The RAGazine

Vol 2
Issue 1

August 2014

Photos: UK skill shortages abound, but in the S West training in radio astronomy and geophysics extends over the 3 to 85 years range. Shown here are trainees fitting dish counter-weights derived from Argos COTS hardware. In related news the unlicensed gang master shown here is reported to be in a weight reduction programme, and the new Modern Slavery Bill is progressing through the committee stage at Westminster. Courtesy: Editor

www.britastro.org/radio/

British Astronomical Association
Radio Astronomy Group

The RAGazine

The bimonthly newsletter of the British Astronomical Association, Radio Astronomy Group (BAA RAG)

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The *RAGazine* is published in primarily electronic form, for download in (usually) low and high resolution .pdf formats at: http://www.britastro.org/radio/downloads.html For a free subscription to *RAGazine,* send an empty e-mail request with 'subscribe' as the header to: baa-rag-subscribe@yahoogroups.com

Publication is now around the first week of Aug, Oct, Dec, Feb, Apr and June. Baa-rag Yahoo! subscribers receive an e-mail alert containing the download links when each new issue is available. A few paper copies may be made available on request. We solicit items of news; articles on construction and observing projects; on outreach and educational areas; book reviews; historical descriptions; anecdotes etc. - anything of potential interest to amateurs in radio astronomy and geophysics. We also encourage inclusion of relevant individual and commercial adverts, for sale and wanted, and volunteer appeals (all at no charge). The deadline for contributions is nominally the 15th of the month before the publication date. Contact :

dave@greenover.net

01769 561 002 / 07527 906 346

Most common file and picture formats are acceptable; where possible please contact the editor with advance notice of any contribution. The intended print/view size is A4.

Contents

Editor's Remarks

View from the kitchen

This is the fifth issue of *RAGazine*, and is the first after the switch to a bimonthly sequence. So we are now in the second year as Vol 2, issue 1, and with six rather than four issues per year.

As reminder, here is the new schedule, as explained last issue:

Aug. issue	appears first week	Aug.	15th July is deadline for inputs
Oct.		Oct.	Sep.
Dec.		Dec.	Nov.
Feb.		Feb.	Jan.
Apr.		Apr.	Mar.
Jun.		Jun.	May

As indicated last time, this publication frequency is of course something of an experiment, so if this proves a little over-ambitious we shall have to revert to the quarterly frequency. So if you want lots of interesting radio astronomy and geophysics material to read, you must not leave the work to just a few contributors but make a resolution to contribute something yourself ! This need not be an item on construction or observation, for example; there is lots of scope for other possible input (news, opinion, ideas, humour, reviews, problems, tips …..). Remember this magazine is for YOU, the reader - neophyte, expert and all shades between and beyond.

Again, I would like to see members' home observatories featured, their outreach activities, co-operative ventures and the like. So please consider this, or at least point the editor in the right direction, as it's not possible to easily discern what all are doing or have accomplished. We also still seek correspondents in several areas. Finally we get very little feedback, so if *RAGazine* does not serve your needs or you have suggestions or comment, please let the editor know.

Personal health issues have meant that there are still certain subject areas not included as yet, and in particular there is as yet no reporting of the recent RAG2014 meeting in Leicester, or the SARA conference at Green Bank inc. the great RASDR2 progress. This should be corrected next time. Nevertheless a few contributors will notice that their inputs are not included this time, but I have done this in an attempt to judiciously smooth out the overall page count over time.

Best wishes

Dave James **Editor** dave@greenover.net

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Coordinator's Remarks

View from the top

There are several events planned for the next few months – please let myself or the editor know if you are aware of any others that you would like to have featured in *RAGazine*.

On the BAA side, those in the north-west might like to note the *Out of London* event being held in Macclesfield Town Hall on 5 - 7 September. Jeff Lashley is providing a talk on the Saturday and we will be having a RAG stand there on that day. Further north, and possibly in a different country by then, Radio Astronomy will be part of the *Back to Basics* meeting being held in Glasgow on August 11th. These events are open to non-BAA members and full details can be found on the BAA website.

Brian Coleman is actively promoting radio astronomy within the amateur radio community and will be providing a talk on the subject at this year's RSGB Convention in Milton Keynes (10 - 12th October). There will also be a special 'break-out' meeting for those interested in hearing more about the subject. We want to support this with a RAG stand and for this audience it would be particularly useful to have a good selection of hardware on display. Please let me know if you can offer anything here – there is still time to build and try out that certain something that you have been meaning to get around to ! If you know of any radio amateurs who have an interest in the subject, tell them to watch out for this.

I'd also like to remind people about the RAG stand at the *Summer Bytes* event at The National Museum of Computing on Saturday 23rd August. Again, it would be good to have some real observing equipment on display, though not necessarily in use given the local noisy environment. Can you help?

I had an enjoyable day helping with a workshop on radio meteor observing organised by RAIG and Nottingham Astronomical Society and hosted by Loughborough University Physics department. This was attended by professional astronomers, radio amateurs and amateur astronomers from Loughborough University and from Leicester, Mansfield, Nottingham and Worcester societies. There are now 10 additional meteor scatter systems in the Midlands and there are plans for a 'Scatterthon' event covering the August *Perseids*. As well as meteor activity, one of the aims of the event will be to record the extent of local noise pollution of the radio spectrum. The hope is that this information will be of use

Tony Abbey, Mike Knowles, unknown, Paul Hyde (standing) with Victoria Penrice and Chris Jackson, after a hectic afternoon constructing antennas in demonstrating the increasing problems from PLT and solar panel systems - a common cause for both the radio amateur and amateur astronomy communities. If anyone would like to participate in this event please let me know or contact the Radio Astronomy Interest Group via the NAS website: www.nottinghamastro.org.uk/?page_id=1243

Best wishes

Paul Hyde **BAA RAG Coordinator** g4csd@yahoo.co.uk

VLF Quarterly Observing Report, to End June 2014

- John Cook jacook@jacook.plus.com

Fig 1 shows activity levels since 2005. Sunspot data is courtesy of the BAA Solar Section. SID figures for the last two months are:

2014 May = 52,
2014 June = 94 (provisional).

While activity in May was rather subdued, the tally of 94 SIDs in June is the highest monthly total since the large peak in 2012 July. Solar cycles 21, 22 and 23 have all shown multiple peaks in sunspot counts, so cycle 24 seems to be following that trend.

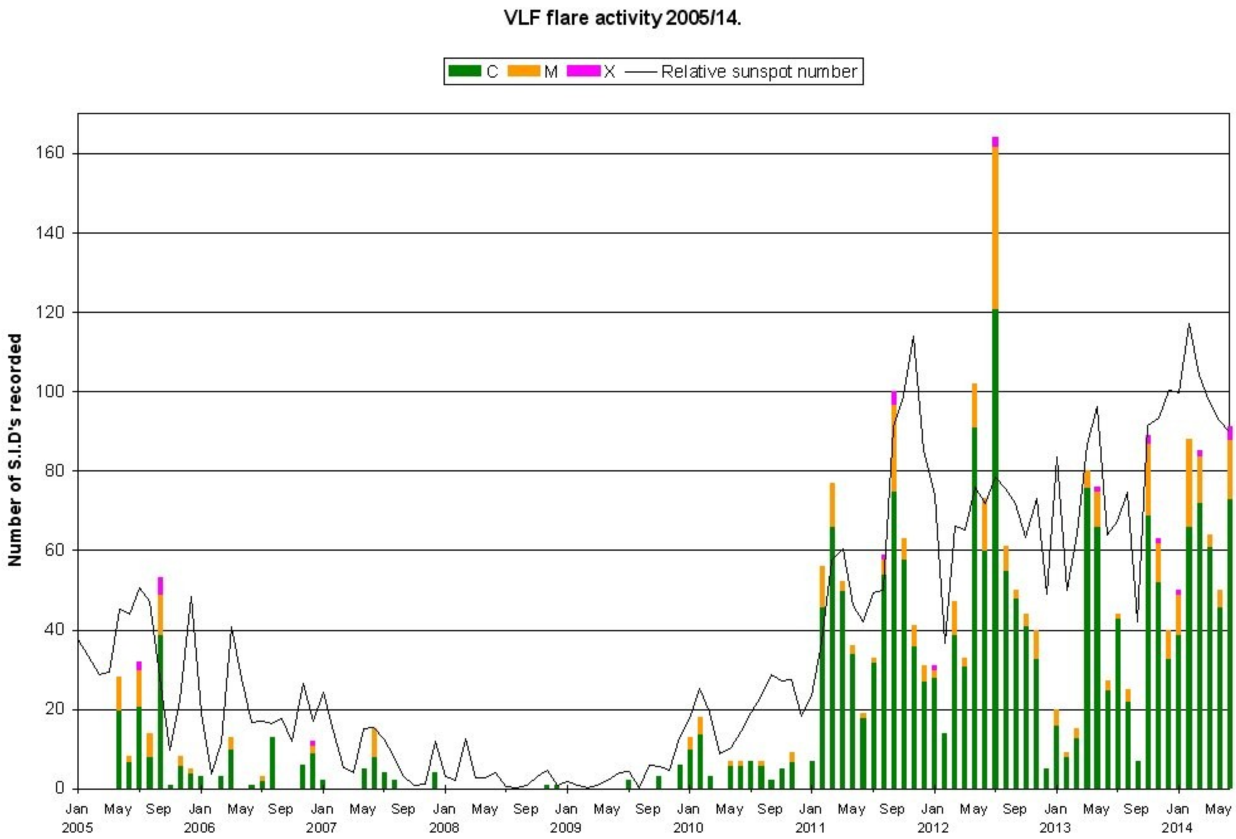


Fig 1 Activity chart

The most energetic flare recorded in May was an M5.2 on the 8th, peaking about 10:10UT, and producing a SID for most observers. The 9th showed the most activity with a total of 7 SIDs recorded, mostly from fairly weak flares. The 14th was dominated by an X-ray event lasting from 12:59 to 16:40UT. The SWPC lists five separate flares in this period from three active regions on the sun. Fig 2 shows my own recording with the GOES15 X-ray flux overlaid. The major peak is marked as the C8.3 flare, while the others are unclassified.

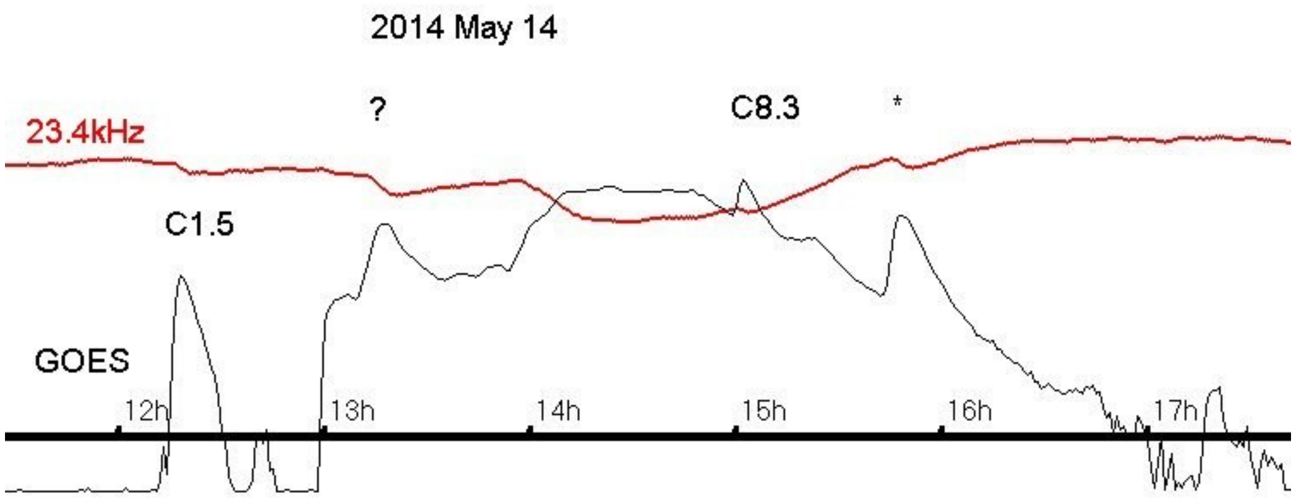


Fig 2: May 14th, John Cook, Wolverhampton

May 17th was the day of the Radio Astronomy Group meeting at the NSC in Leicester. It was a very hot day in central England, but a most enjoyable programme of talks kept us all indoors. Meanwhile the ionosphere was responding to a large volume of warm buoyant air rising from below with some very strong turbulence and oscillations as shown in Fig 3 by Richard Kaye in Birmingham. The sun itself remained fairly quiet throughout the day. Richard's recording is at 20.27kHz (black trace), from the transmitter in Isola di Tavolara, Italy. Red and blue are the long and short wave X-ray flux from GOES15. Mark Edwards in Coventry also recorded very strong oscillations on most signals, the only one unaffected being the trans-atlantic path at 24kHz.

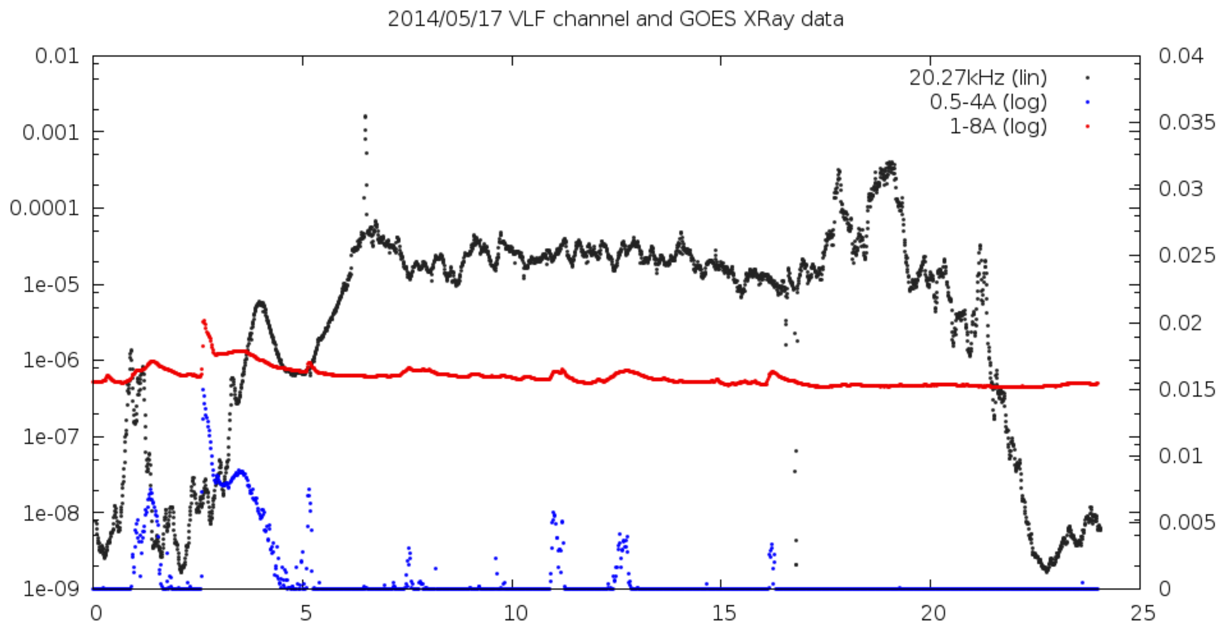


Fig 3: May 17th, Richard Kaye, Birmingham

Magnetic disturbances were very weak throughout May. The few CME's from the Sun were directed away from Earth and so had little effect. CHHSS and southward pointing Bz interaction resulted in the minor disturbances shown in the Bartels diagram.

June started rather quietly, but with periods of strong oscillations noted by Mark Edwards and Richard Kaye on the 2nd. The highlight came on the 10th, with a pair of X-class flares and associated SFEs. Fig 4 shows the SIDs recorded by Paul Hyde, (blue = 23.4kHz, red = 22.1kHz).

The first was X2.2, peaking at 11:43UT, the second was X1.5 peaking at 12:45 in Paul's recording. Fig 5 shows my own recording, including the GOES X-ray flux in black and the magnetometer in green. Small dips in the magnetometer trace can be seen at the peak of both flares. These magnetic effects are a direct result of the sudden increase in ionisation and conductivity in the D-region from the X-ray flux. A further X1.0 flare occurred on the 11th, making a total of 3 X-class and a pair of M-class flares all within 24 hours.

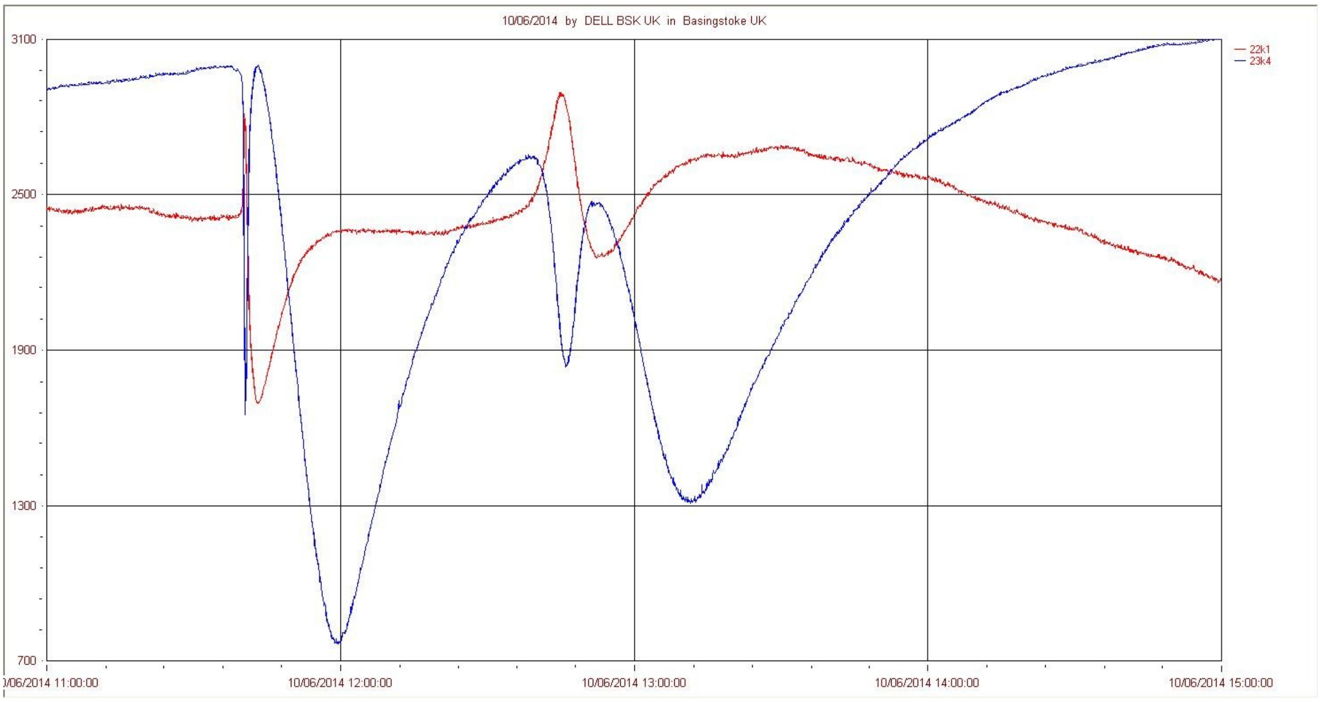


Fig 4: June 10th, Paul Hyde, Basingstoke

Very noticeable in Paul's recording (Fig 4) is the duration of SID recorded at the two frequencies for the first flare. For such a major event the SID at 22.1kHz is very short when compared with the 23.4kHz SID. Both receivers and aerials are of the same design.

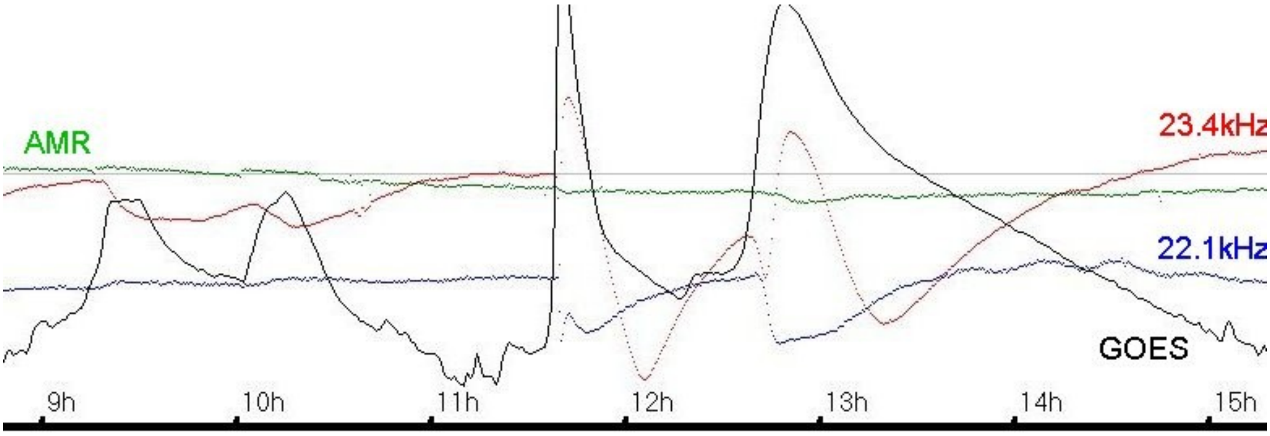


Fig 5: June 10th, John Cook, Wolverhampton

Activity remained high over the following week, slowly fading towards the end of June. By the 24th the D-region had settled sufficiently for Mark Edwards to record SIDs from a trio of B-class flares at 24kHz. A full list of all of these events will be found in the VLF summary, copies of which can be found on the RAG website.

The magnetically active period shown in the Bartels diagram on the 8th was most probably caused by a filament eruption and CME on June 4th. Although effects were first detected in the afternoon of the 7th, the major disturbance began around 03UT on the 8th. There followed a period of very rapid field fluctuations up to 60nT lasting until about 10UT. Fig 6 shows the recording by Colin Clements. The oscillations between 07:30 and 09:00 are unusually rapid, with periods of 5..10 minutes.

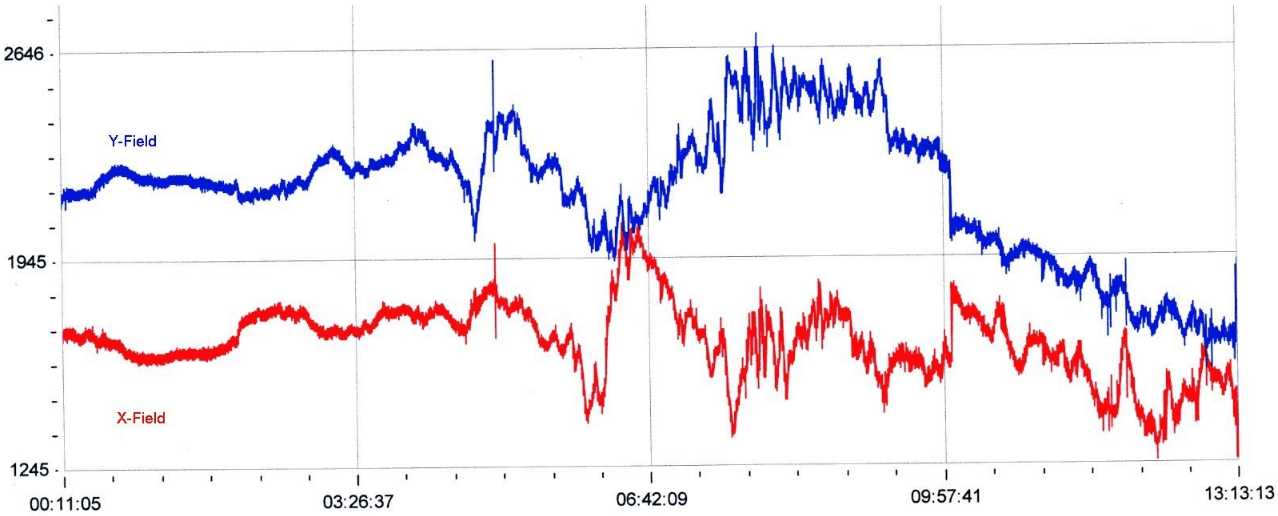


Fig 6: June 8th. Colin Clements, Lisburn

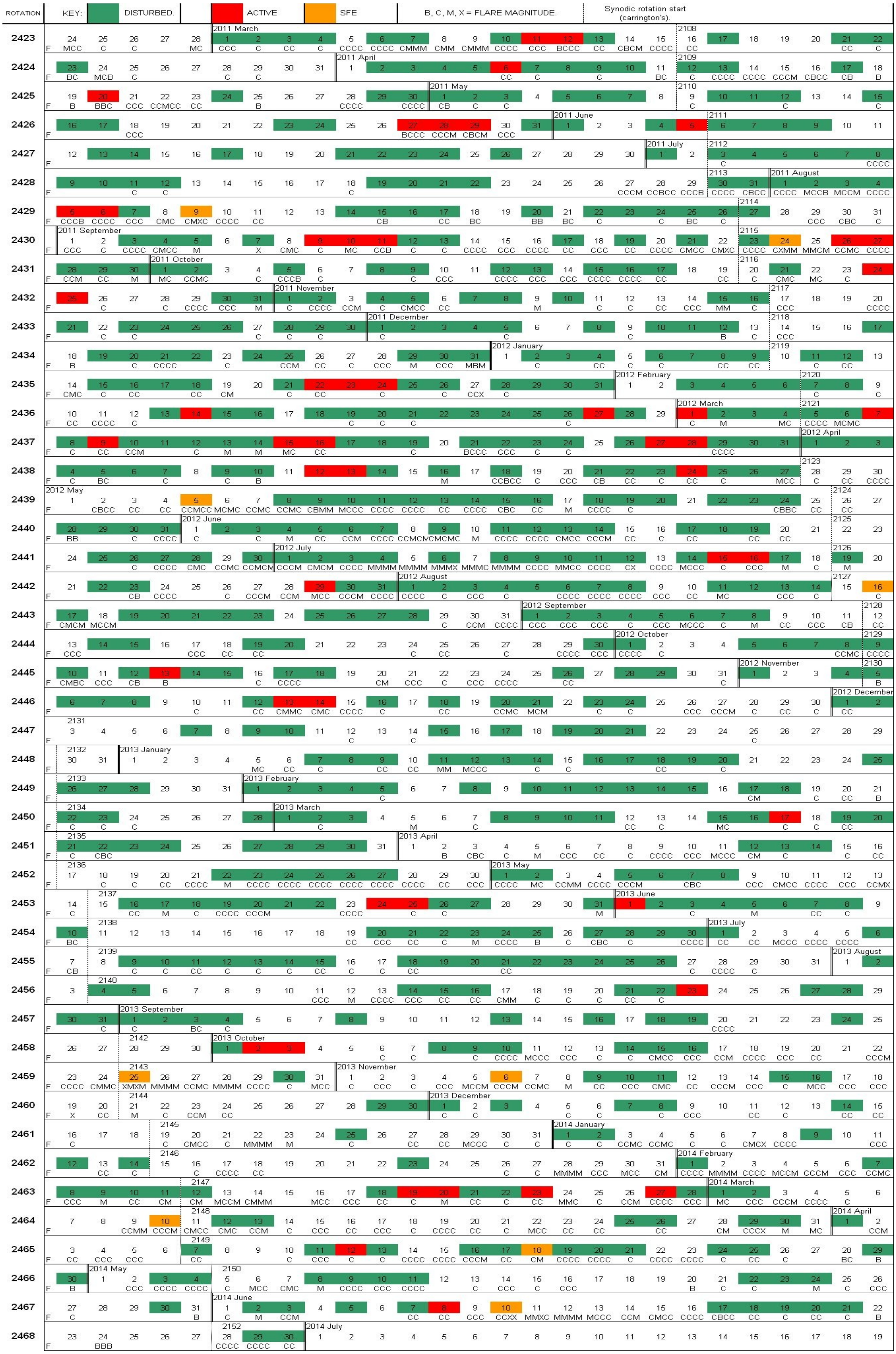
The active regions responsible for the X-class flares were close to the solar limb at the time, and so there were no Earth directed CMEs recorded.

Observers: Roberto Battaiola, Roger Blackwell, Colin Clements, Mark Edwards, John Elliott, Gordon Fiander, Paul Hyde, Richard Kaye, Peter Meadows, Bob Middlefell, Steve Parkinson, John Wardle, Gonzalo Vargas, John Cook.

My thanks to all contributors.

If you would like to add your own observations, please contact jacook@jacook.plus.com.

Fig 7 Bartels chart
/ see over /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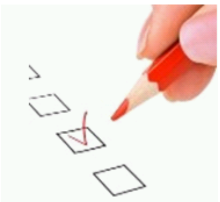
What's On

Diary



Aug	16	2014	UK High Altitude Soc. (UKHAS) Int. Conf., Royal Greenwich
Aug	23	2014	*Summer Bytes Festival*, Nat. Museum of Computing on Bletchley Park; see p. 4. Total festival runs 26 July – 2 Sep
Aug	23-27	2014	EME 2014, Pleumeur Bodou, near Lannion, France
Sep	5-7	2014	*Into the Deep and Dark*, Macclesfield, BAA Autumn Week-end mtg.; see p.4
Sep	6-7	2014	Europ. Conf on Amateur RA, Bad Münstereifel-Eschweiler, Germany
Sep	26-27	2014	National Hamfest (UK), Lincoln
Oct	10-12	2014	RSGB Convention, Milton Keynes; see also p.4
Oct	11	2014	Back to Basics Workshop, Glasgow, BAA; see also p.4
Dec	13	2014	Ord. Mtg. & Christmas Lecture, UCL, London (BAA): lecturer is Lord M Rees
Mar	20-22	2015	SARA Western Conf., Stanford U, Palo Alto (inc. KIPAC visit)
May	15-17	2015	Hamvention, Dayton, OH
Apr	25	2015	*Amateur and Professional Collaboration*, BAA, Ashford
June	21-23	2015	SARA Annual Conf, Green Bank, WV*
June	26-28	2015	Ham Radio, Friedrichshafen, Germany
Sep	4-6	2015	*Astronomy in Space*, BAA Autumn Weekend Mtg, RAL Didcot

* Star Quest (optical) usually immediately precedes, at same location, NRAO.

Simple equipment for SID observations

- John Cook jacook@jacook.plus.com

SID observation requires very little in the way of specialised equipment. Modern computer software can even eliminate the need for any external electronics. Essential to any receiving equipment is an aerial [antenna ! - Ed.], and this will need to be either purchased or home-built.

Aerials

The frequencies of interest are in the region of 15kHz to 30kHz, with wavelengths of 10..20km. Clearly a conventional dipole aerial is going to be very large, and so a loop aerial is normally used. This will respond to the magnetic component of the signal, and can be made quite compact. A simple design might consist of about 100 turns of copper wire (26swg, 0.45mm) wound onto a square former of about 600mm diagonal. The photograph (Fig 1) shows just such a design. Suitable for indoor use, a little time spent in making a neat wooden former with a coat of varnish or paint will result in an aerial that would fit neatly on a bookshelf or cupboard. This basic design can be scaled upwards to increase sensitivity, just ensuring that the resistance of the copper wire does not get too high. Increasing the number of turns to 120 or 130 would be fine. Attention also needs to be paid to the self-capacitance of the coil, ensuring that the self-resonant frequency does not fall into the VLF range.

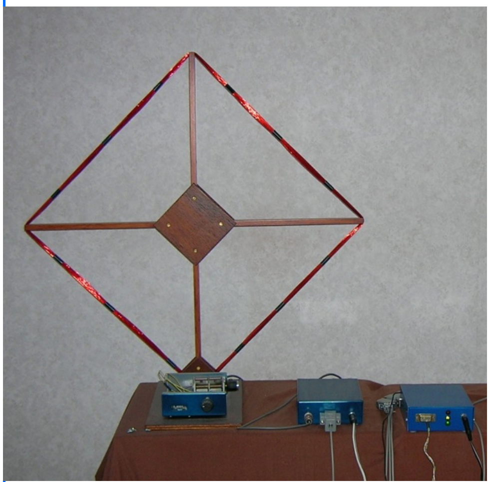


Fig 1: Simple loop antenna

A much smaller aerial can be constructed by winding the coil onto a long ferrite rod of the sort once used in medium and long wave radio receivers. Fig 2 shows the arrangement. With either design, ensure that the wire is tight and secure on its former, so that it does not de-tune itself over time.

Some observers have used active aerials, where a relatively short vertical whip is interfaced by an impedance matching amplifier circuit to the main receiver. This sort of aerial responds to the electric field component of the signal, and would need to be mounted outside and above local obstructions. This leaves it vulnerable to electrostatic fields, which could be quite destructive.

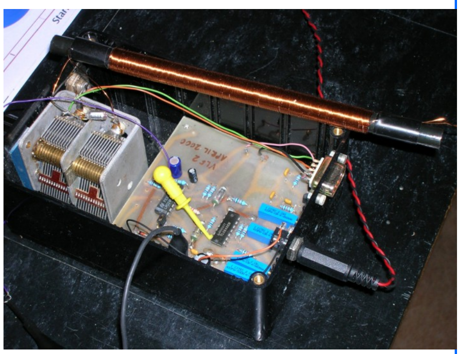


Fig 2: VLF receiver using ferrite rod antenna

Receiver

There are two options for a receiver. A conventional tuned-radio-frequency (TRF) receiver can be used for single signal reception, or a software programme running on a PC can be used. The software option has the advantage of being able to monitor several signals, but does require a computer to be running all the time. There is also a risk of computer system faults losing data, for computers do have a habit of crashing just at the wrong time ! A separate receiver can be quite low power, and a lot smaller than most PCs. So such a receiver comprises aerial, tuner and data logger.

Software receiver

The widely used SPECTRUM LAB software is excellent for this job, and can be freely downloaded from the web. It will require some initial setting up to select the required frequencies, but can then be left to run. The aerial does not need tuning, and can simply be connected to the microphone input with a small jack plug and a metre or two of audio cable. After adding the required frequencies to its watch list, daily recordings can then be exported as '.csv' files for analysis and plotting. This is also a good way to investigate what signals are active when tuning up a conventional TRF receiver.

TRF receiver

The essential need here is a high gain, high-Q filter. The output should have any modulation smoothed out with a suitable time constant (1 second is fine), before being fed into a data logger. There are a number of designs to be found on the internet, as well as ready built and tested modules from UKRAA. Monitoring just a single frequency, a TRF receiver will work best if the aerial is tuned to the correct frequency with a variable capacitor. Modern multi-meters often include inductance ranges, and so the required capacitance can be easily calculated. Remember to include the self-capacitance of the loop and the connecting cable in the calculation.

Data logging

In bygone days a chart recorder would have used, but there are several modern alternatives. A computer could be used with SKYPIPE software and an external analogue to digital converter (ADC), creating data files directly to disc. A dedicated logger could be built or bought, data then being downloaded to a computer at suitable intervals (e.g. daily). The major requirement is reasonable time keeping, so that recorded SIDs can be timed at least to the nearest minute or two. If a complete system is to be purchased from UKRAA, then the controller module will include the ADC and look after logging the data and time keeping. STARBASE software can then be used to download and analyse the data files.

Choice of signal

This is always a compromise for a single receiver system, so time spent in trying out different signals is worthwhile. In the UK we have a choice of transmitters in France, Germany, Italy and the UK. The German signal (DHO, 23.4kHz) is often used, but has an annoying off-period of about an hour most days. There are several French signals (HWU, 18.3kHz or 22.6kHz, FTA, 20.9kHz), but they tend to swap around so that receiver re-tuning becomes necessary. The Italian signal (ICV, 20.27kHz) may be rather weak, but is worth trying. In the UK, GBZ at 19.6kHz and GQD at 22.1kHz can usually be found. As both are located in the Solway Firth area of north Cumbria, they may be rather too close for recording weaker SIDs. They do work well for observers in the south of England. The old Rugby transmitter at 16kHz no longer exists, so don't bother looking for that one ! For a real long distance path, NAA (24.0kHz) in Cutler, USA, is well worth trying.

If you have any queries or problems with SID receivers, please contact jacook@jacook.plus.com.

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An Introduction to Radio Objects that can be detected by amateur radio astronomers: Part 3 (concluding*)

- **David Morgan**   www.dmradas.co.uk

RA Basics

9 Thermal Emission Nebulae

There are many emission nebulae where vast clouds of hydrogen are ionised by hot O and B type stars forming within them. The intense UV radiation from the stars ionises the gas at temperatures of around $10{,}000^0$K and this causes the clouds to emit broad spectrum or 'continuum' radiation with thermal spectral characteristics described in section 2.2.1.

One of the best examples of a thermal emission nebula is the Orion nebula depicted in Figure 9.1.

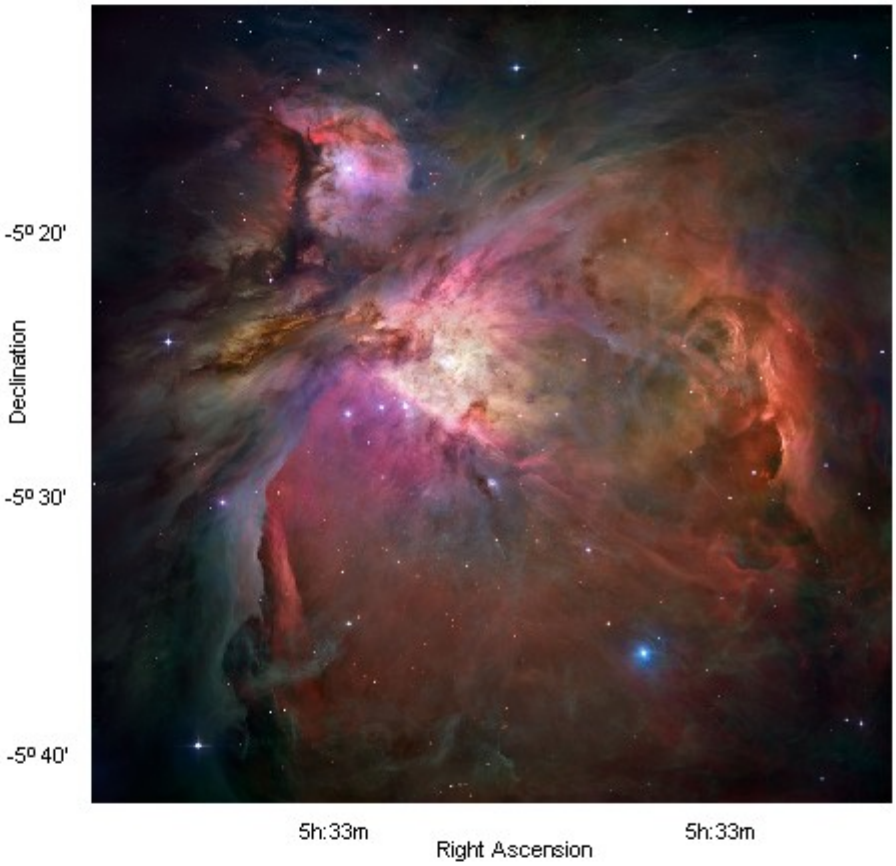
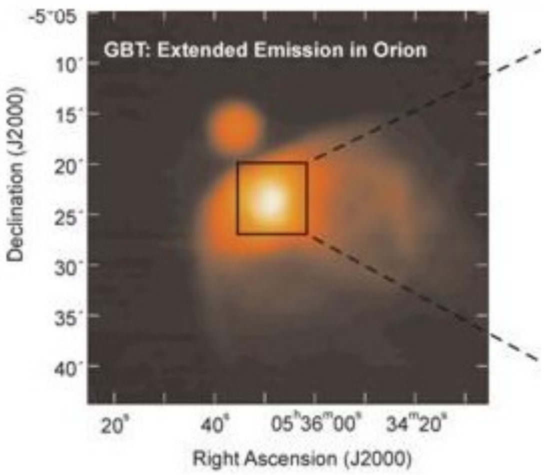


Figure 9.1   The Orion Nebula (HST picture)

The whole nebula is about 0.5^0 across[1] and the ionisation energy comes from the Trapezium cluster of bright stars containing two O stars and several B stars. There is also a large amount of obscuring gas and dust which is clear in the optical image.

The professional radio image from the NARO / AUI telescopes in Figure 9.2 a & b was generated at a frequency of 8.4GHz (3.6cm). Figure 9.2a is centred on RA: 05:35:17.40, Dec: -5:23:28.00 and has a field of view of 0.66^0 square. It shows the hydrogen nebula without the obscuring dust as this is transparent at GHz frequencies.

* Last issue's Part 2 was incorrectly entitled Part 1 (p.18). Part 1 appeared in the March '14 issue



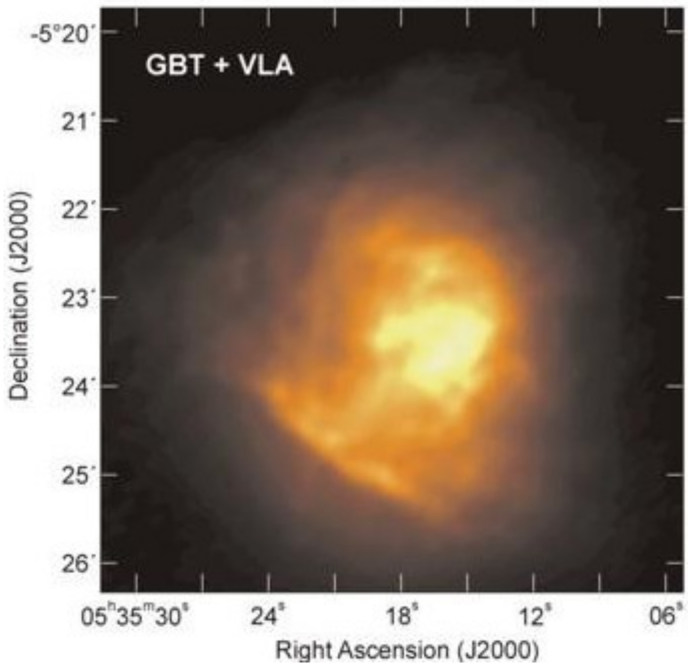


Figure 9.2 a   Orion nebula @ 8.4GHz

Figure 9.2b   Central region of nebula

The thermal emission spectrum of the nebula is shown in Figure 9.3 where the measured values agree with a theoretical prediction based an electron temperature of 10,000^{0}K. It is clear that the amateur radio astronomer would have the best chance of detecting the Orion nebula at wavelengths around 10cm or smaller. A C band satellite TV antenna and feed, such as that shown in Figure 5.1 could be used to make observations at around 4 GHz (7.5cm). The expected signal strength would be of the order of 500Jy.

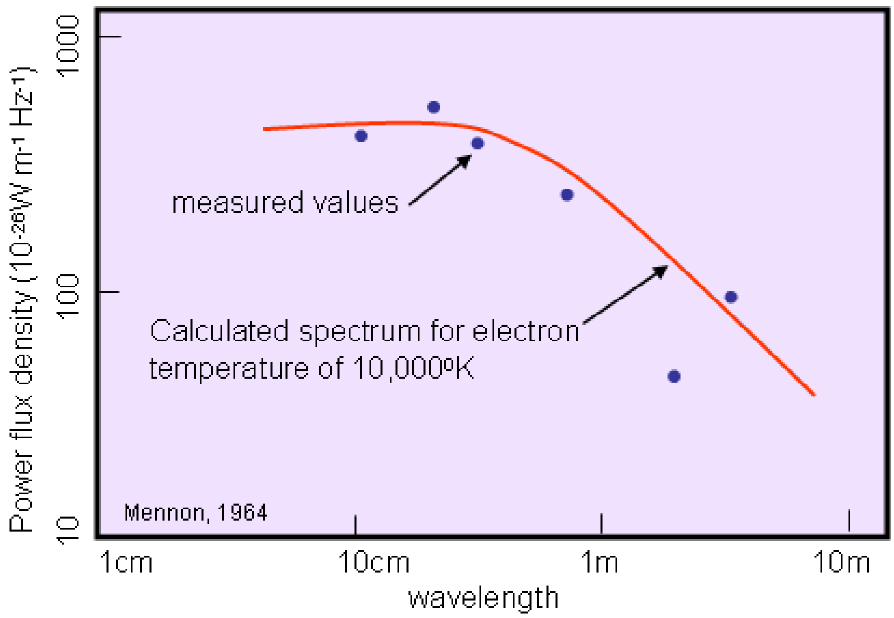


Figure 9.3   Thermal spectrum of the Orion nebula

10 Pulsars

10.1 The nature of Pulsars

Pulsars are compact sources that emit a series of fast radio pulses. They are in fact neutron stars about 20 km in diameter and have a mass of about 1.4 times that of our Sun. This means that a neutron star is so dense that on Earth, one teaspoonful would weigh a billion tons. Because of its small size and high density, a neutron star possesses a surface gravitational field about 2 x 10^{11} times that of Earth. They can also have magnetic fields a million times stronger than the strongest magnetic fields produced on Earth[12].

Pulsars were first discovered in late 1967 by graduate student Jocelyn Bell Burnell, as radio sources that blink on and off at a constant frequency. Now we observe the brightest ones at almost every wavelength. Pulsars are spinning neutron stars that have jets of particles moving almost at the speed of light streaming out above their magnetic poles.

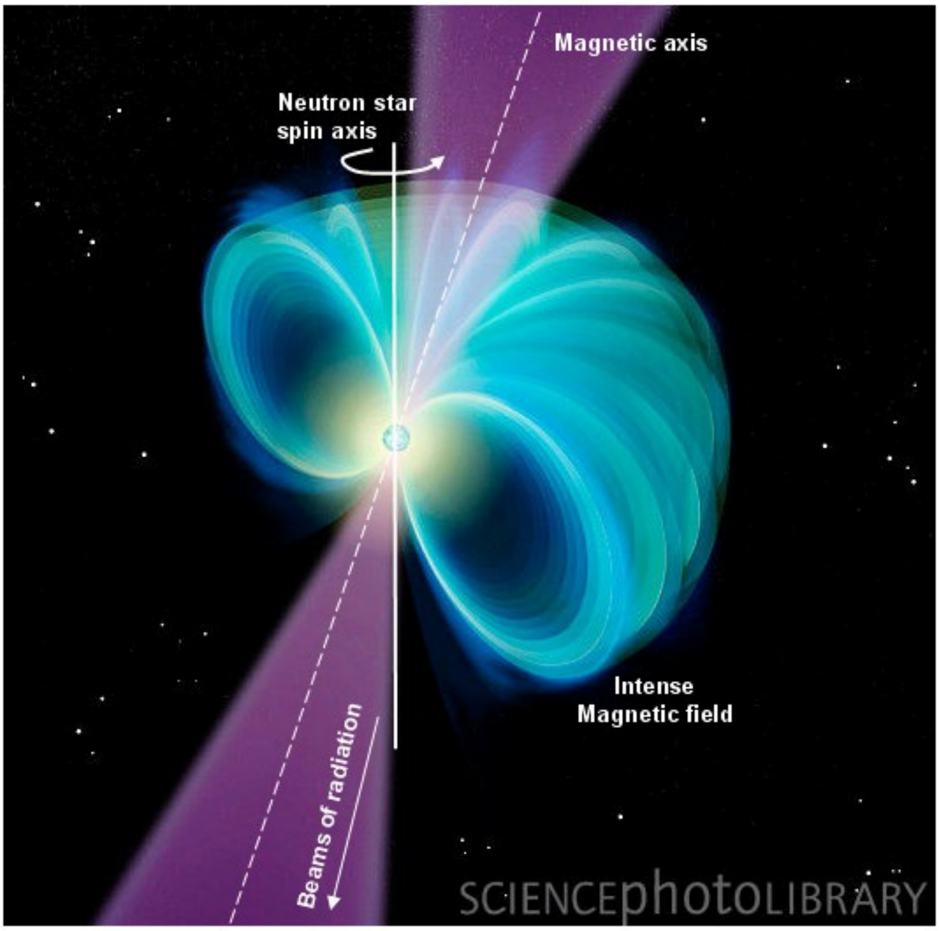


Figure 10.1 A Pulsar - a spinning Neutron Star

In Figure 10.1 we see a compact stellar remnant spinning about its axis of rotation with an intense magnetic field (created as the star collapsed) at some angle to the spin axis. The intense beams of radiation emerging from the magnetic poles sweep around in space like a light-house beam. Each time the beam crosses an observer's location he sees a short intense radio pulse which has the regular period of the Neutron star's rotation. A typical pulse train is shown in Figure 10.2[13].

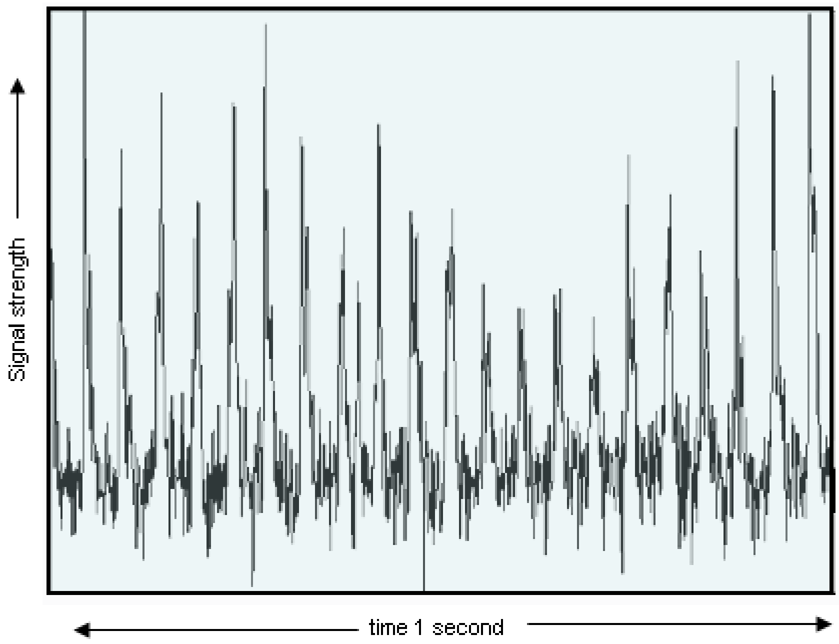


Figure 10.2 Pulsar signal

10.2 Observing Pulsars

There are two characteristics of pulsar signals that make observing them different from all the ‘noise like’ emissions discussed earlier:

- The signals are low level, ~ 1Jy or less
- The signal level pulses with a repetition rate of up to 30Hz

The low signal level requires a large aperture antenna and very low noise receiver, whilst the pulsed nature of the signal means that the observer cannot use signal integration over a period of many seconds to reduce signal variability. Integration would destroy the pulse structure of the signal.

These features make pulsar observations almost the ultimate challenge for the amateur radio astronomer with limited equipment. Some observers[14,15] using a modest 10 foot diameter dish claim to have observed a number of pulsars with the aid of special post detector software which enhances the pulse structure within background noise.

There is still a great deal of work going on by professional radio astronomers to understand the emission generation mechanisms in pulsars. There is a wide variety of pulse rates, emission spectra and source intensities for which a full explanation is currently being sought.

For amateur radio astronomers, simply detecting a pulsar would be an achievement of some note.

Indeed, one of the members of the Society of Amateur Radio Astronomers (SARA)[16] Jim Van Prooyen[17] has made great efforts to detect pulsars with a 10 foot diameter dish - and larger antennas - by developing special software to recover pulses from a noisy signal.

He comments that: “There have been several efforts by amateur radio astronomers to build [pulsar detectors], and for some of us, the detection of pulsars is the *Quest for the Holy Grail* of amateur radio astronomy. There are a number of notable efforts:

- James C. Carroll (A Post Detector Pulsar Extractor – SARA Paper)
- Robert M. Sickels (Pulse Catcher – SARA Paper).”

Van Prooyen has published the graph in Figure 10.3 showing the detection of Pulsar B0031-07 which he made using his post detector software capability.

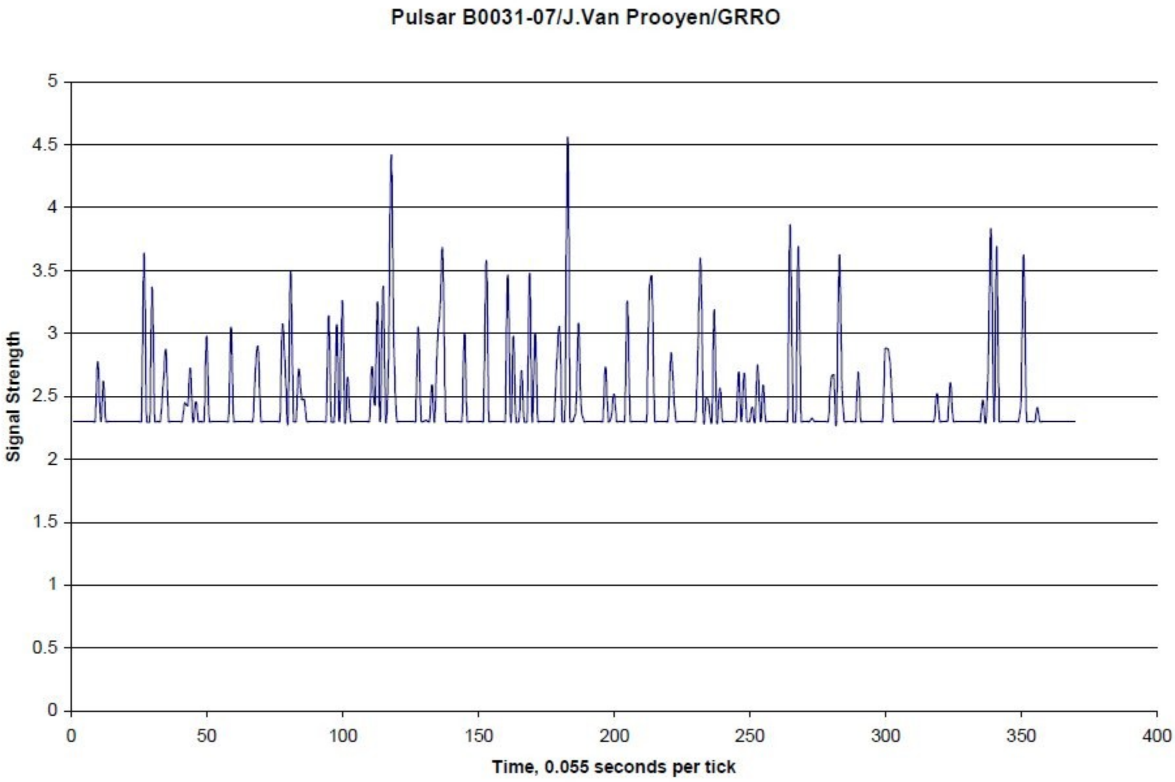


Figure 10.3 Amateur detection of Pulsar (Van Prooyen)

10.3 Pulsar emission spectra

A great deal of work has been carried out by professional radio astronomers to determine the nature of the emission spectra from a large variety of pulsars. In general they follow the simple synchrotron shape as given in Figure 2.5. A spectrum of Pulsar B1557-50 is shown in Figure 10.4.

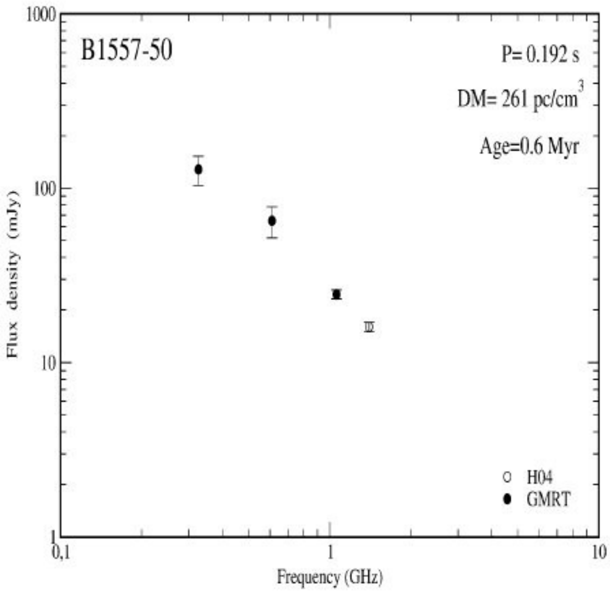


Figure 10.4 Simple Pulsar spectrum

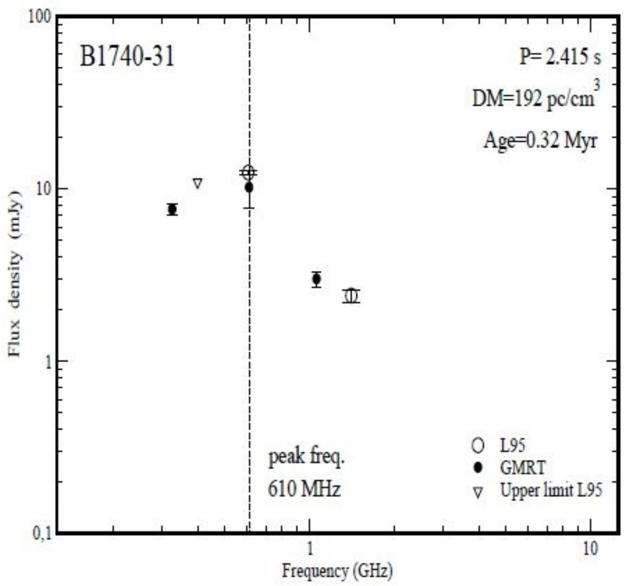


Figure 10.5 'turn over' pulsar spectrum

However evidence has been found of a 'turn over point' where the emission is a maximum – falling away on either side as shown in the example in Figure 10.5 for Pulsar B1740-31.[18] This suggests that a useful frequency to observe is in the UHF band (300MHz up to about 1GHz).

Note that the power flux density for these Pulsars is in the milli-Jansky range (mJy). This is a big challenge for amateur observers !

11 Extra-Galactic sources

11.1 Amateur subjects

There are a few extra-galactic sources that can be observed by amateurs. Two will be highlighted in this section; one is a strong source that is easily detected, the other is something of a challenge.

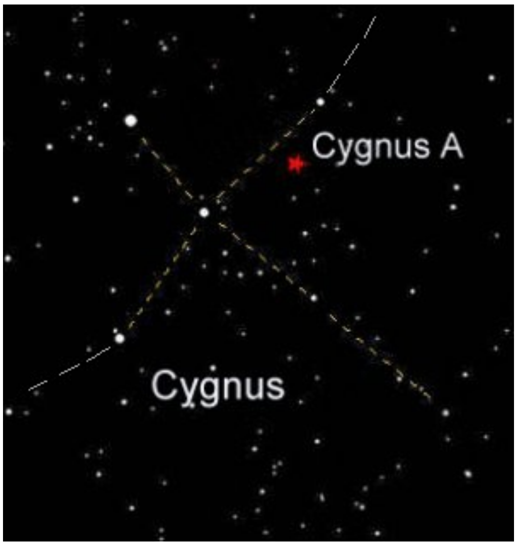
The strong source is Cygnus A (3C405)
RA $19^h\ 59^m\ 28.3566^s$ DEC +40° 44′ 02.096″

The weaker source is Virgo A M87 NGC 4486
RA $12^h\ 30^m$ 49.42338 DEC +12° 23′ 28.0439″

Cygnus A (3C 405) is one of the most famous radio galaxies, and among the strongest radio sources in the sky. It was discovered by Grote Reber in 1939. In 1951, Cygnus A, along with Cassiopeia A, and Puppis A were the first "radio stars" identified with an optical source; of these, Cygnus A became the first radio galaxy.[19]

11.2 Cygnus A

The radio source can be located as shown in Figure 11.1. It is a peculiar-looking, 15th magnitude galaxy located in the constellation Cygnus which would probably never have come under scrutiny were it not for the fact that it is the host for one of the strongest radio sources in the sky [20].



Located 600 million light years away, this galaxy is among the giants of the universe with a mass estimated at 100 trillion times the sun's mass. It consists, apparently, of two nuclei separated by 5500 light years, embedded in a galaxy extending some 450,000 light years across. The two nuclei of Cygnus-A are probably all that remain of two separate galaxies that passed too close to each other and merged together. See Figure 11.2.

Figure 11.1 Cygnus A

It is estimated that the total power radiated by the galaxy is 10^{38} Watts, millions of times more than from the entire Milky Way. The radio emission is produced from a vast area that dwarfs the size of the galaxy. See Figure 11.3

Figure 11.2 Cygnus A (optical)

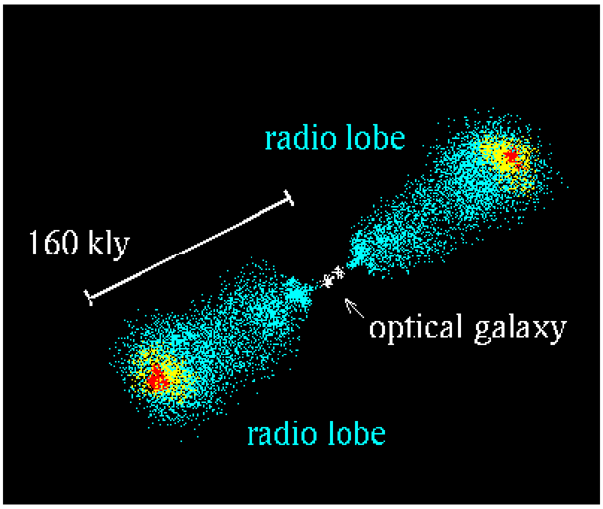


Figure 11.3   Cygnus A (Radio emission)

A professional radio image of Cygnus A can be seen in Figure 11.4 (Image courtesy of NRAO/ AUI).

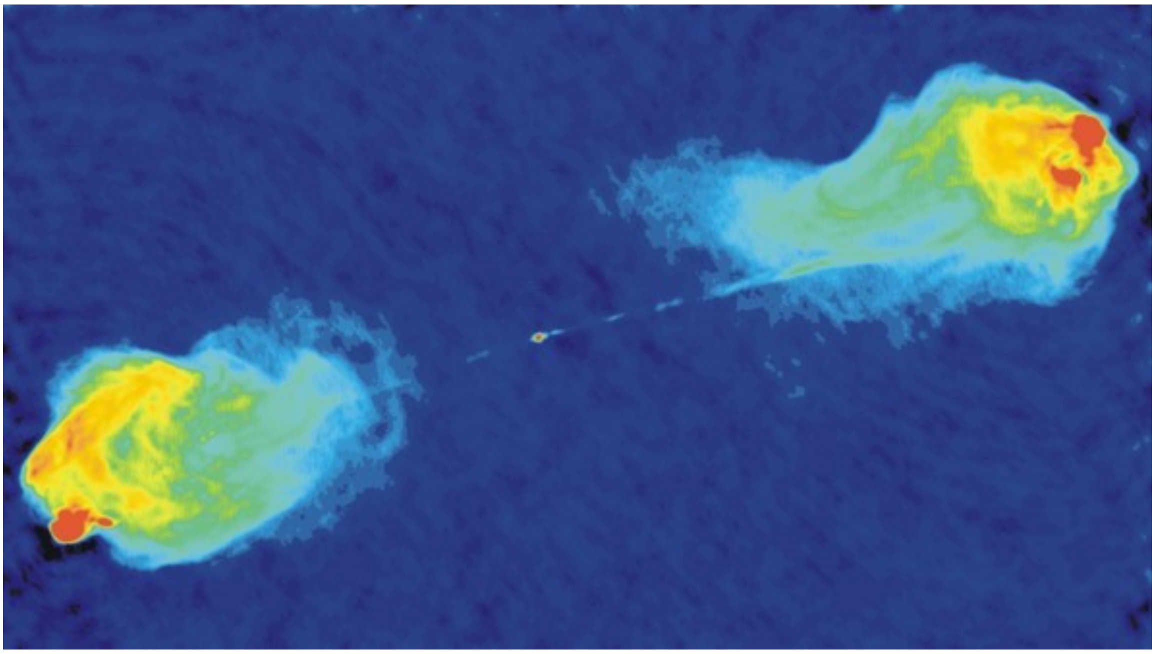


Figure 11.4   Radio image of Cygnus A showing the galaxy & radio lobes (image produced at cm wavelength)

A problem arises for the amateur observer because Cygnus A is located close to Cygnus X (a powerful X ray source that also emits radio energy) and both lie within the galactic plane. It is therefore difficult to separate these components using small antennas with limited angular resolution. It is possible to observe at microwave frequencies where resolution is improved but for frequencies below 2GHz the antenna beams are likely to encompass all the objects. See Figure 11.5 (*Radio Eyes* picture[11]).

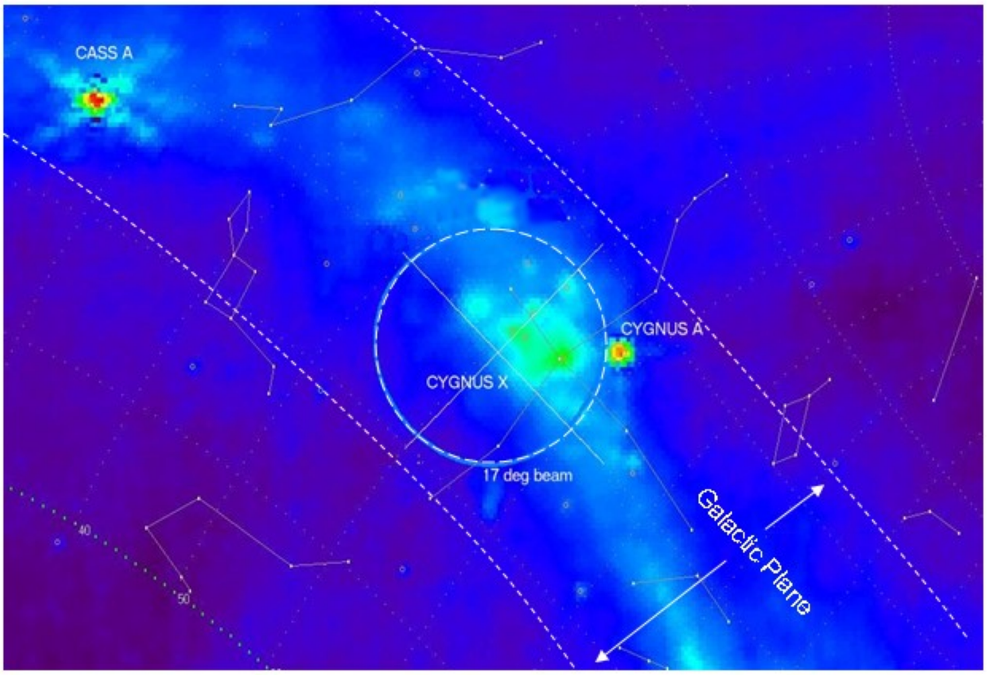


Figure 11.5 Cygnus sources embedded in the galactic plane

Probably the best way to pick out Cygnus A is to use an interferometer that will produce fringes for small diameter objects only (as discussed in section 8). A small sample of the fringe pattern recorded from Cygnus A with an amateur interferometer[21] is shown in Figure 11.6. Due to the strength of the source, the measurement goes 'off scale', but this plot does serve to demonstrate that the detection and separation of Cygnus A from other objects is clearly possible for amateur observers to undertake.

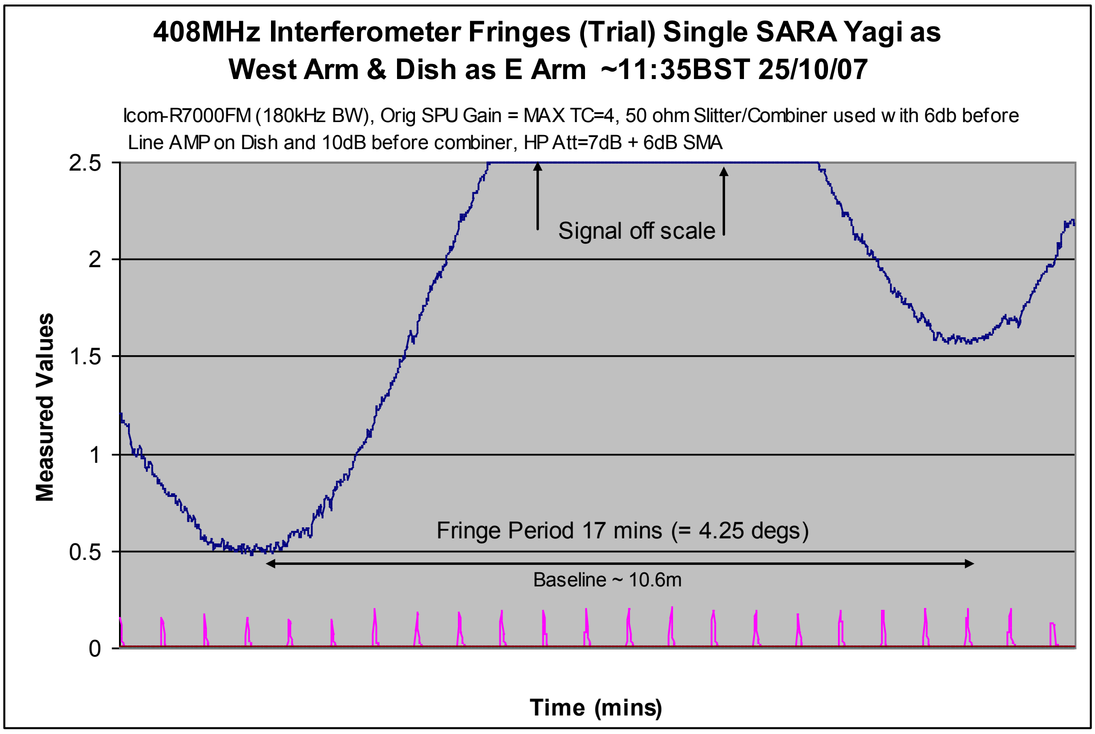


Figure 11.6 Part of fringe pattern from Cygnus A

11.3 Virgo A (M87)

This is a more challenging object to observe. The power flux density at 1420MHz is low, approximately 560Jy – See Figure 2.1.

Virgo A is a super-giant elliptical galaxy. It was discovered in 1781 by French astronomer Charles Messier and is the second brightest galaxy within the northern Virgo Cluster. See Figure 11.7. It is located about 53.5 million light years away from Earth.

Figure 11.7 Optical picture of the Virgo cluster of galaxies of which M87 is a member

M87 was identified with the radio source Virgo A by W. Baade and R. Minkowski in 1954. In 1956, a weaker radio halo was found by J.E. Baldwin and F.G. Smith of Cambridge. The galaxy has a spectacular jet which is better seen on short exposure photographs as shown in Figure 11.8 This is a directional beam of relativistic* plasma issuing from the core of the galaxy and contributes to its radio emissions.

The jet is thought to be produced by a violent active nucleus in the galaxy, probably a massive central object of several billion solar masses concentrated within the innermost sphere with a radius of 60 light years.

From Figure 11.9 it can be seen that it is fortunate that the Virgo A radio source lies well out of the galactic plane - toward the north galactic pole - as this enables it to be detected without clutter from the widely dispersed Galactic noise.

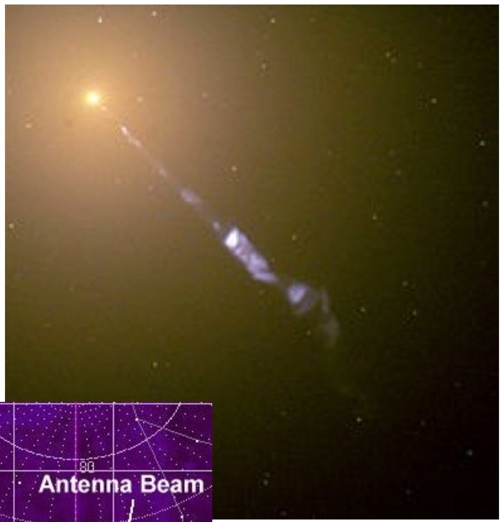


Figure 11.8 Virgo A, showing the relativistic jet

*(* Relativistic particles travel close to the speed of light)*

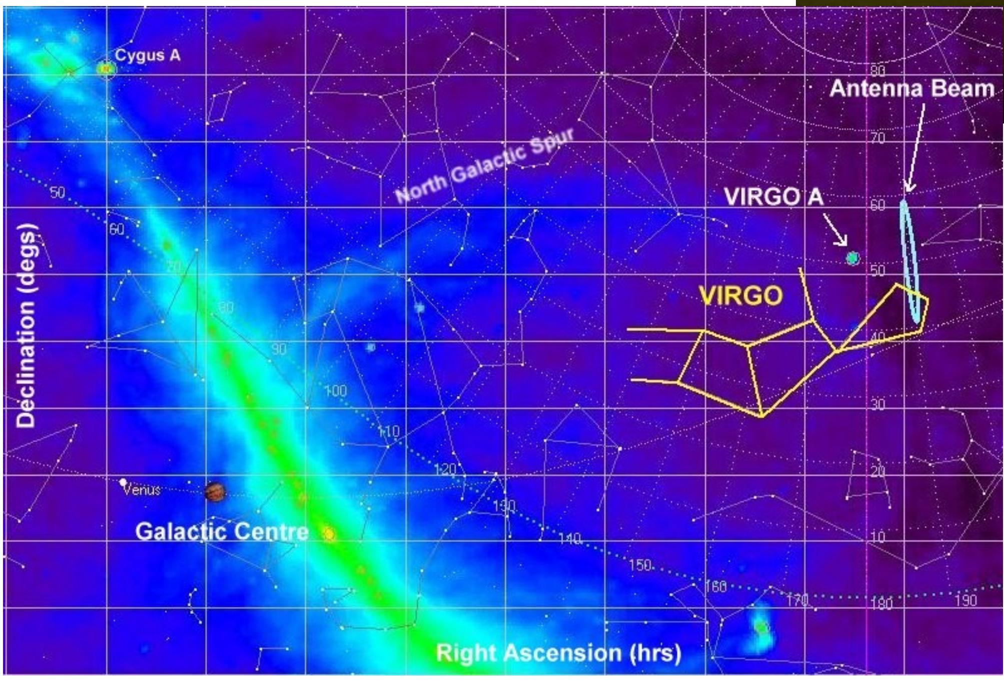


Figure 11.9 Location of Virgo A

As the emission from Virgo A has a synchrotron-like spectrum - which can be seen in Figure 11.10 - to observe this source it is better to use as low a wavelength as possible in order to receive the most signal.

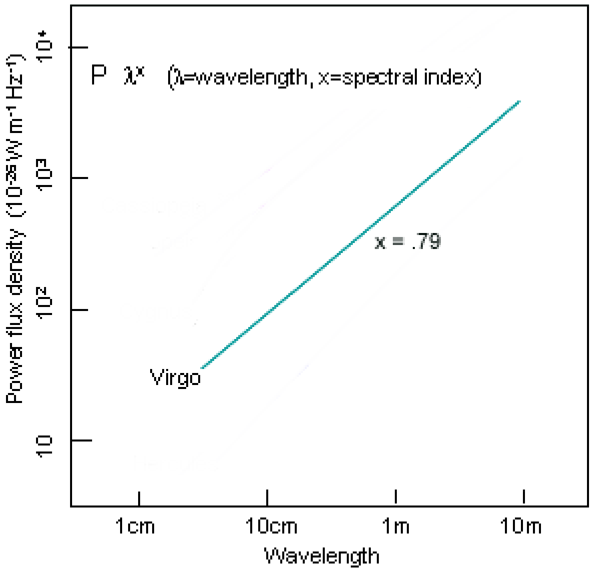


Figure 11.10 Emission spectrum of Virgo A

This usually means having the disadvantage of a wide antenna beamwidth that smears out the point source and the background. Again, by employing an interferometer a narrow beam can be 'synthesised' making the object easier to detect. In Figure 11.9 we see the central lobe of the interferometer antenna pattern with a width of 1.4^0 in the E-W (Right Ascension) direction.

The resulting fringe pattern is shown in Figure 11.11, confirming a good detection of this extra-galactic object.

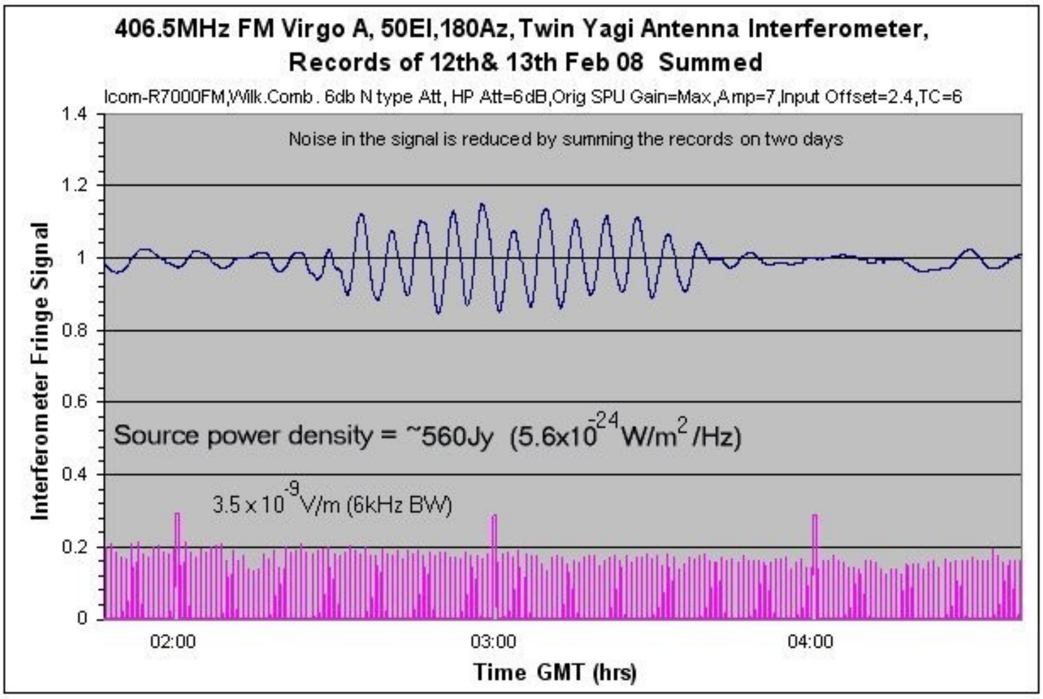


Figure 11.11 Amateur detection of Virgo A (406.5MHz interferometer)

12 Conclusions

Radio astronomy is a fascinating area of technical endeavour and, as this article shows, it is open to people with enquiring minds and some engineering skill. It does not require vast expenditure as much of the equipment can either be home-constructed or obtained from amateur radio outlets.

Some attention to detail is required and patience is needed to assemble and perfect the receiver system to enable the detection of very weak signals with stable gains and a constant low noise background.

Once equipment is in service one can begin by detecting the radiation from the Sun and some planets. Following this, observations can be made of the galactic emissions in the Milky Way. It is interesting to make maps of these emissions.

More exacting measurements can be made of supernova remnants within the galaxy. With amateur equipment it is not possible to map these sources, but detecting them is quite feasible.

Thermal emission nebulae also present a challenge, but again, one within reach of the amateur observer. The best choice is the Orion Nebula.

Pulsars are hard to detect. Only a few amateurs seem to have succeeded using modest sized antennas. The configuration of the receiver chain is different from that used to detect steady signals from the sources discussed so far. The pulsed signals mean that integration over a period of time cannot be used as a technique to improve detectability. In the case of pulsars a lot of raw signal is needed – and this means large antennas. The use of purpose designed post detector software algorithms can improve detectability.

Finally, it is possible for an amateur radio astronomer to detect extra-galactic objects. Cygnus A is a very powerful radio source some 600 million light years away and is quite easy to detect. Virgo A, by contrast, is only 53 million light years away but is a much more difficult proposition.

It is hoped that this paper has indicated some of what an amateur observer can achieve and that interested persons will set up a radio telescope - however modest - and explore the fascinating range of radio objects in the sky.

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9 Stanford Chart software

10 http://scienceworld.wolfram.com/astronomy/GalacticCoordinates.html

11 Radio Eyes software *www.radiosky.com*

12 http://imagine.gsfc.nasa.gov/docs/science/know_l1/pulsars.html

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16 *www.radio-astronomy.org/*

17 *www.radio-astronomy.org/pdf/pulsars.pdf*

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[This concludes this three part series]

The man who made maps of the Moon

Poetry corner

- Murray Lachlan Young

Batty eccentric, Gentleman amateur
Clipped English tones, of an era gone by Dottiest 'boffin' and Crusty old Bachelor Pipe in your mouth and a glass in your eye

Terrible golfer, pussycat stroker,
Right-wing and radical, militant stoker
Serving the masses with lunar crevasses
Around for so long, gone away far too soon With an eminent place in our knowledge of space

As the man who made maps of the moon
The moon
As the man who made maps of the moon

You juggled gravity, built an observatory Gave a fried egg as a cosmic analogy Served up the feast well aware of the joke As we stared with you heavenward, viewing the yolk

Heavenly broker, grey matter poker
Martian and minstrel and avid Pipe smoker A voice and a knack with a rat a tat, tat Drilling deep in our minds to the great cosmic tune With dress sense to match, while you lifted the latch

As the man maps who made of the moon
The moon
As the man who made maps of the moon

Memories of empire, thoughts of old England Fade further now, as your atoms disperse In the final great joke of our temporariness And the black hole you left in our own universe
Where do atheists go when they no longer are?

When they pack up their trunk at the end of the show One could paraphrase you when you talked of the stars 'As in so many cases, we simply don't know'

With the feats of: Gagarin and Armstrong and all?
Amplified to the skies in the infinity's thrall?
Yes you stayed for so long but you left far too soon Yet your legacy orbits our own consciousness

In the maps that you made of the moon
The moon
From the man who made maps of the moon

———

Editor's note:

This poem, in tribute to Sir Patrick Moore (4th March 1923 - 10th December 2012), was commissioned by the BBC and to my knowledge first released on air by the author himself. I recall that it was on the “Today” programme, and the author’s wonderfully lyrical voice nicely echoed the third verse of Lear’s “The Owl and the Pussy-Cat” upon which his poem is styled. This was just three days after the great man’s sad death. Note that the punctuation and layout above is exactly as the author has set it down since, I have not modified or corrupted it.

The same poet, by the way, much earlier wrote another fine and wry tribute to a different sort of PM *viz*. Margaret Thatcher, UK’s Prime Minister: *Farewell Maggie*.

For readers wishing to hear the poet himself reading the tribute to Sir Patrick, this is still available from the BBC web page for the *Last Word* programme of 14th December 2012. It is in the middle of this audio record, along with suitable music and *Sky at Night* clips, and that programme also sadly carried that week’s obituaries to such luminaries as Ravi Shankar, surgeon Joseph Murray and engineer Alex Moulton:

http://www.bbc.co.uk/programmes/b01p7hdl

Of course, the great man himself also dabbled with poetry (e.g. *Within the Glade*), but on that it’s perhaps best to depart the subject here !

UKRAA Update

- **Andrew Lutley** andrew@ajlutley.co.uk

UKRAA

The inaugural issue of *RAGazine* (Sep. '14) carried useful background material on UKRAA, and the following is a short update. The next issue will contain several items from UKRAA, including a new product and more news of planned ones.

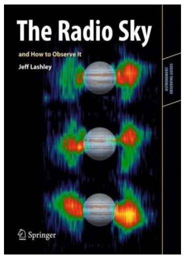
UKRAA (The UK Radio Astronomy Association) is on the lookout for volunteers to join the existing team.

> We have a number of products in development at present including a Multi Frequency VLF Signal Generator, Calibrated Noise Source, Meteor Scatter Aerial, USB Dongle 'Saver', ELF Induction Coil Magnetometer, 12GHz Receiver and a Multi Station VLF Receiver. Some of these are at the concept stage, while others are close to launch, but our resources are thinly stretched. Whatever your availability and skills, we can make use of them ! No radio astronomy expertise is required, just a willingness to lend a hand.

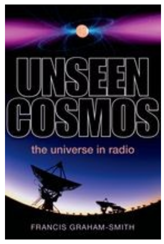
Please contact us at info@ukraa.com for further details. To learn more about UKRAA and its products, go to www.ukraa.com/.

Christmas approaches (yes !) so why not think about a book as gift ? Or stock up right now ready for the darker evenings. UKRAA's bookshop currently lists the following fine titles:

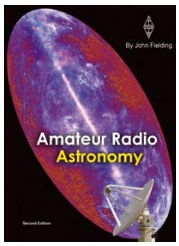
The Radio Sky and How to Observe It - J Lashley



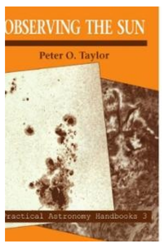
Unseen Cosmos - the universe in Radio - F Graham-Smith



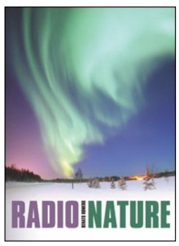
Amateur Radio Astronomy, 2nd Edition - J Fielding (ZS5JF)



Observing the Sun - P O. Taylor



Radio Nature - R Romero, (IK1QF)



Long baseline interferometry with unmatched SDRs

- **Peter W East** pwe@y1pwe.co.uk

[Editor's note: this outline of proposed usage of SDR pairs that are unmatched, for LBI, originally appeared on a Yahoo! posting, but I thought it too good to miss here. And hopefully there will follow some useful discussion of the concept. So - especially for mathematically capable RAGo-nomers - it would be nice, for example, to formally scope the bounds that might be possible. Note that this uses post-processing of data files, where the SDRs are typically 'dongles' and strong sources with low SNRs. This approach contrasts with that of Marko Cebokli (this issue). For Peter's two-part series on using low-cost RTL SDR 'dongles' for HI observing, see the last two issues of *RAGazine.* He solicits comment and suggestions.

And we all wish Peter the very best after his recent operation and some frustrating additional time in hospital and recovery at home.]

Abstract

Long baseline interferometry normally requires frequency locked local oscillators and very high timing accuracy. In this note, a method of measuring interference fringes using SDR dongles having differing tuning frequency accuracies whilst viewing overlapping observation windows is described.

The method requires strong radio sources and uses the source itself to calibrate the SDR receivers: specifically, collecting data files from the antennas pointed at the same source with a few dB signal to noise ratio over roughly the same time window. These data files are processed post data collection; firstly cross-correlated to determine the timing offset, then spectrally correlated using an FFT to determine the second SDR frequency offset. The offset can be corrected by a cyclic shift of one FFT; its Fourier inverse is then phase compared to the original reference data to recover the source phase and derive the interferometer phase difference vector from which interference fringes can be derived.

The Method

Using the Osmocom SDR software, collect data files from two displaced antenna/receiving systems that are observing the same strong source. The data observation windows should be timed to overlap as best as possible, say to within 1second.

The processing sequence steps are:

1. Cross correlate the two overlapping SDR amplitude files to determine the timing error.
2. Correct the timing offset, truncate and align data to ensure timing synchronism.
3. Fourier transform time synchronised sections from the two files and cross correlate to determine any frequency offset.
4. Cyclically rotate the FFT bins of one channel data to adjust for the frequency offset found in 3 above.
5. Inverse FFT the rotated result to obtain the second channel's frequency corrected, sampled data file.
6. Trim the data file phase to remove residual frequency error due to coarse binning correction of

step 4.
7. Phase compare this file with the reference antenna data file section.
8. Vector sum result across the operating band.
9. Repeat the process for further windows to observe fringes/phase rotation as the source traverses the interferometer aperture. Monitoring either the real or imaginary components shows interference fringes.

The sequence is shown in Figure 1.

Some results of a modelling exercise with real HI line raw data input is shown in Fig. 2.

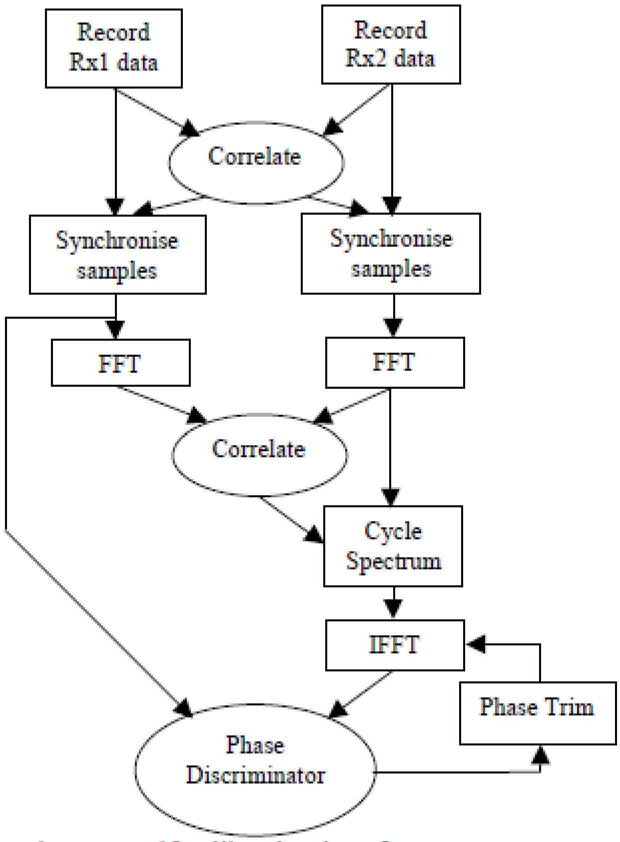


Figure 1 Self calibrating interferometry

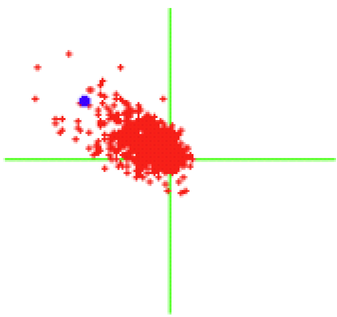


Figure 2 Phase discriminator output vector;
red - sample-by-sample;
blue - block average
Model using H-Line data with Ta/Tsys = 6dB

Diurnal variation of VLF signals

- **Richard Kaye** rwkaye@gmail.com

1 Introduction

Like a number of amateurs in radio instruments, physics and applied mathematics, I have been recording VLF signal strength using a home-made loop antenna, amplifier, and a computer sound-card. Having obtained a number of days data, it seemed to be an interesting exercise to fit the theoretically predicted $\log\sec$ variation with zenith angle of the reflection layer height in the ionosphere D-layer. This short papers attempts just that.

I am no expert in radio astronomy, or radio engineering, or even of the physics involved, though I do have some background knowledge and expertise in mathematics and programming. So much of this short paper explains some of the theory I have learnt in the process of doing this work. I don't claim anything particularly new here, but some of the techniques I use may be of interest and my explanations of the background theory and description of the investigation here may be of interest to other VLF amateurs. There *is* mathematics here, at the upper end of the current A-level standard, including some simple differential equations, but hopefully the presentation will be straightforward enough for readers at this level. It is quite reassuring that some quite significant results on the ionosphere and VLF needs nothing more complicated than this.

2 The theory

The $\log\sec$ variation of the height of the reflection layer is due to Chapman [1]. In the form needed for this work, the theory is very straightforward and accessible to anyone with a knowledge of simple differential equations. I have learnt this theory from reading Ratcliffe [5] though no doubt many other texts are available. The following is a slightly simplified account that gives the results needed.

The first stage (prior to applying Chapman's theory of the production layer) is to understand the height variation of concentration of particles (atoms, molecules, ions) in the atmosphere.

Let h denote height (in m) above some reference level (for convenience, the Earth's surface) and $n = n(h)$ the concentration (in $\mathrm{Mol\,m^{-3}}$) of some species of molecule relevant to a particular ionisation process, such as NO. If each molecule has mass m and $g = g(h)$ is the acceleration due to gravity then the force downwards due to gravity on the molecules in the unit volume is nmg. This is balanced by the difference in pressure p between the top and bottom of the volume so that

$$\frac{\mathrm{d}p}{\mathrm{d}h} = -nmg. \tag{1}$$

Pressure is given by $p = nkT$ where k is Boltzmann's constant and $T = T(h)$ is temperature in K, so

$$\frac{\mathrm{d}}{\mathrm{d}h}(nkT) = -nmg. \tag{2}$$

Now for the range of heights to be taken here that are relevant to the lower ionosphere, h ranging from around 60 to 95 km, and compared to the radius of the Earth of 6371 km, both g and T may be assumed to be more or less constant. Thus

$$\frac{1}{n}\frac{\mathrm{d}n}{\mathrm{d}h} = -\frac{mg}{kT}. \tag{3}$$

We set $H = kT/mg$ (ideally with values of g and T at or near those at the D-layer) and call H the *scale height* or *distribution height* of the species represented by n. The solution of the differential equation above is

$$n = n_0 \mathrm{e}^{-h/H} \tag{4}$$

where n_0 is a constant representing the value of n at the reference height $h = 0$. In other words, concentration n is theoretically an inverse exponential distribution with constant H.

For readers unfamiliar with this and unclear on the significance of H, this distribution is somewhat similar to the familiar distribution in time of the number $N_0 2^{-t/t_0}$ of atoms of a radioactive element undergoing decay. The constant t_0 (a length of time) is the *half-life* of the the element, and waiting one half-life results in halving the number of atoms. Similarly, the scale height H is the height one must travel upwards to decrease n by a factor of $\mathrm{e} = 2.71828\ldots$. For the D-layer it is typically about 5 km, as we shall see.

The next stage is to imagine ionising radiation being applied from above, i.e. from the sun. The sun, we shall assume, is at an angle χ from the zenith, i.e. $\chi = 0$ corresponds to the sun being directly overhead and $\chi = 90°$ it being on the horizon. Just as it was the case that not all air molecules are relevant for ionisation of the D-layer, so it is that not all frequencies are relevant here either. We will assume that a band of frequencies are responsible for ionisation, and the power flux from the sun in this band is I_∞, measured in $\mathrm{W\,m^{-2}}$, so if an area of one square metre were mapped out in space on a plane perpendicular to solar rays, in one second I_∞ Joules of energy in the relevant band would pass though this area. As should be clear, if the plane were not perpendicular to the solar rays the effective area available is less and less energy would pass though it. In fact if the solar radiation were at an angle χ to the plane's perpendicular then $I_\infty \sec\chi$ Joules of energy would pass through the plane, where $\sec\chi = 1/\cos\chi$, and again $\chi = 0$ refers to the rays being exactly perpendicular i.e. directly above.

The sun's energy is absorbed by the atmosphere, and the amount it is absorbed by is proportional to n—the constant of proportionality (called the 'absorption cross-section') will be denoted σ. So the ionisation radiation I varies with height h and as it passes through each unit of volume is decreased by $\sigma n I \sec\chi$. Thus the differential equation for I is

$$\frac{dI}{dh} = \sigma n I \sec\chi \tag{5}$$

(Some care is needed to get the sign right here, but the above is correct since the ionisation energy is coming from above and is absorbed in the atmosphere, so I is decreasing as h decreases.) Our previous equation (4) can be substituted in here and the equation rearranged to give,

$$\frac{1}{I}\frac{dI}{dh} = \sigma n_0 \sec\chi\, e^{-h/H} \tag{6}$$

which when solved gives

$$\log(I/I_\infty) = -H\sigma n_0 \sec\chi\, e^{-h/H}, \tag{7}$$

log being natural logarithm to base e, or

$$I = I_\infty \exp(-H\sigma n_0 \sec\chi\, e^{-h/H}). \tag{8}$$

The energy absorbed by the atmosphere doesn't disappear but goes somewhere: it is either converted to heat or used to ionise the atmosphere. Thus the production rate q of electrons (or other charged particles that can reflect radio waves) is proportional to the amount of energy $\sigma n I \sec\chi$ absorbed. Letting C denote the constant of proportionality, we have

$$q = C\sigma n I \sec\chi \tag{9}$$

or

$$q = C\sigma n_0 e^{-h/H} \sec\chi\, I_\infty \exp(-H\sigma n_0 \sec\chi\, e^{-h/H}). \tag{10}$$

To complete the story, the electrons produced in this way either diffuse to a different height or recombine with other molecules in the air according to one of a number of possible reactions. More details on this are not needed here. What we need to observe here is that the height h_m of the reflecting layer corresponds to the position of greatest rate of electron production. (The reason why this is the right condition is slightly complicated, but my understanding is that it is because the rate of electron recombination is proportional to the concentration of electrons and to the concentration of particles with which they can combine with. It is these simple proportionalities that ensure that the place of greatest change of electron concentration is the same as the place of greatest electron production.) Thus to find the height h_m of the reflecting layer we find the height where q is maximum, and the simple technique of differentiating q and setting the derivative equal to zero is used. The derivative of q is obtained by the chain and product rules (noting the double exponential in h) and $dq/dh = 0$ simplifies to

$$-\frac{1}{H}+\sigma n_0 \sec\chi\, \mathrm{e}^{-h_m/H}=0 \tag{11}$$

or

$$h_m = H\log(H\sigma n_0 \sec\chi) = H\log(H\sigma n_0) + H\log\sec\chi \tag{12}$$

which is the equation alluded to in the introduction. Notice that this is of the form $h_m = A + H\log\sec\chi$ where H is the scale height, a value of some physical importance. The constant $A = H\log(H\sigma n_0)$ represents the height the reflecting layer would have been at, given steady conditions with the same radiation energy but with the sun exactly overhead.

Of course, a VLF receiver does not measure the height of the reflecting layer directly, but this height can sometimes be inferred from measurements. The varying strength of a signal is an indication of an interference between different paths of propagation. Normally, there are many different paths, but for signals from nearby transmitters we can reasonably model the process as being the interference effects between a ground-wave and a bounced sky-wave. This part of the modelling process is essentially just one of geometry without any calculus. The details have no doubt been worked out many times, I summarise the results here, and Mark Edwards [2] gives more detail and additional explanations should they be required.

Given that the ground-wave travels a distance D along the curved surface of the earth and the sky-wave travels a distance L, the phase difference between them (in radians) is

$$\phi = 2\pi(L-D)f/c+\pi \tag{13}$$

where f is the frequency of the transmission (in Hz), c is the speed of light and the additional π is due to a phase change on reflection. By geometry and the cosine rule, the distance L is related to D, h_m and R (the radius of the Earth) by

$$L = 2\sqrt{R^2+(h_m+R)^2-2R(h_m+R)\cos(D/2R)} \tag{14}$$

and the power P of the received wave is proportional to

$$G^2+S^2+2GS\cos\phi \tag{15}$$

where G is the amplitude of the ground wave and S the amplitude of the sky-wave.

3 The practice

The proposal is to look at the variation of the received power over the course of a quiet day, for a nearby transmitter and see how well the observed data for the theoretical pattern described here. Note that there are four unknown variables in the theory: the scale height H, the quantity $H\log(H\sigma n_0)$ representing the height of the reflecting layer at $\chi = 0$, and the amplitudes of the ground and sky-waves.

Thus we want to fit

$$
\begin{aligned}
\text{power} &= Q + 2P\cos\phi & (16)\\
\phi &= 2\pi(L-D)f/c + \pi & (17)\\
L &= 2\sqrt{R^2 + (h_m+R)^2 - 2R(h_m+R)\cos(D/2R)} & (18)\\
h_m &= A + H\log\sec\chi & (19)\\
\chi &= \text{sun's zenith angle at midpoint} & (20)
\end{aligned}
$$

to our data, where $Q = G^2 + S^2$ and $P = GS$ in (15). I used a downloadable algorithm for the sun's zenith angle[1] and readily available data on the position of the transmitter—and hence derived the longitude and latitude of the midpoint. Thus the unknowns are Q, P, A, H only.

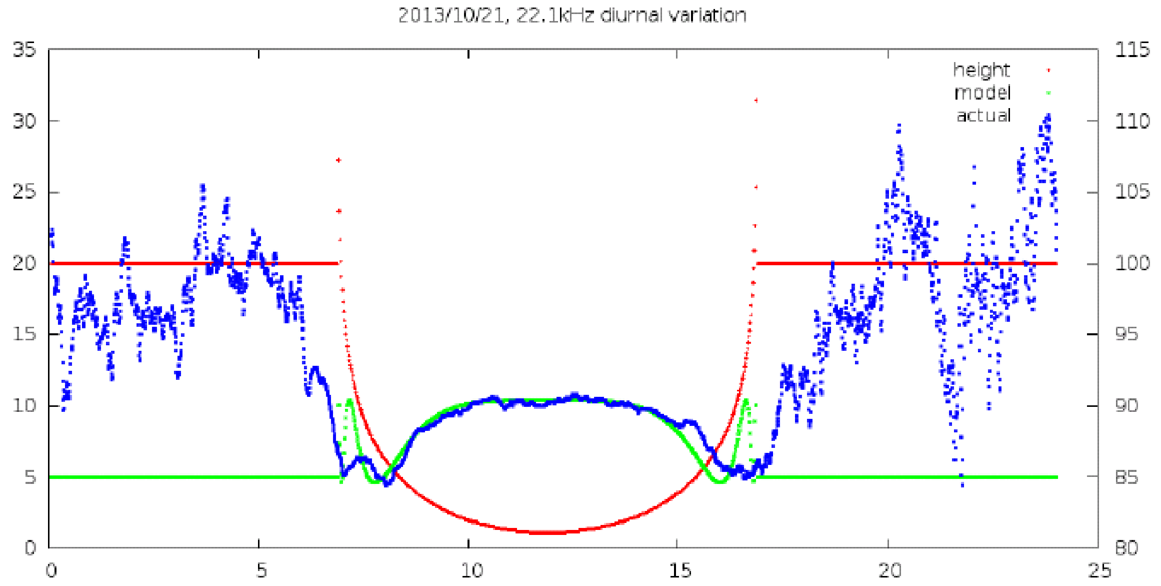
In any curve fitting algorithm, having initial estimates for the unknown values being sought is very useful indeed. In this case the constants can be given rough estimates quite quickly: H is known to be about 8 km at ground level, independent of the species involved [5, page 5]; the height of the reflecting layer is nominally around 90 km; and the quantities $Q = G^2 + S^2$ and $2P = 4GS$ can be estimated quickly from the VLF measurements, as follows. In the daytime, excluding some complicated sunrise/sunset effects which are due to more complicated geometry of a spherical Earth and different propagation paths, the measured signal varies from a minimum at $\phi = 2N\pi - \pi/2$ to a maximum at $\phi = 2N\pi + \pi/2$ (for some integer N which cannot be directly estimated) and thus from (15) the difference between this maximum and minimum is about $4GS$. The quantity $G^2 + S^2$ is then the value exactly halfway between this maximum and minimum.

Even with these initial guesses for the parameters involved, I do not have an ideal curve-fitting algorithm. The main problem is that rather different height estimates sometimes record a 'good fit' simply because the $\cos\phi$ function in (16) is periodic and differing values of ϕ do indeed give reasonably good fits. To say this in another way, it is not really possible to obtain the height h_m from the measured phase information as the mapping from h_m to ϕ is many-to-one. A second problem is the possible occurrence of SIDs—periods when the data do not fit the usual quiet diurnal pattern.

As a compromise, my experimental algorithm discounts a certain percentage of the data (say 10%, though this parameter can be varied). The measure of 'fit' is the sum of the $(v_{\text{measured}} - v_{\text{predicted}})^2$ for all but the 10% greatest values of this quantity. (These squared differences are stored in a heap so that the best 90% can be extracted quickly.) Rather than risking a 'clever' algorithm rapidly settling on a 'bad' value of h_m, I test many values of A, H differing by only a small amount in succession before selecting the 'best' and then refining this value in a similar way. But as it turns out, the curve fitting is relatively stable in the other two parameters S, P so that it is possible to find reasonably good values for A, H using the initial estimates for S, P, using these values to refine the estimates for S, P, and then using these values to refine the values for A, H. Exactly how often this process should continue and in what order and with what step size is still very much open for experiment, but as can be seen, reasonably good fits can indeed be obtained.

[1] From `http://www.psa.es/sdg/sunpos.htm`

In the month of October 2013, the 21st was a comparatively 'quiet' day and will be used to illustrate these methods. The signal from Skelton, UK, on 22.1kHz is the strongest nearby signal at my location, being about 263km distant. I entered the co-ordinates of the midpoint and the distance to the transmitter and started to fit the data. This was the result.



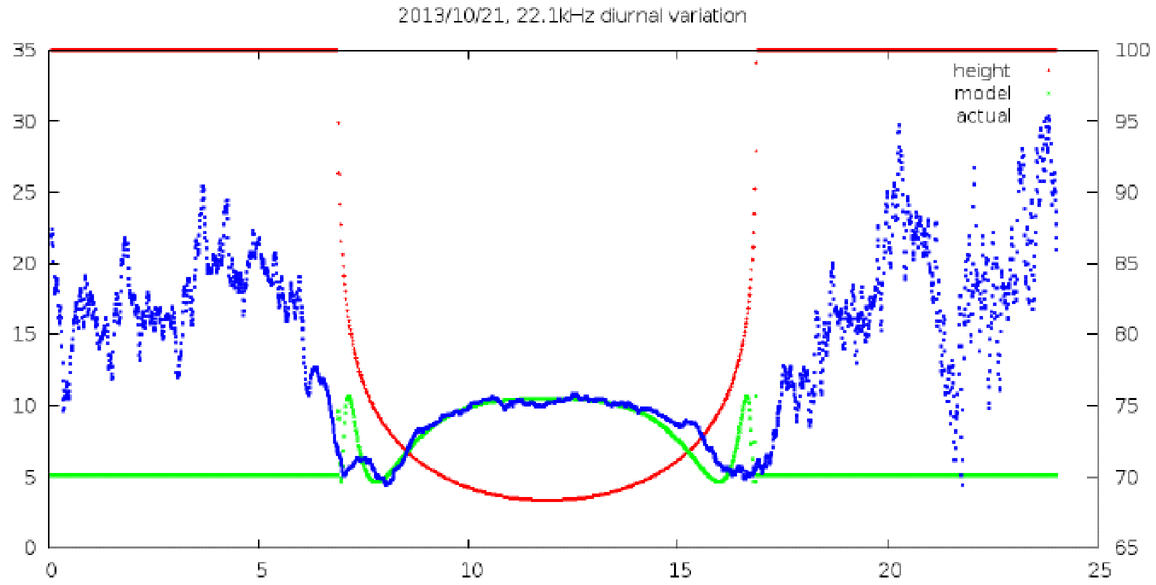
The blue line shows the actual measured values. The red line shows the model's value for the height of the reflecting layer—which is only defined for $0 \leq \chi < 90^\circ$ since $\sec\chi$ approaches infinity near sunset. (Outside this region I arbitrarily set it to 100km.) The green line shows the fitted curve.

The fit seems reasonably good, though not by any means perfect. The values the fit took for the height of the reflecting layer at various times and for A, H in (19) above were $A = 76.84$ and $H = 5.06$. These values seem encouraging, especially as they were chosen from the fitting algorithm over a range of plus or minus 20% and we read

> For VLF waves incident on the ionosphere at steep incidence, the reflection height, h, appears to vary as $h_0 + H \ln\sec\chi$ where χ is the solar zenith angle. h_0 is about 72 km, and H is about 5 km, which happens to be the scale height of the neutral gas in the mesosphere.

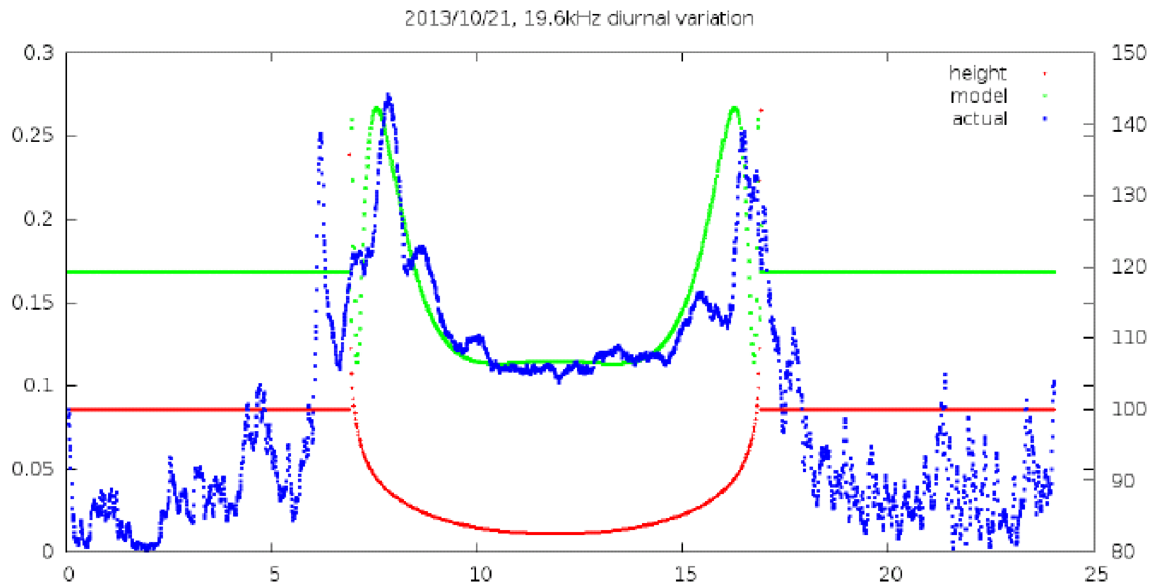
(from Hunsucker and J. K. Hargreaves [4, page 35]).

Unfortunately, one worry is that (as already mentioned) quite different values for the height parameter also fit quite well through using a different period in the $\cos\phi$ function. For example, the following fit



was found with parameters $A = 64.06$ and $H = 5.12$ showing that value obtained by the fit for A is not particularly robust. Similarly values for H from reasonable looking fits were found ranging from 5 to 6.

One possible approach is to look at a number of different signals and compare them. For example, this is the nearby Anthorn signal on 19.6kHz on the same day.



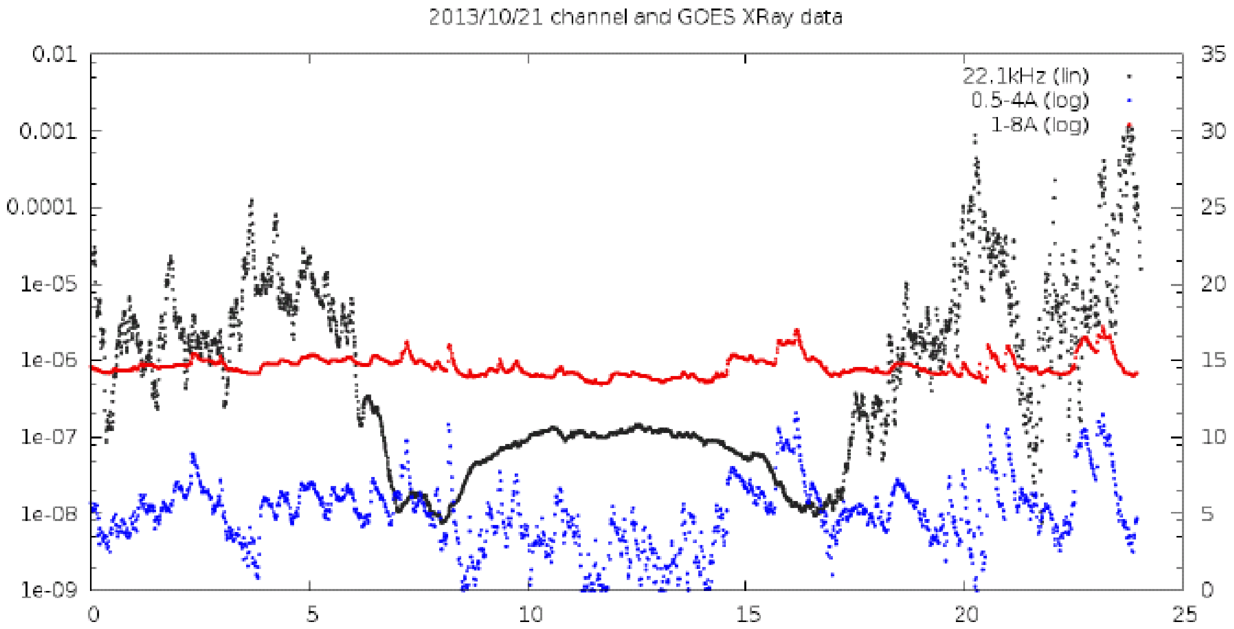
The fit here had $A = 78.23$ and $H = 5.06$. This suggests that these parameters are in the right sort of 'ballpark', but the evidence isn't particularly convincing.

Mark Edwards has pointed out (especially in his presentation to the BAA Radio group in 2011) that the *combination* of these two signals from two transmitters very close together can *together* give an accurate fix on the height of the reflecting D-layer, because they are operating at different frequencies and it so happens that at his location the result is that the daytime signals from these two locations appear almost a mirror image of each other. What's more, the reflection points for the sky-waves for these two transmissions are very close to each other so it is reasonable to assume that the D-layer height is the same in both cases. In this context the simultaneous fit of the log sec model to these data may be only feasible for A around 77 or 78 and H about 5. This is a very sensible suggestion and well worth undertaking where feasible, but in general this will depend on specific local circumstances (such as the availability of suitable nearby transmissions and the distance to the transmitters and frequency of these transmissions). In general, the hope is that an intelligent examination of all the various possible heights in the case of two or more separate transmissions will rule out all but the correct D-layer height, especially if the reflection points in question are very close together. There is obviously more work to be done here.

In both cases, the fit is noticeably not so good near sunrise and sunset, particularly near sunset. Of course one cannot expect a perfect fit near these limits, because for example the model predicts an infinite height at sunrise/sunset, whereas in fact the curvature of the Earth has effects that are not taken into account by the model (such as the possibility that, at 90km above the ground, the ionosphere is radiated by solar radiation even when χ is greater than 90°). Also, other propagation paths come into effect at such extremes, and other mechanisms ionising mechanisms (such as cosmic rays) will become more significant at such times. Some indications that different mechanisms are at play are already evident in the multiple peak structure in the sunrise/sunset pattern for 19.6kHz, which (since the peaks are not at the maximum) cannot be predicted by the simple Chapman model with a single ionising source, and perhaps suggests evidence for more than one source of ionisation. This could be investigated further. Possible improvements to the model include: (a) reworking it for a spherical Earth; (b) incorporating any tilt of the D-layer into the calculations, since there is no particular reason why the D-layer will always be horizontal, especially at sunset and sunrise; and (c) investigating other ray paths. For (c), Edwards [3] reports improvements when an additional double bounce model is added.

Irrespective of the situation at sunrise, the shape of the measured and modelled curves are rather different at sunset, though a casual look at the data prior to making these attempts at fitting the model to them did not suggest there might be a problem. A little investigation explains why.

The next graphic shows the same raw data alongside GOES satellite measurements of X-ray solar flux.



One sees there was enhanced solar X-ray activity from 15:00UT onwards, and particularly from 15:40UT. At its maximum (at 16:12UT) this was at the C2.7 level, which is often small enough to be neglected (especially near sunrise and sunset), and in this case not sharp enough to be an obvious 'flare' creating a peak in the VLF trace. It seems highly likely that the lack of 'fit' at this time and the enhanced solar X-ray activity are related. Indeed this seems to the main value for this technique: that comparing measured data with the model, the places where the measured data does not fit are more obvious and these often will reflect some interesting phenomena going on—in this case a minor X-ray induced ionospheric disturbance—that might have been easy to miss otherwise. Or to put it another way, such analyses have the potential to dramatically enhance the sensitivity of the measurements without changing the hardware in any way.

4 Conclusions

Fitting the Chapman model of diurnal variation can be done, and often seems successful except very close to the points of sunrise and sunset where the model (at least in the form given here) is not meaningful. However drawing conclusions from the model fitting has its difficulties, mainly because the mathematical mapping of reflection layer height (as predicted by the model) to phase difference (as measured) is many-to-one, hence different heights can result in fits that are or appear to be just as good. Any further experiments that exploit this model to obtain measurements of (for example) the scale height will have to resolve this problem and make very clear why the values for heights chosen are indeed the correct ones.

Nevertheless, even if the actual numerical values obtained from the process are not believed, the technique can provide a source of evidence for ionospheric disturbances measured from VLF data near sunrise or sunset when no obvious traditional 'SID pattern' is present in the data. In other words, these techniques can in principle be used to dramatically increase the sensitivity of a SID detector especially near sunrise/sunset.

References

[1] Sydney Chapman. The absorption and dissociative or ionizing effect of monochromatic radiation on a rotating earth. *Proceedings of the Physical Society*, 43:26–45, 1931.

[2] Mark Edwards. Modelling the ionosphere. British Astronomical Association, `http://www.britastro.org/radio/downloads/%linebreak[0]ModellingSIDs.pdf`, accessed 26-Jul-2013, 2010.

[3] Mark Edwards. Modelling the ionosphere - part 2. British Astronomical Association, `http://www.britastro.org/radio/downloads/%linebreak[0]ModellingIonosphere2.pdf`, accessed 25-Nov-2013, 2011.

[4] R. D. Hunsucker and J. K. Hargreaves. *The high-latitude ionosphere and its effects on radio propagation*. Cambridge University Press, 2002.

[5] J. A. Ratcliffe. *An introduction to the ionosphere and magnetosphere*. Cambridge University Press, 1972.

Hydrogen Line Observing Group (HLOG): an update

- **Brian Coleman** brian-coleman@tiscali.co.uk

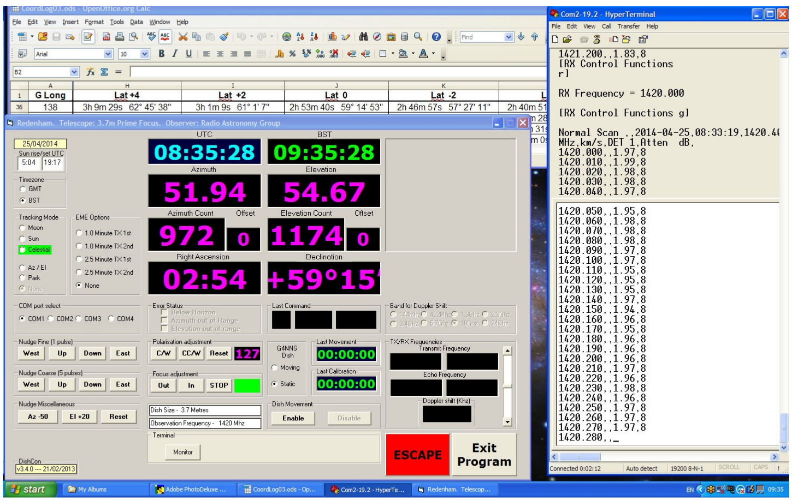
HLOG

The Hydrogen Line Observing group was set up to give interested participants the opportunity to do some practical radio astronomy using my 3.7m Telescope at Redenham and to encourage participants to use the data collected for their own astronomy projects.

We have started with a systematic survey of Hydrogen along the galactic equator and a few degrees of galactic latitude above and below the equator, examining the spectra to capture as much of the structure of the observable part of the galaxy as we can, with limited observing time.

The Telescope and its receiver is largely home made and uses quite a large proportion of surplus components. The receiver is of conventional double conversion design ending in an AM detector with a 15 kHz bandwidth. The receiver is scanned by varying the first local oscillator, a programmable crystal oscillator. The local oscillator and detector are controlled by a PIC which provides overall control of the receiver and logs the data via an RS232 Port. Data is then copied from the terminal program and pasted into spread sheets to record the data and display the spectra. All rather old fashioned compared to SDR, but I understand it !

Tracking is controlled by a program developed for both Earth-Moon-Earth communications ('moon bounce') and astronomy, written in Visual Basic by Robin Lucas (G8APZ).



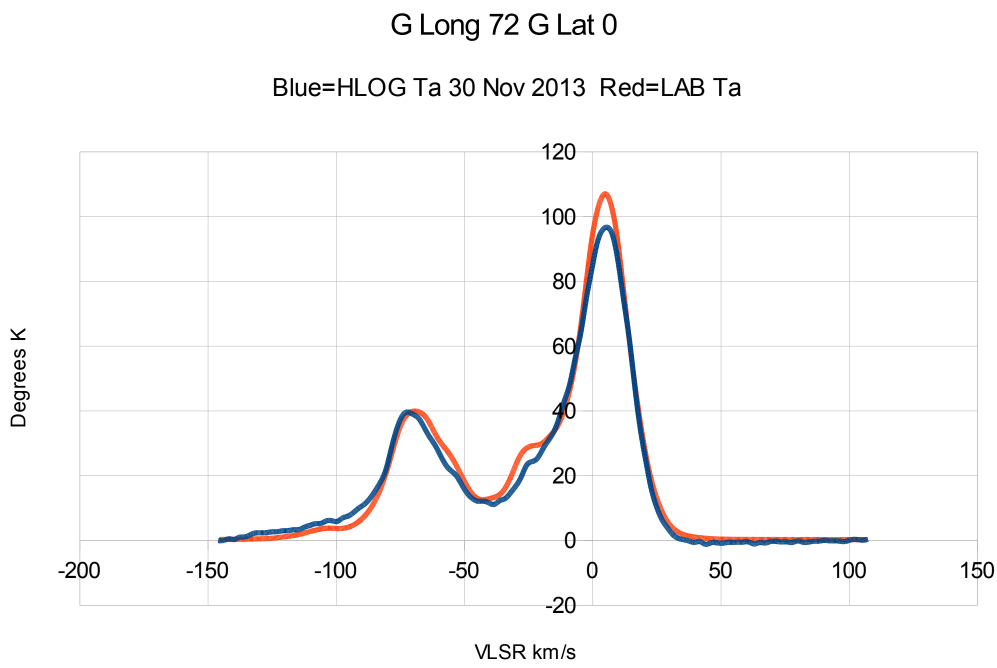
The 3.7m dish is deliberately under illuminated, using a dual mode feed to the W2IMU design. This means the beam width increases to 5 degrees but the G/T is better than with a conventional scalar feed. G/T stands for Gain over Temperature and is a useful indicator of system quality. The calculated gain is 1799 and Tsys is 47.2K giving a G/T of 38.

Using a G4DDK VLNA, followed by a Kuhne Electronics down converter, Tsys is 47.2K according to the maths (VK3UM's EME Calc., Ref 1) and this is born out by Sun noise measurements: Sun Y > 16dB with a quiet sun. (Being a bit of a pessimist I use TSys=50K for the calculation of antenna temperature Ta).

To enable and encourage participation in the observations a single computer runs the tracking, receiver control / data logging and the spread-sheet software (OpenOffice) which also maintains the Observation Log. This computer also provides remote access and control via *GoToMeeting*. Having prepared the system for an observing session this allows the observatory manager (that's me) to pass control to a remote user to make their observations. In the interest of minimising the time required for each observation we currently scan just 1.2MHz, around the expected spectral peaks. We scan in 10KHz steps and with an integration time of 3 seconds. This means that each individual pixel takes about 8 minutes to scan but provides some 120 data points. All these parameters can be changed via software.

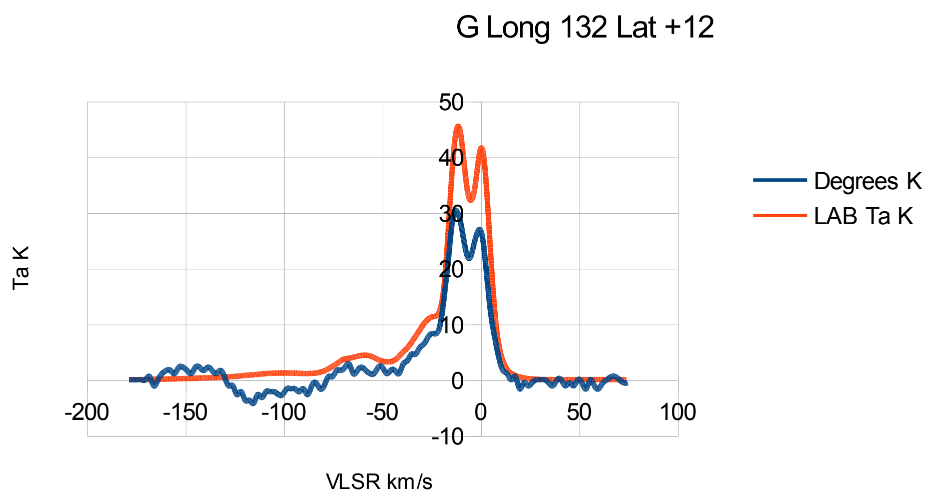
Using this system 10 members of the group have so far completed observations from Galactic Longitude 20 to 134 and 160 to 180 in two degree steps and at latitudes between +8 and -8 also in 2 degree steps, a total of around 500 individual observations. Each observation, with set up time, has taken about 10 minutes. To capture as much of the structure of the hydrogen in the galaxy as possible we have extended the range of latitudes observed as the project has progressed. The receiver logs detector voltage against frequency and the spread-sheet converts the voltage to Antenna Temperature (Ta) and the frequency to Topocentric velocity using the Doppler equation and the rest frequency of Hydrogen. Later we convert the velocity to VLSR using Ed Murphy's calculator (Ref 3). When the data for each observation is entered into the spread-sheet, Ta is plotted against Velocity to display the spectra. We now add comments on the met. conditions to asses their effects. This almost immediate display of the spectra enables the observer to asses the quality of the observation by spotting interference. Fortunately problems with interference are not frequent.

We have compared some of our results with other observations including the LAB survey (Ref 2) and correlation is quite good although we do see some differences which we are studying in more detail as time permits. We now need to go through our data carefully checking against these and other sources. This winter's bad weather may have caused some observations to be of poor quality and we need to identify these and, where necessary, make repeat observations.



This plot shows the HLOG spectra in blue with the predicted spectra from LAB in red.

Realistically our minimum observable Ta appears to be between 5 and 10K, so anything less than that we regard as noise.



Above is an example of a scan 12 degrees above the galactic equator where the low level of radiation means that the receiver is operating close to its limit. Hence the noisy trace. Also, at the HF (-ve VLSR, Blue shifted) end of the trace, there may have been some noise or interference such as ground noise perhaps because the telescope tracked too close to the horizon. This creates an error in the base line calculation.

We are keen that others use our data for their own projects and share these with the group. Perhaps there are RAG members who are skilled at using available software visualisation tools and would like to learn how to apply them to a project such as this.

My own contribution to this project is very much limited to the hardware and observing operation and I had always hoped that others, with IT skills as well as an interest in Astronomy, would join the group and develop and use our data.

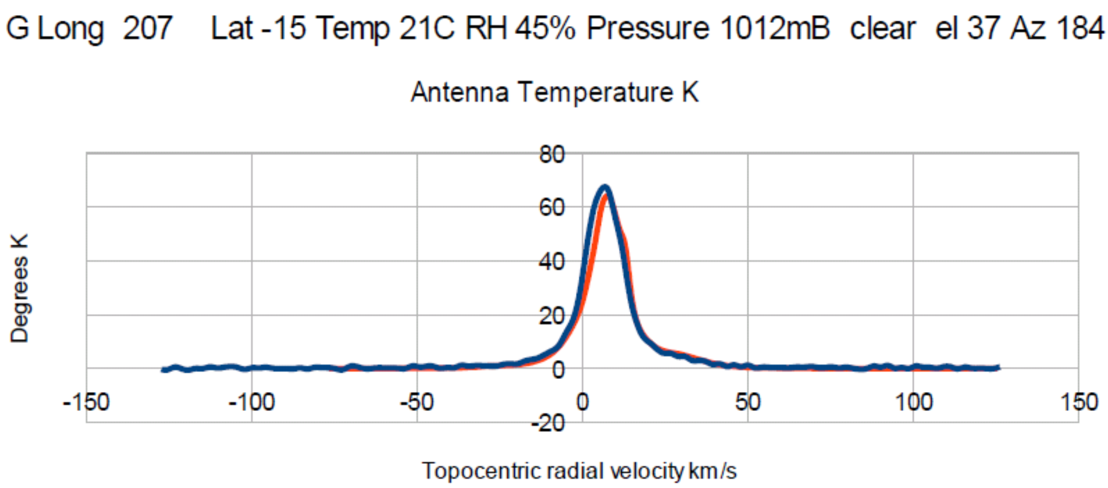
So we are keen to expand the group with participants who can contribute to the project by helping with checking the quality of the data, formatting the data for wider use, perhaps for StarBase, and use the data for visualisation projects.

Whilst observing time is somewhat limited, due to my other commitments, I would be pleased to set up some observing sessions so that new members of the group can get some first hand experience with the telescope.

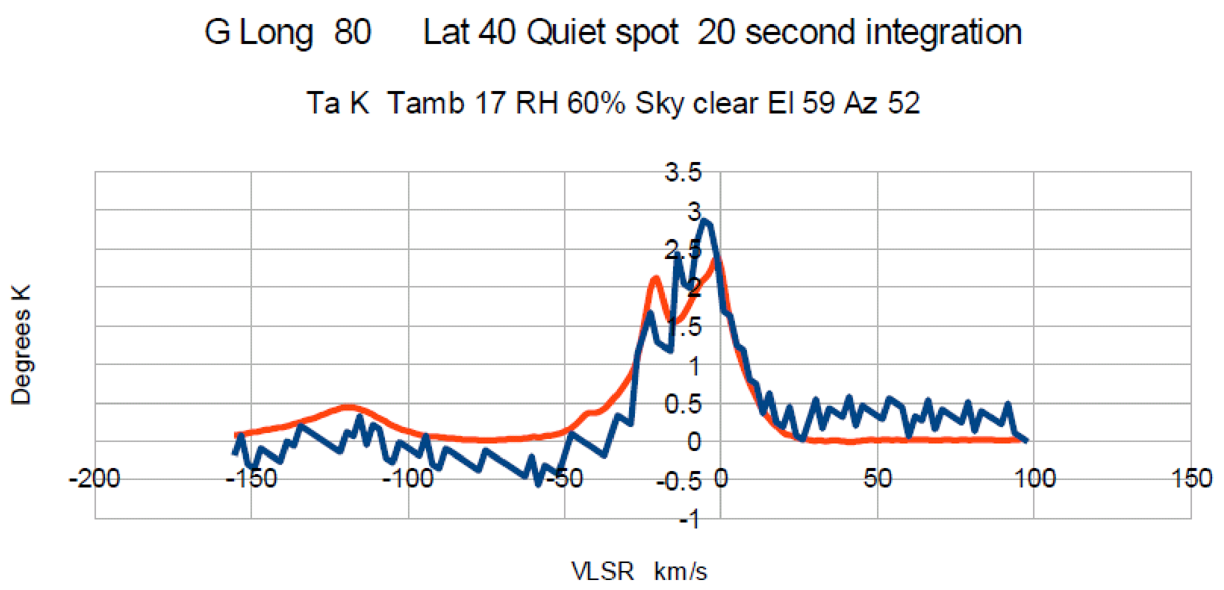
More recent update

Prof P Wilkinson (Jodrell) has been helping in the Group's study of the effects of meteorological conditions on the measurement of antenna temperature, and this study is likely to take several months in order to cover a range of different weather conditions to generate sufficient data.

This study takes advantage of known calibration data for S7, S8 in particular (Ref. 4). As illustration, the figure below is an example of such an observation where our (HLOG) peak was 66K and the LAB prediction (in red) was 64K (S8).



Ref 4 also listed a Low Brightness target which seemed to be interesting on two counts. Firstly it could be used to demonstrate our low Temp resolution. Secondly, this is in a direction in which there can be very little hydrogen in our local galactic arm. This points to where the solar system is in the cross section of the local arm. The following is an example of a Quiet spot observation. It seems remarkable that we can see such low temperatures.



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Ref 1 Doug McArthur. www.VK3UM.com .

Ref 2 LAB Survey:
Kalberla, P.M.W., Burton, W.B., Hartmann, Dap, Arnal, E.M., Bajaja, E., Morras, R., & Pöppel, W.G.L. (2005), A&A, 440, 775 (http://adsabs.harvard.edu/abs/2005A%26A...440..775K)

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• Arnal, E. M., Bajaja, E., Larrarte, J. J., Morras, R., & Pöppel, W. G. L. 2000, A&AS, 142, 35

Observers were Dap Hartmann and W.B. Burton (Leiden University) for the Dwingeloo telescope, and E.M. Arnal, E. Bajaja, J.J. Larrarte, R. Morras, and W.G.L. Pöppel (Argentine Institute for Radio Astronomy) for the Villa Elisa telescope. Correction for stray radiation and combination of the data by P.M.W. Kalberla (Bonn University).

Ref 3 Ed Murphy's VLSR calculator http://fuse.pha.jhu.edu/support/tools/vlsr.html

Ref 4 Brightness temperature calibration for 21-cm line observations: Kalberla, P. M. W.; Mebold, U.; Reif., *Astronomy and Astrophysics*, vol. 106, no. 2, Feb. 1982, p. 190-196

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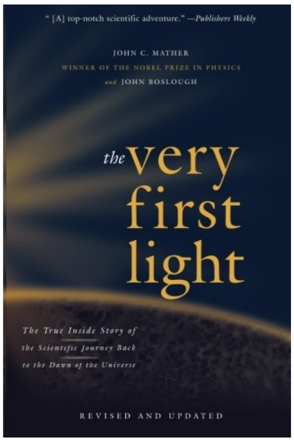
[Editor's note: This update doubtless out of date. Sincere apologies to the author for the delay.]

"The Very First Light" by J Boslough & J C Mather: Book Review

- Dave James dave@greenover.net

Books



The Very First Light:
The True Inside Story of the Scientific Journey Back to the Dawn of the Universe
by J Boslough & J C Mather

Basic Books
384 pp., paperback, ~£15
2008

The edition reviewed here is the latest (2008) edition, which is significantly extended as compared to the original 1996 edition. I am not sure if it is possible to buy the current edition in hardback, but the first edition was in this format - and there are plenty of second hand copies of that.

First, of course, John Mather shared the Nobel Prize in Physics for his scientific leadership of the huge COBE project . This was a NASA project, and some have understandably argued that it has been the agency's finest. Boslough is an admired science writer, with books that include *Stephen Hawking's Universe* and *Masters of Time: Cosmology at the End of Innocence.* One might think that this 'ghosting' double act would show the seams between the two authors' styles, but for the most part this is not so. The style is consistent, easily digested and the story is very long, exhausting, frustrating, exhilarating, amusing, and then despairing, convoluted, tiring, exciting …. It was a real roller-coaster ride - but importantly under sustained, very fine leadership. Mather - who gave a fine presentation recently at the SARA annual conference at NRAO, the second of two Nobel prize-winners in any as many days, the other being Joe Taylor !) - is currently responsible for the overall technical leadership of the James Webb telescope, too.

Well, what was it all about, if you have not been following COBE from the early days ? (I have so, fascinated for years because my previous work touched on may of the space techniques and technologies used.) First, the name is pronounced "co-bee" for Cosmic Background Explorer, and the whole programme cost near $0.4B. The spacecraft was finally launched from Vandenberg in 1989 by a Delta rocket. The seeds of the overall idea were sown by Wilson and Penzias of bell Labs with their 1964 discovery of the CMB - for which they were awarded the Nobel Prize. After this Mather and others try to gain greater precision on this radiation (~3K), including the use of high altitude balloons. In 1974 Mather proposed a design for what some two decades later became the launched COBE craft. Three experimental packages were outlined and remained the heart of the craft right to the end (when the cryostats and fuel ran out).

It is an extraordinary story, involving some 1,800 engineers and scientist in all (They are listed at the back). Often over-looked is the fact that the Shuttle was to launch the craft, but that was shelved after the several major disasters so that the whole thing was shoe-horned into the Delta fairing against almost impossible odds and timescales. There are all the common aspects on major hi-tech. complex projects: money, politics, bureaucracy, accidents, new fabrication techniques, hubris, personnel clashes, skunk works, family stresses and huge workloads, and so on. The coverage is quite detailed up to a point. If you are seeking the fullest technical description, though, you will be regularly slightly disappointed. But despite the blurb, I would say this would be a little hard for the non-technical layman to follow. For readers of *RAGazine*, this book should be very appealing, and has almost the pace of a thriller, it's far from dry and fusty. There are plenty of amusing and amazing vignettes of some of the key players, and the issue of the senior team member who broke ranks to prematurely step into the media limelight at one point and spill the beans is very well and fairly described.

One key instrument on board the spacecraft was the DMR (Differential Microwave Radiometer) - basically an ultra-sensitive, precision Dicke switched scheme that most amateurs will be familiar with. One of the other two was the FIRAS (Far Infrared Absolute Spectrophotometer). The FIRAS data provided 'nearly perfect' spectrum detected, and the DMR provided the crucial measurement of the anisotropy in the CBR. Just two years after launch there had been near 900 professional papers published that were directly related to or based on the COBE data.

It was all about nothing less than confirming the Big Bang theory and determining the precise circumstances just after the period of inflation (10^{-43} secs after the Big Bang up to only 3×10^5 years after. In 1992 when the NASA team announced to the world's media that the minute variations in the microwave background radiation had been precisely measured, the astrophysics and cosmological community applauded the achievement, and Stephen Hawking was moved to pronounce: "Its is the discovery of the century, if not of all time" ! A little later, 1993, Mather announced that the latest data revealed that >99.97 % of the early radiant energy of the universe (assuming there is just the one !) was released within the first year after the Big Bang. It became more and more certain that there were not many "little Bangs" or after-shocks that followed, too. And the data analysis continues world wide…..

This is a well written book, a valuable and detailed record of a wonderful project that drew the very best talent available to exploit extraordinary engineering to brilliantly accomplish an important scientific achievement. Highly recommended.

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SIDI, the Simple Digital Interferometer

- Marko Cebokli S57UUU s57uuu@hamradio.si

SIDI is my attempt at a contribution to the to be kept as simple as possible, mainly by putting as much processing as possible into the software. Keeping the hardware simple also makes it cheaper, and accessible for self construction by those who like the smell of the soldering iron.

- High performance: it should at least match the performance of the best existing amateur analog interferometers, like those by Hans Michlmayr [2] or IRO [3].

- VLBI capability: this is the long term goal, as set by ALLBIN. The plan with SIDI is to see how far the fancy phase locking hardware and disciplined clocks could be replaced with software in post processing.

2. Basic design choices

2.1 Choice of operating frequency

Most celestial sources are stronger on lower frequencies, and VLBI synchronization also gets simpler as one goes lower in frequency. But on the other hand, the density and levels of undesired interference also increase fast with decreasing frequency, and the available bandwidth gets smaller.

I decided to choose the well known 21cm band, for several reasons:

- devices like filters, LNAs, feedhorns, etc. are widely available from several sources

- cheap satellite TV coax cable has low enough loss for baselines up to 50m

- cheap satellite TV line amplifiers are available

- there are enough bright sources in the sky, for example the VLA 1.4GHz survey [4] lists 61 sources stronger than 10Jy and 2206 sources stronger than one Jansky

- it is close to the 23cm amateur band. There are quite a few radio hams who do EME on 23cm, and have big, fully steerable antennas for the band. Many of them are interested in radio astronomy !

- it is close to the GPS band. Being able to receive GPS with the same hardware, with the same time base, is very desirable for VLBI experiments.

- in a quiet location, bandwidths up to a few tens of MHz should be possible.

2.2 Direct conversion

In interferometry, the local oscillators in all of the frequency conversions must be coherent. To keep the hardware simple, it makes sense to reduce the number of oscillators to the minimum possible: one. Once upon the time, such direct conversion receivers were considered inferior, but today, a single I/Q down-conversion followed by a powerful DSP engine can have excellent performance, and is the design of choice in many professional radio systems like GSM, GPS, etc.

2.3 One bit A/D conversion

The signals at the input of radio astronomy receivers are well below the noise level, so sampling them with high precision doesn't make much sense. In fact, when a limit on the available bit-rate is given by the digital hardware, the best strategy is to trade precision for bandwidth, and the most sensitive receiver is the one with single bit sampling and maximum bandwidth. This is also the main reason why SIDI uses none of the commercially available SDR platforms, like USRP or RTLSDR.

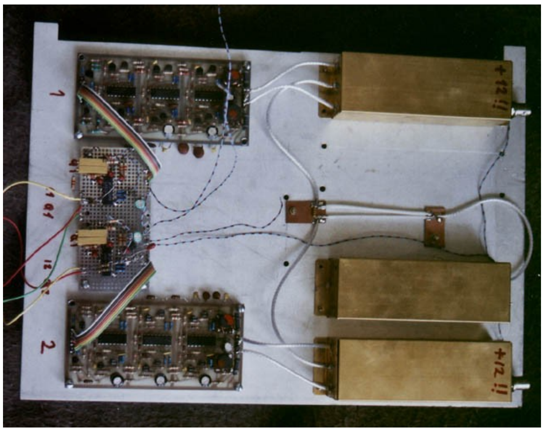
2.4 Open system

Another important decision made early on, was to make SIDI "fully open": all of the schematics, PCB layouts and software sources should be published on the web [5], under GNU or similar licenses. People should be able to experiment with their own ideas for improvement and further development.

3. History of SIDI development

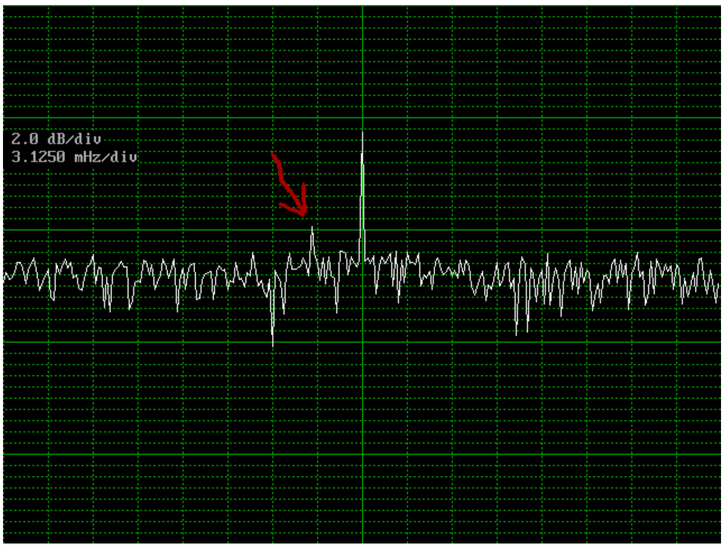
3.1 Version 1.0

The main goal of this version was to see if the "direct conversion + one bit sampling + correlation in software" idea is viable. I made a simple interferometer (SIDI v1.0, [6]) out of some modules that I had lying around (fig below), from Matjaz Vidmar's packet radio system [7]. The sampling was done with a DOS computer, over the parallel port with a simple software loop that could run at about 600k samples per second. The low-pass filters on the IF boards were set to about 150kHz, giving about 300kHz of bandwidth with I/Q sampling.



It worked on a fixed frequency in the 23 cm amateur band, the LO being a simple crystal oscillator followed by frequency multiplication. This proved to be a problem, as it was impossible to evade interference by changing the frequency.

Luckily, my friend Pavle Reberc (S57RA) lives in a secluded valley, with the nearest neighbour a couple of km away, behind a hill. He does EME and is also interested in radio astronomy, so all the following experiments with SIDI were done at his location.



There, we were able to get the first fringes from SIDI, using small antennas and simple S53MV style 0.4dB NF low noise amplifiers [8]. By changing the baseline, we successfully measured the angular diameter of the Sun, which could be received even with small (10cm) dipoles with reflectors. With 16dBi short backfire antennas [9] (SBFA, diameter 48cm, A_{ef} = 0.17m^2) we were just barely able to see the big Cygnus A source, by using FFT on the fringes (see fig: centre peak is DC, Cygnus A is the small peak under the red arrow).

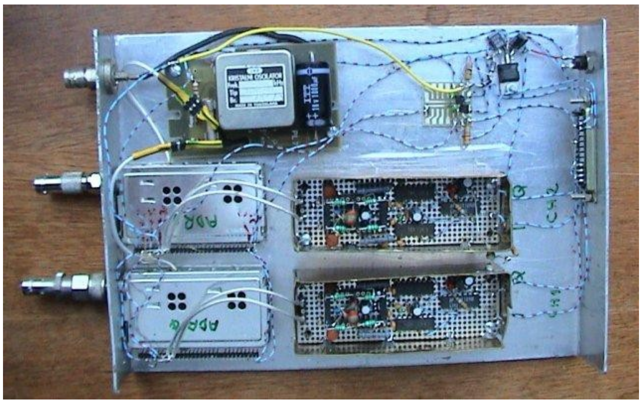
The sensitivity was a few dB less than calculated, probably because of the complicated IF amplifiers with AGC. The experiments had also shown that frequency agility is almost indispensable. Therefore, I decided to try with sat-TV tuners as frequency agile front ends, and develop simple limiting IF amplifiers for the next version of SIDI.

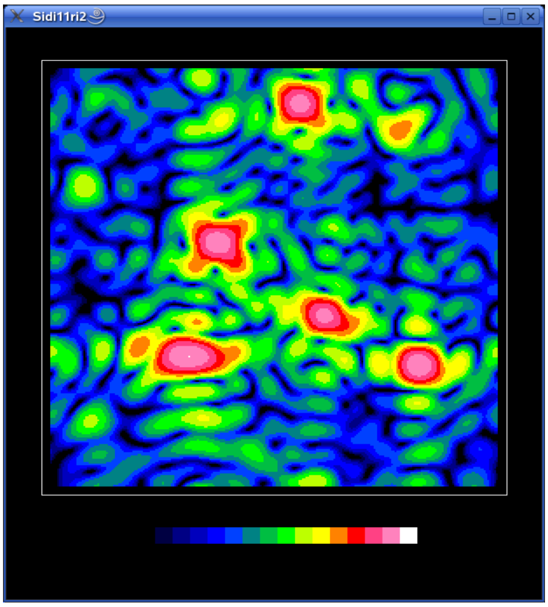
3.2 Version 1.1

The main goal of the second version was to see if the synthesizers in the satellite TV receivers are stable enough for interferometry.

I have used tuners from old "SkyStar" computer DVB boards. A few modifications were needed [10], like skipping the demodulator chip, replacing the reference crystals with external inputs, and changing the I2C address of one tuner. Adding a couple of TBA120 based limiting IF strips, a TCXO, and a simple parallel port based I2C interface, gave a nice compact unit [11] (fig. below). Sampling was still done with a software loop on a DOS machine, and the filters were chosen for a 400kHz bandwidth.

At Pavle's location, we tried for some fringes from the Moon, but got an unknown satellite signal in the first try. This gave me the idea to play a little with the GPS signals [12], since these were planned to be used as a reference in the future. This led to the next experiment, which was to make an image of the GPS 'birds' in the sky. Using two small active GPS antennas, and moving one manually through the 256 positions in a regular 16x16 grid drawn on the tarmac in front of the house [13], we succeeded in getting a synthesized radio image (fig below).





I presented SIDI 1.1 at the 2006 ERAC congress in Germany[14], and it won a special double-decker version of the ERAC's FFT-DSP award (fig. below left).

At least two other people have successfully built their versions of SIDI 1.1 [15][16].

The conclusion after experimenting with SIDI v1.1 was, that sat-TV tuners are well suitable for interferometry. They have a few weak points, like poor selectivity and a relatively high noise figure. The noise figure worsens rapidly, when their gain is reduced via the AGC pin. To get the NF below

10dB, they have to be run at maximum gain, making them very prone to overloading by off-frequency signals. Kimmo Lehtinen mentioned above [15] found that he needed to use band-pass filters in front of them.

But in general, they work quite well, especially considering that they cover the huge range of frequencies from 950 to 2150 MHz.

Now, it was time to say goodbye to software timed sampling and the parallel port, for several reasons:

- software loops can only run uninterrupted on simple operating systems like DOS

- a software loop can not be synchronized to an external clock, as needed for VLBI

- the parallel port is too slow, only sampling rates below a MHz or so are possible

- there is no parallel port on modern computers.

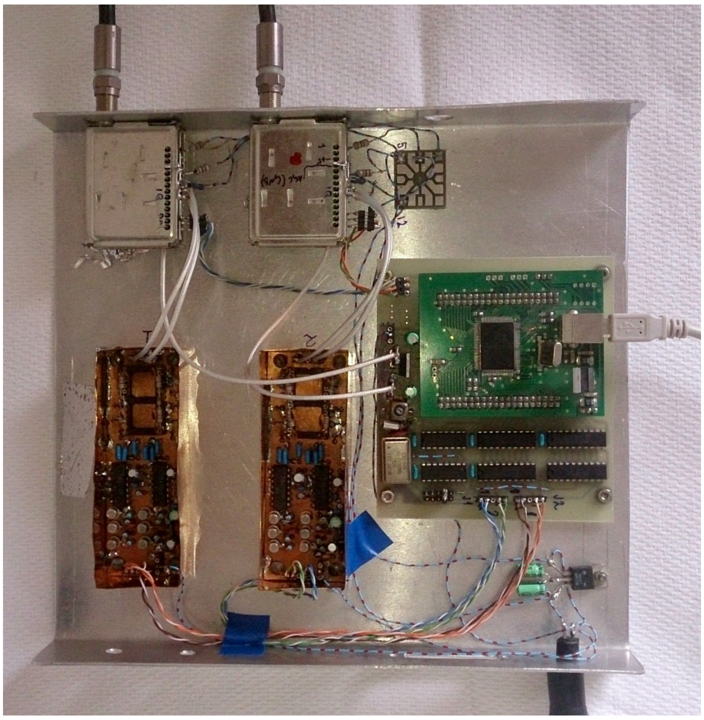
After pondering about several interfacing options like Firewire and PCI, I decided to use USB, because it is widely available, has an adequate bandwidth, and it looks (I hope) that it won't become obsolete very soon. In its 2.0 version, it has a theoretical maximum raw throughput of 480 Mbit/s. In practice, with moderate sized FIFOs on the device side, about 100 to 200 Mbit/s can be pumped through it continuously, without loosing data due to OS latencies.

In 2007 I made an USB interface [17], and a simple sampler [18], that could sample at up to 40MHz on four channels (two interferometer channels with I/Q each). I upgraded and ported the software to Linux/gcc, and did the first table-top tests with SIDI v1.2.

But then, I got married, and Pavle founded a start-up company, so SIDI v 1.2 got sidelined for some years !

4. Current state of SIDI development

In January 2014, I dusted off SIDI v1.2 (fig. below), and restarted work on it. Pavle has some nice 3m dishes, so I made a couple of simple "cantenna" feeds from 4kg cans used for peppers and pickles, acquired in the cafeteria at my work.



In March, I visited Pavle, and we set up a baseline of around 42m E-W, with two 3m dishes. One of them was just laid on sloping ground, and fixed with some sticks and ropes [19]. It determined the fixed declination of about -0.5 degrees, at which the setup then ran in drift scan mode for about a month.

The signals were fed into the house via two equally long cables, made of low loss "satellite TV" coax, the type having foil shielding and foam dielectric.

The cables had about 15dB of loss, and the LNAs had >35dB of gain, leaving about 20dB to cover the tuner noise. This is somewhat marginal, considering that the tuner's ~3000K figure still contributed 30K to the system noise, about the same as the LNAs and the antenna noise. I estimated the total system noise to be around 100K.

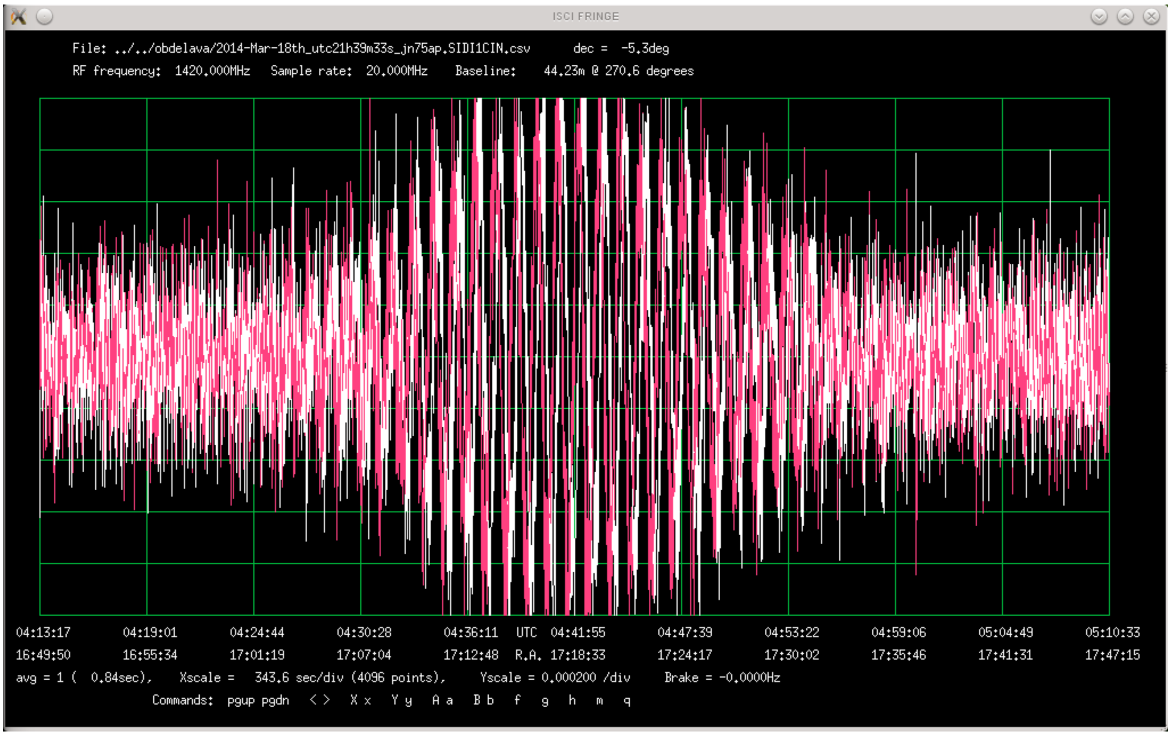
Sampling ran at 20MHz, and the observation software averaged 16M (2^24) samples in real time for each correlation value recorded into the file. This gave a recorded data rate of ~ 1.2Hz, creating a 3.5MB file in 24 hours.

The recorded files can be later reviewed with a special viewing and filtering program called "isci_fringe" (means "search for fringes" in Slovene), which can:

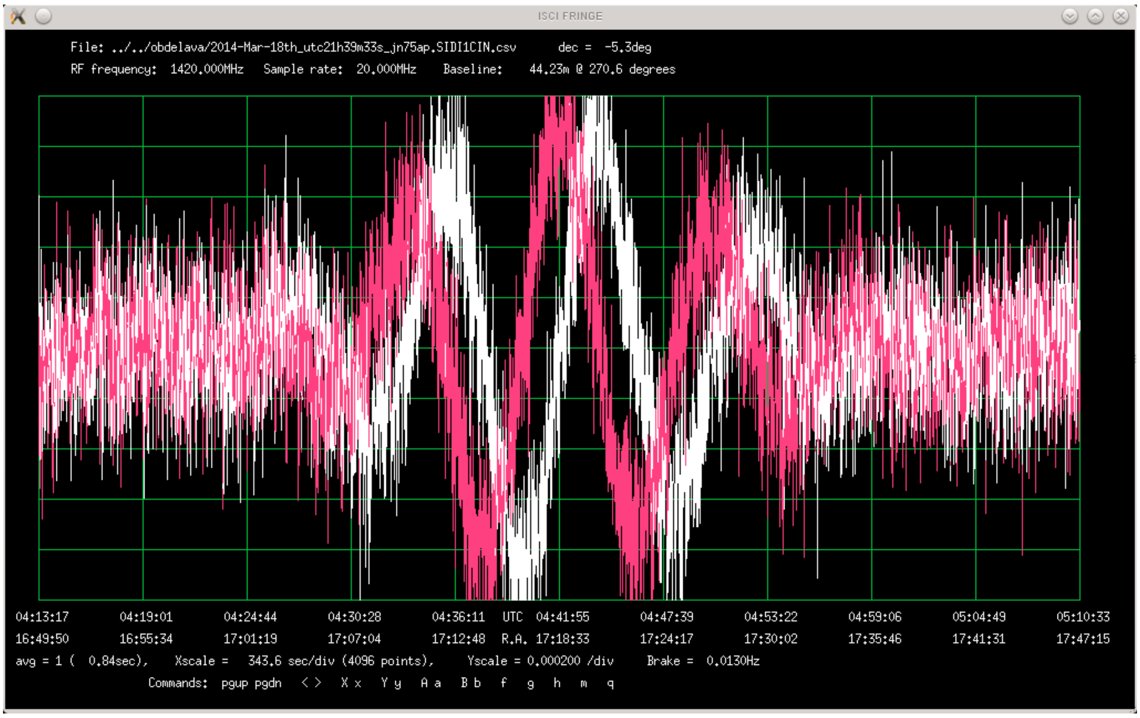
- remove impulsive noise (pulse blanker)
- filter out DC offset and image frequencies
- average together several files
- slow down the fringes
- apply additional time averaging
- show the FFT spectrum of the fringes
- show a spectrogram over the whole duration of a file
- show fringe amplitude and phase

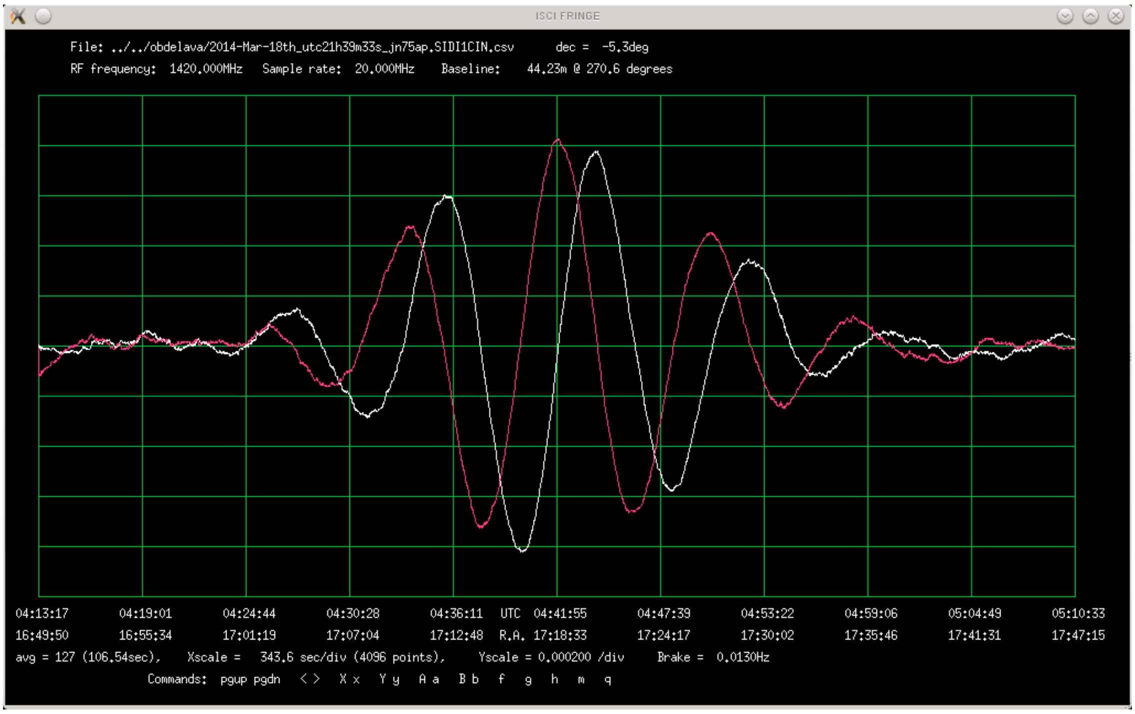
5. Some results of the first observations with SIDI v1.2

Pavle has put many of the daily recordings on his webpage [20], where they can be downloaded. The fig. below shows a section from one of the first recorded files, with only pulse blanking and DC/image filtering applied. The fringes are from a group of unresolved sources at 1720-0058 with a total flux of about 55Jy. (The declination value shown is wrong, it was about -1 degree.)

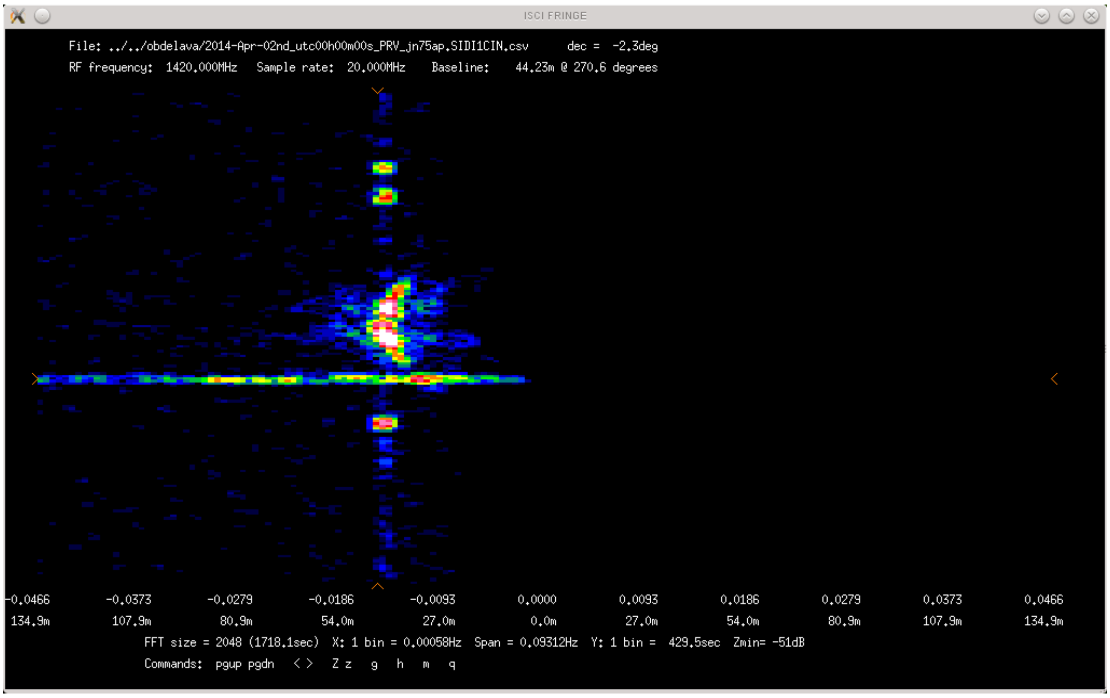


The figure below just below shows the same data after a slowdown of 13mHz. The slowdown is a simple frequency conversion, done by multiplication with a complex sinusoid. Now, additional averaging over 127 points can be applied, with the results shown in the bottom figure.





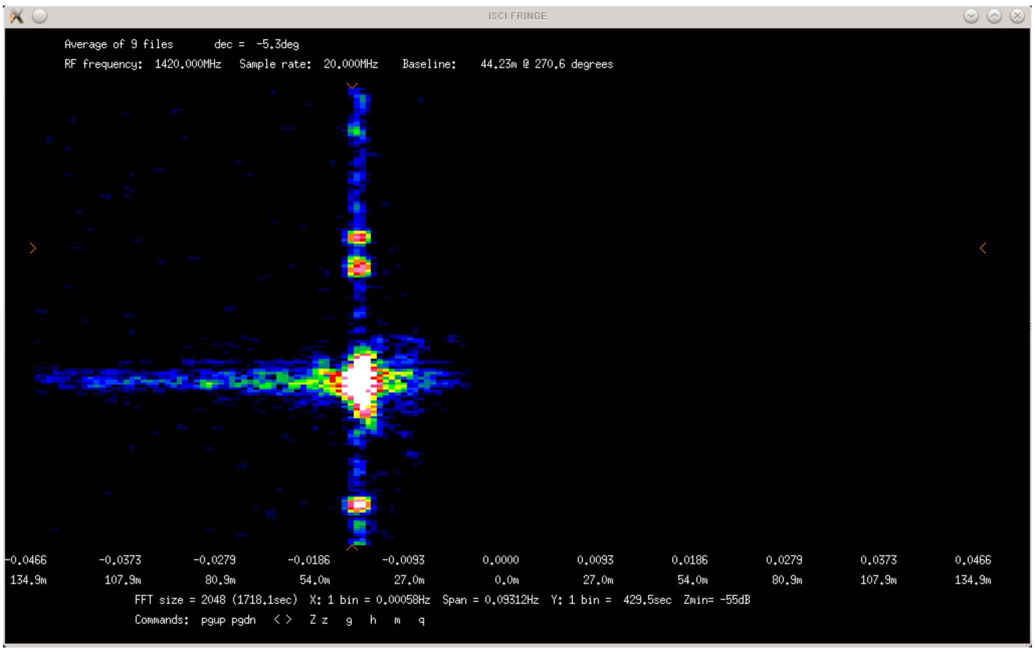
On the second of April, an interesting side catch appeared in the recording. At first I thought it was just terrestrial QRM, but later next day, when I saw people discussing a solar burst on the SARA mailing list, I checked the timing and it was 'dead on' ! The following figure shows the spectrogram of the file recorded that day (Sun burst on 02 Apr 2014).



Time goes vertically from top to bottom, and fringe frequency is on the horizontal axis. The bright crescent is the quiet Sun, coming in through the side-lobes a few degrees off the main beam. The crescent shape comes from the changing fringe frequency, as the projection of the baseline is changing. The vertical string of blobs through the left part of the Sun's crescent are the sidereal sources at the fringe frequency, that corresponds to meridian transit with the given baseline. The source shown in the preceding three figs. is the topmost blob with a red core.

The solar burst is the bright horizontal line below the Sun crescent. To be sure it is not QRM, I checked the phase history, and it is quite smooth, fitting well with a source at the Sun's position. The wide spread over the frequencies is caused by the strong amplitude variations during the burst's duration.

Combining files from multiple scans can improve the sensitivity. The figure below shows the spectrogram of an average of nine files, recorded end of March 2014. On the fringe frequency, there is almost no place without some activity, meaning that we have increased the sensitivity to the point of reaching the confusion limit.



6. Plans for the future

In SIDI version 1.2, both the sampling clock and the tuner synthesizer references are derived from the same oscillator, so it is already suitable for VLBI experiments. So, the very next thing planned are some experiments in this direction.

The plan is to use two SIDIs with free running oscillators, and record a reference signal on one of the channels at each side. For the reference signal, I plan to use EGNOS [21]. This is a GPS-like signal, but transmitted from geostationary satellites. For our application it has several advantages over normal GPS:

- the same satellite is visible over a very wide area
- does not rise and set, can be locked on continuously
- Doppler correction is much smaller and simpler
- a directional antenna can be used, for better S/N

On the hardware side, the next step will probably be to put the sampling interface into a CPLD and make a small board that can be piggy-backed on some commercial USB2 breakout board. Next, I would like to replace the "tin box" tuners with single chip tuners, like MAX2112. This would ultimately allow a small production run of SIDIs to be made, because the clumsy tuner modifications wouldn't be needed any more.

Pavle has the idea of making fiber optic extensions using the dual fiber optical LAN cables. That would permit connected mode operation with baselines up to a few hundred meters. The receivers and samplers would be located at the antennas. The uplink fiber would carry a reference frequency and tuner commands, and the sampled data would be multiplexed onto the downlink fiber. 1Gb/s optical transceiver modules are available cheaply, and first experiments have shown that they are quite easy to interface.

For the latest news about SIDI development, check at the ERAC-VLBI Yahoo group [22].

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[2] Hans Michlmayr's wavelab:
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[6] SIDI v1.0:
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[7] S53MV packet RTX:
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[9] S53MV SBFA:
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[10] SAT tuner modification for SIDI:
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[12] SIDI 1.1 first fringes:
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[13] SIDI 1.1 radio imaging:
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[15] Kimmo Lehtinen's SIDI presentation:
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[16] Alex Plaha, forum posts:
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http://www.astroclub.kiev.ua/forum/index.php?page=100

[17] The UUUSB board:
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[18] SIDI v1.2 description:
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[19] S57RA SIDI photo gallery:
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[20] S57RA SIDI recorded data:
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[21] EGNOS wiki:
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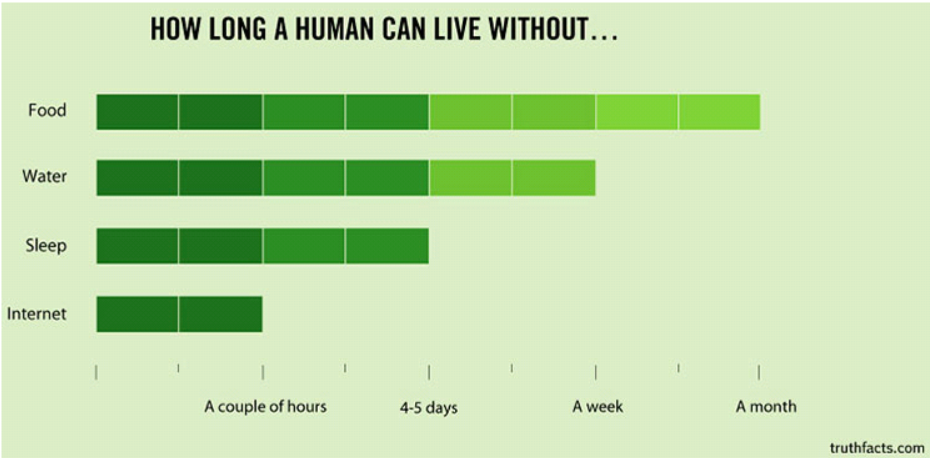
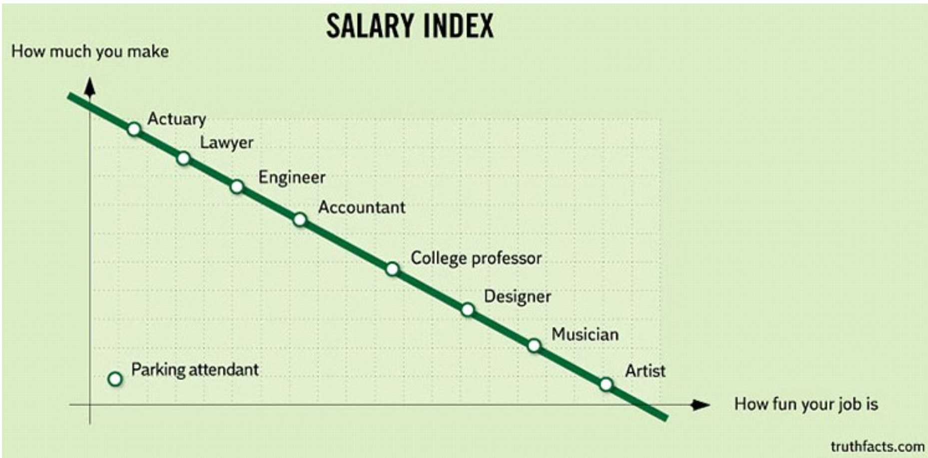
https://groups.yahoo.com/neo/groups/erac-vlbi/info

Twisted humour

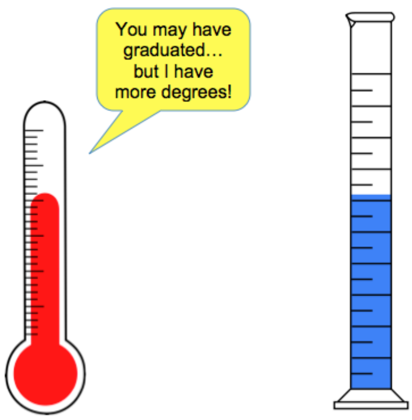
Light relief

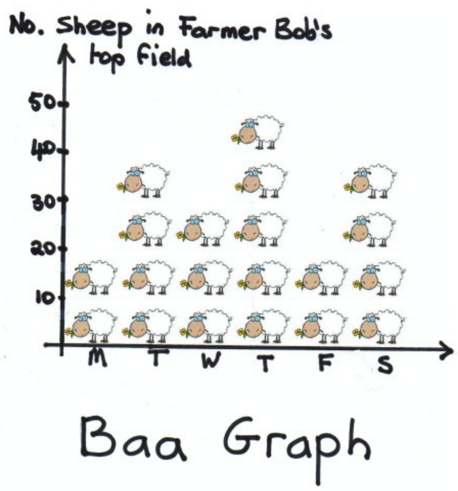




Sir Isaac Newton had a theory of how to get the best outcomes in a courtroom. He suggested to lawyers that they should drag their arguments into the late afternoon hours. The English judges of his day would never abandon their 4 o'clock tea time, and therefore would always bring down their hammer and enter a hasty, positive decision so they could retire to their chambers for a cup of Earl Grey. This tactic used by the British lawyers is still recalled as Newton's Law of Gavel Tea.

Q How many ears does Captain Kirk have ?
A Three. A left ear, a right ear, and a final frontier!





Receiving moon-bounce signals from the GRAVES radar

- Paul Hyde g4csd@yahoo.co.uk

Observing, meteor-s

It is known that the GRAVES radar system (143.05 MHz) produces a very strong signal, with meteor reflections receivable on a range of antennas, including long wires and HF ‘Triband’ antennas as well as the simple 3-element Yagis designed for the GRAVES frequency. I also see moon-bounce signals on a fairly regular basis, despite using a low-gain 3-element Yagi with no preamplifier and a 30 metre RG58 down lead. On occasions these signals are in excess of 17dB above the background noise and hence trigger the meteor detection system. They are easily distinguishable from the equally prevalent Tropospheric Scatter signals by their slowly varying frequency due to Doppler shift as the Moon transits the sky. The freely downloadable VK3UM EME Planner application allows you to compare the received frequency with the predicted Doppler shift for moon bounce to obtain definitive confirmation of what is happening.

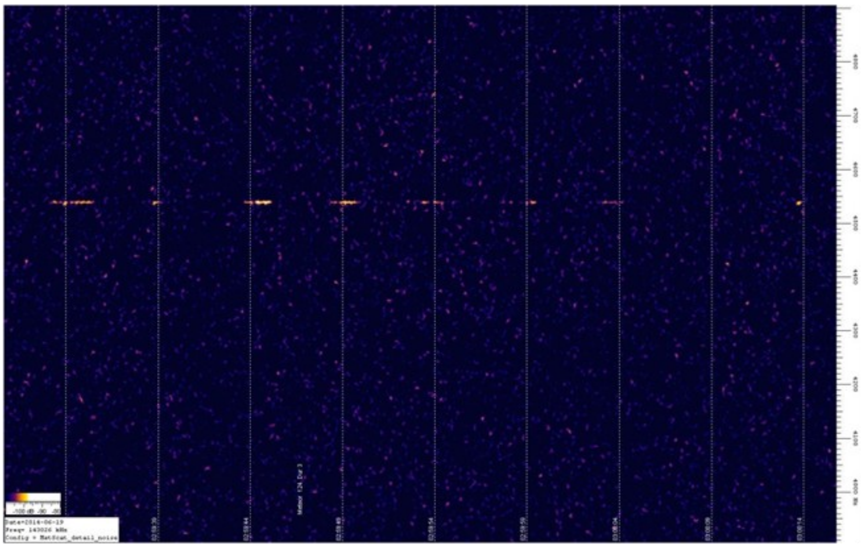
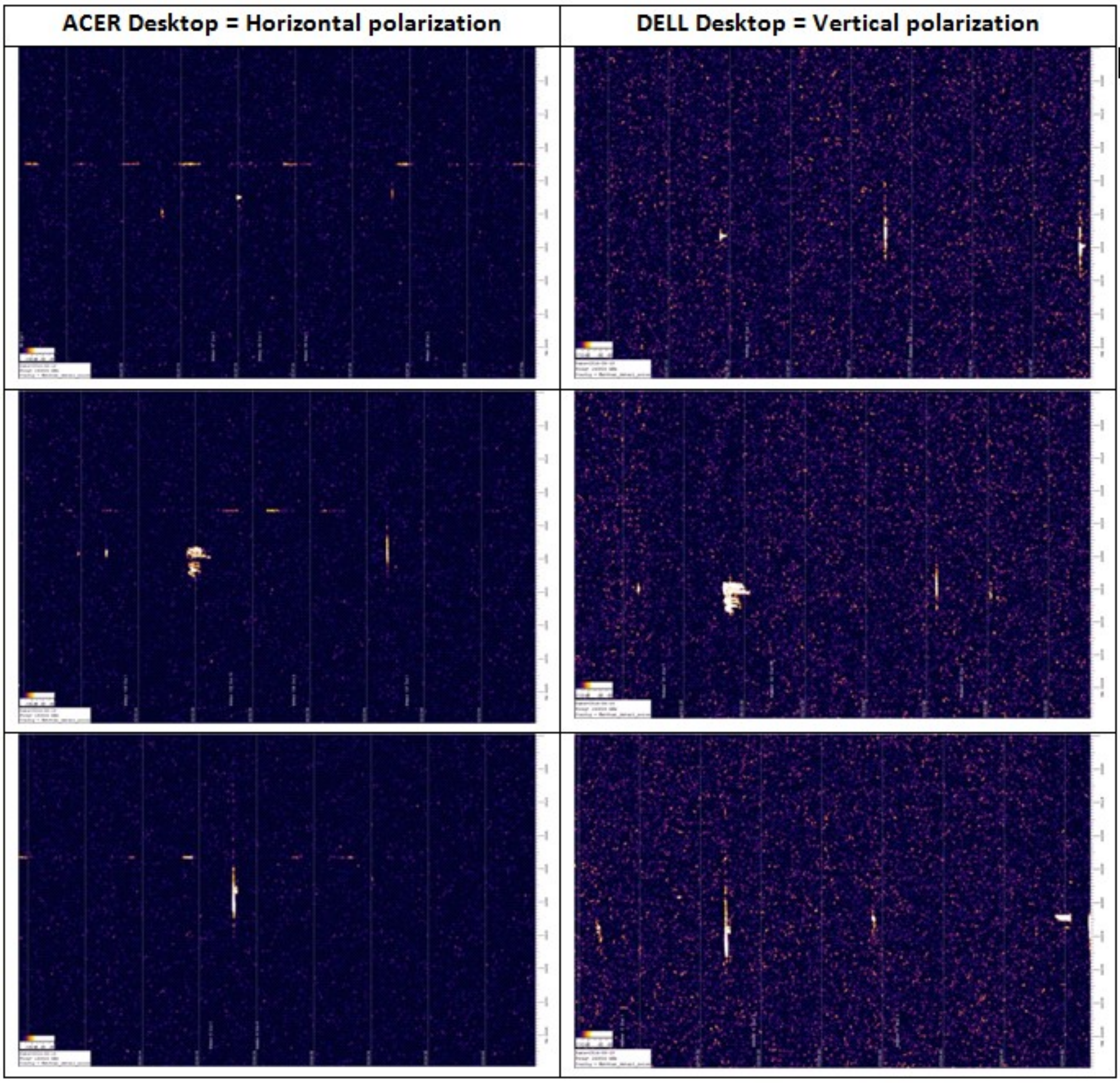


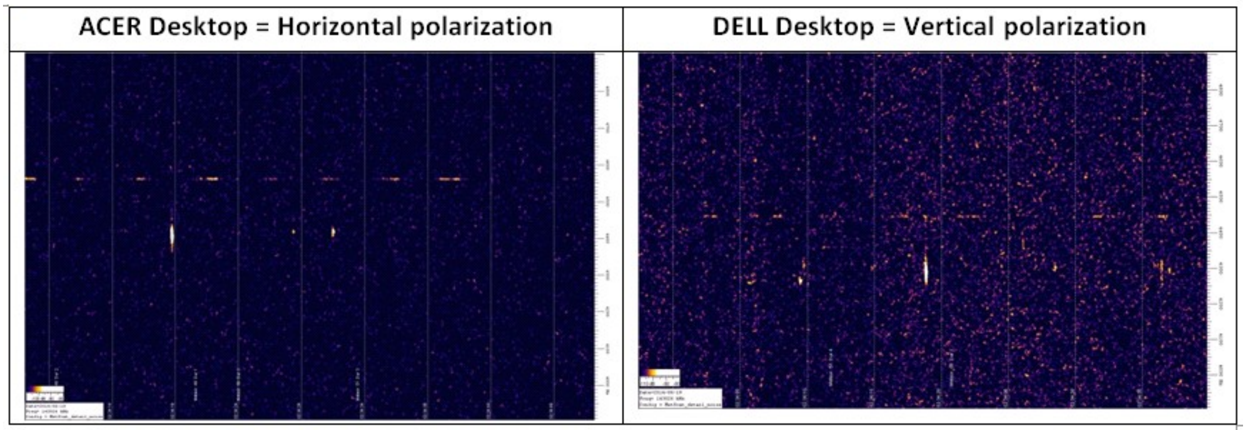
Fig 1 Moon-bounce signals at 4540 Hz. The FUNcube receiver was set for 143.046 MHz and has a frequency error of 420 Hz, so the signal is 120 Hz higher than GRAVES. The VK3UM Planner gave a predicted value of 127 Hz. Note that one of the bursts is strong enough to trigger the screen capture mechanism.

I do not know of anyone else who has observed this effect. This may be because no-one else has looked, or because I am monitoring meteor scatter using both vertical and horizontal polarisation systems. The usual practice is to monitor vertical polarisation because of the stronger scatter signals, but I rarely see moon-bounce on this channel. This is an interesting observation in itself - why are moon-bounce signals predominantly horizontally polarised signals whilst meteor reflections favour the vertically polarised component ?

The following screenshots compare three events where moon-bounce is evident on the horizontal polarised signal but not on the vertical. The background noise level is higher with vertical polarisation which complicates the comparison, but I do not believe that it would totally obscure a weak moon-bounce signal. The noise is believed to be due to a nearby solar panel system and it would be useful to repeat this exercise in a location that does not suffer this problem.



On a few occasions it is possible to see the moonbounce signal on the vertical polarisation channel but this is a rare event occurring perhaps 2% of the times that moonbounce is seen on the horizontal polarised channel.



As an experiment I decided to map the position of the Moon when moon-bounce signals were present. This was carried out over the period between 16th and 22nd June 2014 to produce the following chart.

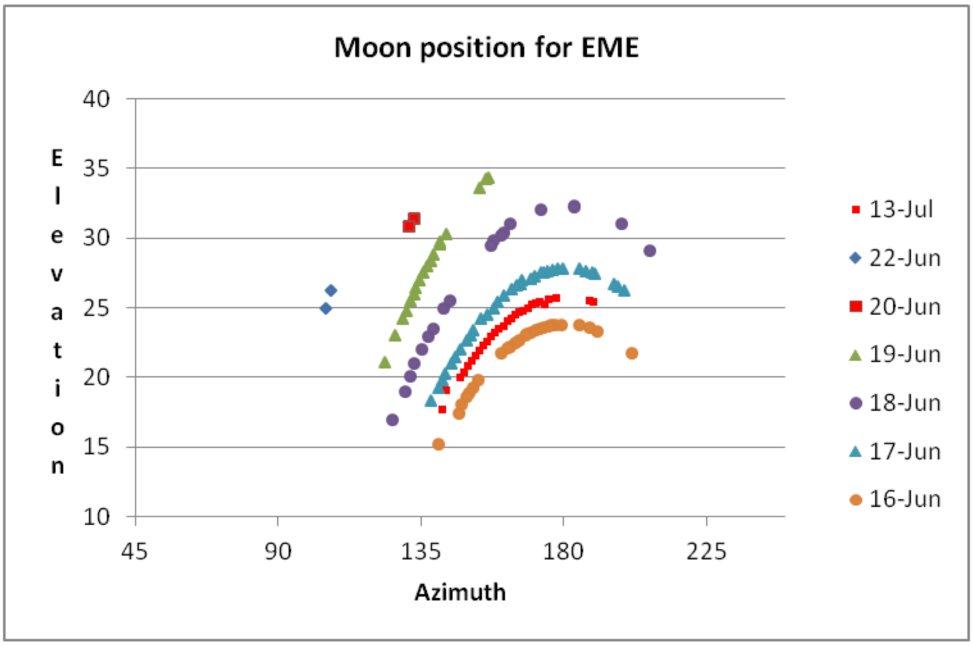


Fig 2 Location of Moon for those screen captures showing moon-bounce signals

Predictably, moon-bounce only occurs when the Moon is in a particular region of the sky. Only 2 out of 125 moon-bounce occurrences happened when it was outside the region between 124 and 207 degrees Azimuth (so approximately SE to SSW) and 15 and 35 degrees in Elevation.

However, the lack of moon-bounce when the Moon is at elevations above 35 degrees seems odd. I have several screenshots of meteor echoes after the last position marked in Fig 2 for the 19th June when the moon was continuing to rise, but none of these show sign of moon-bounce. When mounted horizontally the G4CQM 'MetScat' antenna I use should cover elevations up to 80 degrees, so the absence of moon-bounce signals appears to be due to the Moon not being illuminated by the GRAVES radar beam, rather than by any lack of sensitivity at the receiving installation.

Other oddities include the presence of only two images showing moon-bounce on the 20th June, none at all on the 21st, and then two on the 22nd which lie apart from the main grouping. I then graded the images in terms of the approximate strength of the reflections. This is very subjective, taking into account the number of reflections seen on a screenshot and their average amplitude. Although the geometry of the signal path changes very slowly, the screenshots above show rapid changes in the amplitude of the reflected signal. My assumption is that this is down to ionospheric effects and again it would be interesting to compare observations from a number of different locations.

Figure 3 has a suggestion of the reflected signal being stronger at certain bearings than others. The problem is the overlying variation in signal strength and more observations are needed to establish whether there is a pattern there or not.

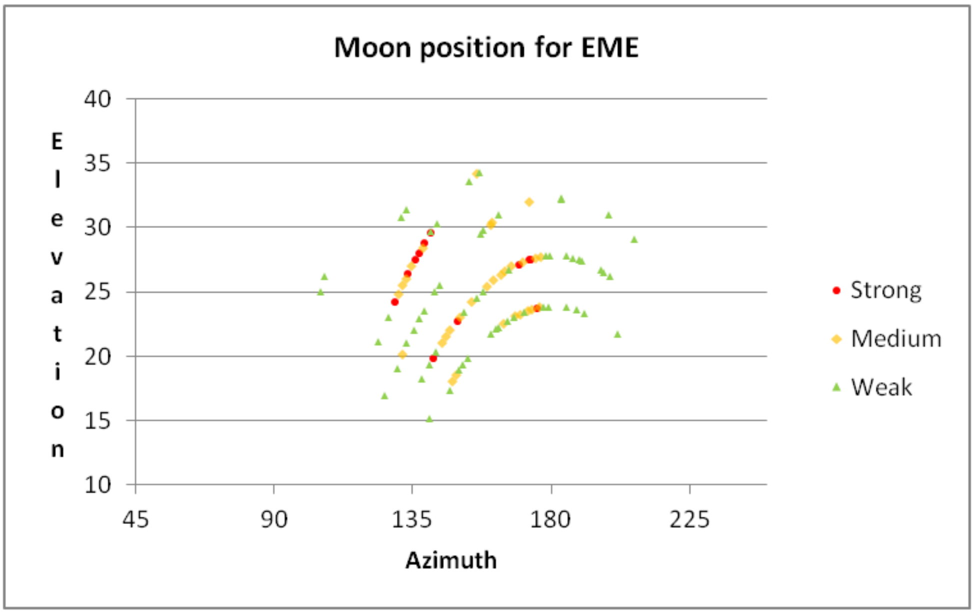


Fig 3 Data re-plotted to show the approximate strength of the moon-bounce signal

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[Editor's note: Newcomers to MS observing may find this site on GRAVES of benefit: http://www.itr-datanet.com/~pe1itr/graves/ . It includes moon, aircraft and ISS reflections, with sample plots. For a very good e-reflector on EME, search for *moon-net*, where there is frequent discussion of polarisation, Faraday rotation etc. There was some excellent related survey and new measurement material generated by amateurs presented at the recent World EME Conference in N France (see calendar, this issue); for those unable to go, there is a CD available containing the full proceedings.]