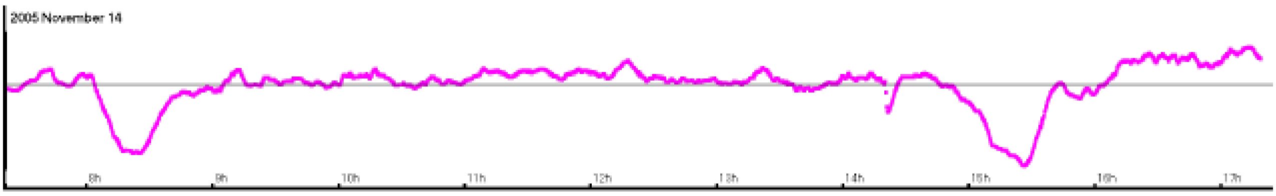
The antenna is an indoor loop with 600mm sides, having about 110 turns tuned by a large three-gang variable capacitor. It is quite selective and directional.

To collect the data I built my own version of John Cook's data logger, which avoids having to leave the computer on all day. The software John has written allows easy operation of the logger and the facility to print out the data as a graph.

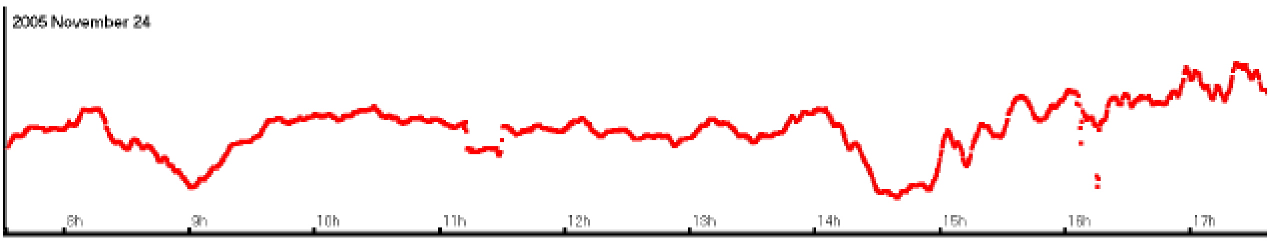
Since I started observations at the beginning of November the Sun has continued to be relatively quiet, but I have recorded a small number of ionospheric disturbances. John collects the data from a team of observers and publishes the results each month.

The beauty of radio astronomy is that the amount of cloud cover does not matter at all! However, I am still keen to get my small reflector outside on clear nights to see things for myself!

The photo of my radio shack below shows the loop antenna with the receiver and logger just in front of the loop. Happily the operation of my ham radio station on the HF bands does not interfere at all with the VLF recordings.



2005 November 14



2005 November 24

Radio Astronomy Experiments at 12GHz

Tony Razzell

tony@uraniborg.freeserve.co.uk

Normal amateur astronomy uses a tiny fraction of the available electromagnetic spectrum, between about 0.4 and 0.7 microns wavelength. The first of the 'New Astronomies' that appeared in the 20th century was radio astronomy, at wavelengths less than ~20 metres. The first amateur radio astronomer was Grote Reber, a ham radio enthusiast who built a 30ft dish in has back garden in Illinois, and produced the first ever maps of the sky at radio wavelengths. Since Reber's pioneering work, the development of electronics has been enormous in the intervening 60 odd years. Satellite television has resulted in the availability of very sensitive microwave receivers at very low cost, which are comparable with some that the professionals were using in the 60's and 70's. A number of amateur radio astronomers have built radio telescopes using surplus satellite TV equipment, so I thought I'd have a go at doing the same.

A simple amateur radio telescope (known as a total power instrument) consists of an antenna to collect radio waves from space, a low noise amplifier to increase the signal strength whilst adding minimal noise and frequency converter to drop the signal down to a lower frequency, an IF (intermediate frequency amplifier), and a detector to convert the signal to a DC voltage. An IF amplifier is used as it is easier to build high gain amplifiers at lower frequencies (this receiver arrangement is known as the superheterodyne or superhet). The low noise amplifier and frequency converter are usually built into the same unit for satellite TV, and sit at the focus of a small dish antenna. A schematic arrangement of the telescope is shown in Fig.1.

The first problem was the microwave receiver and dish antenna. I acquired my first receiver (known in the satellite TV trade as a Low Noise Block or LNB) for £5 at an amateur radio rally. This was followed by a rather bent Sky TV dish and LNB found by a friend of mine in a skip. I then came across a really good 0.9m dish with an offset feed, mounting and LNB which was dumped next to the lane along which I go to and from work. A Sky minidish (newer technology than the old Sky TV unit) also turned up dumped in the lane, so that was collected as well.

Having got a selection of LNBs, I needed something to plug them into. An LNB converts the microwave signal from the satellite frequency ~12Ghz (or 2.5cm wavelength) into a lower frequency (0.9-2.1GHz) that is used by the satellite tuner that sits on top of the TV. What I needed was an equivalent unit to the tuner to act as the IF amplifier, but which converted the signal into a voltage that I could record or read with a meter. The book on Amateur Radio Astronomy by William Lonc is a very good source of information, as well as several sites on the Internet. Eventually, I decided to make my own IF amplifier, based on application notes for MAR-6 MMA devices and the book by Lonc. The circuit diagram is shown in Fig. 2.

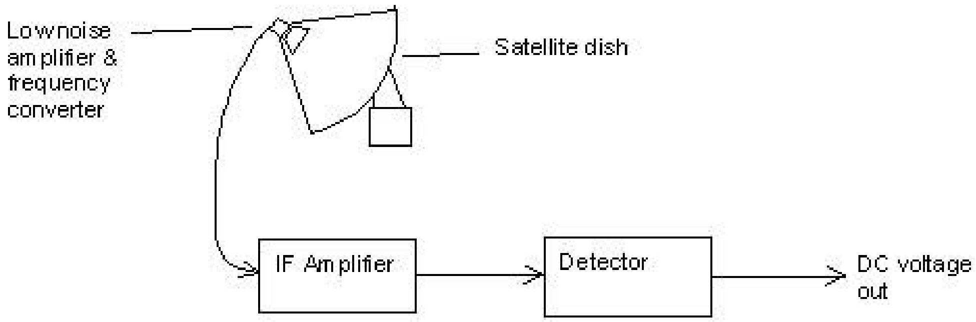


Fig.1 Simple total power instrument

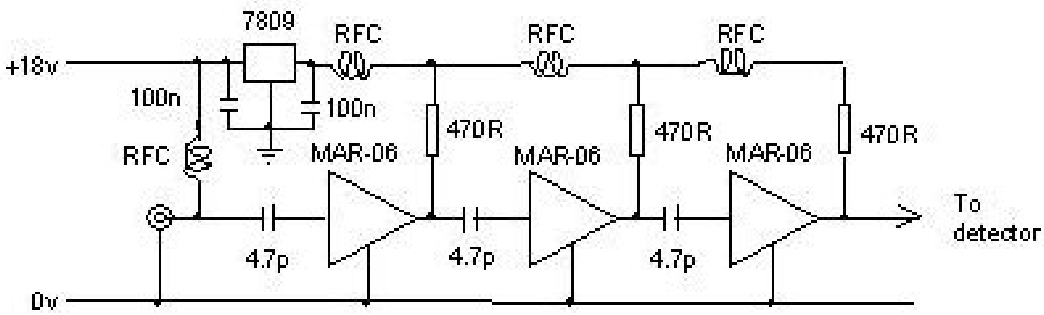


Fig.2 IF amplifier circuit diagram

The IF strip uses monolithic microwave amplifiers (MMA's) which provide wide bandwidth amplification at 1-2GHz with minimal effort (not having a wide range signal generator, the actual bandwidth is unknown but is assumed to be at least 500MHz). An inductor is used as a radio frequency choke to supply power to the LNB without losing the signal coming back (the same cable is used for power supply and signal). The signal from the LNB is then fed into the first of three MMAs which are linked together to produce a gain of ~60dB. Appropriate decoupling and short leads must be used at these frequencies, and I made a circuit board with a copper ground plane on the back for stability. The third MMA is followed by an envelope detector. I used a circuit from a web site by Michael Fletcher (www.qsl.net/oh2aue/fig20.gif), which uses a Schottky diode, plus identical reference diodes to compensate for temperature variation (a simpler single diode circuit could equally be used). Variation of gain and therefore output with temperature is one of the main practical issues faced by the would-be radio astronomer (see later). A potentiometer is used to adjust the DC offset so that the cold sky can be set somewhere near zero. An alternative (used by many beginning amateur radio astronomers) is to use a dish alignment meter or a signal strength output from the satellite TV tuner if it has one.

When the IF strip was complete, I connected an LNB, a power supply and a meter on the output. The sun was very easily detectable on the old Sky TV dish/LNB, as well as strong signals from the various satellites that live in an arc about 38° above the horizon in the south. My main dish is the offset fed 0.9m as this captures the greatest incoming signal and has the narrowest beam width. The Sky minidish produced a huge signal, even compared to the 0.9m dish, which appeared to have a high quality German LNB on it.

To record signals properly, I used an ancient, but serviceable Acorn Archimedes 310 computer with an analogue input board (essentially mimicking the BBC Micro model B I/O facilities). A separate DC amplifier was used to increase the output voltage from the IF strip unit from a few tens of millivolts to a few volts. A data logger programme was used to record data on the Archimedes, which was easily transferable to a PC as a comma separated variable text file on a floppy disc.

To record an object in the sky, I used a transit method where the dish was pointed at a fixed altitude and azimuth slightly to the west of the object to be observed, and the output from the radio telescope recorded as the object drifts through the beam. In this way, the earths rotation scans the sky and the signal from the object shows as a peak in the recorded signal strength. The 0.9m dish has a beam width at the 3dB points (50% power) of ~2° at 12GHz. At an altitude ~38° the rate of drift is ~1° every four minutes, so a scan of ~30 minutes is enough a capture the sun as it drifts through the beam of the dish. A transit curve from the sun is shown in Fig. 3 (it was found that the peak amplitude varied somewhat from trace to trace, probably due to pointing inaccuracies).

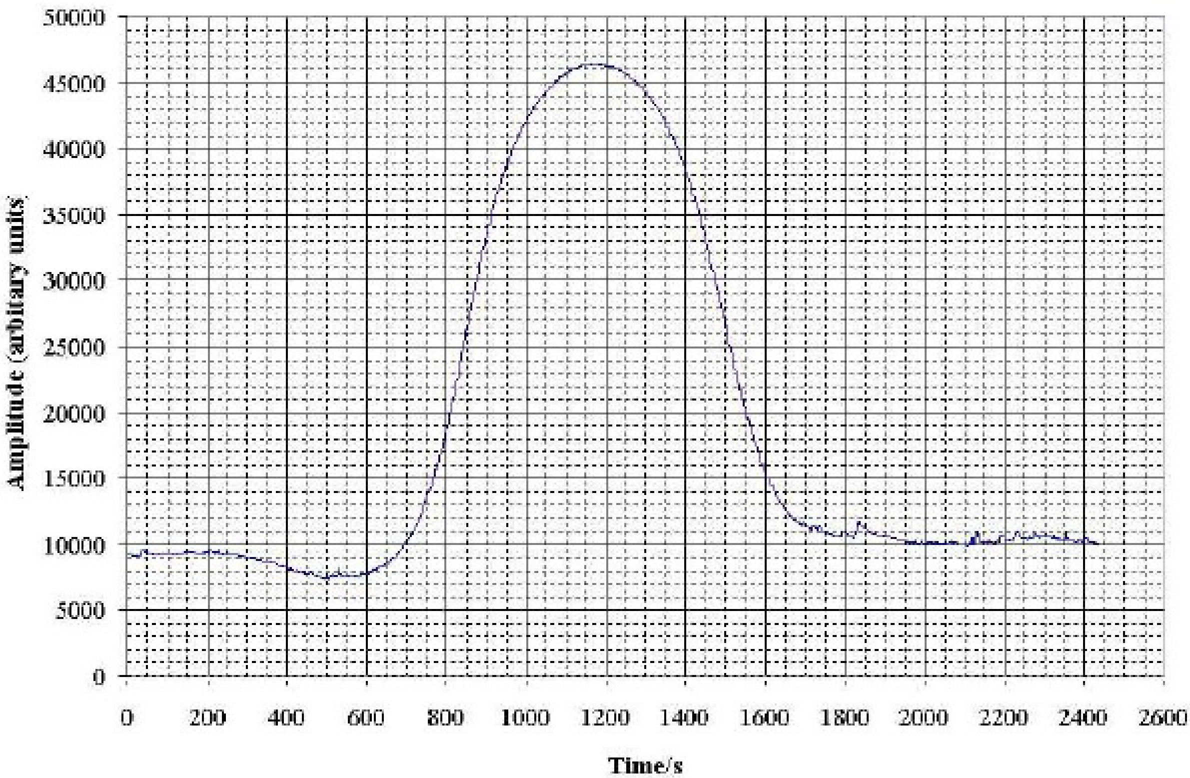


Fig. 3 Transit observation of the Sun

A problem immediately noticed was drift of the output voltage. This is caused primarily by changes in temperature, which varies the gain of the instrument. This is illustrated in Fig. 4, where the telescope was left running for several hours, with an accompanying increase in output voltage, exceeding the peak from the sun drifting through the beam. As can be seen on the x (time) axis, this drift was during the late afternoon/early evening accompanied by a drop in temperature.

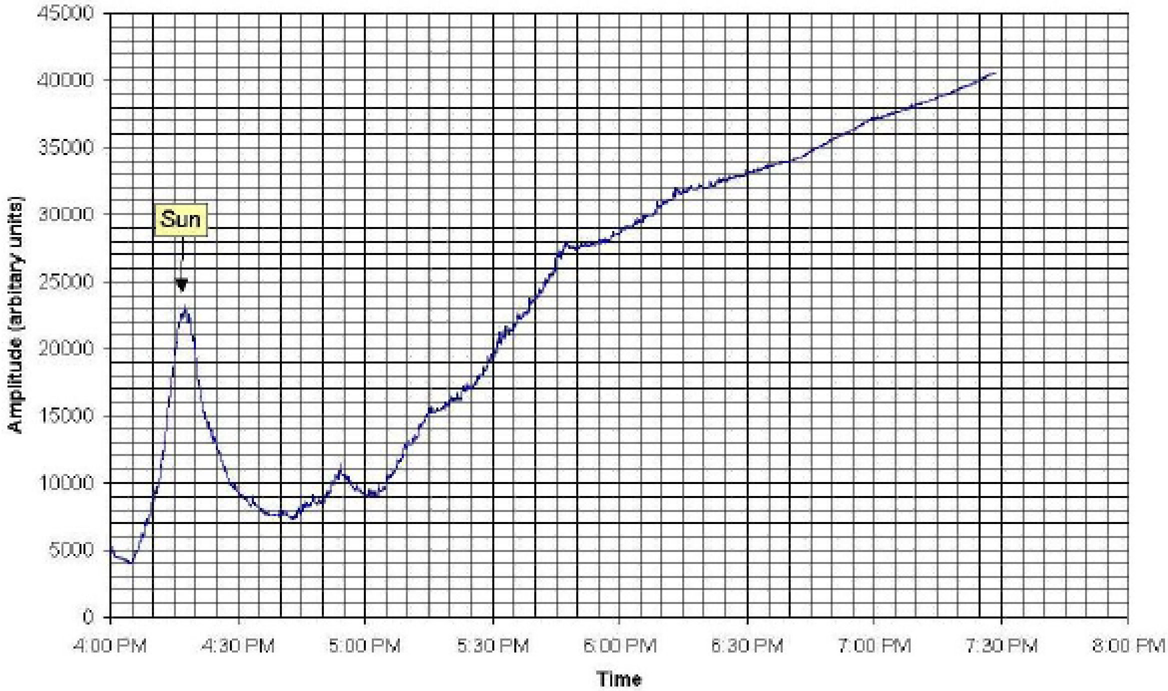


Fig. 4 Drift due to change in receiver gain caused by temperature drop

A more difficult object to detect is the Moon. This was achieved, but the resultant signal is similar in magnitude to the thermal drift of the instrument, and fairly noisy (Fig. 5). The spikes at the beginning and end of the trace are the ~310K blackbody radiation coming from a hand placed over the mouth of the LNB in an attempt at providing a crude calibration.

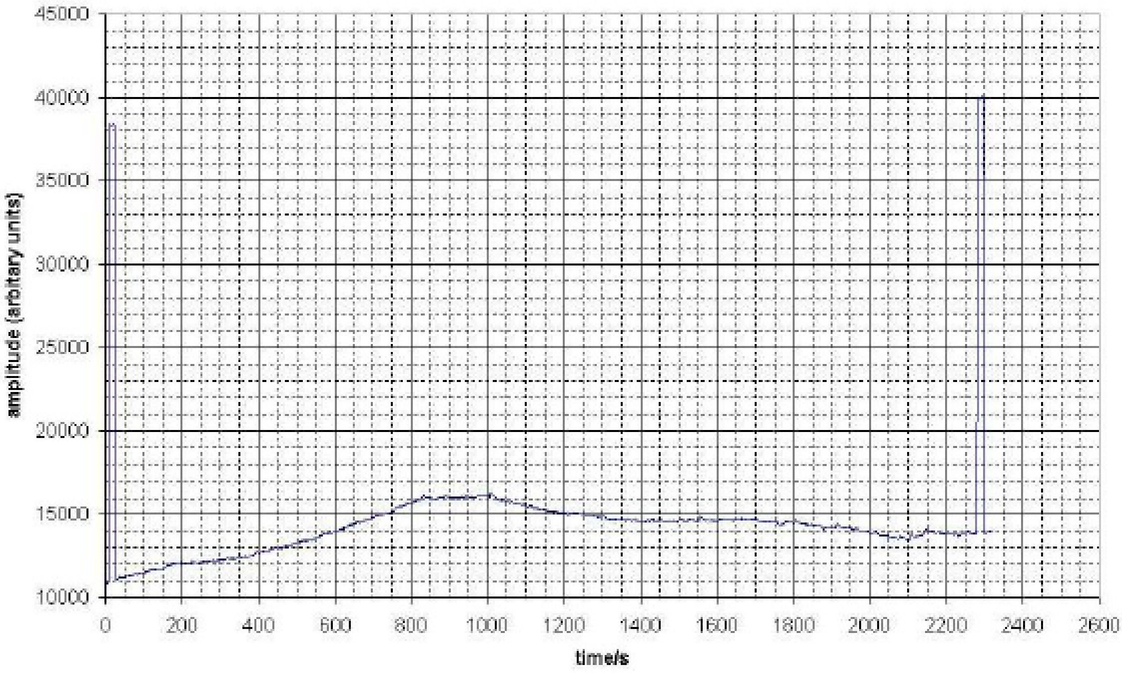


Fig. 5 Raw Moon transit observation

An attempt was made to correct for thermal drift by fitting a notional straight line between the background start and end points and subtracting this from the data. The corrected plot is shown in fig. 6. The reason for flat top during the transit is unknown, 'shoulder' is assumed to be short term drift.

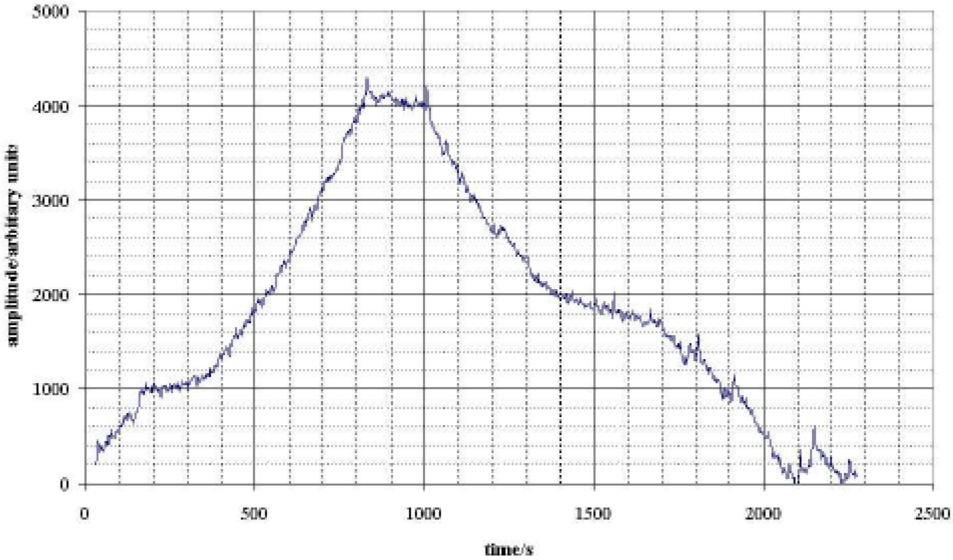


Fig. 6 'Corrected' transit of the Moon

A combined plot of the moon and the sun is shown in fig. 7 to (roughly) the same amplitude scale, offset to give approximately the same background sky level.

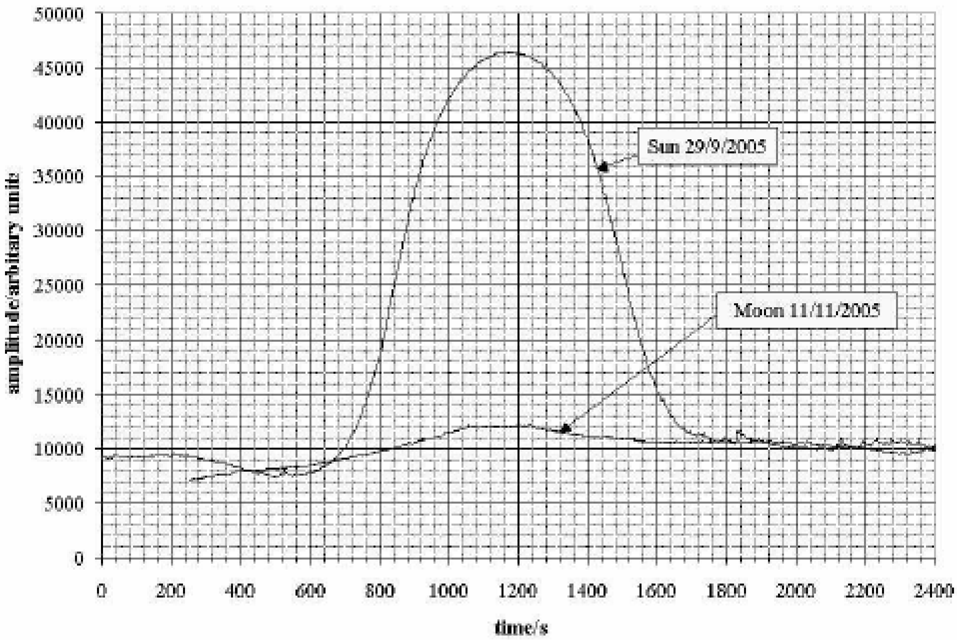


Fig. 7 Combined Sun and Moon transits to approximately the same scale

Future improvements to the instrument will concentrate on improving gain stability. One way of doing this is to periodically switch the input from the antenna to a stable reference signal. In this way, any drift in gain can be subtracted from the wanted signal, eliminating the baseline drift effect seen in fig.4. At 10GHz, this is not a trivial task, and I may resort to a mechanical approach such as periodically putting a lossy absorbant material in front of the LNB horn. This arrangement is known as a Dicke switch, and was an early development in radio astronomy. A more elegant solution would be to electrically switch the LNB input from the horn to a reference (or dummy load) using diodes or transistors. This would be preferable as the reference could be kept at a stable temperature. I have modified an old Sky TV LNB connecting one of the two inputs to a 50Ω resistor to act as a dummy load (the units have two inputs to allow for polarised signals from the satellite), and experiments with this are ongoing. Another approach would be to put the electronics in a temperature stabilised box, which I am also considering.

I have enjoyed building the 12GHz telescope, and found it fascinating to see blackbody radiation from the Sun, Moon and even my own body. The satellite equipment at 12GHz is very cheap (free for most of mine) and easy to set up to detect the Sun and I intend to publish updates in future issues of Baseline.

Northampton Meeting Report

Karen Holland
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On 2005 October 8th, the Radio Astronomy Group held the first meeting of the renewed group at the Humfrey Rooms in Northampton, courtesy of the Northamptonshire Natural History Society.

55 people attended the meeting, many of whom were unfamiliar faces to regular BAA meeting attendees, and so it seemed to me, that many visitors were new to the BAA.

There was a good programme of talks booked for the day, and after very brief introductions from Martin Taylor (the president of the NNHS), Bob Marriot (Secretary of the Astronomy Section of the NNHS), and Laurence Newell (leader of the Radio Astronomy Group), the key speaker for the day began his talk: Dr Tim O'Brien, a professional scientist from Jodrell Bank, spoke about Jodrell Bank's 6.4m Robotic Radio Telescope. He particularly enjoys working with teachers, and in the pursuit of the public understanding of science, and described in some detail (amongst other topics) a Rotarian and Royal Institution-funded project that he had initiated, in which a number of schools were permitted to use the Jodrell bank telescope remotely, in order to map out their allocated portion of the sky. Over 1240 students took part in this project, mapping out their school's own 20 degree wide strip of the sky from longitudes 20-220 degrees. After all schools had completed their part, then the results were combined to produce a complete map. A conference was held at the Royal Institution, at which school representatives were invited to share their results, and discuss their experiences with the other schools.

At rest between presentations

Following Tim was Murray Niman, who spoke about Challenges to the Radio Astronomy Spectrum. Murray outlined how years ago, the old radio communications agency used to be run by many good engineers, who were laid-off when Ofcom was created a few years ago. Ofcom employees tended to consist mainly of lawyers and broadcasters, and their aim, on the whole, seemed to be to try not to spend treasury money, so there were now very few people involved in spectrum protection. The result of this was that specialist scientists needed to be more aware of what was going on, and to do more themselves to try to protect the remaining spectrum where possible. The overall forecast demand for radio spectrum was actually far, far more over the next few years than the available spectrum, so the remaining bits that weren't currently occupied would be closely scrutinised. Since last November there had been nearly a consultation per week, and the UK Microwave group, of which Murray was an active member, had been very busy submitting papers, to fill in the gap that was appearing; Jodrell Bank and PPARC had also been getting up to speed responding to the consultations. Murray encouraged the newly reformed Radio Astronomy group to formulate responses to consultations wherever possible, as they already had done on one occasion.

Part of the poster display

Richard Lines then talked about his personal work attempting to monitor the Schumaker-Levy Jupiter impact at 21MHz, and making solar observations at 600MHz. Richard was very clearly an experienced and knowledgeable constructor of radio receivers, who loved rummaging in skips to find useful components from which to build his systems. He explained that the source of the Jupiter radiation was the generation of decametric radiation which occurs between 5 and 40MHz; there is a window of opportunity when the ionosphere doesn't get in the way to detect this, and it can be reasonably strong. Using largely scrap bits and pieces, Richard built a half wave dipole and a receiver, which he designed to be able to take out into the countryside out of the way of interference. His experience attempting to monitor Jupiter during the impact was a good-learning process, even though his observations were negative. Spurred-on, he built a 600MHz radio telescope, diving into skips on his way home from work (his mark 1 used a scrap TV aerial!). He described in some detail, the receiver electronics that he had developed for this telescope and showed the resulting real signal obtained from monitoring the sun. Richard is clearly a real enthusiast, who we will hopefully hear a great deal more from in the future.

After lunch the raffle was drawn, for which a good number of prizes had been donated, including a number of excellent books from Cambridge University Press, and a 1.4Ghz low-noise amplifier from Jeff Lichtman of Radio Supplies.

Then Laurence Newell, the leader of the Radio Group, outlined the activities and the work of the group, spending some time outlining the plans behind the proposed Plug and Play Observatory system that was being developed to enable observers without electronics experience to have a go at doing some radio astronomy using a simple-to-use system. The aim is to have a controller that will plug into a PC, which will interface directly to a number of receivers. At the moment, receiver designs for operation at VLF, 1420MHz and 2.7GHz are being produced. The user will be able to choose a receiver, and the system should prove simple to use, and make the logging of data, and its submission to the group's database, simple to achieve.

Another view of the delegates

John Cook, one of the officers of the group, who is responsible for the development of the VLF receiver, outlined the design and use of his simple VLF receiver for Solar flare monitoring. He had been using such a receiver for some time now, to monitor solar flares, by detecting a radio signal transmitted from a transmitter a long way around the earth, after the signal had bounced off the ionosphere. It was only possible to do this kind of observation during the daytime, when the ionosphere was particularly reflective to radio signals, and solar flare are then evident as a characteristic change in the signal.

Peter King talked about the 151 MHz steerable array at the Mullard Radio Astronomy Observatory, which is being re-commissioned for the BAA to use. Peter is conducting much of the re-commissioning work himself, and is overseeing other parts of the work which other observatory staff are doing for us. He outlined the current state of the telescope: unfortunately, when the Ryle telescope was constructed, the stanchions of the 151MHz were lowered to the ground, and the cables inside had snapped, and so these would have to be re-cut to a precise length; the Yagis had been found new in a hangar nearby, and were installed, and 6 out of the 7 declination motors had been replaced. Peter described the outstanding work, and the way in which he hoped that it might be used once it was available to BAA members. He hoped to work together with the Variable Star Section to monitor flare stars, to see if a correlation between the optical and radio activity could be found.

After tea, James Wilhelm talked about the John Smith 408MHz All Sky Survey, which was dedicated to the memory of John Smith, who had led the decision to start the survey. Ken Tapping, who was a professional involved in the project, later moved to Canada, and John continued the work. The first receiver which operated at 136 MHz,is now located near Cranleigh; the telescope was moved twice over the years. The aim of the survey was to attempt to map radiation from our galaxy, and some bright sources. This was a transit telescope, for which the declination was changed every week or so; this meant that they obtained several scans at the same declination. The data was gathered and then distributed to processors via a website. James said that a paper would be published on the survey website in the future. He showed a short video of Gordon Brown interviewing John Smith, who talked about the benefit of solar observing and gave a brief demonstration of the radio telescope collecting data, showing an increase in the noise as it scanned across the sun.

Bob Marriott then gave an entertaining talk about the History of Radio Astronomy in the BAA. He started by talking about the first ever paper that appeared in the BAA Journal, which was written Clegg, Hughes and Lovell; it actually gave the results from people who had collected their own data on radio echo work of a meteor stream. Two years later, Arthur C Clarke wrote a paper on *The Radio telescope*. Clarke was involved in the development of radar in the 1940s and in 1945, and he had submitted a paper about stationary rockets in earth orbit (geostationary telecommunications satellite design) which had been published in Wireless World. His published BAA journal article was in April 1949, and included a straightforward explanation of what radio astronomy was about. The BAA Radio and Electronics Section was founded in 1957, which was the year that Jodrell bank was inaugurated, the launch of the Sky at Night television programme, and the launch of Sputnik; it later became the Radio Astronomy section in 1964. Bob continued to give a brief history of the Radio Astronomy Section, in his characteristically entertaining way, and concluded with a surprise communication that he had received from Arthur C Clarke by email as follows:

Bob,

Thanks for your letter. Nice to hear from you! Glad you are reviving one of my late Jurassic papers! Who was it who said that radio astronomy was nonsense because radio waves won't go through the Heaviside layer? I wish you all the very best with your efforts. Here's an update on my affairs.

Arthur

In the discussion time at the end of the meeting, Andy Thomas gave a brief presentation describing some of the work that he had been doing. Andy is a radio ham who lives in Market Harborough. He described how he had used a surplus satellite TV receiver that had an AGC line, to detect radio emission from the sun. He monitored a solar eclipse at 11 GHz using a Yagi, and a chart recorder, and was able to detect the unobscured and then later, obscured sun. Professional astronomers at Nancay in France had been interested in these observations.

A number of the attendees had brought along posters to the meeting, which were displayed on boards around the room, and stimulated discussion. Of particular note, was Alan Penzer's poster….

Of the 55 attendees, 28 returned a questionnaire that was given out at the meeting. The responses were unanimously favourable regarding the opinion of the work and aims of the group. Attendees had travelled up to 200 miles to the event, and were keen to attend another one day meeting next year. All were very keen to receive a circular, and were willing to pay for the circular in paper format, although most indicated that they'd be happy to receive it for free in PDF format, with a wide range of topics suggested for the content.

Of the attendees, 19 were completely new to radio astronomy, saying that they had no experience of radio astronomy, and had come along to learn more, although respondents indicated that they had a wide range of technical expertise, in general, ranging from TCP/IP to PCB and database design.

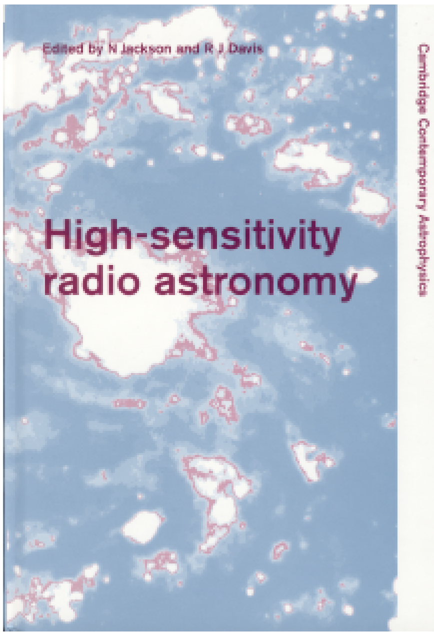
Terry Ashton and Tom Boles discuss the relative merits of beer and whisky

Richard Lines Tim O'Brien James Wilhelm Laurence Newell Peter King John Cook Bob Marriott Murray Niman

Book Reviews

High-Sensitivity Radio Astronomy

Martin Rolls
biggmartin@hotmail.com



Edited by N Jackson and R J Davis
Published by Cambridge University Press
ISBN 0 521 57350 5

Back in October I learnt that there was to be a meeting of a Radio Astronomy Group in Northampton not knowing very much about Radio Astronomy but having an interest in low frequency radio I thought I would go along. To be truthful what really interested me was that a simple VLF receiver would be discussed.

I am one of those people who never win anything when I buy a raffle ticket so when the raffle was drawn I was very surprised when my ticket number was drawn out of the bucket it took me several seconds to realize it was my raffle ticket number; I was even more surprised when I received a book called High-Sensitivity Radio Astronomy as I said earlier my knowledge of Radio Astronomy is somewhat limited, limited in fact to having a good look at the dishes at Jodrell Bank as I passed on my way home after a visit to Manchester. The book contains the proceedings of a conference held in January 1996 at Jodrell Bank to review the developments in high-sensitivity radio astronomy.

The foreword to the book is by Sir Bernard Lovell and makes interesting reading especially the last paragraph in which he says fifty years ago talk of radio galaxies, quasars, pulsars, the cosmic background, spectral lines and even magnetic fields would nearly all have lain in the realms of science fiction, I wonder what will be discovered in the next fifty years.

But back from the future to the present and the book.

As a complete novice discussions about High-sensitivity observations of circumstellar masers and Variable sources and jets in Cepheus A are a bit intimidating so before I became to over whelmed I turned to the chapters towards the back of the book New-generation telescopes and I began to understand the problems that radio astronomers have when telescopes have to be renovated and upgraded. In this part of the book the speakers at the conference described what was being planned for the future and what was in progress in 1996 to upgrade their telescopes.

Two presentations that have attracted my interest so far are the Lovell Telescope upgrade and The Giant Metrewave Radio telescope. The chapter; The Lovell Telescope upgrade revels the problems that were faced to increase the frequency range of the telescope and the solutions that were put forward to rebuild the mechanical structure.

In the talk, The Giant Metrewave Radiotelescope a description of an unusual method to my mind at least was given on the construction of the 45m dish using Stretched Mesh and Rope Trusses. If the reader would like to know how it was carried out you will have to get a copy of the book.

Until I read this book I never appreciated the problems faced by the researchers and engineers. This is a fascinating book the first part as a new comer I found hard going but the later chapters I found interesting as I could identify with the problems that the speakers faced.

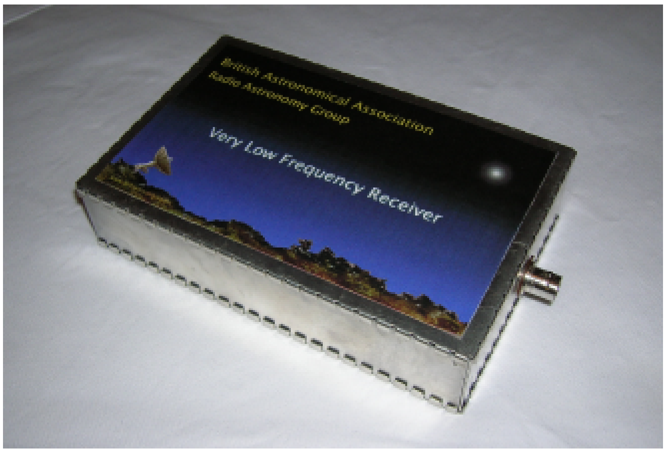
The conference took place in 1996; did the Lovell Telescope upgrade go ahead and was it successful is R.J. Davis who presented the talk happy with the results and was the construction of The Giant Metrewave Radio telescope successful and is G. Swarup and his team satisfied with the results or are they planning more upgrades and modifications? Will the readers ever know?

The more experienced reader will find this book useful to be able look back and compare what the presenters hoped for and what has been achieved.

Many thanks to Martin for his review. All readers are invited to send in their comments concerning other books and publications that may be of interest to our members.

RAG Mart

VLF Module



The BAA RAG *VLF Receiver*, our first real product, should soon be available for sale as a ready assembled and tested module. The receiver is intended to plug in to a *Starbase* controller (as yet unavailable), and requires +/- 15V DC power supplies. The receiver output is a voltage in the range 0 to 5V DC. Please contact John Cook for technical details, and Karen Holland for supplies.

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Perancea also has available a useful guide to shielding and a handy comparison of material screening properties, both available on request.

Peter Hendrick
sales@Perancea.com
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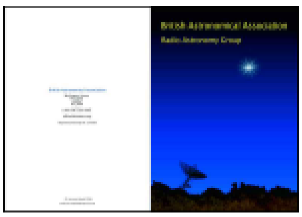
Meeting Photograph

If there is sufficient interest, we intend to produce professionally framed copies of the Meeting photograph (shown inside the back cover). Please contact Karen Holland for details.

RAG Greetings Card



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

Guidance for Contributors

Laurence Newell
Radiogroup@btinternet.com

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- 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.
- 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!

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Beyond the Fringes

Laurence Newell

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We now have winners for the two competitions in the last issue. Since there were only three entries for the Captions, and one for the Stickers, I will not be having any more competitions!

Caption Competiton

The Caption Competition was won by Rev. John Wardle.

Where do you switch this thing on?

Bumper Sticker

The Bumper Sticker Competition was won by Alan Morgan.

Radio Astronomers don't have to do it with the lights out

Thanks also to Jeff Lichtman for supplying Radio Astronomy Supplies stickers for the Northampton Meeting.

Postal Subscriptions

The *Circular* is issued free of charge as a PDF document, downloaded from the Group website. If you wish to receive a paper copy (colour covers, b&w inside), then please send a cheque for £3.00 per issue (including postage) to Karen Holland. You may pay in advance for a single issue or as many as you prefer.

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.

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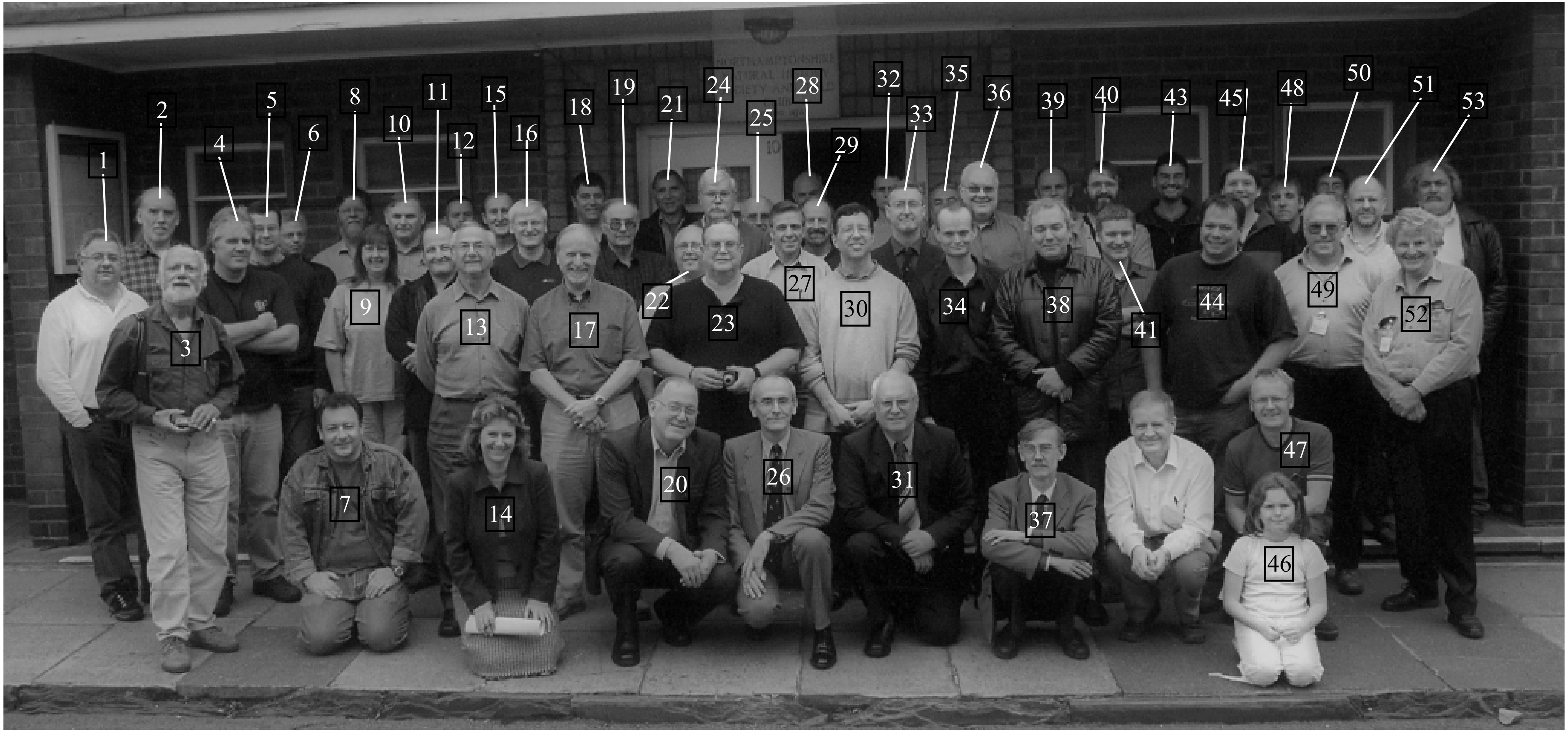
The Group yellow is R234, G225, B014.



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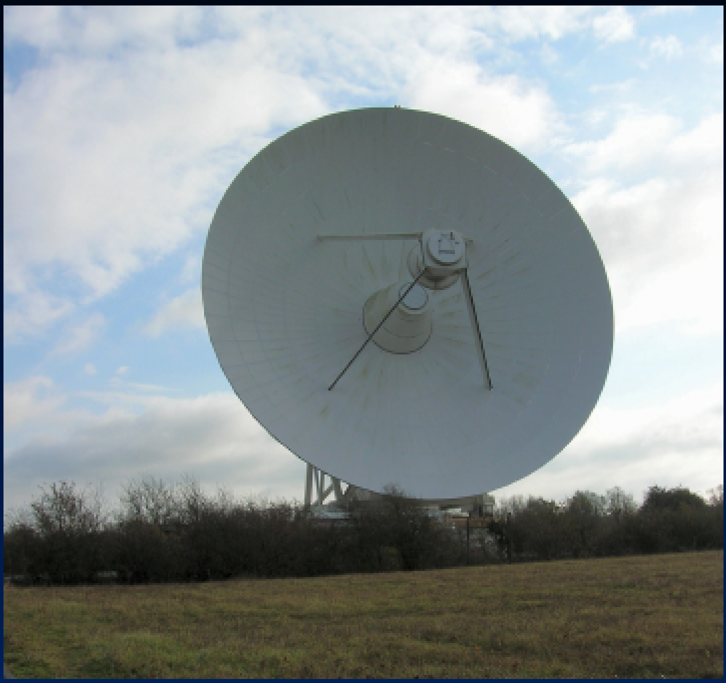
Many thanks to Tom Boles for taking the photograph

British Astronomical Association

Radio Astronomy Group

The Humfrey Rooms, Northampton

2005 October 8th



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