# The RAGazine

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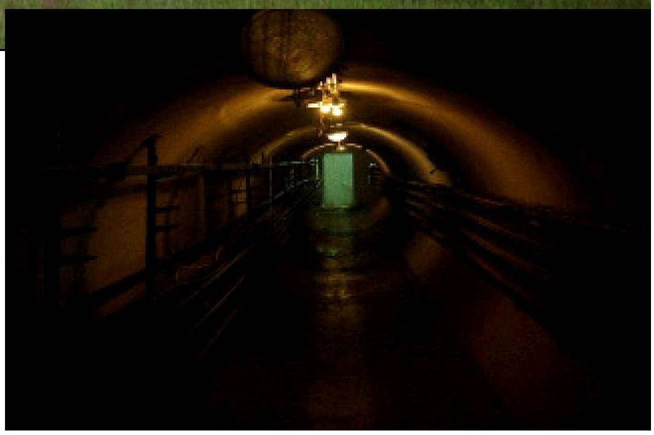

Photos: The SSRT near Irkutsk, Siberia, showing the 5.7 GHz solar cross interferometer with 128 2.5m dia. dishes in each 622m long N-S, E-W line. The tunnels (right) carry wave-guide interconnects. See also p3. Courtesy: ISTP, Russia

www.britastro.org/radio/

British Astronomical Association
Radio Astronomy Group

The RAGazine

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

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BAA, Burlington House, Picadilly, London,

W1J 0DU

(+44) 207 734 4145

Reg charity 210769

RAG co-ordinator Paul Hyde

*RAGazine* editor Dave James

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dave@greenover.net

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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

The first two issues seemed to have found favour generally - even my choice of humorous snippets has been tolerated ! As explained in the first issue, *RAGazine* aims to be a little different from many newsletters, and in particular the fairly short and often quite formal ones produced by some BAA Sections - and to some extent RAG's four *Baseline* issues published in 2005/6. *RAGazine* is quarterly and intended to be informally user-friendly. As explained before, *RAGazine* does not purport to be a learned or professional journal; it is for amateurs involved in or interested in radio astronomy and geophysics

Paul Hyde and I decided initially on the simpler, single column format which aids on-screen reading at the expense of a slightly slicker look; and as editor this does make my task easier, too. Readers seem content with this. Articles covering work in progress are very much welcomed, too, and I fear that most of us are rather too timid and shy on this aspect. So when in doubt, please consider writing on incomplete projects, including areas of struggle, difficult choice or novelty etc, for this will be appreciated by our wide-ranging readership and we can all learn from each other. I am happy to work with contributors to help complete or re-format suitable material, but please remember a single .pdf file will rarely suffice (as demonstrated some in this issue).

I hope you like this third issue, which I think has some tasty gems for all, neophyte through seasoned old hand. Look out for the Jansky paper as a real treat, and I plan on extending coverage of seminal developments in the history of radio astronomy in later issues. We <u>can</u> learn a lot from history, despite terrible political examples on a global scale. One or two regular feature areas have still not surfaced, but hopefully this will be completed next issue. Suggestions are welcomed.

It would also be useful if you would let me know your thoughts on the frequency of the *RAGazine*. It might be possible, for example, to move to a bimonthly (every other month !) basis, with a somewhat smaller page count. This could have the advantage of more timely reporting and news coverage, and paradoxically I suspect could mean a few <u>more</u> articles being input, as at three months intervals many of us just put such writing notions aside as it seems so far off, there is plenty of time yet … and yet still …. until there isn't. Your views are sought.

I am also keen to feature members' home observatories, their outreach activities, co-operative ventures and the like. So please consider this, or at least point me in the right direction, as it's not possible for me to easily discern what all are doing or have accomplished.

Finally, I would also like to remind readers that I still wish to find one or two more contributing editors or correspondents for specific areas. Tony Abbey has recently volunteered in one area and his most welcome input on useful technology developments is included for the first time here. PLEASE take note and consider volunteering, too !

Best wishes

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

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**Cover photos:** Suspecting that there may be more interest than normal in the subject featured on the cover - which is not well known in the West - I have provided a little profile on the SSRT, in one of the regular features on universities and other institutions, p60.

# Coordinator's Remarks

View from the top

This is the last edition of *RAGazine* before the RAG 2014 meeting at the National Space Centre in Leicester on 17th May. We do have a change in one of the Keynote speakers with Professor Paul Cannon. Details of the event are included later in this issue and you will see that, once again, we will be covering a wide range of subjects. With nine presentations it will be a busy day. Ticket sales are currently running at three times those of the last event, for which we had to declare a sell-out prior to the day, so please be sure to book yours well in advance. Tickets are on sale via the BAA Office, but importantly you do not need to be a BAA member to purchase them.

We are also on the lookout for demonstrations and poster material for the lunchtime interval. If you have anything that will help and inspire others, please let me know. Given prior notice we can make tables available for the hardware. We encourage posters both in support of information and results for such hardware displays, and also as poster contributions in their own right. We may be able to help you in the production of posters.

If there is sufficient interest we have had a kind offer from Ian Lever to bring along equipment for measuring the performance of passive filters for hydrogen line receivers. The equipment is heavy and bulky so it is only worth doing this if there are several people who can make use of the opportunity. Conversely, Ian does not want to miss out on the main event, so there will be a maximum of six slots, based on those making bookings before the day. Please note that this will be for checking performance only as there will not be time to do any alignment work. If you are interested, please contact me by the end of March so that we can decide whether to go ahead with this or not.

Those who subscribe to the BAA RAG Yahoo! Group will know that the first week in March is National Astronomy Week and this year the focus will be on Jupiter. This is well positioned for optical astronomers, at elevations of 60 degrees or more, but of course it can also produce some very strong radio emissions. The best frequencies to listen on are around 20 MHz which means that any reasonable quality shortwave receiver can be used, assuming access to a decent antenna. Activity is strongly affected by the relative positions of Jupiter, its innermost moon Io, and the Earth. There is a lot of information available via the internet as well as software to calculate when there is a higher probability of receiving these emissions. I'd like to hear from anyone who has a go at this, successfully or otherwise !

As I write this it doesn't look as if we are quite out of the bad weather, but Spring is almost upon us offering an incentive to do all that experimentation that you have been thinking about. I wish everyone the best of success and I hope to meet you in Leicester on May 17th.

Best wishes

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

# RAG 2014, Leicester: Saturday 17th May



Once again the BAA Radio Astronomy Group will be holding its General Meeting at the National Space Centre, Leicester, LE4 5NS. This has been a popular event in past years with the previous two meetings selling out before the day. The format is of two expert, keynote speakers supported by talks from members of the Group. The aim is to present a range of subjects to provide something for all interests, and from the armchair observer to the seasoned campaigner.

There is a change to the previous speaker line up with Prof Paul Cannon replacing Dr Eloy de Lera Acedo. Paul Cannon is the Professor of Radio Science and Systems at the University of Birmingham and currently the Editor-in-Chief of the US journal "Radio Science" and a Vice-President of the International Union of Radio Science. He is a fellow of the Royal Academy of Engineering and was awarded an OBE in the 2014 New Years Honours. He initiated the UK ionospheric space weather mitigation programme in 1986 and he led and nurtured it for over 25 years. Paul currently serves on the UK Cabinet Office, Space Weather Project Board, has been an expert witness to the House of Commons Science and Technology Select Committee.

Tickets for the event cost £12 for BAA members and £15 for non-members, including free parking at the NSC and free admission to the main attraction, excluding the Planetarium show. Tea and coffee will be provided during the breaks, but lunch is not included. Delegates are welcome to bring their own lunch or alternatively lunch can be purchased at the NSC shop (Boosters), which sells a range of sandwiches and other refreshments. (It would help the NSC if you could also note the number of people in your party that are likely to use Boosters when you book tickets).

Tickets can be purchased by BAA and non-BAA members alike using the Booking Form available on the BAA RAG website at http://www.britastro.org/radio/ This should be returned to the British Astronomical Association at the address on the form. You can also fax the form, book by phone or e-mail the completed form to the BAA office, but please remember that e-mail is not secure.

Please contact radiogroup@britastro.org if you have any queries on the above.

You do not need to be a BAA member to participate in the Radio Astronomy Group, or to attend this meeting, and we welcome news of any activity related to radio astronomy.

The following synopses have been provided by the various speakers, but may be subject to last minute changes. The order below may not reflect the exact programme order on the day.

## Solar superstorms – a storm in a teacup, or danger for the nation and the world?

Prof Paul S Cannon, OBE, FREng, Univ. of Birmingham

Solar superstorms generate X-rays and solar radio bursts, accelerate solar particles to relativistic velocities and cause detrimental effects to the electricity grid, satellites, avionics, air passengers, signals from satellite navigation systems, mobile telephones and more. Since the start of the space age, there has been no true solar superstorm and consequently our understanding is limited. Mitigation of such storms necessitates a number of technology-specific approaches which boil down to engineering out as much risk as is reasonably possible, and then adopting operational strategies to deal with the residual risk. Forecasting a solar storm is a challenge, and contemporary techniques are unlikely to deliver actionable advice. Irrespective of forecasting ability, space and terrestrial sensors of the Sun and the near space environment provide critical space situational awareness, an ability to undertake post-event analysis, and the infrastructure to improve our understanding of this environment.

## Cosmic explosions at radio wavelengths: the afterglows of gamma-ray bursts

Dr Klaas Wiersema University of Leicester

New radio telescope technology now allows us to explore the "transient" radio Universe. Radio transients (new sources that are detectable for a short time before fading away forever) come in a wide variety: from the mysterious milli-second duration "fast radio bursts", to the energetic afterglows of gamma-ray bursts (GRBs), which are sometimes visible for years. This talk will show how we observe these GRB afterglows at radio wavelengths, and how we use these observations to understand the physics of these transients. Finally, we will show how new technology, particularly the LOFAR observatory and new instruments on the venerable WSRT, allow us to study afterglows and other transients in a completely new way.

## An Ultra-Low Cost Hydrogen Line Radio Telescope using the RTL TV Dongle

Peter East

Detecting the hydrogen line in the arms of our galaxy using modern available technology is now made easy. With a home-made Yagi, a couple of modest amplifiers, a cheap RTL 2832U TV dongle, some free software and a bit of effort, for well less than £200 you can measure the velocity and positions of the spiral arms, some tens of thousands of light years away. Of course a 5m dish gives a lot more signal and resolution, but that can be another project - and you've already got the receiver ! The paper describes what to buy and how to build so that you can soon collect and analyse your first hydrogen line data as shown.

## Modelling Galactic Topology: Project Update

Gordon Dennis

The Hydrogen Line Observing Group (HLOG) is attempting to construct a three dimensional image of a part of our Milky Way galaxy by observing the “brightness / temperature” and the Doppler shift of radiation from neutral Hydrogen that resides in the spiral arms. The 3.7 metre telescope at Redenham Observatory is operated on-line by a dispersed team of observers with various backgrounds and experience. All data collected will be available to all participants to use as they wish. The core team is using the data to construct the “3D” map and plans to write a paper for publication in the amateur astronomy press, describing the project. This paper presents a progress report and summarises both the science behind the project, the equipment and software, and the organisation required to run the project.

## The State of Flux: An Arduino Based Magnetometer

Jonathan Rawlinson

The Arduino is a multipurpose, open-source micro-controller platform that is used by amateurs and professionals alike in a wide range of areas. Here a combination of Arduino and Raspberry Pi is used to create a system that is capable of taking data from a wide range of sources, logging the data to a safe area and uploading the data to the user’s website. For the purposes of this presentation the system is connected to a FGM-3 flux-gate magnetometer in a setup designed to detect fluctuations in the geo-magnetic field. This will allow the user to detect and monitor solar events and other magnetic disturbances. All software and hardware for this project are easily available; the name of the software is "PyDat". The system was designed with three major criteria in mind: simple deployment, high level of reliability, and extendibility. This presentation will discuss the system in detail, how it can be used and what related developments are planned.

## Making and analysing observations with Starbase

Dr Laurence Newell

The Starbase software observatory has been developed by RAG members primarily for radio astronomy applications, but has a variety of uses in data collection, analysis and display. The presentation will give a brief introduction to the facilities available in the virtual observatory, and then concentrate on how it can be used with external hardware (and other software) to make some simple (simulated) observations. Finally examples of real observations will be shown, e.g. from a VLF Receiver and a Magnetometer, illustrating the various ways in which these data may be exported and published.

## Some limitations of Amateur Radio Astronomy

Dr David Morgan

This paper briefly covers the basic equations for antenna gain and beam width and considers some of the implications arising when using small diameter antennas with HPBW of 5 to 10 degrees to detect radio astronomical objects. The problems in detecting SNRs and extra-galactic objects against a diffuse radio background with such beams are explored. The desirability of access to >10m diameter class antennas is expressed - and the possibility of a collaborative effort to achieve this by UK amateur radio astronomers is considered.

## The Harold Clayton Observatory: RA and Geophysics amongst the sheep

Dr Dave James

This paper describes the recent programme to develop a new, private RA and Geophysics observatory in the rural S West. Different measurement types from static H-field, including proton precession and flux-gate magnetometers, through ELF, VLF, HF, VHF, UHF through L-band sensors are described. The practical issues addressed include quiet site selection, data link, solar and wind power, coping with the elements, on-site EMC, local planning approval, time stamping, interferometer design, security and RFI - and co-existence with the landlord farmer's haylage and sheep rearing needs. Also mentioned are measures taken to allow extension to larger antennas and higher frequencies, possible collaboration with other amateurs, and local outreach.

## Development of the East Anglian Amateur Radio Observatory (EAARO)

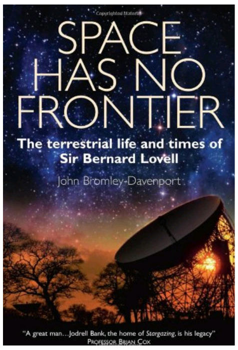
Jason Williams

EAARO (the East Anglian Amateur Radio Observatory) is a scientific and educational charitable company establishing a new radio observatory and ground station near Cambridge, UK, to undertake meaningful research projects, support satellite missions, and encourage young people to pursue STEM (science, technology, engineering and mathematics) subjects and careers. Scheduled to commence initial operations in early 2014, we will report on our current progress and future plans, and discuss the results of EAARO's first major project in support of the KickSat satellite mission.

# "Space Has No Frontier" by J Bromley-Davenport: Book Review

**- Dave James**

Books




**Space Has No Frontier:**
**the terrestrial life and times of Sir Bernard Lovell**
by J Bromley-Davenport, Bene Factum Pub., 2013
320 pp., £20 rrp

In the last issue Paul Hyde reviewed *Unseen Cosmos* by Sir Francis Graham-Smith, and most readers will already know that both Lovell and Graham-Smith are post-war giants in radio astronomy, and the former especially so as the 'father' of the eponymous radio telescope at Jodrell Bank. Sir Bernard sadly died some short while after a stroke, peacefully as a frail near-centenarian, in August 2012. He is most recognised as the Director of the University of Manchester's Jodrell Bank Observatory for a staggering 35 years.

First, this book does not set out to educate well the reader on the science covered, but whilst the author is a layman, so to speak, he does a quite creditable job of conveying the essence of the physics, radio technology and radio astronomy involved. Bromley-Davenport as QC, actor, puplic speaker and general *bon viveur* of sorts, might seem an unusual author for such a biography. But the author lived very close to Sir Bernard in the quiet and attractive little village of Swettenham near Jodrell, and knew him quite well for much of his life, and most significantly his father, Lt. Col. (later Sir) Walter Bromley-Davenport was MP for Knutsford (a Conservative !) was a stalwart and effective advocate for Sir Bernard - especially over the real threat at one point of massive housing development on the Cheshire Plain for Manchester's 'overspill' as it was delicately described. This would have had a very deleterious effect on Jodrell's performance. As it happens, I used to live in Macclesfield in the 70's and 80's, and Sir Bernard was already a well loved but little glimpsed local celebrity, whose many eccentricities were often enjoyed - and exaggerated. In the early days, Sir Bernard needed all the friends he could muster, and sadly his MP had difficulties of his own, which led to his partial demise in the Commons but increased his effectiveness in his political support for Sir Bernard. This excerpt explains it well and also conveys something of the author's style more generally:

" ….. Bromley-Davenport, was strongly opposed to the plans for a new town at Mobberley. The story of his departure from the Whips Office following an incident in the … Commons is well known: believing a gentleman lurking in the corridor to be a Conservative Member, who should have been in the Division Lobby on a three line whip, he aimed a sharp kick at the offender's backside projecting him down the stairs; unfortunately the well padded posterior with which the Colonel's highly polished size-nine connected belonged not to an Honourable Member but to the Belgian Ambassador. This explains, in part, why he resigned the next morning ….. His position as a government Whip had prevented him from voicing his opposition to the Mobberley development openly. Resignation gave him the freedom to represent the interests of …"

This book is full of such insights, in part covering the same ground as in Sir Bernard's own wonderfully enjoyable and thorough book on the building of Jodrell Bank telescope in *Voice of the Universe* (Praeger Pub., 1968). But this is more informal in style. These two books nicely complement each other, in fact - although there is also, of course, Sullivan's superb *Cosmic Noise as* reviewed here in *RAGazine's* first Issue.

Of course, *Space Has No Frontier* covers Sir Bernard's whole life, near a century. He grew up in a Methodist family, near Bath and Bristol in the West Country, and developed a love of the piano, then took up organ playing as a small boy. This was then followed by a passion for cricket, and then for rudimentary radio. He tinkered with the new mains generator his father had installed to replace the oil and candle lamps, but he was not that good at school until he had the opportunity one day to hear the luminary Prof Tyndall at Bristol University on a special school trip. This clearly inspired Lovell, and he set out to study physics under Tyndall at Bristol. It was also interesting for me to read that it was not only the dramatic sparks-and-ultra violet light demonstration that was part of Tyndall's lecture, but it was the grandeur of the Henry Wills (tobacco magnate's) Building that made a huge impression on young Lovell; for many years later from my high school, also near Bath, I too went on just such an inspiring event in the very same lecture theatre in the Wills Building, in my case for a Schools Christmas Lecture on physics.

He was a diligent worker all his life, and after a good physics degree from Bristol he did post-graduate work on electrical conductivity of thin metal films. Whilst there he also met, and disliked, the young mathematician Fuchs, who later spied against the UK and who caused great damage. Then he went to Manchester, and the author does a great job in conveying the nature of the maturing physicist and his wide musical and other interests. After cosmic ray research, he then moved to the Telecommunications Research Establishment (TRE) and did significant work from the outset of War on radar systems, direction finding and so on. Recall that this was the time when the magnetron was brand new, and very secret, and the klystron was until then the only source of microwave power. One of the most important developments that Lovell was responsible for was the airborne radar that had such a key - indeed vital - role in defeating enemy U-boats, and he was awarded the OBE in 1946 for all these radar related developments made at such a great pace during the War. As he stated later: "Nobody ever worried about the cost. There were only two questions. Can you do it ? And when can we have it ?"

Returning to Manchester after the War, he restarted cosmic ray studies, using a military radar, and it was interference from trams that led to a search for an electrically quiet site, and it was almost by chance that Jodrell as a site came about. The rest is almost a legend now. But this book also covers the interactions with the Soviets, his (limited) work in espionage, the Sputnik era, the alleged attempt to poison him, the building up of the Observatory, the willingness outside strict science to help the MOD and the USA in the Cold War, ICBM tracking, cooperation with NASA, MERLIN, his friendship with Sir Patrick Moore, the wonderful arboretum at Swettenham, and much more.

This is an enjoyable, very satisfying book, covering a key figure in the development of radio astronomy internationally. The author has benefited from the release of many documents since Lovell's death. He has provided plenty of references and colourful vignettes to convey his subject's passions, and intense frustrations at times. Lovell's humanity comes through very clearly: a great family man, hard-working, proud but quite modest in demeanour, a man of faith, a good organist and cricketer, something of a renaissance man to many. He had met Churchill, Eisenhower; worked with R V Jones, Tyndall, Hey, Ryle, Graham-Smith, Lyne *et al*; under 'Bomber' Harris, and above all battled against all odds to complete the world's first really large steerable radio telescope at a time when funds, technology and manufacturing were pushed to the limit. After chronicling such a rich, full life, the author turns in the last few chapters to cover the sad decline in health of Lovell's beloved wife and then Lovell's own increasing frailty and declining sight, and this is chronicled most clearly and movingly. There are fine photos showing the arboretum and he and his wife together in later years, a fine a poignant addition to all the other well selected pictures recording his work and achievements.

This book is an affectionate, well written, fitting tribute to a wonderful pioneer in radar and then radio astronomy - indeed one of our British heroes.

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# VLF Quarterly Observing Report, to February End 2014

**- John Cook** jacook@jacook.plus.com

Observing, VLF

Fig 1 shows activity levels since 2005. The relative sunspot number is a weighted 13 month average, and so values over the last six months are provisional. Sunspot data is courtesy of the BAA Solar Section. SID figures for the last three months are:

2013 November = 63,
2013 December = 40,
2014 January = 48.

The figure for January is also provisional, as I do not have all of the reports to hand yet. Included in these totals are two X-class flares, one in November and one in January.

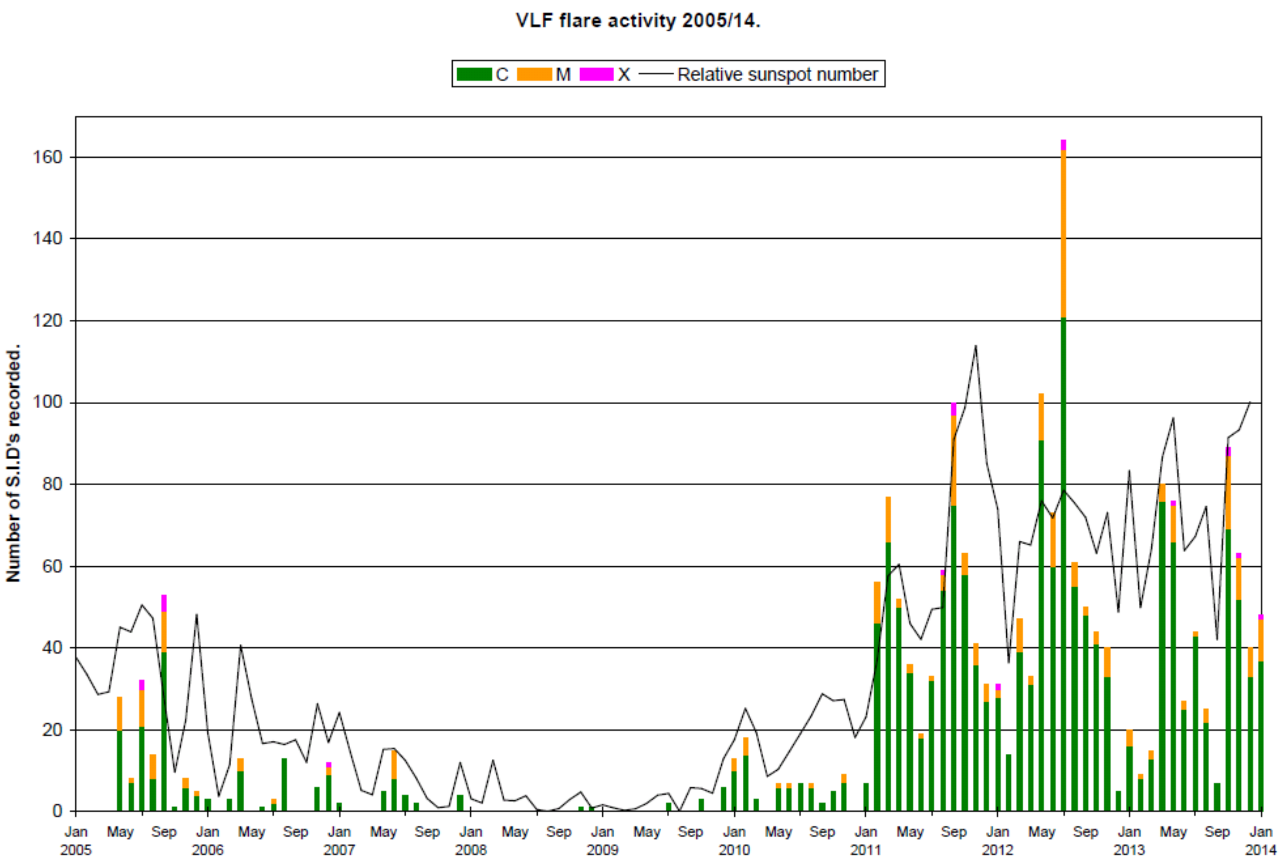



Fig 1 Activity chart

The X1.0 flare on November 19th was well timed for recording as a SID, with an X-ray peak just before 10:30UT. Paul Hyde recorded this at 19.6kHz, 22.1kHz and 23.4kHz, shown in Fig 2. The response at each frequency is different, 19.6kHz (red) showing the 'classic SID' shape. 22.1kHz (blue) and 23.4kHz (yellow) both show a 'spike and wave' shape, although one is inverted relative to the other. This shape is caused by the shifting sky wave / ground wave interference pattern moving through adding and cancelling phases as a result of the changing D-region height. There were also 10 SIDs from M-class flares recorded in November, spread fairly evenly through the month.

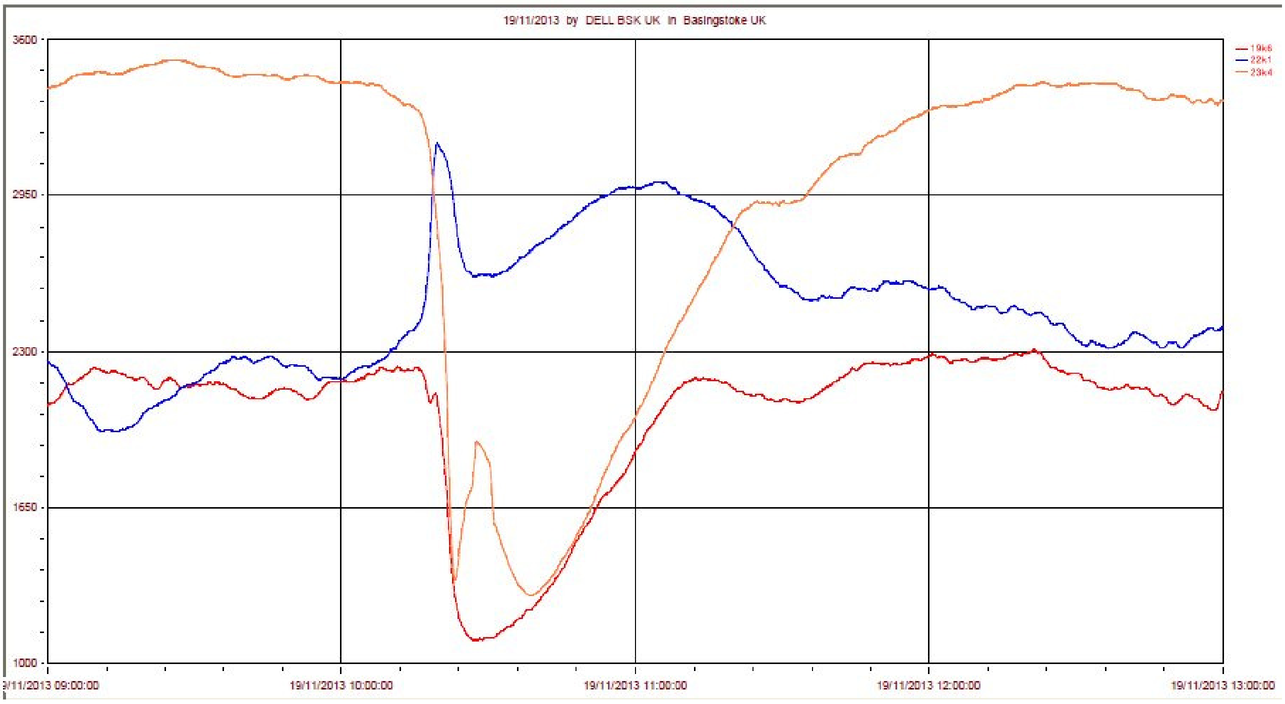



Fig 2 Paul Hyde, Nov 19th

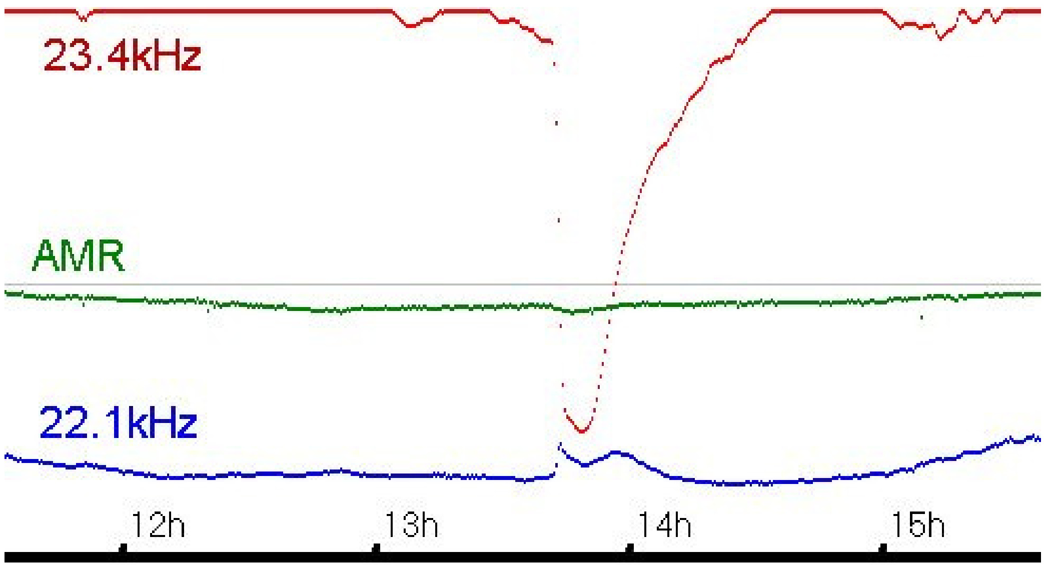



Fig 3 John Cook, Nov 6th

In the last update I reported a possible SFE on 2013 October 25th. This has since been confirmed in the BGS magnetic bulletin. A further SFE was recorded on November 6th, bringing the total to six. Fig 3 shows my own recording of the SFE and SID from an M3.8 flare peaking at 13:49UT. A very small dip in the magnetometer (green trace) of about 4nT can be seen coincident with the SID. The remaining disturbances were due to CH HSS effects, with no CME's recorded despite a number of strong flares.

Activity dropped in December, partly due to lower solar activity, and partly due to the reduced winter daylight hours. The low altitude of the sun generally results in less D-region ionisation such that weaker flares do not produce detectable SIDs. Even under quiet conditions, received signal strength can be quite variable making small SIDs difficult to sort out of the noise. 23.4kHz also has an annual shut-down over the Christmas and New Year holiday period. There were however four M-class flares on December 22nd, well recorded by Roberto Battaiola in Milan. See Fig 4. Being a few degrees further south makes a big difference at this time of year!

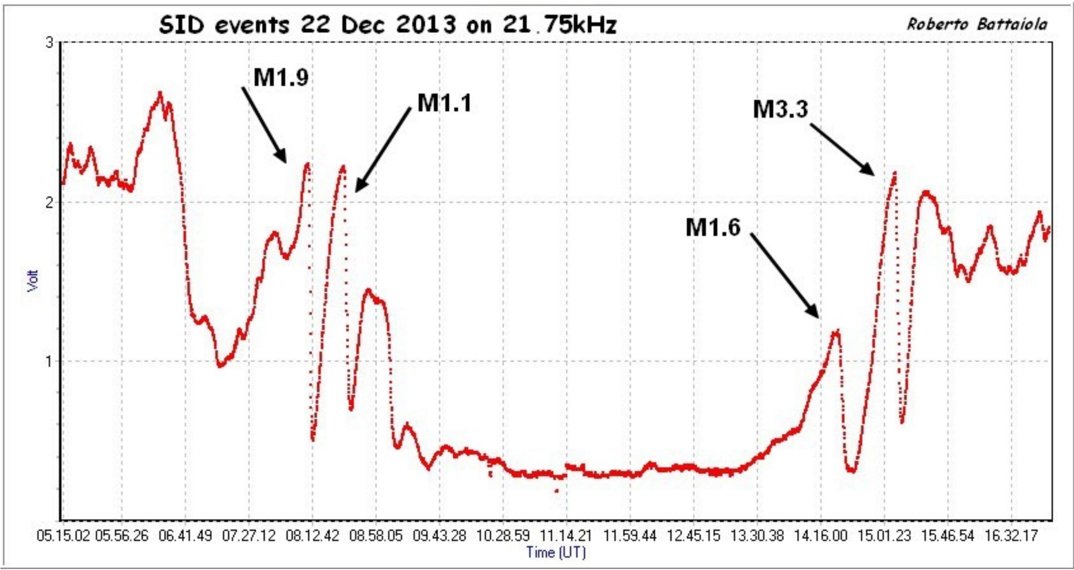



Fig 4 Roberto Battaiola, Dec 22nd

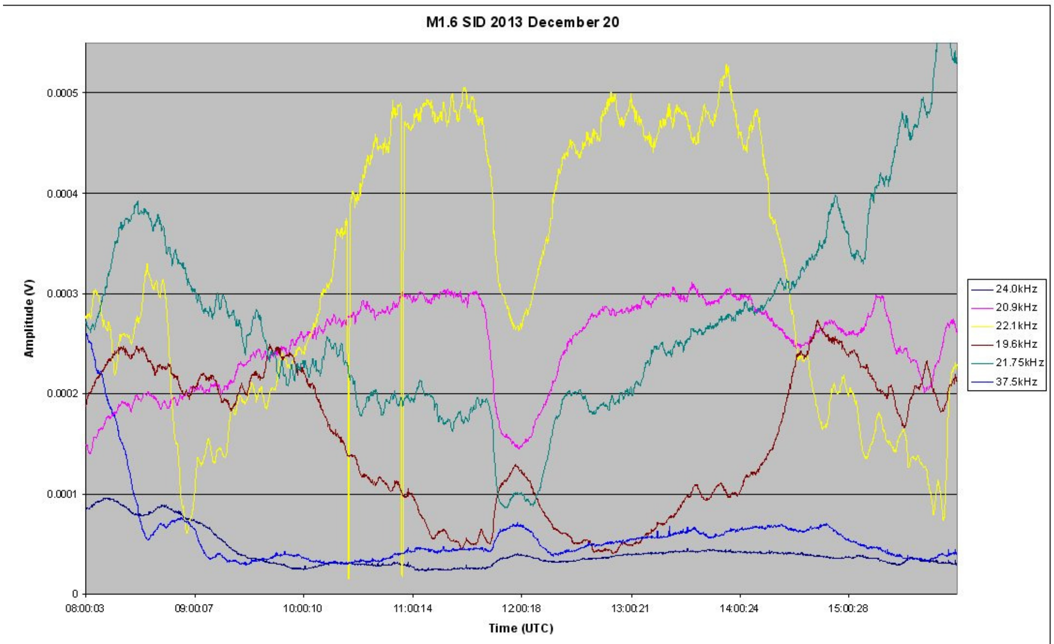



Fig 5 Mark Edwards, Dec 22nd

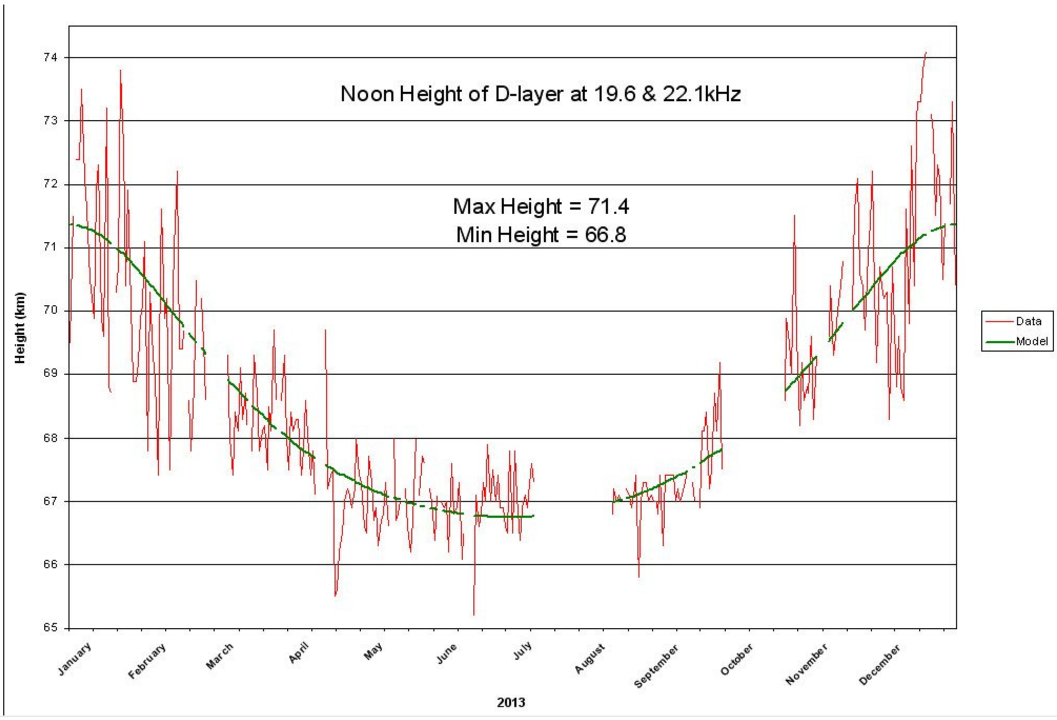



Fig 6
Mark Edwards

An M1.6 flare on December 20th was widely recorded by observers. Mark Edwards' chart is shown in Fig 5. Mark also provides an annual summary of D-region height over the year, Fig 6. This shows the minimum height derived using a single reflection fit to both 19.6kHz and 22.1kHz simultaneously. Details of the modelling that Mark uses can be found on the RAG website. Similar charts were included in the December summaries for 2010, 2011 and 2012, also available through the website. The maximum and minimum heights for each year are broadly similar, so it will be interesting to see if there any changes as solar cycle 24 activity fades.

Magnetic activity in December was again rather low. Although a number of CME's were produced, they came from active areas close to the solar limb and were not directed towards Earth. CH HSS effects were responsible for the disturbances shown in the Bartels chart shown at the end of this article.

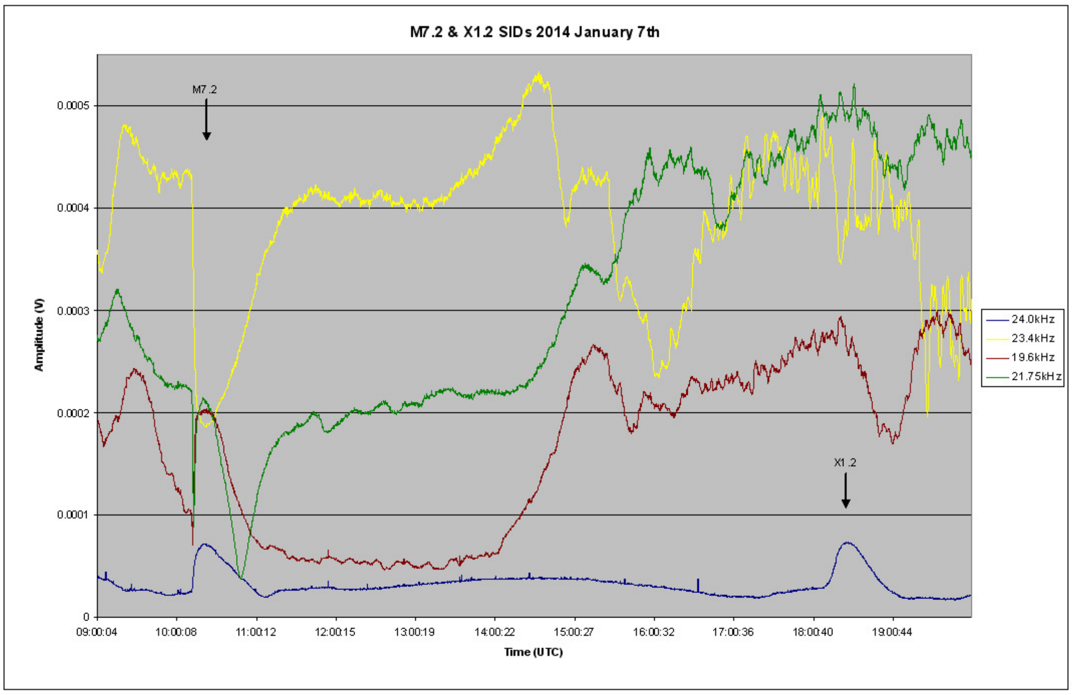



Fig 7 Mark Edwards, Jan 7th

Flare activity increased again in January, with another X-class flare on the 7th. Peaking at 18:25UT it was rather late in the afternoon to produce a SID on European signals, but Mark Edwards recorded it on the Atlantic path from NAA at 24.0kHz (Fig 7). AR11944 was a large complex active region close to the eastern limb of the sun when it produced a C9.5 flare on January 2nd. Fig 8 shows my 22.1kHz recording with the GOES X-ray flux added. The SID is fairly weak on my recording due to high levels of local interference. Unfortunately 23.4kHz was still off-air. There are several peaks to the X-ray profile, the peak shown in the SWPC bulletin being at 12:26UT, with a start time of 11:25UT. I see two SIDs from this event, with peaks at 11:33 and 12:28UT.

Magnetic activity was still very low in January. CME's have again been directed away from Earth. The few disturbances listed appear to be from CH HSS effects.

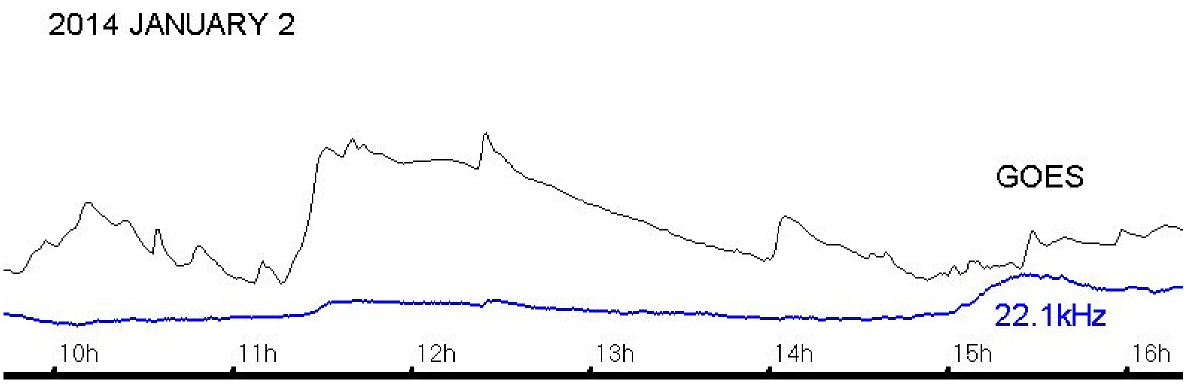


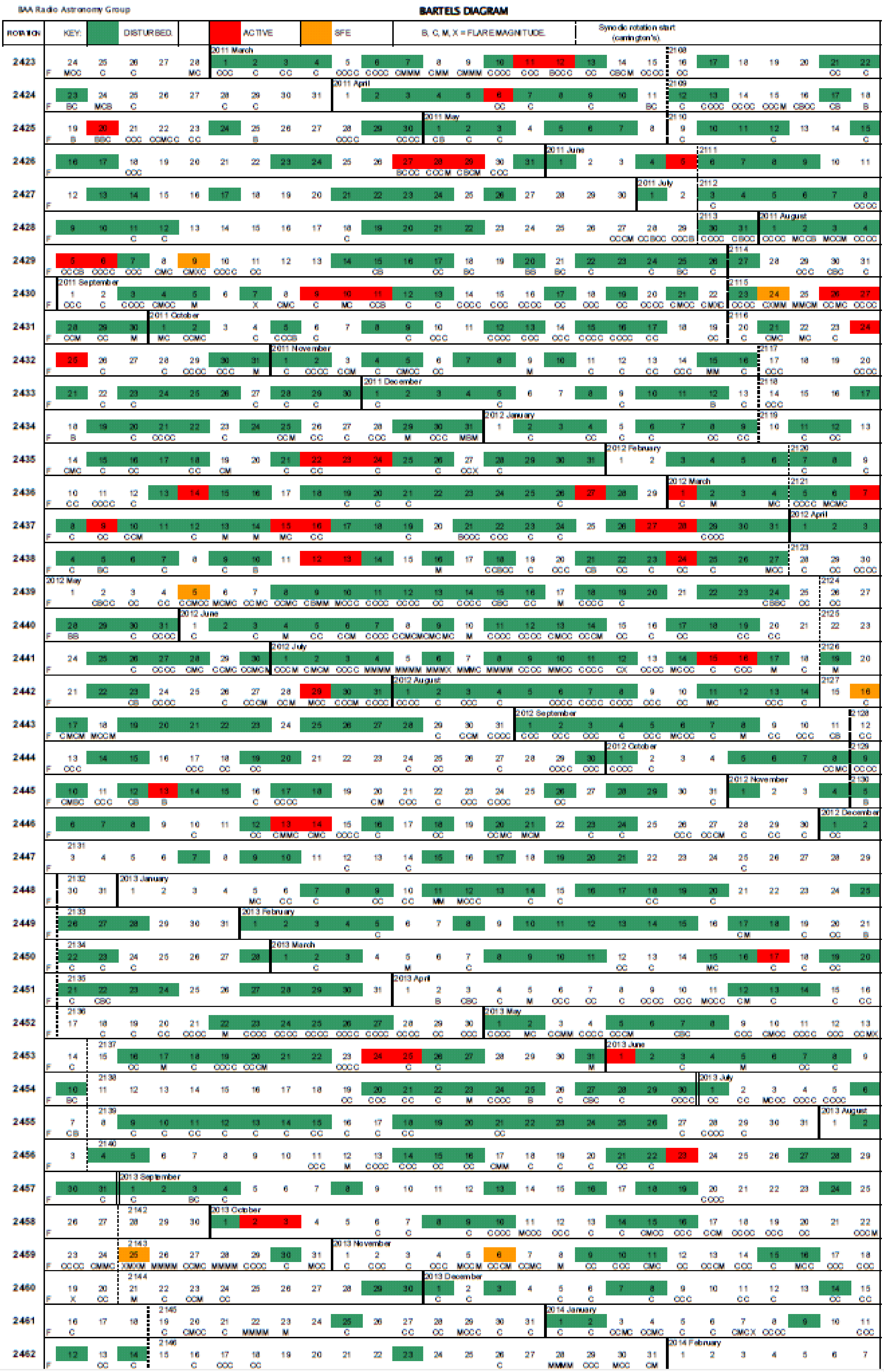

Fig 8  John Cook, Jan 2nd

**Observers:** Roberto Battaiola, Roger Blackwell, Colin Clements, Mark Edwards, John Elliot, Paul Hyde, Richard Kaye, Peter King, 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.

I have also included a brief appendix following the Bartels chart, explaining some of the abbreviations used in these quarterly reports.

Fig 9  Bartels chart
/ see over /


BAA Radio Astronomy Group
BARTELS DIAGRAM
ROTATION
KEY:
DISTURBED
ACTIVE
SFE
B, C, M, X = FLARE MAGNITUDE
Synodic rotation start (carrington's)

## Appendix: Common Abbreviations

In general it can be very confusing to newcomers, but can also be a useful shorthand when writing. This list should help to explain those used in my summaries of Solar and magnetic activity.

**SIDs**: Sudden Ionospheric Disturbances.
These are the characteristic effects seen in the Earth's ionosphere in response to solar X-ray flares. They are recorded by monitoring the signal strength of a remote terrestrial transmitter, and take the form of sudden changes in received signal strength. Signals in the VLF (q.v.) spectrum are used, as they are reflected / refracted by the ionosphere's D-region (q.v.) where the X-ray and UV energy has its greatest effect.

**SEA**: Sudden Enhancement of Atmospherics.
Rather than monitoring a known transmitter to detect solar flares, natural atmospherics from remote lightning storms can be used instead. As with a SID, the D-region disturbance can be recorded as an enhanced reception of these natural VLF radio signals. SEA monitoring was very popular in the early days of BAA radio astronomy.

**VLF**: Very Low Frequency.
Usually refers to the spectrum between 3kHz and 30kHz. For solar flare monitoring the range in use is usually 15kHz to 40kHz.

**D-region**:
This is the name given to the lowest part of the Earth's ionosphere at an altitude of about 70km. The level of ionisation present in the D-region (the electron density) is directly controlled by Solar radiation such that its radio wave propagation characteristics can be used to detect changes in Solar activity. Normal daytime radiation from the Sun produces a level of ionisation that varies with the Sun's altitude in the sky through the day. The absence of sunlight at night allows electrons to recombine leaving a neutral charge.

**SI**: Sudden Impulse.
An abrupt change in the Earth's magnetic field, caused by the arrival of a region of enhanced solar wind velocity or density.

**SSC**: Storm Sudden Commencement.
A change in the rhythm of the Earth's magnetic field following a Sudden Impulse. This is often followed by a longer lasting magnetic storm.

**CME**: Coronal Mass Ejection.
The ejection of a part of the Sun's corona following a solar flare. Depending on the geometry of the flare, the CME may or may not be directed towards the Earth. CMEs are usually responsible for the SI/SSC transients recorded in magnetograms. The ejected mass is in the form of charged particles, and so travels through space much more slowly than the electromagnetic radiation from the original flare.

**SFE**: Solar Flare Effect.
A SFE occurs when a very rapid increase in D-region electron density is produced by the X-ray and UV output of a solar flare. This rapid change in ionisation causes a rapid change in current flow in the D-region, and therefore a rapid change in the magnetic field. On a magnetogram, an SFE occurs at the same time as the flare (or recorded SID), while a SI or SSC will be delayed by a day or more according to the solar wind speed.

**nT**: Nano Tesla.
The SI unit of magnetic flux density, named after Nicola Tesla.

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# Physics, Engineering Maths, and more ….

Light relief

Einstein: “You know, Henri, I once studied mathematics, but gave it up for physics.”

Poincaré: “Oh, really, Albert, why is that ?”

Einstein: “Because although I could tell the true statements from the false, I just couldn’t tell which facts were the important ones.”

Poincaré: “That is very interesting, Albert, because I originally studied physics, but left the field for mathematics.”

Einstein: “Really, why ?”

Poincaré: “Because I couldn’t tell which of the important facts were true.”

——

Al-Gore-rithm, *n*: a mathematical operation which is repeated many times until it converges to the desired result, especially in Florida.

*The Grapevine*

——

Russia is a country with an unpredictable past

Y Afanasiev

——

I am a mathematician to this extent: I can follow triple integrals if they are done slowly on a large blackboard by a personal friend.

J W McReynolds

——

Mathematics may explore the fourth dimension and the world of what is possible, but the Czar can be overthrown only in the third dimension.

V I Lenin

——

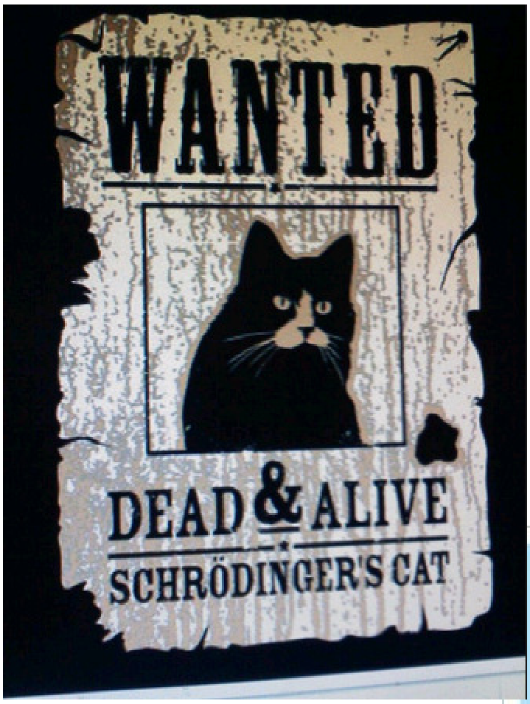
A programmer’s wife tells him: “Run to the store and pick up a loaf of bread. If they have eggs, get a dozen.” The programmer comes home with 12 loaves of bread.

——

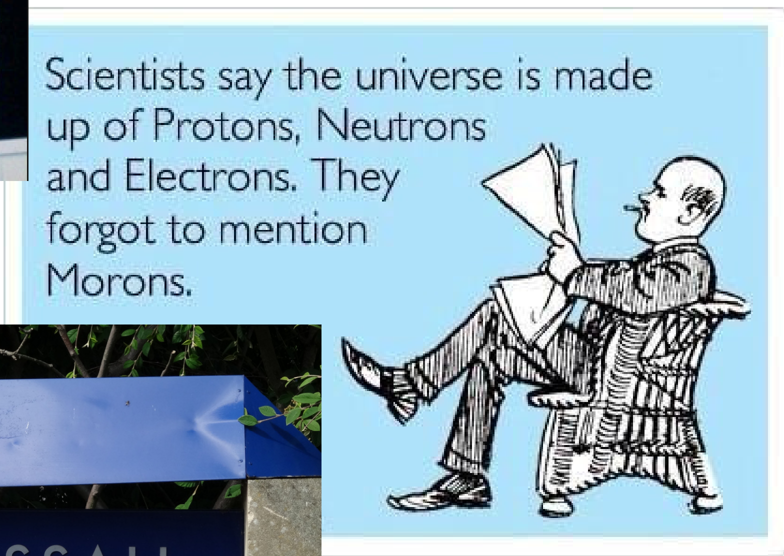
Jean-Paul Sartre is sitting at a French café, revising his draft of Being and Nothingness. He says to the waitress: “I’d like a cup of coffee, please, with no cream.” The waitress replies: “I’m sorry, Monsieur, but we’re out of cream. How about with no milk?”

——

## and more ….










**After explaining to a student through various lessons and examples that:**

$$\lim_{x \to 8} \frac{1}{x-8} = \infty$$

**I tried to check if she really understood that, so I gave her a different example. This was the result:**

$$\lim_{x \to 5} \frac{1}{x-5} = \text{ᔕ}$$

# What's On

| | | | |
|---|---|---|---|
| March | 1-8 | 2014 | National Astronomy Week - with a Jupiter focus |
| March | 22-23 | 2014 | SARA Western Conf., OVRO nr Bishop, Ca: see SARA web site |
| April | 11-13 | 2014 | BAA Winchester Weekend, Sparsholt, Hants.: see BAA web ite or Dec '13 J Brit Astron. Assoc.** |
| May | 17 | 2014 | RAG2014 at NSC, Leicester: see this issue |
| June | 27-29 | 2014 | Ham Radio Fest, Friedricshafen, Germany |
| June | 29– 2 July | 2014 | SARA Annual Conf., Green Bank, WV: see SARA web site* |
| July | 2-3 | 2014 | Radio JOVE Conf., Green Bank, WV: see above |
| *July* | *TBA* | *2014* | *Possible BAA RAG Workshop on Meteor Scatter* |
| July | 25-27 | 2014 | AMSAT Colloquium, Guildford |
| Aug | 23-27 | 2014 | EME 2014,  Pleumeur Bodou, near Lannion, France |
| *Sep* | *13-14, TBA* | | *Possible 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 |

** Includes SKA lecture by Prof Wilkinson, Manchester U

* Star Quest (optical) immediately precedes, 25-29 June at same location, NRAO.

## Frequency Ranges per ITU-R (more or less)



Lest we get confused through loose or incorrect usage of abbreviations ……

| Frequency | Wavelength | Designation | Abbreviation |
|---|---|---|---|
| 3 – 30 Hz | $10^5$ – $10^4$ km | Extremely low frequency | ELF |
| 30 – 300 Hz | $10^4$ – $10^3$ km | Super low frequency | SLF |
| 300 – 3000 Hz | $10^3$ – 100 km | Ultra low frequency | ULF |
| 3 – 30 kHz | 100 – 10 km | Very low frequency | VLF |
| 30 – 300 kHz | 10 – 1 km | Low frequency | LF |
| 300 kHz – 3 MHz | 1 km – 100 m | Medium frequency | MF |
| 3 – 30 MHz | 100 – 10 m | High frequency | HF |
| 30 – 300 MHz | 10 – 1 m | Very high frequency | VHF |
| 300 MHz – 3 GHz | 1 m – 10 cm | Ultra high frequency | UHF |
| 3 – 30 GHz | 10 – 1 cm | Super high frequency | SHF |
| 30 – 300 GHz | 1 cm – 1 mm | Extremely high frequency | EHF |
| 300 GHz - 3000 GHz | 1 mm - 0.1 mm | Tremendously high frequency | THF |

# The State of Flux - An *Arduino* Based Magnetometer

**- Jonathan Rawlinson**

Data collection, magnetometry

## Introduction

This article is a description of my progress towards an open source data collection system that is able to run on an low power mini PC. The reason why I want to do this is because I would like a data collection system in a small form factor that can be easily run by an off-grid power source which is cheap and easy to construct and can be extended for many purposes. I have been following small embedded systems for a while now and decided to focus on a combination of Arduinos and a Raspberry Pi mostly due to the low cost and the high level of community support provided.

I have three major criteria for my project:

- easy deployment. The system must be easy to construct for an unfamiliar user and not require any "out of the ordinary" components. I have tried to source all of my components from two main outlets, rapidonline.co.uk and Amazon.co.uk.

- reliability and durability. The system must be able to "put up" with events such as power cuts and other annoyances without losing valuable data.

- extendability. The system must be easy to extend for different uses. The system could also be extended for non RA uses such as monitoring power systems, humidity levels or the temperature of my beer fermenter !

I am using Python 2.7 for writing the software. This is because the language is easy to learn, there is lots of community support and the code can be run on many different systems and architectures. To develop the first phase of my software I decided to work towards an Arduino based magnetometer. I chose this sensor as I have always been interested in the earth's magnetic field and I had some FGM-3 sensors "in stock"!

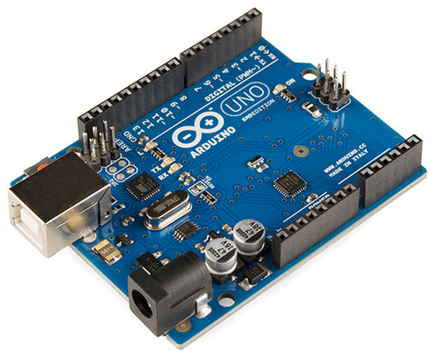


Figure 1 Arduino Uno R3

## Sources


http://helios.gsfc.nasa.gov/magnet.html
http://en.wikipedia.org/wiki/Geomagnetic_storm
http://stereo.gsfc.nasa.gov/classroom/definitions.shtml#CME
http://www.gnuplot.info/

## The Earth’s Magnetosphere

Above the ionosphere, the Earth's magnetosphere extends thousands of kilometres into space. The magnetosphere is compressed into the shape of a "tear drop" by the solar wind as the charged ions in the solar plasma interact with the Earth's magnetic field (as shown in the image below). The magnetosphere is able to protect the earth from the solar wind due to the fact that it is able to interact with these charged ions. In doing this it funnels the charged particles from the sun to the earth's poles. This is what produces the Aurora in the northern and southern regions of the earth. When there are solar disturbances such as CMEs (Coronal Mass Ejections) the intensity of the solar wind changes and hence the magnetosphere is affected as the number of charged particles that it is interacting with changes. By using highly accurate magnetometers scientists can monitor the status of the magnetic field and gain information about the magnetosphere, the solar wind and the Sun itself.

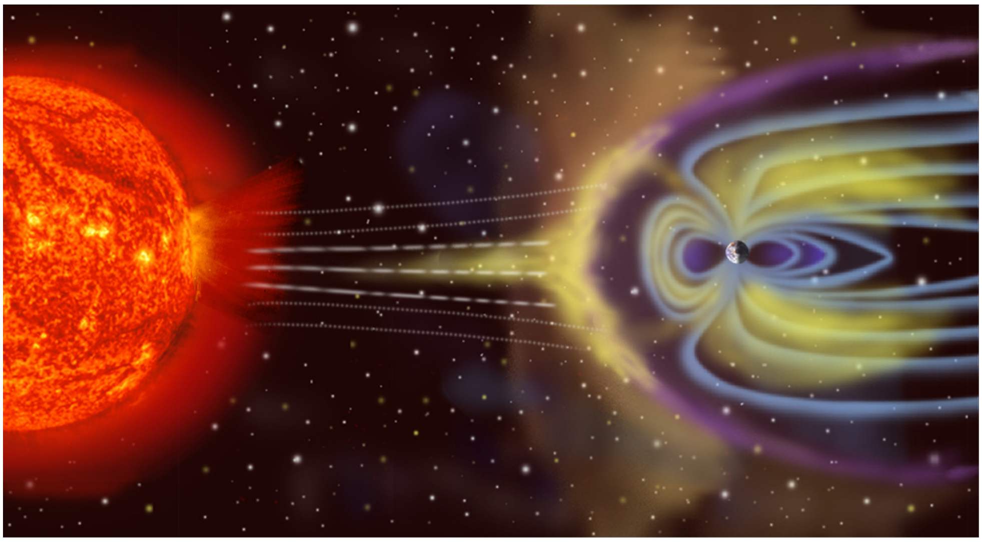


Figure 2 The Earth's Magnetosphere being compressed by the solar wind.

Source: wikipedia

## Project Structure

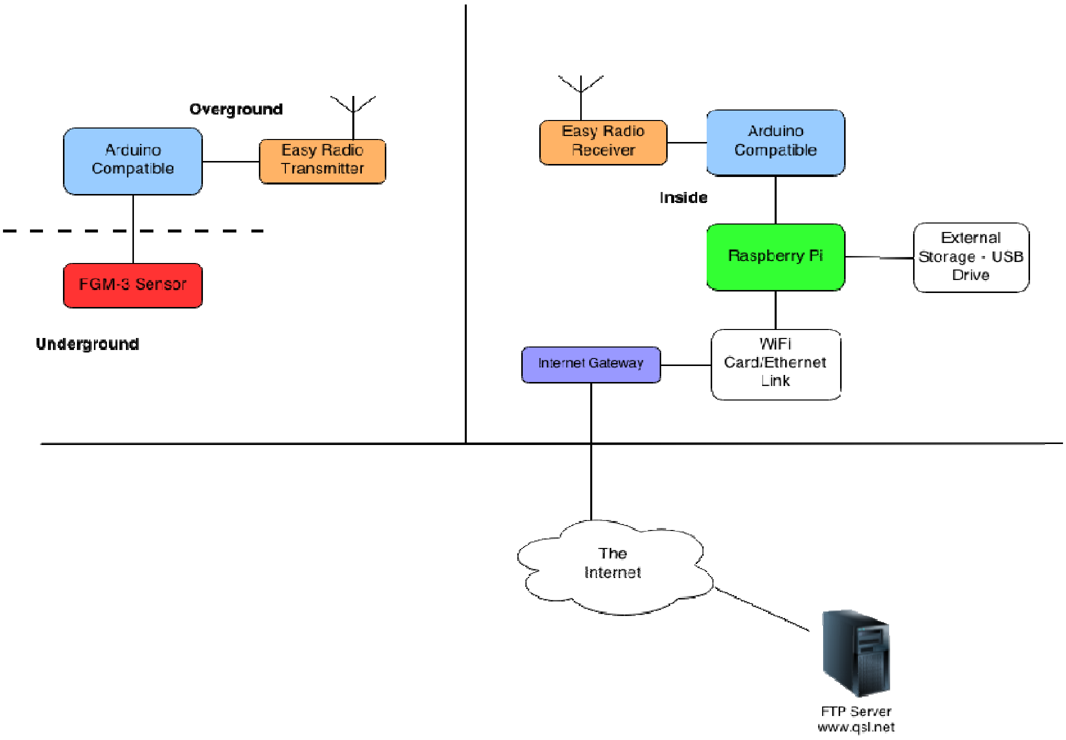



Figure 3 Block diagram of the proposed system

The magnetometer in the field takes a reading and then sends this reading inside to the Raspberry Pi via an *EasyRadio* RF link. This data is then read by the Raspberry Pi and periodically graphed by Gnuplot The graphs produced are then uploaded to an FTP site (in my case www.qsl.net) via the internet.

## The System

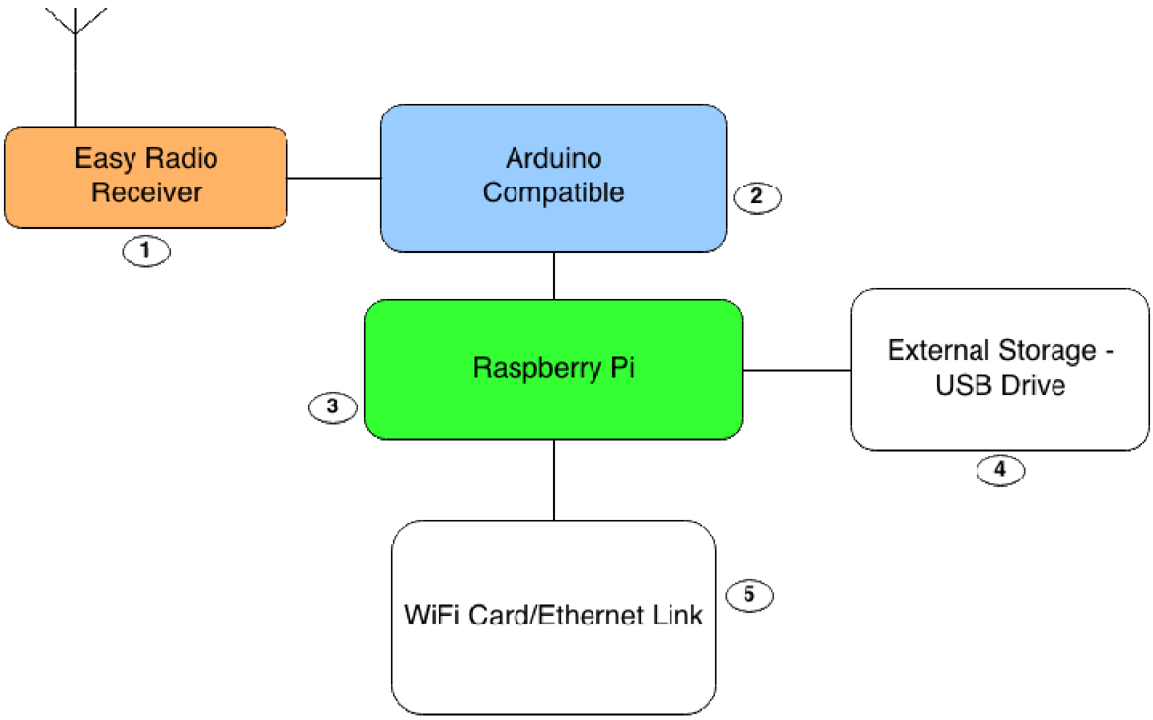



Figure 4 Raspberry Pi Block Layout

1 To get the data from the external sensor to the Raspberry Pi a radio link is used. In my setup I am using two "EasyRadio" modules but any other similar units could be used e.g. Zigbee. I decided to separate the sensor and the mainframe so that all of the sensitive electronics are kept safe inside whilst the sensor is able to get a more reliable reading in a less busy environment (electronically).

2 To interface between the radio module and the Raspberry Pi I have used an Arduino. I have done this so that there is a buffer in place between the Raspberry Pi and radio module. In addition to this having an Arduino in line may be useful if I wanted to extend the functionality of my system e.g. GPS Time Sync or extra mainframe based sensors such as temperature sensors.

3 To do all the 'heavy lifting' in the system I have used a Raspberry Pi. At the moment there are many different cheap Mini PCs on the market that run Linux on an ARM processor. For example:

A) Raspberry Pi (Model B)
B) Cubieboard
C) eagleBone Black
D) MK802 & RK3188 Based PCs

All of the above units have different advantages and disadvantages. Overall I chose the Raspberry Pi due to the extremely low cost and high level of community support. At some point I would like to test more of these devices to see what they are capable of. I was also considering using a cheap Android tablet for the data collection but I decided that a Raspberry Pi would be more suitable for this purpose.

I have written all of the code for my project in "Python". I decided to choose Python as it is a powerful and portable programming language that is relativity easy to learn. In addition to this there is extremely good community support available on the internet. Python is the recommended language for the Raspberry Pi.

4 As there is limited storage on the SD card in the Raspberry Pi (approximately 5 GB is free when the system is installed on a 8 GB SD card) I decided to use a USB flash drive as my main storage area. This means that adding data capacity is relatively easy, cheap and convenient.

5 To let my Raspberry Pi connect to the outside world I am either using a cable link to the router or an *Edimax* USB WiFi card.

### The Sensor

Speake and Co (Based in Llanfapley, Wales) produce a range of scientific grade magnetometers (the FGM Series). I chose to use the FGM-3 as it is the most sensitive sensor (and it is the cheapest !). An image of the sensor is below:


Figure 5 FGM-3 Sensor

## Example Data

Now for what you have all been waiting for ! In the next figures are three images created with the latest version of my software. The sensor was not yet underground. For testing purposes the sensor was left on my desk/workbench. Figures 4 & 5 show some sort of magnetic disturbance. This was most probably due to me using other pieces of electrical equipment (laptops, 3D printers, etc) relatively close to the sensor at the time the data was recorded. In the real setup the sensor will be installed underground to try and avoid interference like this and to help with thermal stability. This provides an interesting insight into the impact of consumer electronics on sensitive scientific equipment. The reader may notice that the images are actually displaying a larger amount of time than stated in the title. This is a known software bug that will be fixed in the future. The timing labels are added for clarity.

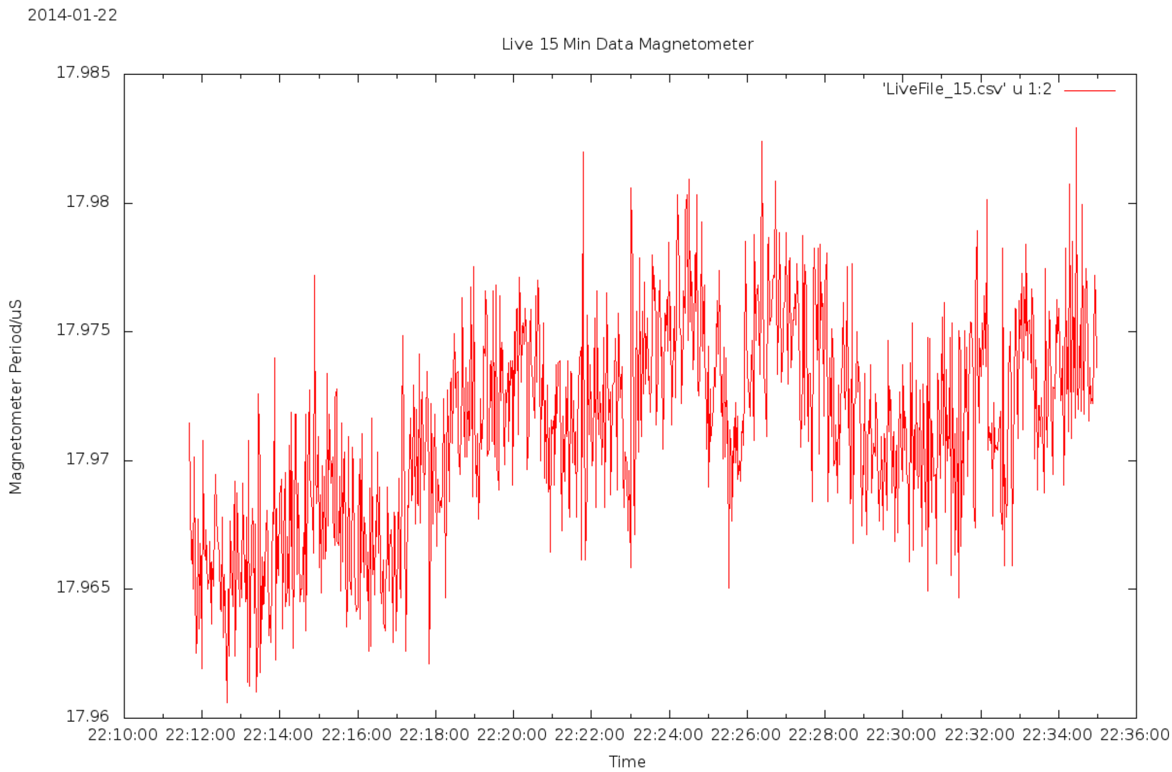



Figure 6 Example of 15 minute data graph

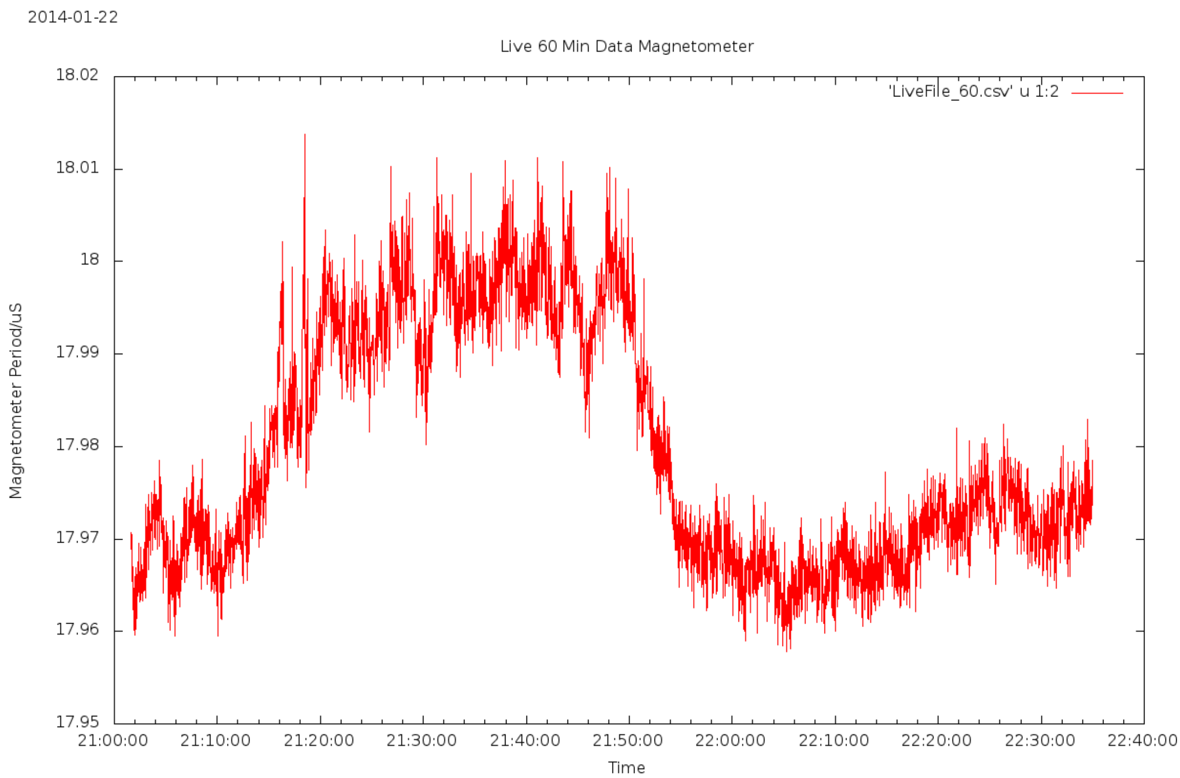



Figure 7 Example of 60 minute data graph

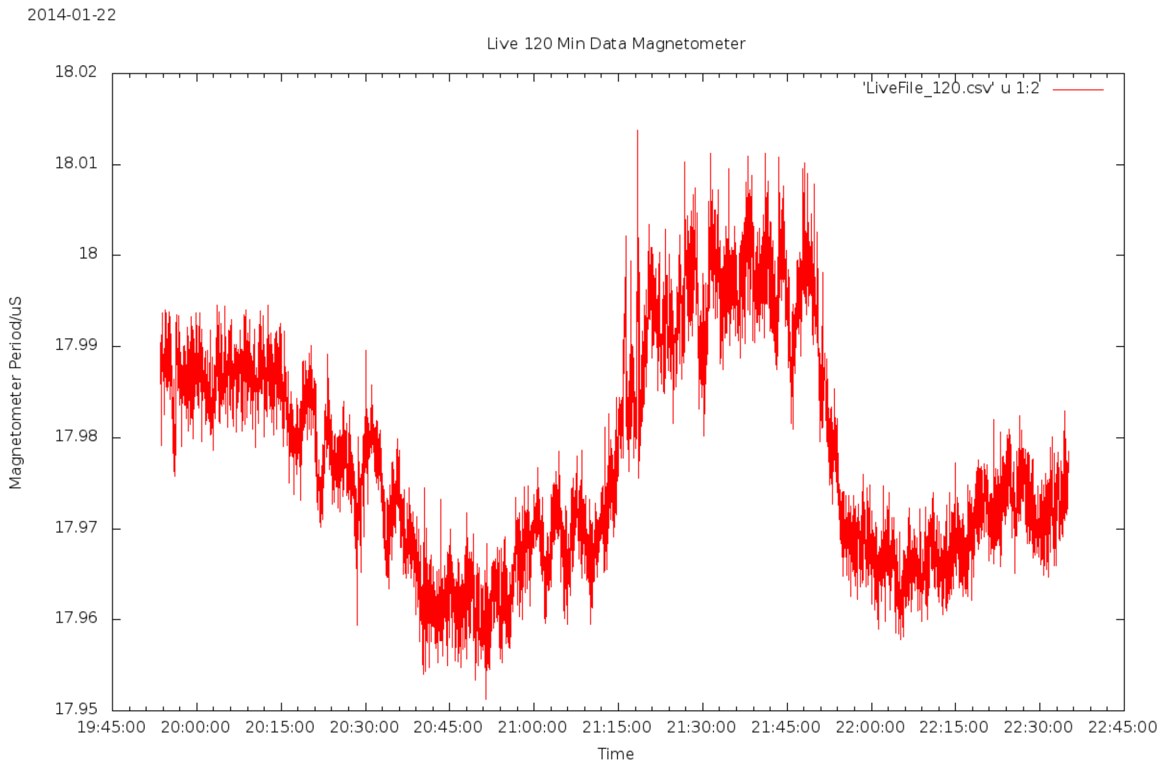



Figure 8 Example of 120 minute data graph

## The Test Setup

Below is an image of the "inside" elements of my present test setup. Note the Raspberry Pi in the pink case and the Arduino with my home made receiver "shield". The WiFi card is on top of the white USB extension lead.

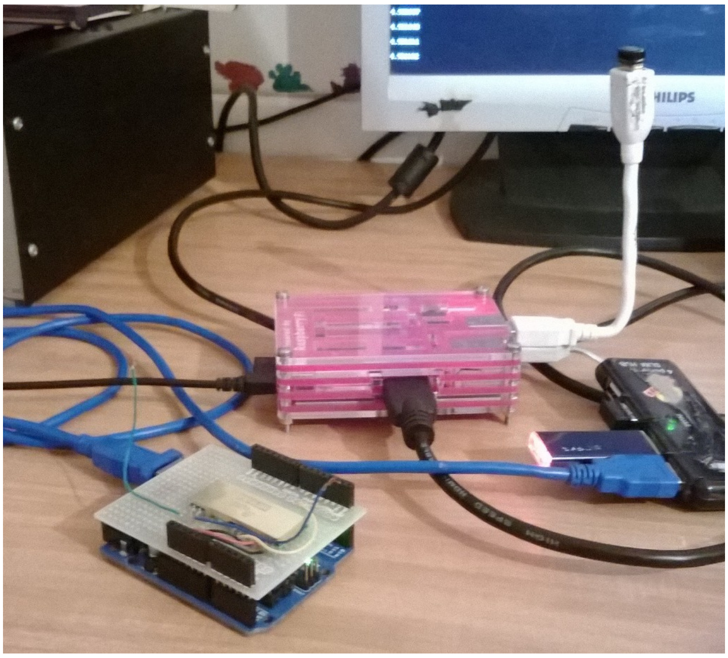


Figure 9 PyDat "inside" test Setup

Below is an image of the prototype "outside" unit. Please note the SD card and RTC (Real Time Clock) on top of the Arduino for future use:

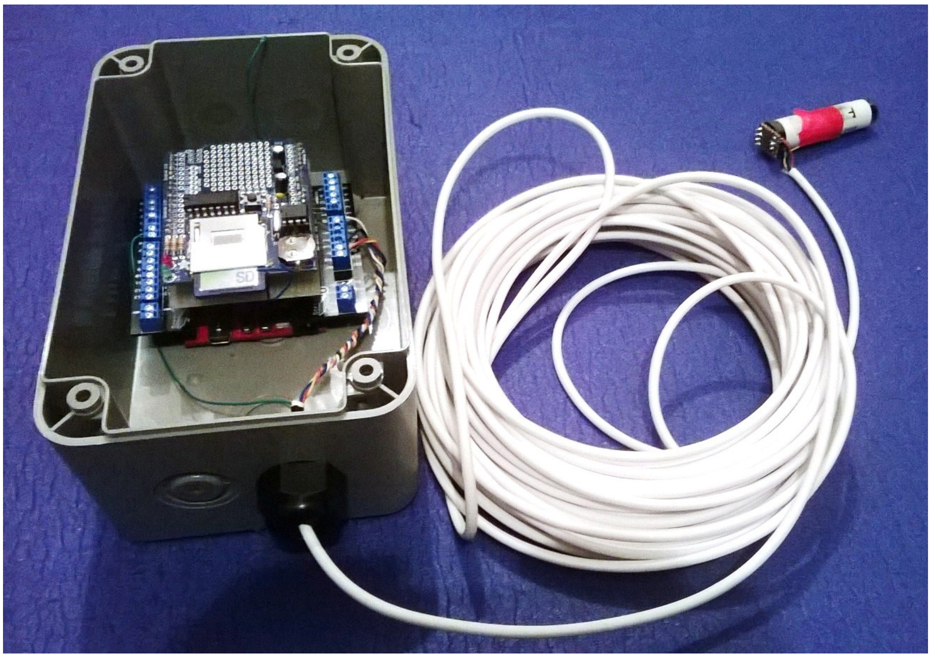


Figure 10 PyDat "outside" setup

## Future Targets, Next Steps

The ability to share data with Radio Skypipe (using the UDS system)
Live graph view and GUI of some description.
Reliable Wireless Link to internet
Possibility of GPRS/3G upload
GPS time Sync
Remove the need for receive Arduino (Radio receiver directly connected to Raspberry Pi)
Bug fixing
Documentation
Test on other operating systems
RTL SDR total power measurement logging (using pyrtlsdr)

I look forward to meeting many of you at the RAG conference in May !

If you would like to track my experiments, I will be doing my best to keep my web page up to date with my latest progress. Hopefully reliable live magnetometer data will also be up soon (if we stop getting power cuts !)

My site: http://www.qsl.net/m/m0zjo/

73 de M0ZJO !!!

*Proceedings of the Institute of Radio Engineers*
*Volume 20, Number 12* *December, 1932*



# DIRECTIONAL STUDIES OF ATMOSPHERICS AT HIGH FREQUENCIES*

By

KARL G. JANSKY
(Bell Telephone Laboratories, New York City)

**Summary**—*A system for recording the direction of arrival and intensity of static on short waves is described. The system consists of a rotating directional antenna array, a double detection receiver and an energy operated automatic recorder. The operation of the system is such that the output of the receiver is kept constant regardless of the intensity of the static.*

*Data obtained with this system show the presence of three separate groups of static: Group 1, static from local thunderstorms; Group 2, static from distant thunderstorms, and Group 3, a steady hiss type static of unknown origin.*

*Curves are given showing the direction of arrival and intensity of static of the first group plotted against time of day and for several different thunderstorms.*

*Static of the second group was found to correspond to that on long waves in the direction of arrival and is heard only when the long wave static is very strong. The static of this group comes most of the time from directions lying between southeast and southwest as does the long wave static.*

*Curves are given showing the direction of arrival of static of group three plotted against time of day. The direction varies gradually throughout the day going almost completely around the compass in 24 hours. The evidence indicates that the source of this static is somehow associated with the sun.*

## INTRODUCTION

FOR some time various investigators have made records of one type or another of the direction of arrival of static on the long wavelengths. Watson Watt has made a comprehensive study of the direction of arrival of static in England. Others working under him have used apparatus similar to his in Australia and Africa. Captain Bureau has done considerable work on the study of static in France. In this country, L. W. Austin with E. B. Judson working with him has worked on the long-wave static problem. Harper and Dean, also of this country, have made a study of the direction of arrival of long-wave static in Maine. Very little work, however, has been done on the direction of arrival of short and very short-wave static with the exception of the series of observations made by Mr. Potter as described in his paper on short-wave noise.[1]

* Decimal classification: R114. Original manuscript received by the Institute, May 26, 1932. Presented at the meeting of the American Section of the U.R.S.I. at Washington, D. C., April 29, 1932.

[1] R. K. Potter, "High-frequency atmospheric noise," PROC. I.R.E., vol. 19, p. 1731; October, (1931).

## Description of Apparatus

Since the middle of August, 1931, records have been taken at Holmdel, N. J., of the direction of arrival and the intensity of static on 14.6 meters. Fig. 1 shows a schematic diagram of the recording system. It consists of a rotating antenna array, a short-wave measuring set, and a Leeds and Northrup temperature recorder revamped to record field strengths.[2]

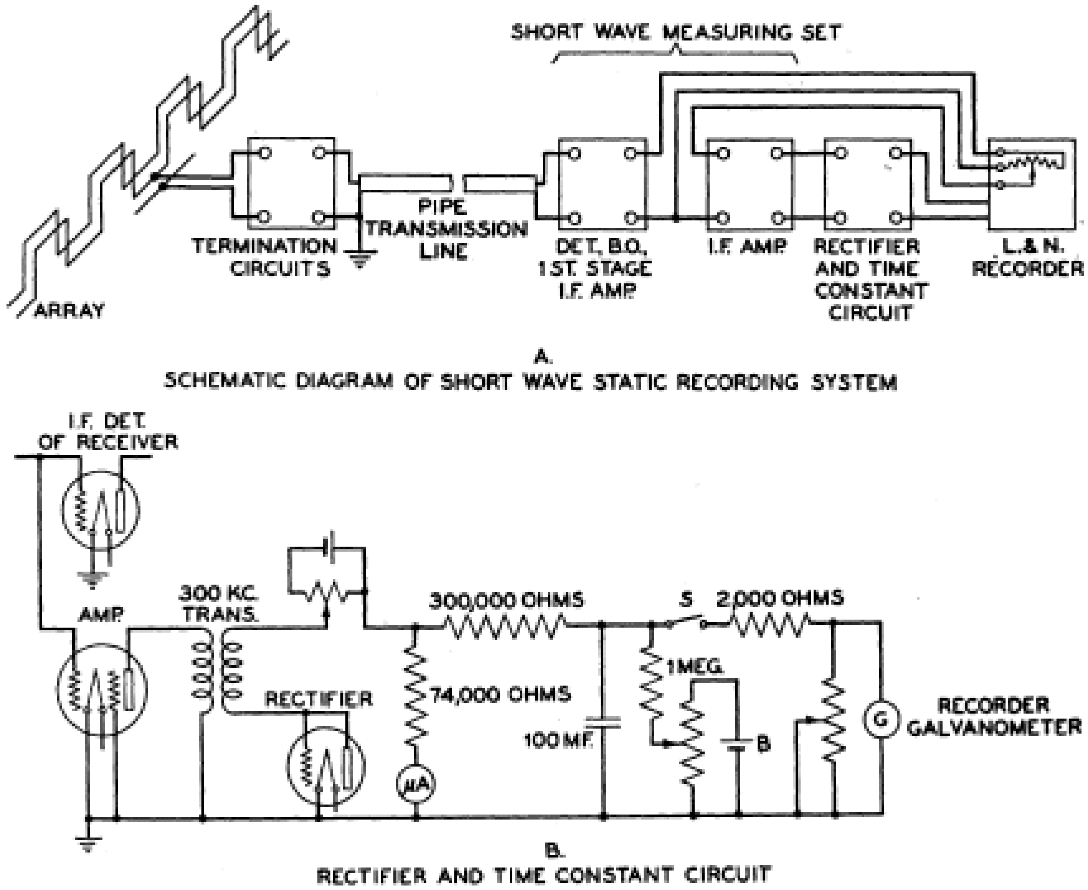



Fig. 1

The rotating antenna, a photograph of which is shown in Fig. 2, is a Bruce type broadside receiving array[3] two wavelengths long made of 3/4-inch brass pipe. The array was designed to operate on a wavelength of 14.5 meters. As shown in the photograph it is mounted on a wooden framework which in turn is mounted on a set of four wheels and a central pivot. The structure is connected by a chain drive to a small synchronous motor geared down so that the array makes a complete rotation once every twenty minutes.

[2] A detailed description of the measuring set and recorder is given in a paper by W. W. Mutch, Proceedings, this issue, pp. 1914–1919.

[3] A. A. Oswald, "Transoceanic telephone service, short wave equipment," *Jour. A.I.E.E.*, vol. 49, p. 267; April, (1930).

Since static on short waves is extremely weak most of the time, the recording system had to be made very sensitive; so sensitive in fact that the first circuit noise of the receiver is recorded.[4] On account of interference which was found on 14.5 meters, it was necessary to operate the system on a wavelength of 14.6 meters. This, however, made

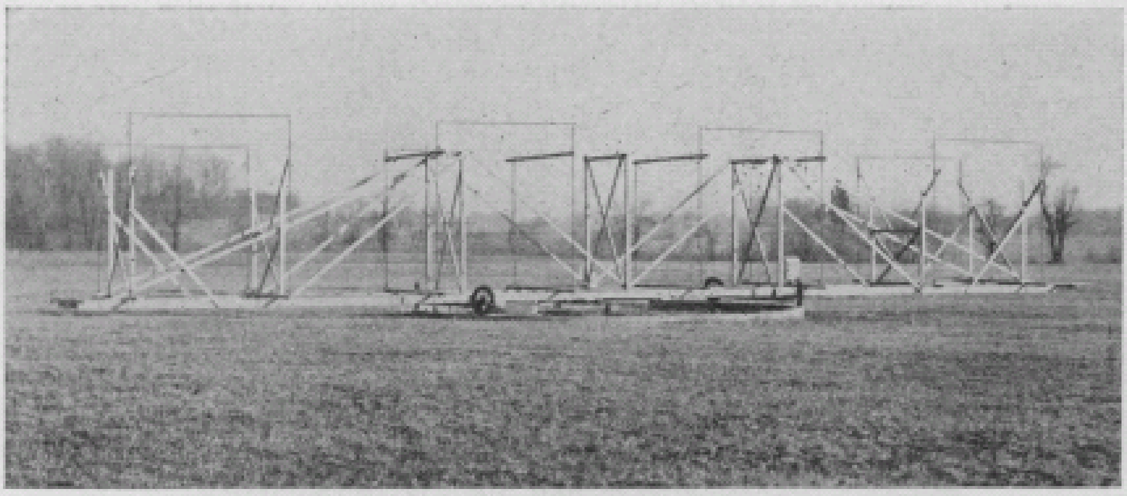


Fig. 2—Short-wave rotating antenna array.

little difference in the directivity of the array, the directional characteristic of which at this wavelength is shown in Fig. 3.

The array termination equipment is housed in a box mounted on the array and is connected to the measuring set in a small house about 275 feet away by means of a 3/8-inch copper concentric pipe transmis-

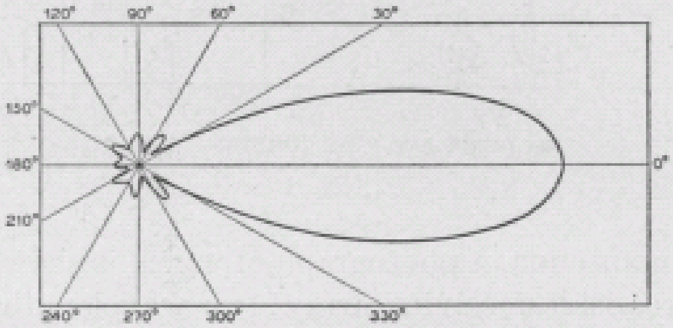



Fig. 3—Directional characteristic of array at 14.6 meters.

sion line buried about 6 inches in the ground. Fig. 4 is a schematic diagram of the array, the termination equipment and the copper pipe transmission line.

Fig. 5 is a photograph of the inside of the house, showing two receivers with their associated recorders. The apparatus on the right

[4] F. B. Llewellyn, "A study of noise in vacuum tubes and attached circuits," Proc. I.R.E., vol. 18, p. 243; February, (1930).

is the short-wave recording system. That on the left is a long-wave recording system, the records of which were used to compare with those

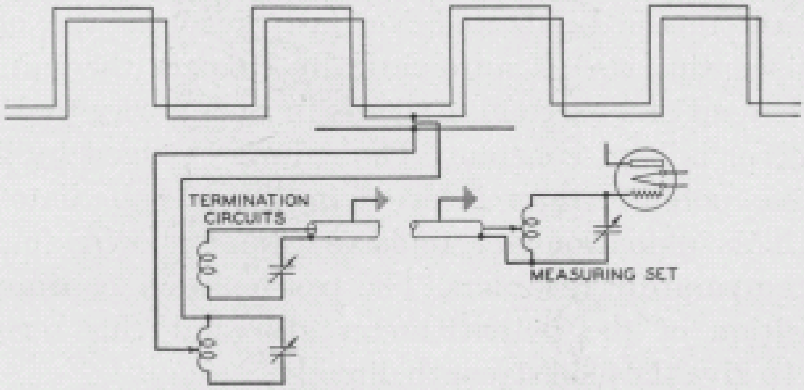



Fig. 4—Schematic diagram of array, termination, and pipe transmission line.

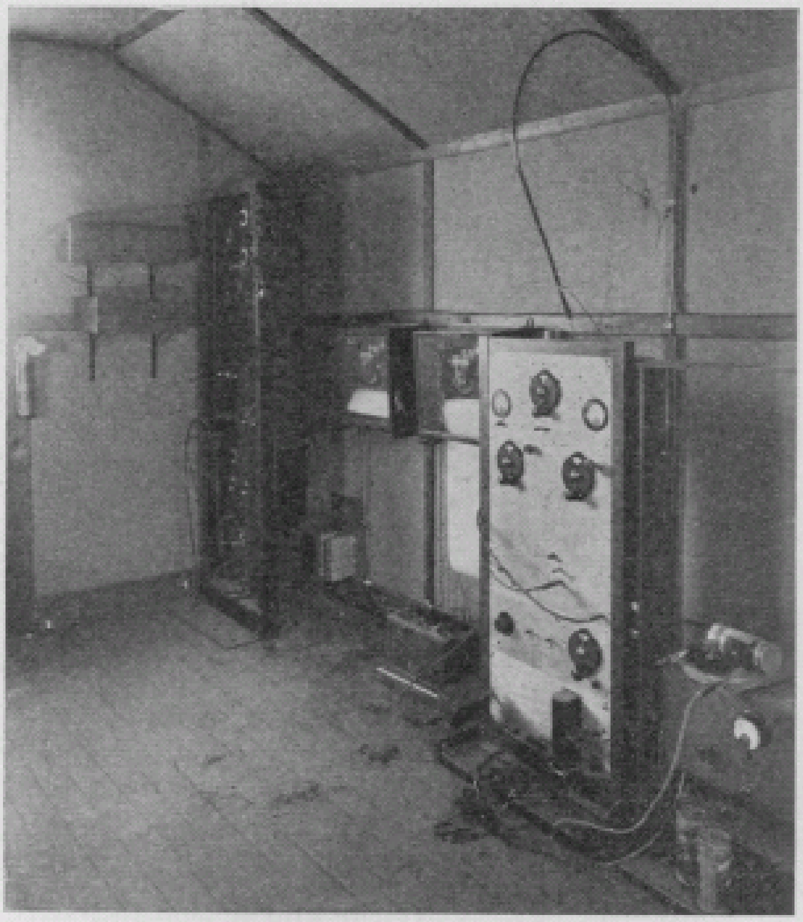


Fig. 5—Long- and short-wave static recording systems.

of the short-wave system. The long-wave antenna system consists of a rotating loop and an $L$ type stationary antenna giving the familiar cardioid-shaped directional characteristic.

The receiver used is a short-wave field strength measuring set of the double detection type which was described some time ago.[5]

The output of this receiver is connected through a circuit with a long time constant to the Leeds and Northrup recorder the operation of which is discontinuous.[2] It automatically changes the gain of the receiver at the end of 10-second intervals in such a way that the output of the receiver is kept constant. The gain is changed by means of a noninductive potentiometer inserted in the intermediate frequency amplifier. This potentiometer replaces the slide wire found on the standard temperature recorders. The pen makes a continuous record of the position of the potentiometer arm and this record can be calibrated to give the field strength directly.

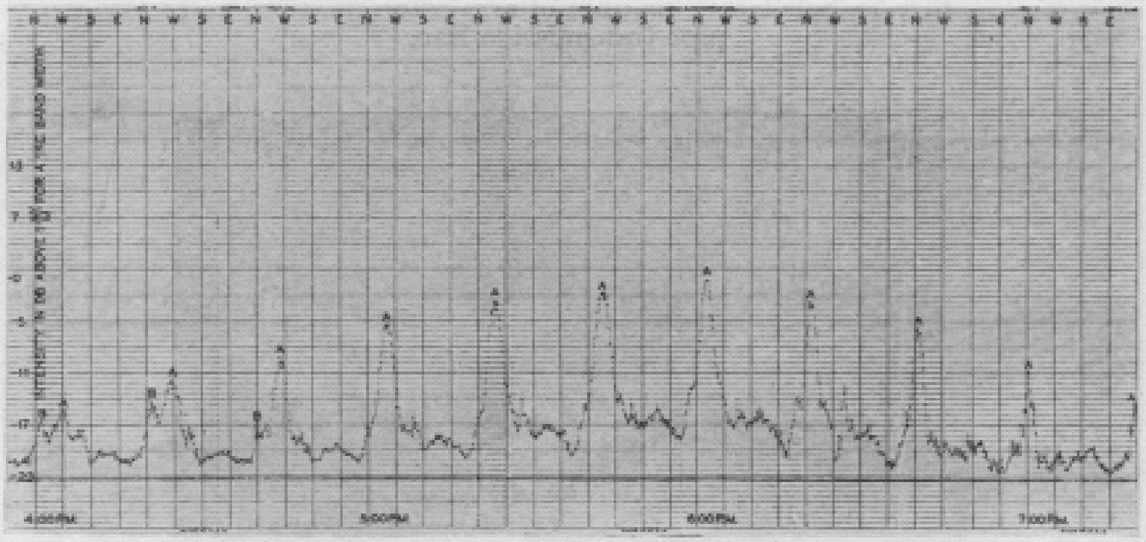


Fig. 6—Sample record of local thunderstorm static on short waves. August 27, 1931.

The operation of the recorder is as follows: For a period of 9 seconds the rectified output from the set charges the 100-microfarad condenser through the 300,000-ohm resistance, see Fig. 1B, the charge being proportional to the energy received from the static during the 9 seconds providing the rectifier is a square law device. During the same time the battery $B$ charges the condenser in the opposite sense to the static. The battery $B$ and associated resistance are adjusted so that if there is no change in the average static over the 9-second period the resulting charge on the condenser is zero. At the end of the interval the switch $S$ is closed by a cam on the recorder shaft and the condenser is discharged through the recorder galvanometer. If the static level has not changed during the interval there will be no charge on the condenser

[5] H. T. Friis and E. Bruce, "A radio field strength measuring system for frequencies up to forty megacycles," Proc. I.R.E., vol. 14, p. 507; August, (1926).

and, hence the galvanometer will not be deflected and the gain of the receiver will remain unchanged. If the static level has increased or decreased the galvanometer will show a corresponding deflection and the recorder mechanism will decrease or increase the gain of the set accordingly.

In the system used the rectifier is not exactly a "square law" device being a two element rectifier in series with a resistance; however, as it was operated with a very small current ($5 \times 10^{-6}$ amperes) it approximated the square law sufficiently accurate for the present purpose.

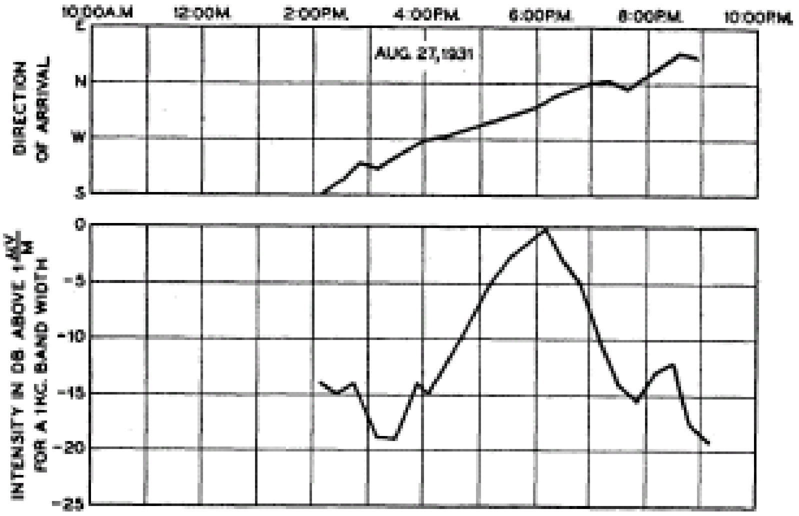



Fig. 7—Direction of arrival and intensity of local storm type static on 14.6 meters.

## RESULTS

From the data obtained it is found that three distinct groups of static are recorded. The first group is composed of the static received from local thunderstorms and storm centers. Static in this group is nearly always of the crash type. It is very intermittent, but the crashes often have very high peak voltages. The second group is composed of very steady weak static coming probably by Heaviside layer refractions from thunderstorms some distance away. The third group is composed of a very steady hiss type static the origin of which is not yet known.

During the time that records have been taken, static of the first group arising from several local thunderstorms has been recorded and studied. The data from a few typical records of these storms have been replotted and are shown in Figs. 7, 9, 10, 11, and 12. In these figures the upper curve shows the direction of arrival of the main stream or streams of static plotted against time and the lower curve shows the intensity of these streams at the corresponding times.[6] In addition to the main streams shown there were usually other minor streams, but these are difficult to follow in detail due to interference from random static from local squalls which are generally present during these periods. Fig. 6 is a section of a typical record of this type of static. It is the record for August 27 of which Fig. 7 is the replot. The peaks marked *A* indicate the position of the main storm. Those marked *B* show the position of one of the minor storms.

Fig. 7 shows the data obtained from this record. It represents a severe electrical storm that passed Holmdel early in the evening. During the early afternoon hours the storm was preceded by several thunder squalls. The static from these squalls was recorded, but there were so many of them and the direction of each changed so fast (as could be observed visually) that it was not possible to follow them on the records. During the late afternoon and early evening hours the static from the south grew stronger than that from the local squalls indicating that a definite storm center was forming there or approaching within range of the receiver from that direction. From then on this storm center did not follow a straight path but, as shown by the records, circled around the receiver and disappeared in the northeast. The manner in which the intensity increased and decreased as the storm passed is clearly shown on the lower curve of the figure.

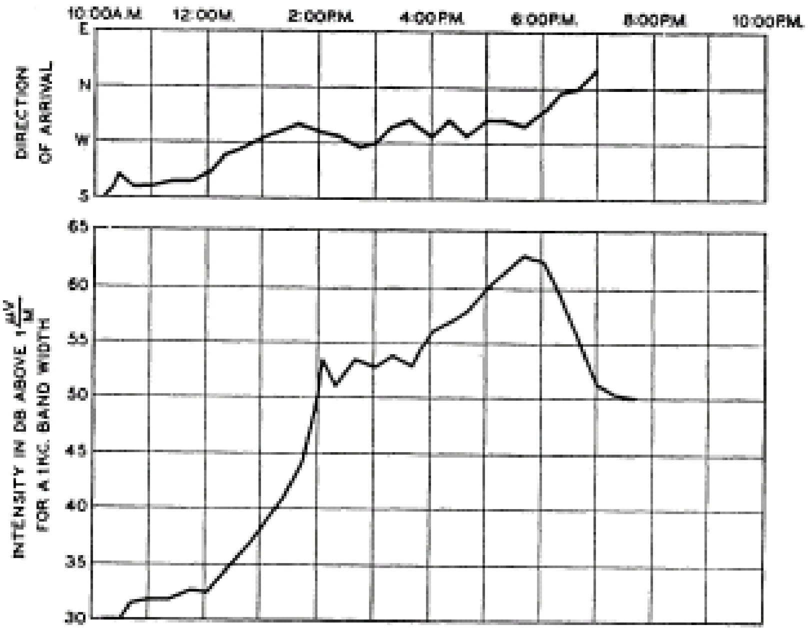



Fig. 8—Direction of arrival and intensity of local storm type static on 6936 meters. August 27, 1931.

[6] The band width of the receiver used was 26 kc but before plotting, the data were reduced to the case of a receiver having a band width of 1 kc, i.e., the intensity values were reduced by a factor of $\sqrt{26}$.

For the purpose of comparison, Fig. 8 shows the replot of the long-wave record for the same day.[7] Note that the ratio of the intensity of the long-wave static in microvolts per meter for a 1-kilocycle band width to that of the short-wave static was 63 db when the storm was

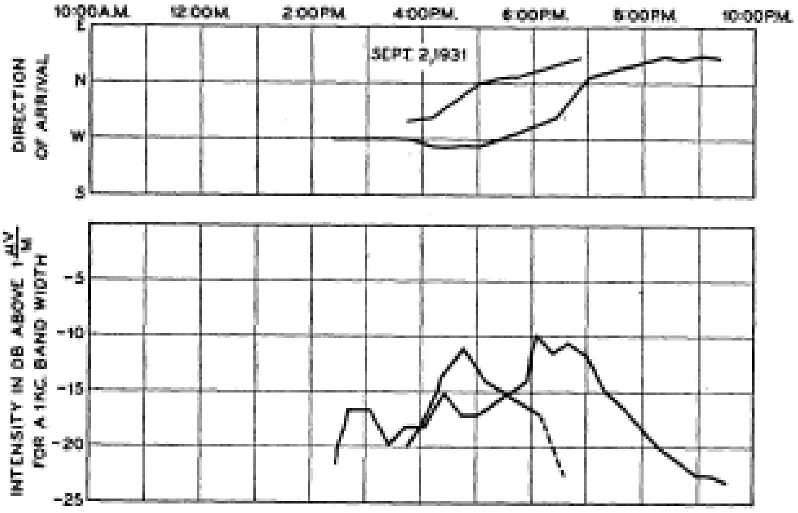



Fig. 9—Direction of arrival and intensity of local storm type static on 14.6 meters.

the severest. This ratio is probably a little too high because the rectifier device was not truly "square law." If we assume the inverse frequency law for the intensity of static this ratio should have been 53.5 db.

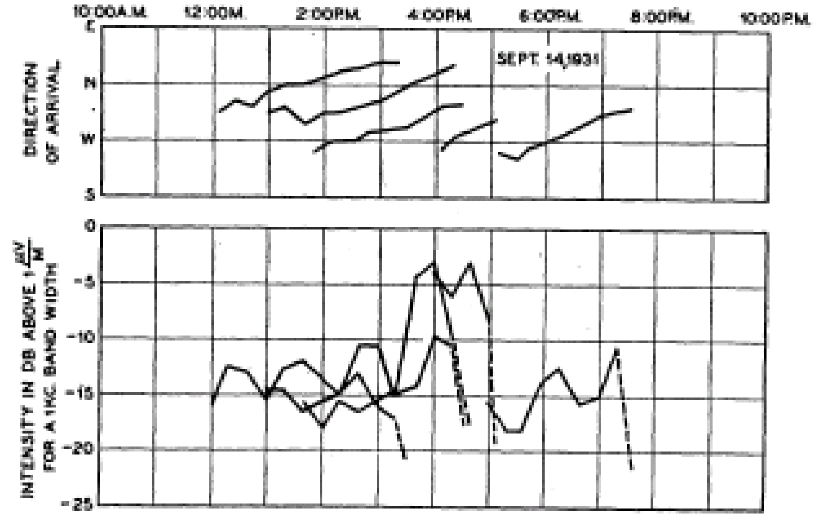



Fig. 10—Direction of arrival and intensity of local storm type static on 14.6 meters.

Fig. 9 shows the data obtained from the record of a well defined storm center that traveled in a straight or nearly straight line towards

[7] The long-wave data mentioned in this paper are all taken on a wavelength of 6936 meters.

the receiver. The static came from the west early in the afternoon, continued to come from that direction as the storm approached, and then as the storm passed Holmdel the direction shifted rapidly from the west through northwest and north to the northeast where it remained as the storm receded until the static no longer was strong enough to record. A minor storm preceded this main one by about an hour as is shown by the short curve preceding the main one. The main storm could clearly be seen passing Holmdel along the northern horizon, but at no time did it approach closer than 15 miles.

Fig. 10 shows the data obtained from the record of several small, but well defined storm centers that followed each other in rapid succession. On this day several small thunder squalls could be seen passing along the northern horizon.

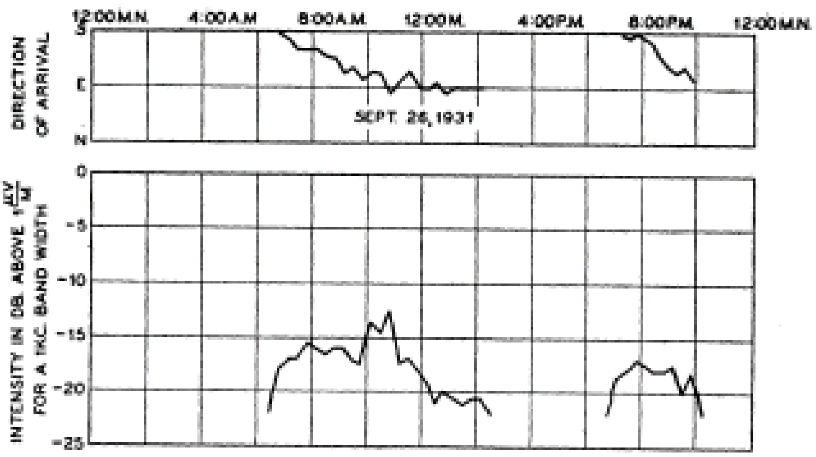



**Fig. 11—Direction of arrival and intensity of local storm type static on 14.6 meters.**

So far all of the records discussed have been of storms that approached from the southwest or west and passed northwest of the receiver. Fig. 11, on the other hand, shows the data from the record of two storms occurring the same day that approached from the south and passed the receiver on the southeast.

Finally Fig. 12 shows the data from a record of a storm that approached the receiver from the west and split, part of it passing to the north and part to the south of the receiver.

From these figures it is evident that on the average the thunderstorms were audible for four hours before and four hours after they reached Holmdel. Taking 35 miles an hour as the average velocity of a thunderstorm[8] this gives a distance of 140 miles that the storm centers were distant from Holmdel when the static could still be heard.

[8] *See* W. J. Humphreys, "Physics of the Air," p. 365. Also Ward, "The Climates of the United States," p. 322.

It is also worthy of note that by far the majority of storms came from the southwest and west and passed north of the receiver with only an occasional one passing south and southeast. The directions lying between southeast and northeast appear to be substantially free of this type of static at Holmdel and directional antennas built there to receive from those directions on short waves should be troubled with static only infrequently. Of course, this would not necessarily hold for other receiving locations. Locations in some sections, for example, would probably receive an equal amount of this type of static from all directions.

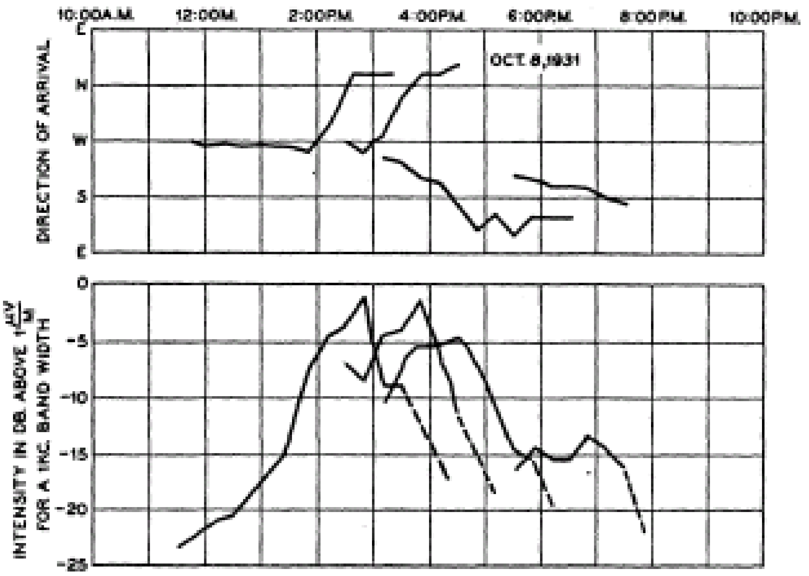



Fig. 12—Direction of arrival and intensity of local storm type static on 14.6 meters.

The static from the second group, which probably originates at long distances, is usually very weak on 14.6 meters. In fact, only occasionally is it strong enough to actuate the recorder. Because of this very few satisfactory records have been obtained of it. From the records that have been obtained, however, and from aural observations it has been determined that this static is of the crash and rumble type; its direction of arrival follows very closely that of the long wave static; and finally it is heard only when the long wave static coming from distant thunderstorms is very strong. It, therefore, probably comes from thunderstorms located some distance from the receiver. The most common directions of arrival of this static, as for the long wave static, are those directions lying between southeast and southwest.

On March 1, 1932, this kind of static was recorded by the short wave recorder from 2:30 P.M. to 3:50 P.M. The data obtained are shown and compared with those obtained on long waves in Table I. The direction of arrival for both the long and short wave static on this day was southeast. As shown in the table the difference between the intensity of the long and short wave static varied between 56 and 62 db. These values should also probably be somewhat lower because the rectifier is not a "square-law" device.

TABLE 1

| Time | Intensity of static in db above 1(microvolt per meter) For a 1—kc band width | | Difference |
|---|---|---|---|
| | Long-Wave | Short-Wave | |
| 2:30 P.M. | 34.0 | −22.0 | 56.0 |
| 2:50 | 37.5 | −24.0 | 61.5 |
| 3:10 | 37.0 | −22.5 | 59.5 |
| 3:30 | 35.5 | −24.0 | 59.5 |
| 3:50 | 37.0 | −25.0 | 62.0 |

Since this static is so weak that it cannot be recorded much of the time, the crash method[1] of measuring static as used by Potter could probably be used to great advantage to measure it.

The static of the third group is also very weak. It is, however, very steady, causing a hiss in the phones that can hardly be distinguished from the hiss caused by set noise. It is readily distinguished from ordinary static and probably does not originate in thunderstorm areas. The direction of arrival of this static changes gradually throughout the day going almost completely around the compass in twenty-four hours. It does not quite complete the cricuit, but in the middle of the night when it reaches the northwest, it begins to die out and at the same time static from the northeast begins to appear on the record. This new static then gradually shifts in direction throughout the day and dies out in the northwest also and the process is repeated day after day. Fig. 13 shows the direction of arrival of this static for three different days plotted against time of day. Curve 1 is for January 2, 1932, curve 2 is for January 26, 1932, and curve 3 is for February 24, 1932. Fig. 14 is a photograph of a section of one of the records.

This type of static was first definitely recognized only this last January. Previous to this time it had been considered merely as interference from some unmodulated carrier. Now, however, that it has been detected it is possible to go back to the old records and trace its position on them.

During the latter part of December and the first part of January the direction of arrival of this static coincided, for most of the daylight hours, with the direction of the sun from the receiver. (See curve 1, Fig. 13.) However, during January and February the direction has gradually shifted so that now (March 1) it precedes in time the direction of the sun by as much as an hour. It will be noticed that the curves

2 and 3 of Fig. 13 have shifted to the left.[9] Since December 21, the sun's rays have been getting more and more perpendicular at the receiving location causing sunrise to occur at the receiver earlier and earlier each day. It would appear that the change in the latitude of

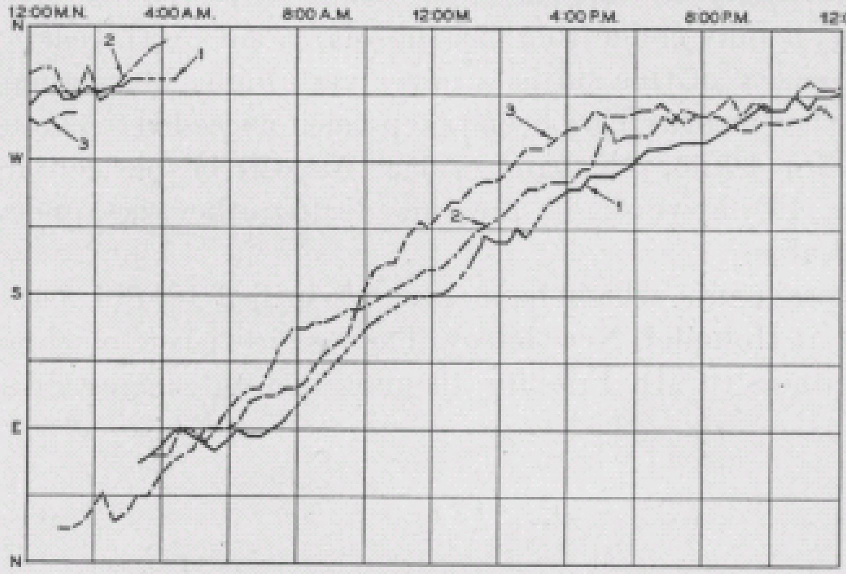



Fig. 13.—Direction of arrival of hiss type static on 14.6 meters.


Fig. 14—Sample record of short-wave hiss type static.
February 24, 1932.

the sun is connected with the changing position of the curves. However, the data as yet only cover observations taken over a few months and more observations are necessary before any hard and fast deductions can be drawn.

The fact that the direction of arrival changes almost 360 degrees

[9] Since this paper was written the curve has shifted much further to the left. Now (May 25) it crosses south at 4:30 A.M.

during twenty-four hours and that the shift in the position of the curve observed during the three months over which data has been taken corresponds to the change in latitude of the sun affords definite indication that the source of this static is somehow associated with the position of the sun. It may be that the static comes directly from the sun or, more likely, it may come from the subsolar point on the earth.

The intensity of this static is never very high. At no time during the period that records have been taken has it exceeded 0.39 microvolts per meter for 1-kilocycle band width. As will be noticed from the record (Fig. 14), however, its presence during otherwise quiet periods is unmistakable.

The experiments which have been described in this paper were carried out at Holmdel, New Jersey. The writer wishes to acknowledge his indebtedness to Mr. Friis for his many helpful suggestions.

# An Introduction to Radio Objects that can be detected by amateur radio astronomers: Part 1 (of 3)

- David Morgan

RA Basics

## 1 Scope

This article considers a number of radio emitting objects that can be observed by amateur radio astronomers using a modest range of equipment. The order in which these objects are discussed is largely determined by their distance from Earth and this is loosely related to their ease of detection.

Radio emissions generated within the Earth's Magnetosphere and Ionosphere are not considered here. Emissions such as Whistlers and Chorus are however of interest to amateur radio astronomers, and much has been written elsewhere about the impact of Solar X rays on the Ionosphere resulting in Sudden Ionospheric Disturbances (SIDs).

The strength and emission spectrum of a variety of distant radio sources are considered and related to the physical mechanism by which they are generated. This gives some insight into the range of processes by which naturally occurring radio emissions can be produced from sources within the Solar System to those out in intergalactic space.

Describing the equipment that can be used to detect these sources is not the main purpose of this article but is touched upon where appropriate, to illustrate the scale and technical complexity of instruments required to observe some sources.

# 2 Overview of source signal strengths and spectra

## 2.1 Signal strength

The signal strength from natural radio sources may be thousands of times smaller than those from radio and TV stations, which are usually around 100µV/m. Radio astronomers use power flux density as the unit of signal strength and this is in Watts per square metre per Hz ($W\ m^{-2}\ Hz^{-1}$). In honour of the first radio astronomer Karl Jansky, the very small value of $10^{-26} W\ m^{-2}\ Hz^{-1}$ is called 1 Jansky - or 1 Jy.

The relationship between typical power densities of some radio sources discussed in this paper is given in Figure 2.1. This illustrates the wide range of source signal strengths. Each source has a different signal strength as a function of frequency and in Figure 2.1 this is covered by representing the range of signal strengths as a coloured block.

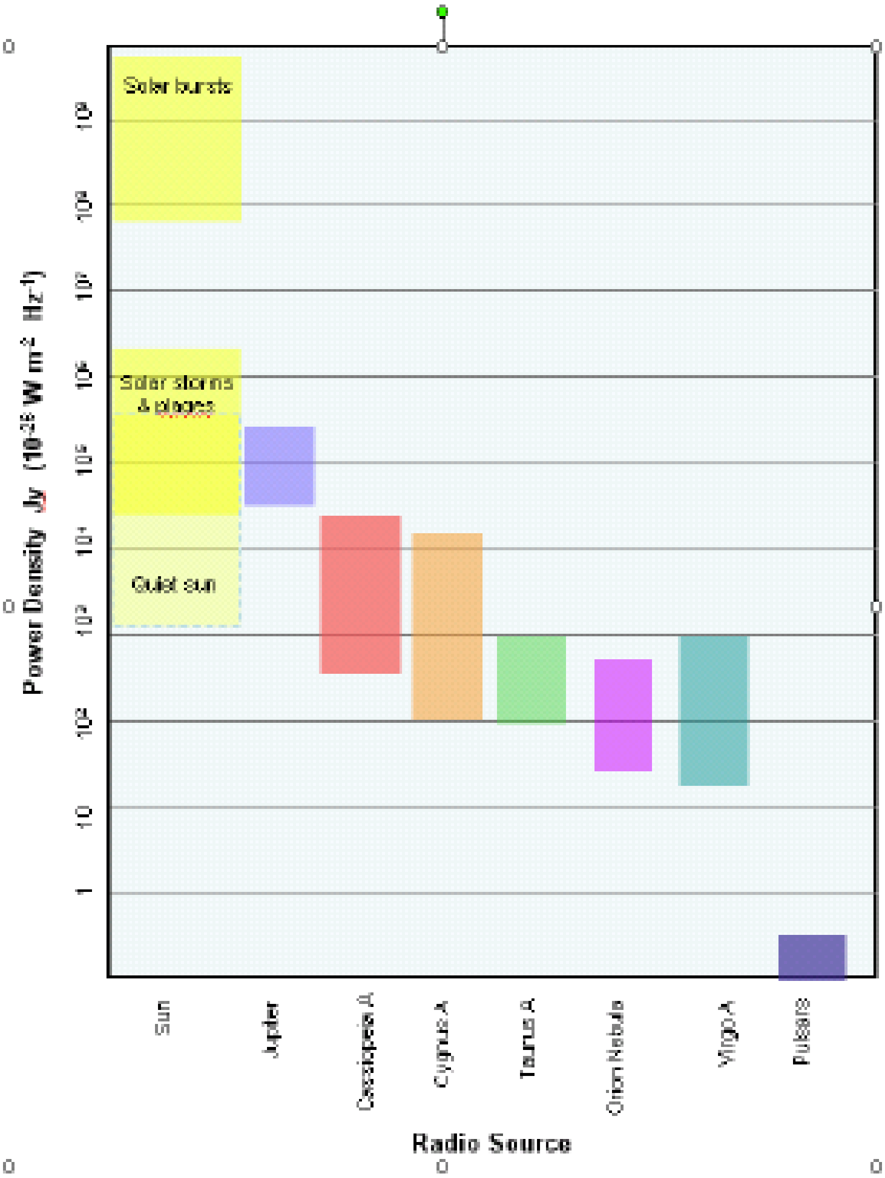



Figure 2.1 Power density of various radio sources

There are nearly eight orders of magnitude between the strongest and weakest sources that an amateur might detect. Very strong solar bursts can have strengths up to $10^9$ Jy and an external radio galaxy like Virgo A may have a strength of only 100 Jy. The level of equipment sophistication required to detect these sources will therefore vary considerably – from a standard communications receiver to detect solar bursts, to special temperature controlled receivers and preamplifiers to detect external galaxies.

Almost all amateurs begin by detecting the Sun. This is easy to do, especially in the middle of the Sun spot cycle where there are many solar storms and bursts. The next goal might be to detect Jupiter or a quiet Sun, followed by a supernova remnant such as Cassiopeia. With this level of sensitivity it is then possible to make maps of radio noise in the Milky Way and to detect and plot the distribution of the neutral Hydrogen emission line at 1420.4MHz.

## 2.2 Spectra of radio sources

There are three main types of astronomical radio emission mechanism:

- Thermal noise
- Non-thermal e.g. synchrotron generation
- Line emissions from atoms and molecules

Each of these mechanisms produces a different spectrum of radiation and in a real measurement they will all be present to some extent. The task of the radio astronomer is to separate out the different spectra that make up the observed spectrum in order to determine the physical generation mechanism - or mechanisms – that are taking place in the region of space being observed. This is how knowledge of some of the physics behind the observed Universe is uncovered.

### 2.2.1 Thermal noise

Solid objects at some temperature T, radiate a continuum of electromagnetic radiation due to the vibration of the constituents of atoms and molecules. There are very few free electrons, and displacements are small, resulting in low levels of emission. For objects at a few hundred degrees Kelvin most of the radiation is at infra red wavelengths. The hotter the object becomes the wavelength of the peak emission of the radiation decreases toward the optical – the object becomes ‘red or yellow hot’.

The emission spectrum of a perfect hot ‘black body’ was derived theoretically in 1901 by the famous physicist Max Plank and is shown in Figure 2.2.

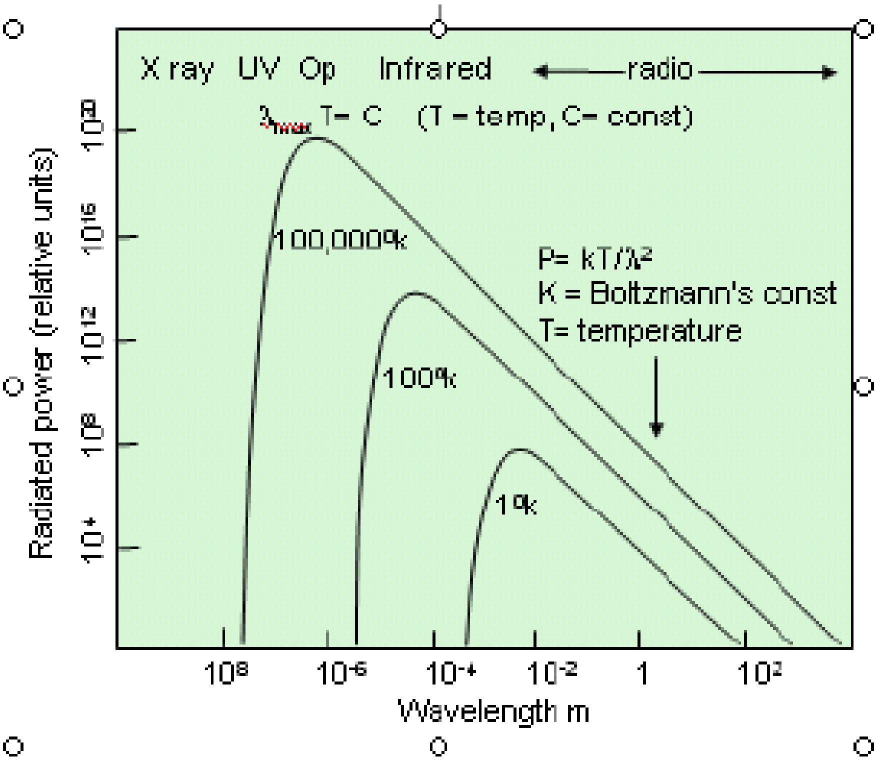



Figure 2.2 Black body spectrum

It can be seen that as the temperature increases, the wavelength of the peak emission decreases. For wavelengths much longer than $\lambda_{max}$ the power of the emissions fall according to the Rayleigh-Jeans law $P= kT/\lambda^2$ .

A gas heated to a high temperature can emit more radiation as the particles move with greater speed. Ultimately, the gas atoms break up into charged ions and free electrons - a so called plasma. See Figure 2.3. Under these conditions the gas can radiate a significant amount of electromagnetic energy across a broad spectrum. In radio astronomy we do detect thermal emissions from cool solid objects such as the moon, but more often from regions of ionised gas such as in nebulae or around stars.

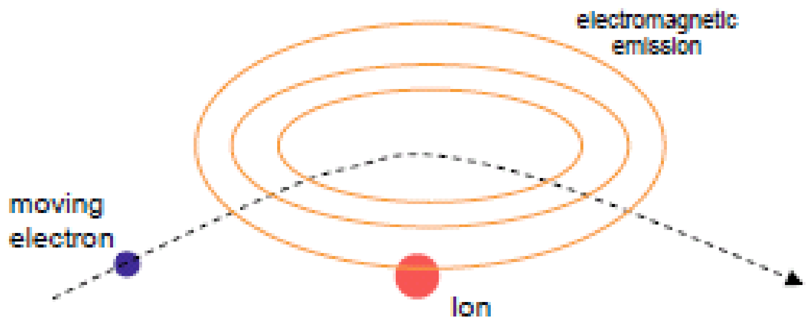



Figure 2,3 Emission from an accelerating electron

In this figure the electron is deflected (accelerated|) by the electric field of the ion and this causes it to emit radiation. The radiation may however be absorbed by other electrons and an energy balance between radiation and particles is achieved. With trillions of such encounters in a body of gas, all with random accelerations, a broad thermal noise spectrum is produced.

The radio emission spectrum of a dense excited gas (where self absorption occurs) can be described by the Rayleigh-Jeans law, but if the gas is tenuous - i.e. it is semi-transparent to the radio emissions – the equation must be modified to include a constant $\varepsilon$ which depends on the self absorption of the gas. Thus we have:

$$P = \varepsilon\, kT/\lambda^2 \qquad \textit{equation 2.1}$$

For a dense opaque gas $\varepsilon = 1$ but in a semi-transparent gas (which is often observed in space) $\varepsilon$ is proportional to $\lambda^2$, so the wavelength dependency in equation 2.1 falls out and the radiated power is constant.

This is shown in Figure 2.4 where the semi-transparent region is shown from x to y and the opaque region from y to z.

We know that the emission mechanism is thermal if this sort of spectrum is measured. It is also possible to determine something about the density of the gas cloud from its emission spectrum.

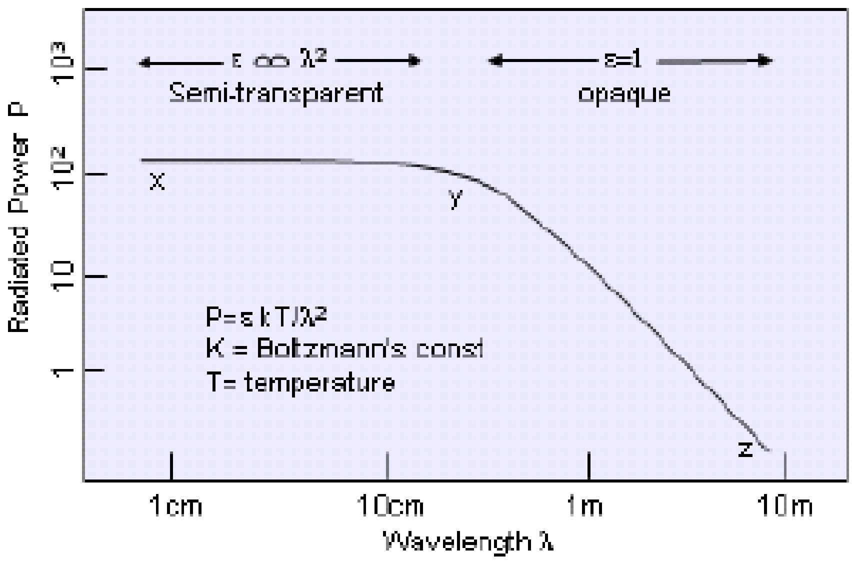



Figure 2.4 Thermal radio emission spectrum from a gas

## 2.2.2 Non-thermal radio emission

There are mechanisms that produce strong radio emissions that are not due to random thermal motions of electrons. The processes are more 'organised' and the agent is often a magnetic field. The emission spectrum produced has the opposite frequency dependence to thermal emissions. The radiated power increases with wavelength as shown in Figure 2.5.

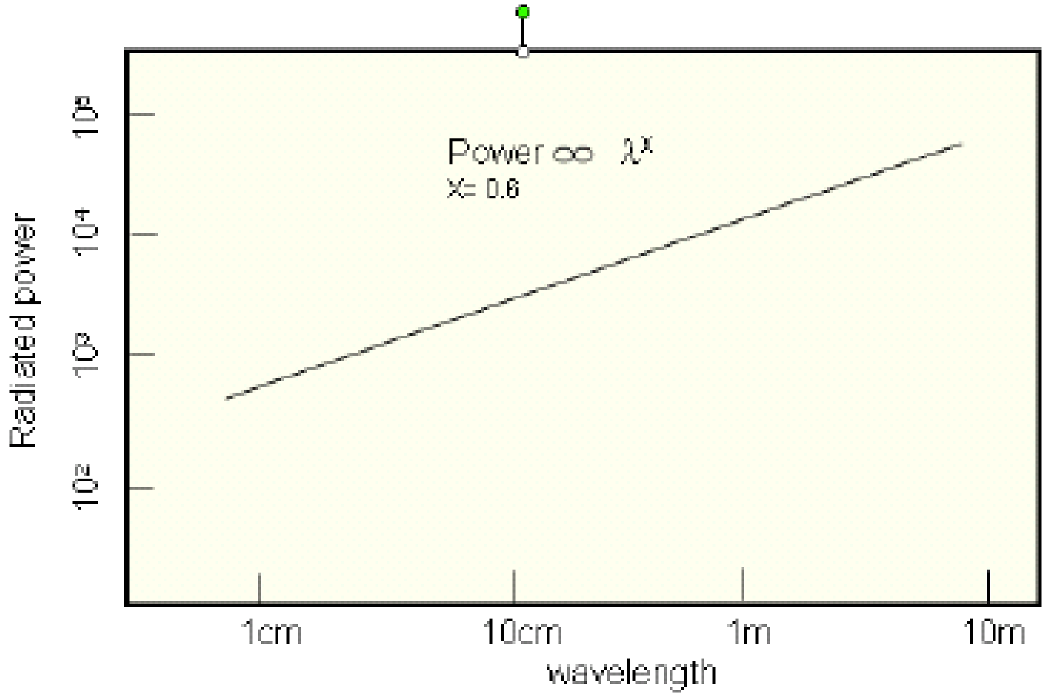



Figure 2.5 Typical spectrum of a non thermal source

Fast moving charged particles from very hot plasma or cosmic rays will interact with a magnetic field that may be present in the medium in a certain way. They will rotate around the field lines as shown in Figure 2.6 and as their direction is constantly changing, they are being accelerated – and thus they radiate electromagnetic energy.

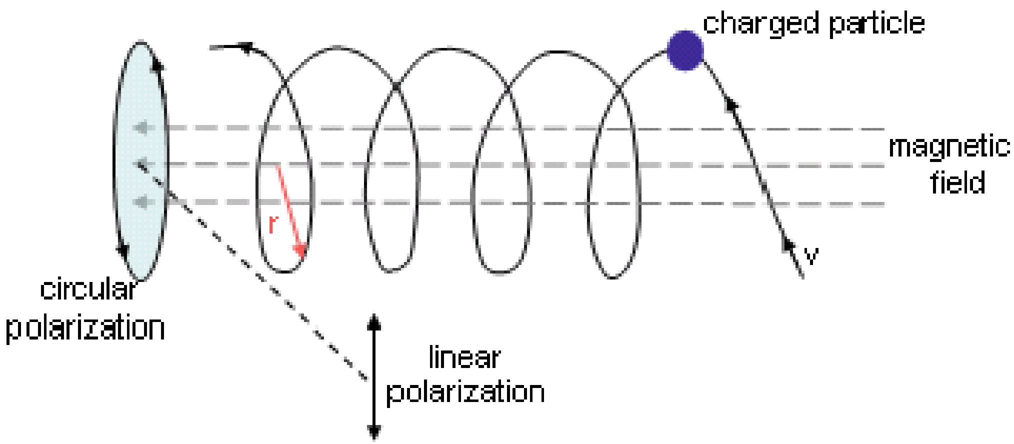



Figure 2.6 Charged particle in a magnetic field

When a charged particle moving with a velocity v encounters a magnetic field it will enter into a spiral orbit with a radius r around the field lines and radiate energy with circular polarization when looked at along the field lines. If viewed from normal to the field lines the polarization appears linear.

If, when observing a celestial source, we detect a polarized signal, this is clear indication of the presence of fast moving charged particles in a magnetic field.

When the velocity of the particle is much less than the speed of light the interaction is called a cyclotron process – and the radiation is called cyclotron radiation. When the velocity of the particle approaches the speed of light, as it does with cosmic rays or in plasma jets of neutron stars or black holes, relativistic physics becomes important and the cyclotron process becomes a synchrotron process as shown in Figure 2.7.

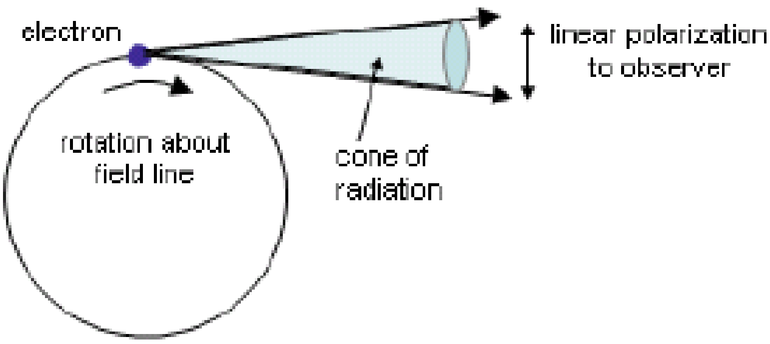



Figure 2.7 Relativistic electron – Synchrotron process

The inclusion of relativistic effects results in the radiation being beamed in a narrow cone away from the electron as it rotates about the field lines. This magnifies the power density of the radiation 'beamed' toward the observer. Many strong radio sources are generated by this mechanism as the electrons have such a large store of energy due to their high velocity.

The non-thermal spectrum from a synchrotron source is compared with that from a thermal source in Figure 2.8.

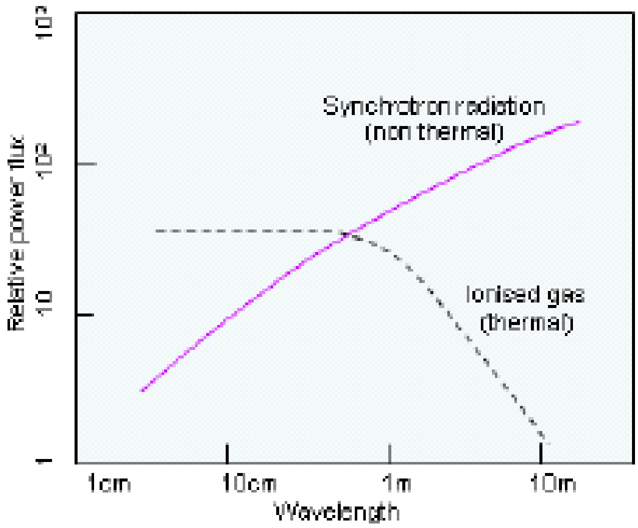



Figure 2.8 Synchrotron and thermal spectra

The spectra of many astronomical sources are non-thermal as can be seen in Figure 2.9.

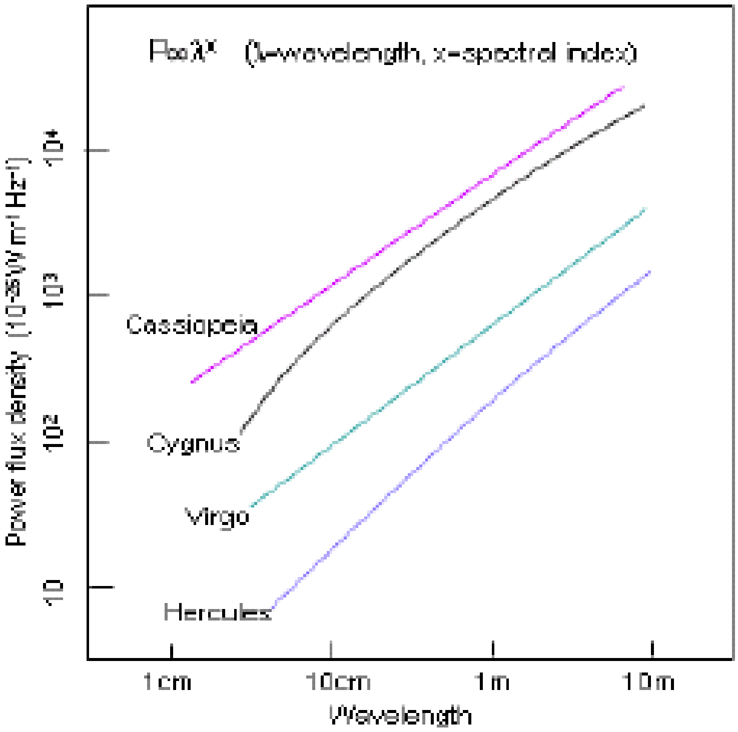



Figure 2.9 Non-thermal spectra of sources

### 2.2.3 Spectral line emissions

These narrow bandwidth emissions are created when the quantum state of an atom changes. It was shown by Plank and Bohr in the early 20th century that atoms absorb or emit energy in discrete steps called quanta. It was shown that:

$$E = h\nu \qquad \textit{equation 2.2}$$

Where E = quantum energy
h = Planks constant
ν = frequency

Consider the case shown in Figure 2.10 where a neutral hydrogen atom is shown in two quantum states. On the left the particle 'spins' are aligned – on the right they are opposed. There is a difference in energy between these two states and this manifests itself by the emission of radiation with a specific frequency $\nu_T$ (the transition frequency).

This is the frequency emitted by the 'spin transition' in the 'lowest energy state of the hydrogen atom - known as the 'ground state' - and occurs at 1420.4MHz , or ~ 21cm wavelength.

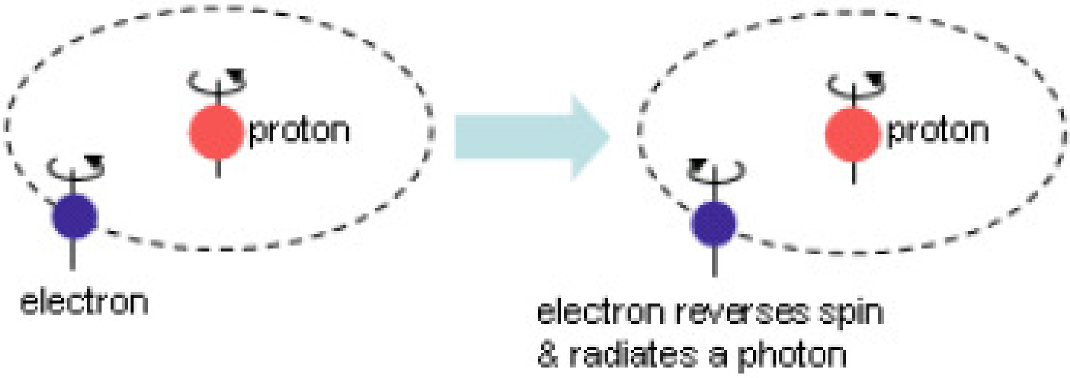



Figure 2.10 Spin transition in Hydrogen ground state

Many radio line emissions can be generated by atoms and molecules. The most common is Hydrogen, due to its abundance in the Universe, but OH, CO, $H_2O$ and many other have been detected and mapped by modern professional radio telescopes. The frequencies of some of these emissions are given in Table 2.1.

## Rest frequency of spectral lines

| Atom/Molecule | Line Name | Rest frequency (GHZ) |
|---|---|---|
| HI | neutral hydrogen | 1.420405752 |
| OH | hydroxyl radical | 1.6122310 |
| OH | hydroxyl radical | 1.6654018 |
| OH | hydroxyl radical | 1.6673590 |
| OH | hydroxyl radical | 1.7205300 |
| $H_2CO$ | ortho-formaldehyde | 4.829660 |
| $CH_3OH$ | methanol | 6.668518 |
| $HC_3N$ | cyanoacetylene | 9.009833 |
| $CH_30H$ | methanol | 12.178593 |
| $H_2CO$ | ortho-formaldehyde | 14.488490 |
| $C_3H_2$ | ortho-cyclopropenylidene | 18.434145 |
| $H_20$ | ortho-water | 22.23507985 |
| $NH_3$ | para-ammonia | 23.694506 |
| $NH_3$ | para-ammonia | 23.722634 |
| $NH_3$ | ortho-ammonia | 23.870130 |

### 2.2.4 Summary

We have seen the key mechanisms by which radio sources emit signals. Each mechanism has its own spectral characteristics and will be found in different radio objects in space. By measuring the total emissions from a source and picking out the various spectral components much can learned about the physics of the region being studied.

We move now to a description of some individual radio sources and discuss how easy or difficult they are for detection and measurement by amateur radio astronomers.

# 3 The Sun

## 3.1 The Quiet Sun

The Sun is a relatively strong emitter of electromagnetic waves over a wide range of frequencies from metric, through infra red and optical to ultra violet and X rays. It is undoubtedly the brightest radio object in the sky and can be detected with modest equipment.

Many radio astronomers start by observing the Sun, especially when 'Solar storms' are occurring as the emissions produced are many orders of magnitude larger than those from a quiet or 'quiescent' Sun.

A typical spectrum of radio emissions under quiet conditions is given in Figure 3.1. We see that signal strength increases with frequency and decreases with wavelength. This is typical of a *thermal* source where the generation mechanism is due to thermal agitation of the gaseous material of which the Sun is composed.

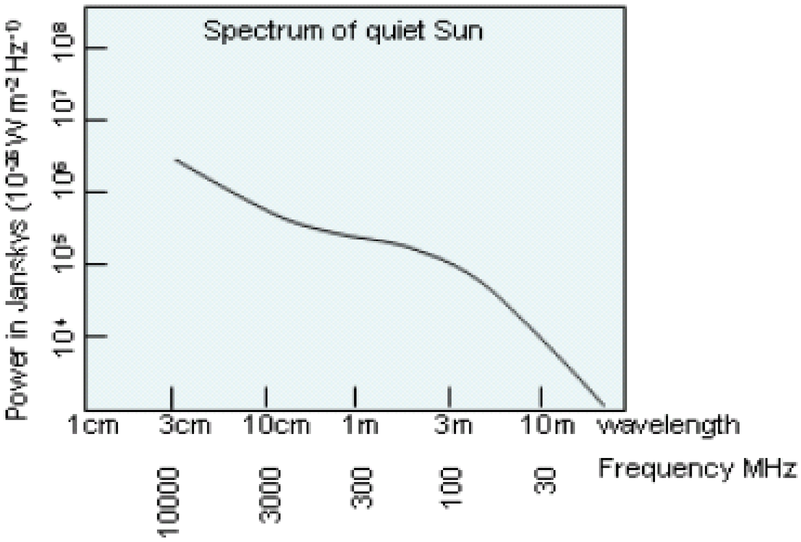



Figure 3.1 Radio spectrum of 'quiet' Sun

## 3.2 Solar storms

When significant sunspots occur, the radio output increases with sharp signal 'spikes' as shown in Figure 3.2 [1]

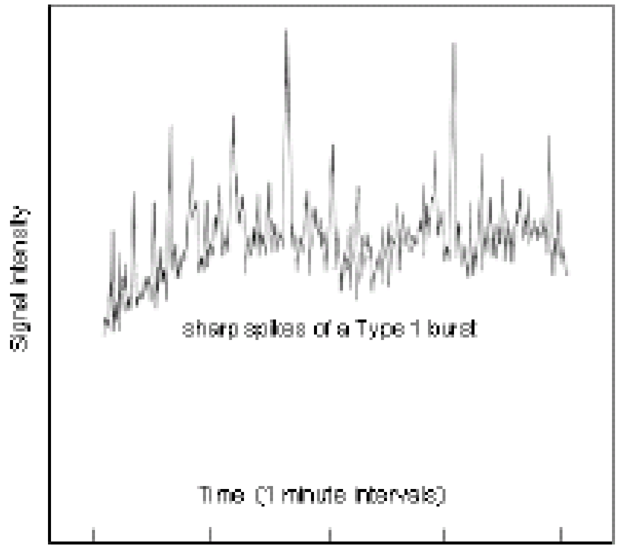



Figure 3.2 Type 1 solar bursts

The spectrum of storms and bursts is shown in Figure 3.3 and clearly suggests that the generation mechanism is non-thermal (the spectrum slopes the opposite way to the thermal emission from a quiet Sun). The waves from bursts are also strongly circularly polarized by the intense magnetic field associated with sun spots.

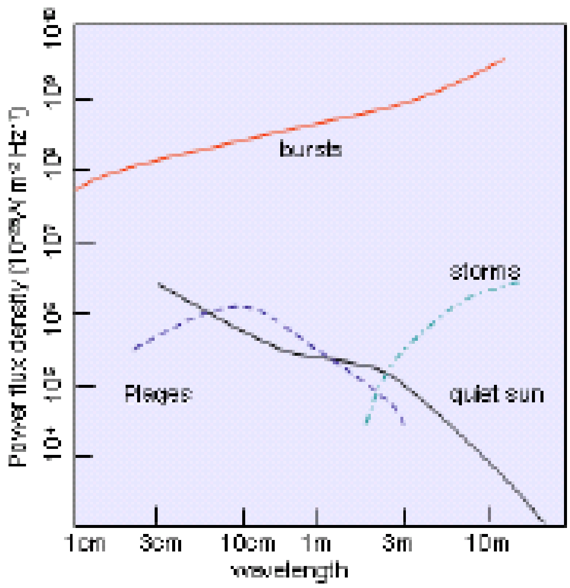



Figure 3.3 Spectra of Solar emissions

There are other outbursts from the Sun. Type 2 are found to drift from high to low frequencies with a rate of about 1MHz/ second, are randomly polarized and are believed to be produced by plasma oscillations. Type 3 emissions are sometimes called 'fast drift' bursts because the change frequency is at around 20MHz/ second. Occasionally after a large solar flare there is a long burst of wideband radiation from metres to low microwaves – these are called Type 4 emissions. See Figure 3.4 [2].

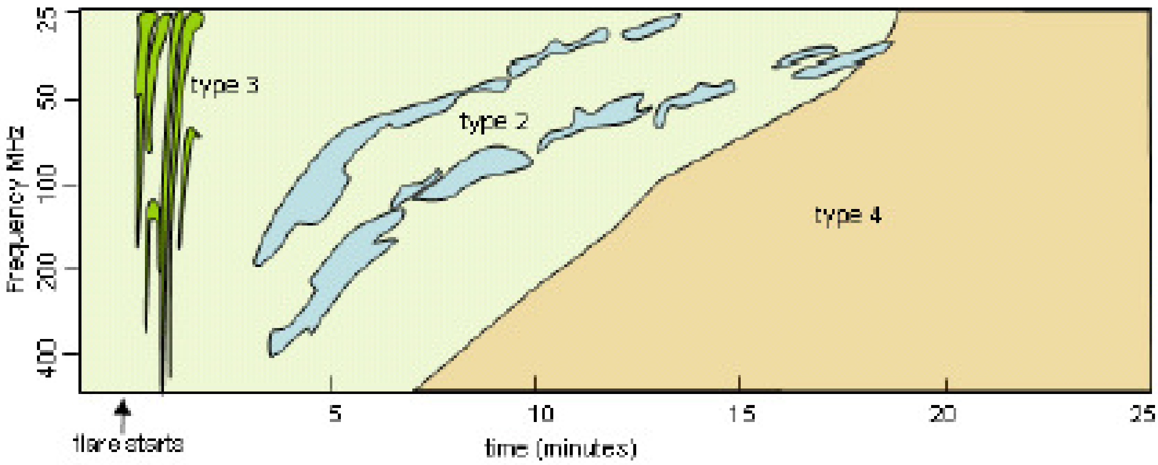



Figure 3.4 Dynamic behaviour of Solar emissions

Plages - radio bright areas of the sun associated with regions of sunspot activity.

Figure 3.5 shows an enormous solar eruption that occurred in October 2003 – note the size of the plasma ejection compared to the Earth.

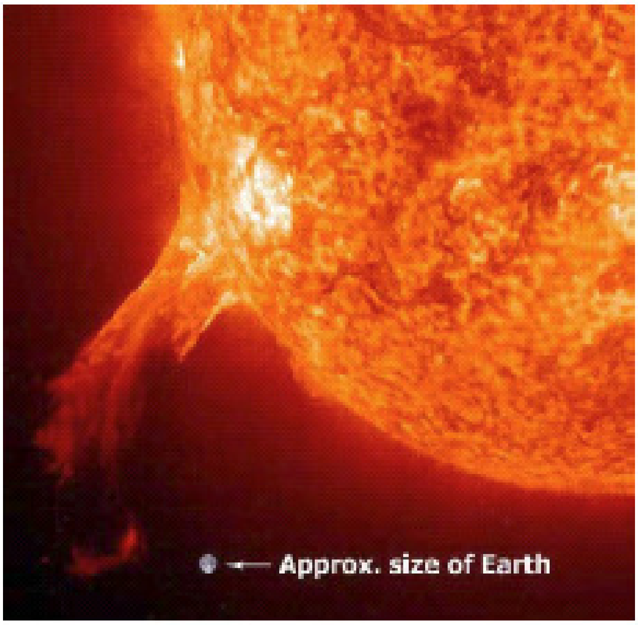



Figure 3.5 A Solar eruption

There is much that can be studied on the Sun by measuring the radio output at a number of frequencies that can be received with a general purpose communications receiver and a few types of antenna designed for the HF and VHF bands. Amateur radio astronomers can start by setting up such equipment and monitoring the Sun over long periods of time to establish trends and sudden events such as solar storms.

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[ Part 2 will appear in the next issue ]

# Technology Watch

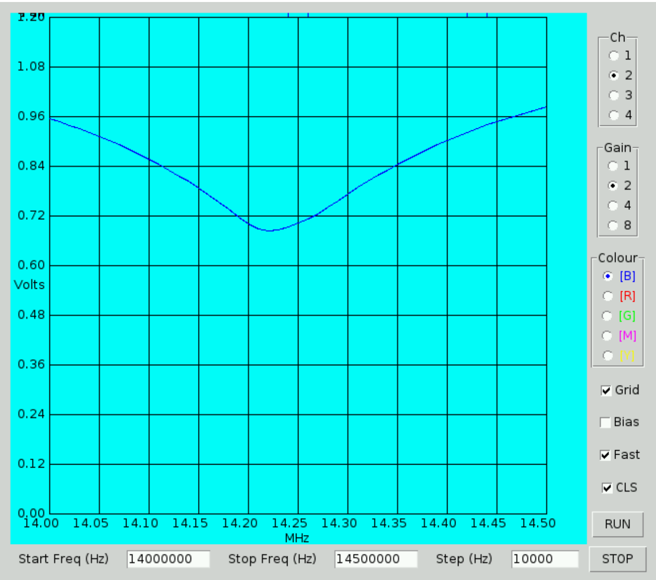
## - Tony Abbey

Technology

1 The first is work I have been doing myself with the Raspberry Pi Wobbulator. There is a Yahoo group where the project started.:

https://groups.yahoo.com/neo/groups/rpiwobbulator/info

This allows an Analog Devices DDS synthesiser of 0 - 40MHz range to be swept between any limits and step size and its o/p applied to a circuit under test whose o/p is then fed to an Analog Devices log amplifier into an ADC. The circuit is controlled from a Python program on the Raspberry Pi, making a very low cost scalar analyser. I have also built a return loss bridge which when inserted between the DDS and the input can measure reflected power from an antenna, antenna tuner etc. I have attached a plot from the Raspberry Pi screen of a Z-match tuner attached to my multi-band antenna tuned for the 14 MHz amateur band. A level of 0.6V represents 1:1 SWR in this case. I am still developing a readout of SWR values, but the usefulness of the system can be seen.




A different Analog Devices synthesiser would allow sweeping to higher frequencies which could be very useful for design and alignment of VHF antennas.

The return loss bridge was built from a kit supplied by the group who are running another Yahoo Group for the PHSNA - "Poor Ham's Scalar Network Analyser": https://groups.yahoo.com/neo/groups/PHSNA/info
It consists of a small bifilar wound toroid and 3 X 50ohm resistors, and is described in the files section of the PHSNA site.

2 Another project which could attract the attention of the RA community is the Airspy USB receiver. This is midway in price between cheap TV dongles and the FunCube Dongles, and will have a 10MHz bandwidth with an embedded ARM processor with open source software. The inbuilt processor should allow RA specific applications - say as an H-line spectrometer feeding low bandwidth samples to a subsequent data collection system. The design can have an external local oscillator leading to synchronised receivers for interferometry.

The Yahoo discussion group is at:

https://uk.groups.yahoo.com/neo/groups/airspy/info

It is expected to cost between $99 and $149 depending on the size of the production run.

3 An announcement has recently been made on raspberrypi.org that as a result of discussion with Eben at the RSGB Convention last year, accelerated FFTs are now available on the Rasp-

berry Pi by borrowing processing power from the video processor. Over 10X speed-up can be achieved over the bare ARM processor, which in any case has hardware floating point making it pretty fast. The article is at:

http://www.raspberrypi.org/archives/5934

4 In a related article, Andrew Holme has built a GPS system from scratch using a small amount of RF hardware, an FPGA and a Raspberry Pi. This article is worth reading just to see how inventive our best designers can be, and I wonder what the RA community can learn from it:

http://www.aholme.co.uk/GPS/Main.htm

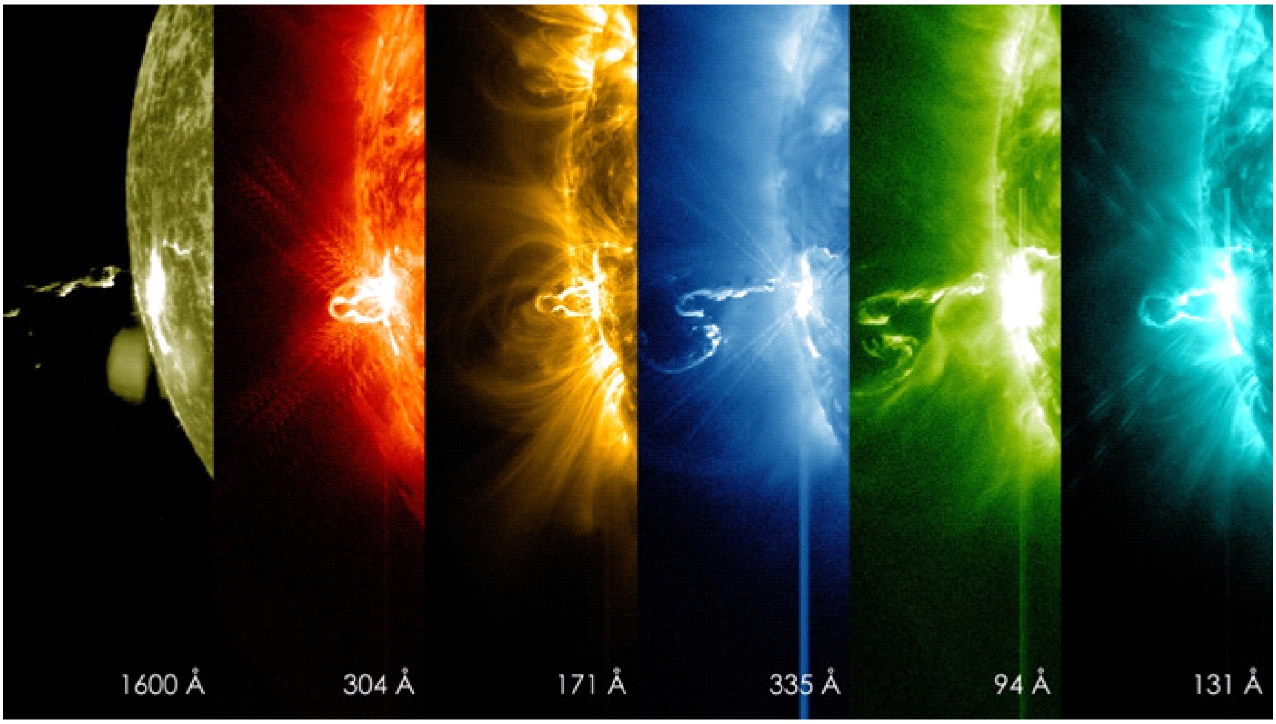
5 Finally, a crowd funded project called NavSpark plans to receive GPS and, using 32bit Leon RISC/FPU with an Arduino compatible pin-out, this could be used as a 1PPS clock with 10ns accuracy and would cost less than $15:

http://www.indiegogo.com/projects/navspark-arduino-compatible-with-gps-gnss-receiver

*[Editor's note: I am working on a more precise, compact PPS clock, and would welcome some help on this, anyway ! But I mention this here as my approach is more expensive than the less precise NavSpark, and if anyone is already active and knowledgeable in the NavSpark community perhaps the necessary additional 'hooks and eyes' - if not missing capability - might be included in at least later devices ? ]*

## Solar Flare, Feb 24 2014

Solar Physics, and eye candy




On Feb. 24, 2014, the sun emitted a significant solar flare, peaking at 7:49 p.m. EST. NASA's Solar Dynamics Observatory (SDO), which keeps a constant watch on the sun, captured images of the event. These SDO images from 7:25 p.m. EST on Feb. 24 show the first moments of this X-class flare in different wavelengths of light -- seen as the bright spot that appears on the left limb of the sun. Hot solar material can be seen hovering above the active region in the sun's atmosphere, the corona. Solar flares are powerful bursts of radiation, appearing as giant flashes of light in the SDO images. Harmful radiation from a flare cannot pass through Earth's atmosphere to physically affect humans on the ground, however -- when intense enough -- they can disturb the atmosphere in the layer where GPS and communications signals travel.

Image Credit: NASA/SDO

# SSRT, the Siberian Solar Radio Telescope

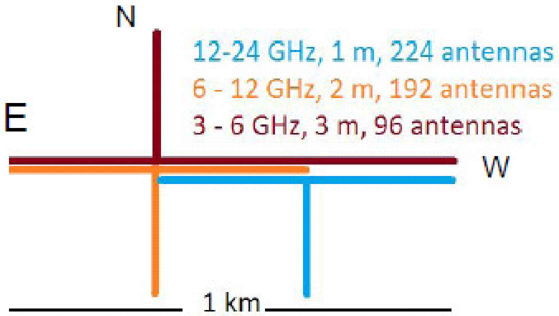


The SSRT is part of the Institute of Solar-terrestrial Physics, and is near Irkutsk, Russia. It was built in the 70s and 80s, originally to operate in the one-dimensional mode, but then enjoyed a number of hardware and software improvements. In 1991 the first two-dimensional maps were generated from one-dimensional observations using aperture synthesis via Earth rotation. The following year fast one-dimensional imaging was started, then by 1996 several images per day was achieved in two-dimensional mode. A major upgrade has been made very recently. The telescope operates at 5.7 GHz (5.67 - 5.79 GHz) and now features a cross of 128 antennas each arm. The arm lengths are 622m, and each antenna is 2.5m. dia.

RCP and LCP polarizations are used, and the spatial resolutions are 15 arcsecs (1D) and 21 arcsecs (2D), with temporal resolutions of 14 ms (1D) and 2 min (2D). This unique facility enables coronal magnetography. Measurements of, for example, the dependence of apparent sizes of sub-second sources on the distance from the solar centre has led to the notion that abnormally high levels of turbulence are formed in the lower corona - and several UK universities work on modelling and simulation of this sort of thing for both the sun and exo-planets (MHD and GAFD).

By 2015 a major advance should see a re-arrangement to provide 4-8 GHz radioheliograph coverage, albeit not instantaneous full band. With 10 MHz bandwidth it is expected to get a brightness sensitivity near 100K, spatial resolution of 13 arcsecs at 8 GHz. The 96 new 1.8m dia. dishes have already been mounted on the SSRT rotators. Optical fiber linkages between the antennas uses the East-West tunnel facility that was originally built to carry the waveguide connections. Five-frequency observations will have cadences of 1 sec.

By 2020 it may be possible to extend coverage to 3-24 GHz, with 15 frequencies simultaneously, 0.1 sec cadence, RCP and LCP, 100K sensitivity. The likely arrangement in plan view is said to be like this:




Currently the telescope produces images without measuring visibilities; solar rotation provides the hour angle change, frequency scanning the altitude (over the 120 MHz band). Dynamic range of the maps derived is some 30 dB. For extended sources (e.g. sun) there has been derived a clever technique that combines an adapted form of MS-CLEAN (Multi-scale CLEAN) with the direct imaging SSRT capability. This now makes it possible to see lower brightness features.

The Institute also features a plethora of geophysical instruments, a large solar vacuum telescope, an incoherent scatter radar (IRIS), photometers and spectrometers, cosmic ray spectrograph etc.

**Reference:** www.en.iszf.irk.ru/