The RAGazine

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The RAGazine

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Radio Astronomy Group

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Notes for content submission

Content should be emailed to the RAGazine editor a minimum of fourteen days before the next publication date. Content submitted after that may not appear the next issue, but will be held for a later issue.

Observational reports are very welcome on topics where radio techniques are applied to observe astronomical objects, or geophysical events. Articles are welcome on topics of radio astronomy observational techniques, radio hardware and related technology, scientific programming, events, data processing, educational out-reach, book reviews, radio astronomy history etc.

The preferred format for submissions is Microsoft Word (.doc or .docx format). However, I know that not everyone has access to Microsoft Office, note that the free office suite LibreOffice is available for Windows, Linux and Mac OS. Note that LibreOffice can save documents in Microsoft Word .docx format. If neither of these applications are available, then plain text (.txt) is fine.

Images can be supplied embedded in the document or as separate files. Please include the author credits you require to be included in the article, and indicate whether you want your email address to be shown in the publication.

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2016 Publication dates and submission deadlines

Release Date	Submission deadline
8th August 2016	25th July 2016
14th November 2016	31st October 2016

RAG Coordinator report

By Jeff Lashley

Welcome to the May edition of Ragazine. Things have changed in BAA RAG this month, when Paul Hyde stepped down as coordinator. I think you will agree that Paul deserves a big vote of thanks for his hard work over the last few years in leading the Group. I understand he is still active in the radio meteor field, and I look forward to working with him on future projects, as I take over the reins of organising the Groups work.

One of my main tasks for the near future is to sort out the state of the RAG website. It is in big need of an update. After this edition of Ragazine is published I will start to tackle updates on the current site, which will give us a little time to implement something much better later on.

Groups such as ours survive, and indeed thrive, by the hard work and input from a relatively small team of individuals. Now that I have taken over from Paul, I currently retain the hat of Ragazine editor, while I am prepared to continue to do so, I would like to call for volunteers to help out. All you need is a modern word processor; Word is preferred but LibreOffice equivalents work too. Please contact me directly if you are interested.

I would like to offer the readers chance to provide feedback on the services we offer you. For example does anyone read this! Also what do you want to see on the new website, and what kind of meetings would you like to see in future. Again feel free to email me direct with your thoughts. I know some people prefer to remain anonymous, so I will try to introduce some anonymous polls on the website in future.

Another area we need to develop in the future is to introduce more formalised observing programs and data collection methods. My aim here is to collect relevant data which could lead to the publication of a Paper in the BAA Journal. Our core 'committee' have talked from time to time about a data repository. Before we get that far however we need a detailed definition of the data fields we need to collect in order to form a useful repository. The two primary areas I see that we can do this is in Solar SID monitoring, and Meteor scatter. At this point I need to congratulate the work of Chris Jackson and Victoria Prentice on the development of Scatterthon. It is the only attempt in a long time that I am aware of at developing a technique to sort out and clean up raw meteor scatter data. If it was not for their work, a weakness in the Spectrum Lab package would not have been spotted, which as a consequence has since been addressed.

In conclusion, we as a group have achieved some great successes, but there is much more work required yet. With your help we can continue.

Jeff Lashley

RAG Coordinator.

Solar Activity 1st Quarter 2016

By John Cook

Fig 1 shows activity levels since 2005. Sunspot numbers are courtesy of the BAA Solar Section. SID numbers since the last report are as follows: -

January = 5 (no M-class).

February = 30 (including 4 M-class).

March = 8 (no M-class).

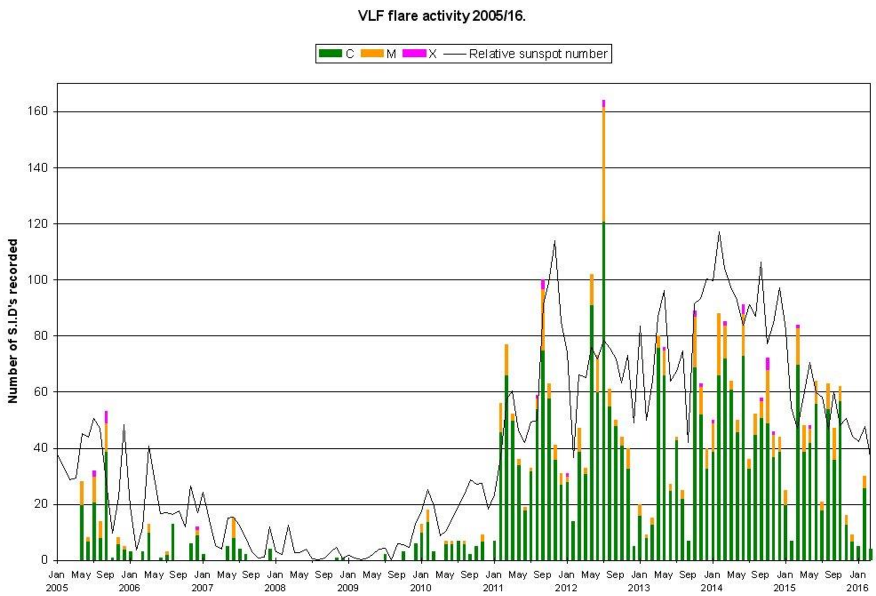


Fig 1.

2016 started with a very inactive sun. There were just five C-class flares recorded as SIDs, the strongest being C9.6 at midday on January 28th. The background X-ray flux through most of the month was at the B2-B3 level, increasing just slightly in the last week. Fig 2 shows the C9.6 flare recorded by Colin Clements at 23.4kHz and 22.1kHz. Compare this with Fig 2, his recording from the 29th. There were no flares during the daytime on the 29th, but ionospheric instability has caused considerable noise and oscillations on both signals. This is often a problem during the winter months with the Sun low in the sky, but is much worse when the X-ray flux is also low. Strong storms battered the UK at the end of January, and may well have increased the magnitude of the instability. Mark Edwards reported similar ionospheric disturbances, and used his modelling software to show a significant increase in the D-region height by the end of the month. His chart of D-region height for 2015 was included in the last Ragazine.

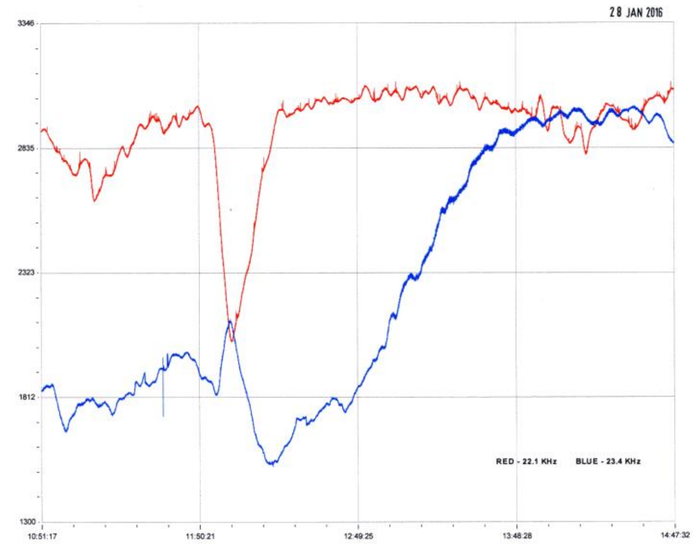


Fig 2.

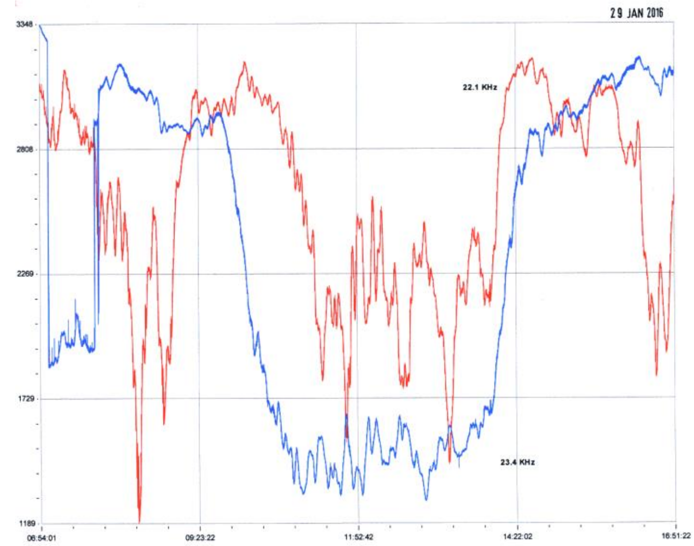


Fig 3.

Also mentioned in the last Ragazine was a CME associated with an M1.8 flare on December 28th. A strong SSC was recorded at 00:51UT on the 31st, with a very active period of magnetic disturbance in the morning of January 1st. Fig 4 shows my own magnetic recording. An extended period of disturbance was recorded from the 18th to 22nd. This was due to a filament eruption in the solar southern hemisphere on the 14th. By the 21st a strong CHHSS added to the strength of the disturbance.

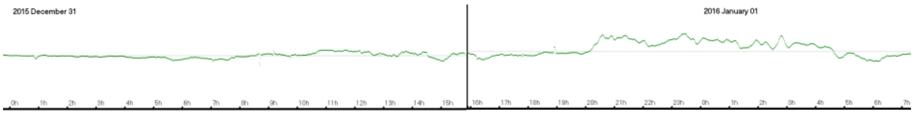


Fig 4

Activity was much higher in February as AR12497 crossed the visible hemisphere mid-month. The 15th was the busiest day, with 6 classified flares recorded. Fig 5 shows the SIDs recorded by Roberto Battaiola in Milan. Also note the disturbance seen in the late afternoon in this recording. This type of interference is often caused by local thunderstorms, more often seen here in the UK during the summer. The first of the M-class flares was on the 12th, shown as a very strong SID at 8 frequencies by Mark Edwards in Coventry (Fig 6). This was an M1.0 flare, peaking at 10:48UT.

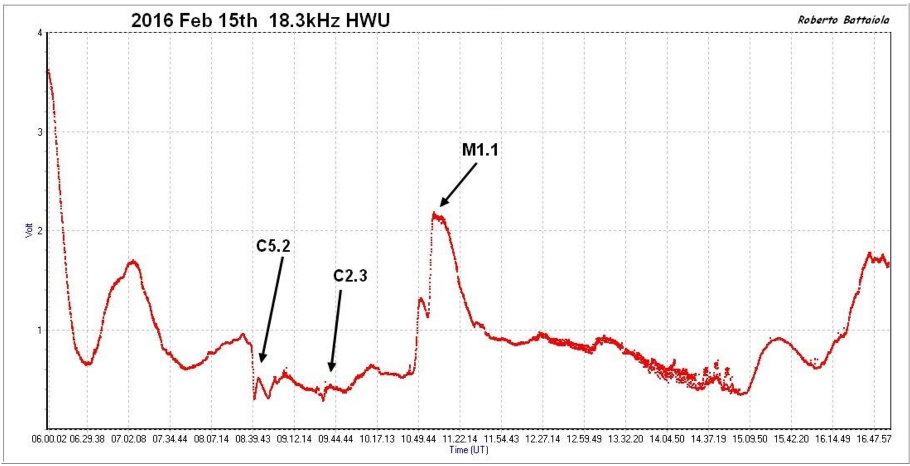


Fig 5.

Despite the flaring activity there were no major Earth-directed CMEs in February. A large coronal hole developed near the solar south pole, which had stretched nearly to the equator by the 14th. The solar wind speed measured by the ACE satellite rose from 400km/s to 700km/s during the 16th, remaining high for several days. It had fallen back to 340km/s by the 21st. This CHHSS led to some strong magnetic activity from the 16th to 18th. By the 24th a further large coronal hole had opened near the solar north pole. This one did not stretch quite as far towards the equator, and had much less effect on the terrestrial magnetic field. Peak activity was on the 16th, as shown in Fig 7 by Roger Blackwell in Mull.

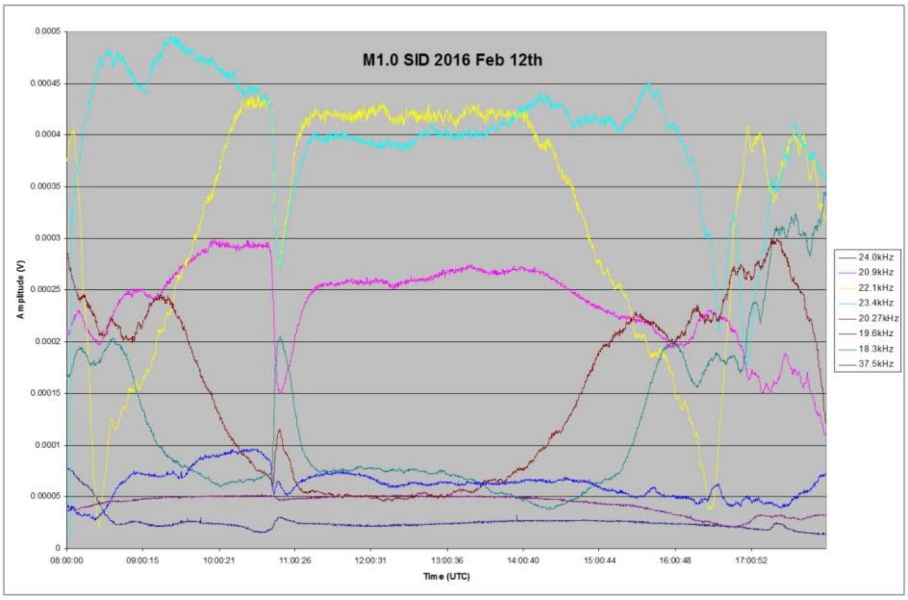


Fig 6.

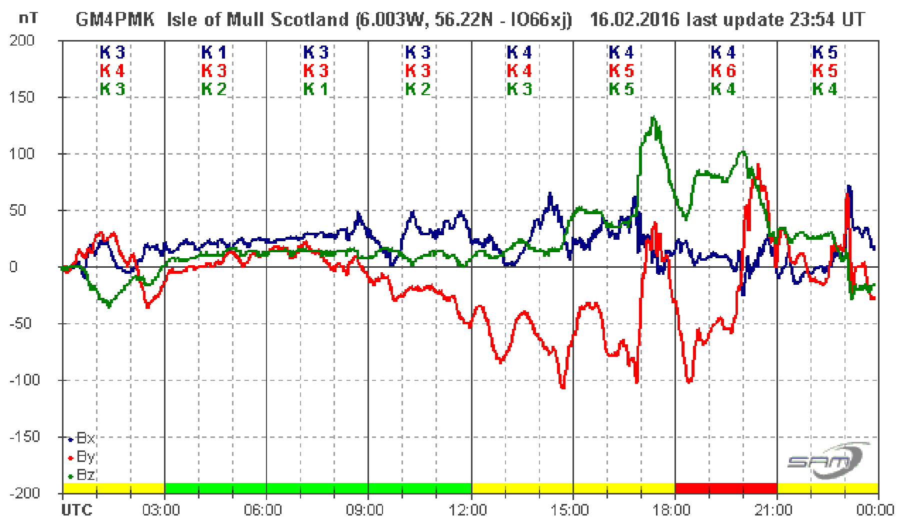


Fig 7.

Solar activity in March fell back to a low level again, with just 8 flares recorded as SIDs despite the longer day length. An interesting feature is the number of smaller C- and B-class flares recorded. Fig 8 shows my own recording from March 8th, with the GOES15 X-ray data added in black. The C1.5 flare has made a very distinct SID at 23.4kHz, and even shows well at 22.1kHz. A B8.4 followed less than 10 minutes later, and has added to the earlier event creating a double SID at 23.4kHz. The background X-ray flux had been very low prior to these events.

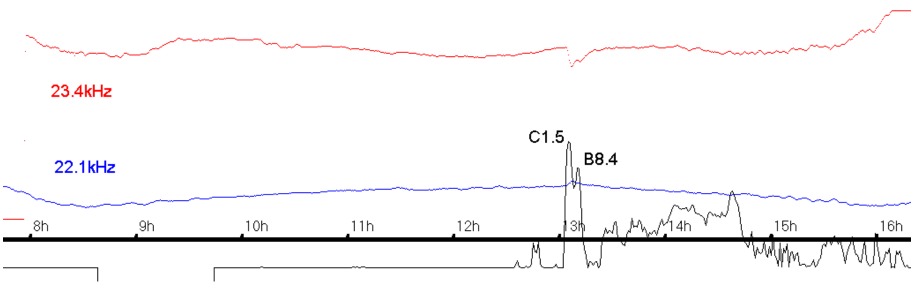


Fig 8.

The largest magnetic disturbance in March was on the 6th, shown in the recording by Roger Blackwell, Fig 9. A large coronal hole opened early in the month, with a strong Earth-directed CHHSS arriving around midday on the 6th. Roger's magnetogram shows a very active period in the evening, with a smaller disturbance continuing through the 7th. Note the change in vertical scale between the two days in Fig 9.

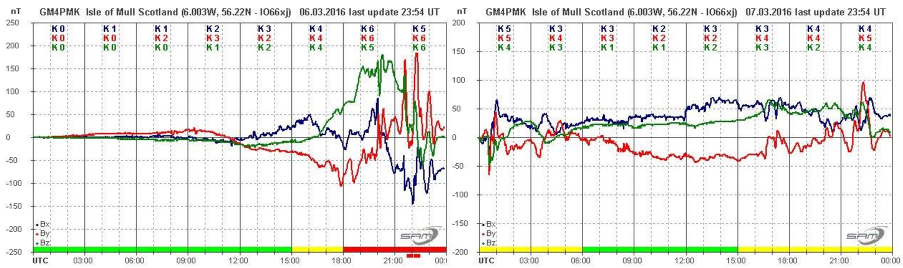
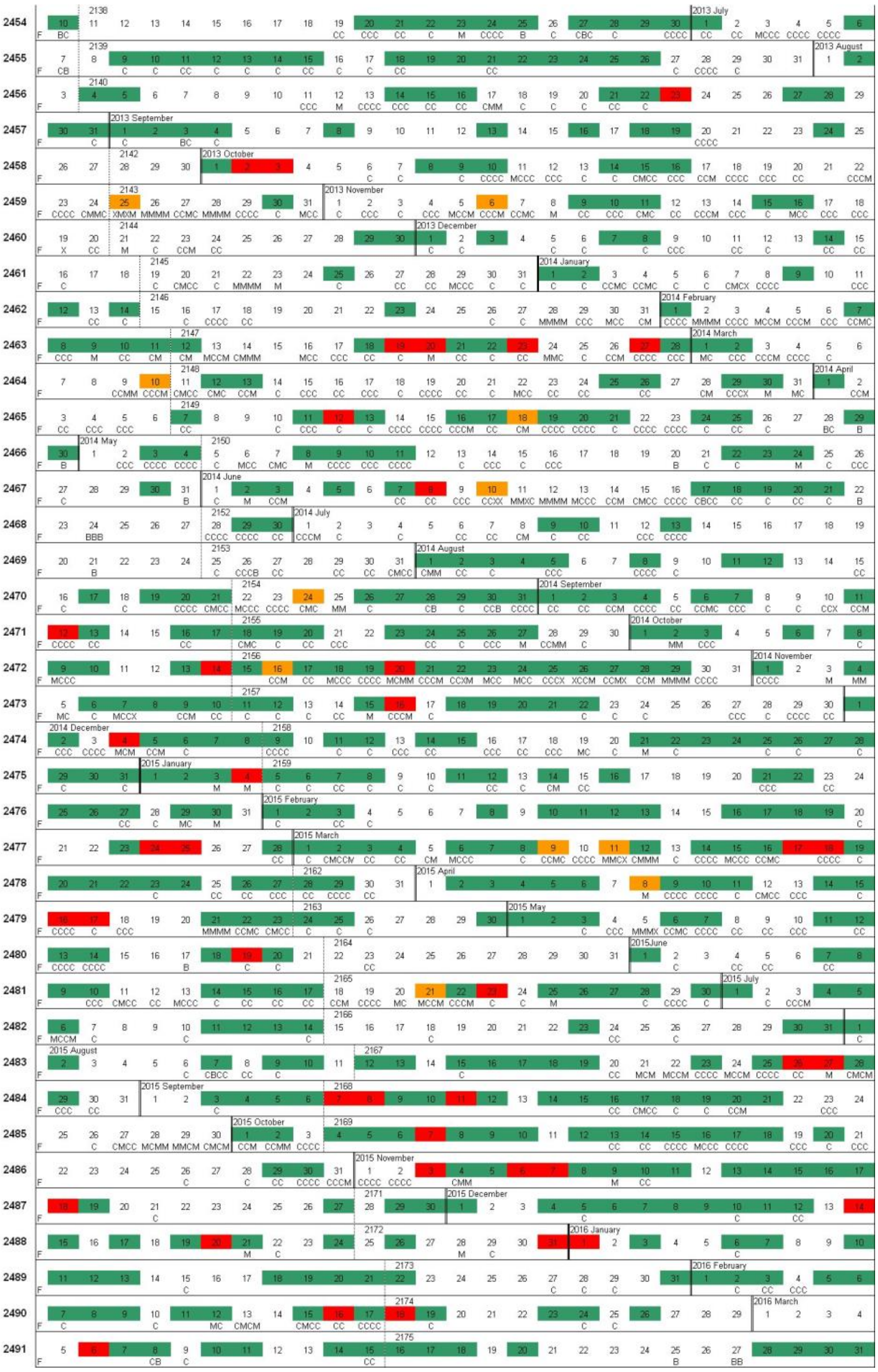


Fig 9.

All of the month's activity was from CHHSS effects, there being no major CMEs in March.

A full description of these events as well as listings of SID timings can be found in my monthly VLF summaries. Unfortunately the Radio Group website does not currently include the most recent reports, so do please contact me directly (details below) if you would like copies.Observers: Roberto Battaiola, Jim Barber, Roger Blackwell, Colin Clements, Mark Edwards, John Elliot, Paul Hyde, Steve Parkinson, Phil Rourke, Gonzalo Vargas, John Wardle and John Cook. My thanks to all contributors. If you would like to add your own observations, please contact jacook@jacook.plus.com.

May **2016**



The EUCARA 2016 conference

Paul Hyde

EUCARA 2016 (European Conference on Amateur Radio Astronomy) was held between 15 – 17th April and followed the very successful EUCARA 2014 event held at the Stockert Radio Telescope in Germany and which was reported in Vol 2 Issue 2 of RAGazine. This time the event was hosted by CAMRAS (the CA Muller Radio Astronomy Society) in northern Holland. CAMRAS is a charitable trust set up to restore and operate the Dwingeloo radio telescope, located next to the main offices of ASTRON, the Netherlands Institute for Radio Astronomy. In the UK ASTRON is perhaps best known for the LOFAR radio telescope but it has been a leading player in the development of European radio astronomy.

The Dwingeloo and Stockert radio telescopes have several similarities. They are both 25 metre instruments set up in the aftermath of WW2. EUCARA 2016 coincided with the 60th anniversary of the opening of the Dwingeloo instrument, which was then the world's largest fully steerable radio telescope, a position held until the opening of the 76-metre metre dish at Jodrell Bank in 1957. (Figure 1 Conference delegates assembling for the obligatory group photograph in front of the Dwingeloo radio

Figure 1.

telescope. All the drive and control facilities are contained within the cabin which rotates as part of the dish structure.)

Both instruments are now 'retired' and both are designated national heritage sites within their respective countries. Each has an active team of volunteers keeping the instruments open for the public to visit. The original purpose of the dishes has meant that each is located in protected parts of the countryside which are now popular with walkers and tourists. Both instruments continue to be used for amateur observations. Whilst the Stockert dish has developed a particular reputation for pulsar work, Dwingeloo has an active amateur radio contingent and has undertaken a lot of Earth–Moon-Earth (EME) work as well as radio astronomy observations.

(Figure 2 The Control Room of the Dwingeloo radio telescope)

The conference opened with a presentation from ASTRON's General Director, Professor Mike Garrett , which covered the evolution of radio astronomy from the Dwingeloo Telescope to the forthcoming Square Kilometre Array (SKA). As well as dramatic increases in the sensitivity of receivers, observing capabilities are now being enhanced by greatly expanding the Field of View obtainable at any one time. An example is the APERTIF Focal Plane Array (FPA) currently being deployed at the nearby Westerbork Synthesis Radio Telescope. The development of such technology will culminate in the construction of the Square Kilometre Array, an instrument which will provide a huge increase in the capabilities of radio telescopes.

(Figure 3 ASTRON's offices adjacent to the Dwingeloo dish)

Andries Boone (Midden Nederland Observatory, Amersfoort) then described the work being done at the observatory on receiving 21 cm hydrogen line emissions using low-cost RTL2832 TV 'dongles'. The idea is to develop something to support demonstrations of practical radio astronomy by public observatories and educational institutions.

Rob Stammes has always had a keen interest in Very Low Frequency (VLF) Radio Astronomy and the Northern Lights, and used to run an auroral watch organisation in the Netherlands. He then set up the 'Polarlightcenter' on the Norwegian island of Lofoten inside the Arctic Circle which offers visitors a chance of observing the Northern Lights under spectacular viewing conditions. In the meantime Rob continues his VLF studies, often trekking several miles across the ice and snow to his remote observing point, spending the nights under canvas.

Paul Hyde provided a short description of the work carried out by BAA RAG on meteor forward scatter, highlighting the advantages of working with the strong signals generated by the GRAVES radar system. Meteor activity is dynamic with some degree of unpredictability, making it a good target for amateur observing. There is also the potential for future development in conjunction with observations by the several meteor video networks being developed across Europe.

Professor Hugo van Woerden reflected on the development of radio astronomy over the past 70 years and the part payed by the Dwingeloo radio telescope. He was at Leiden University at the same time as Jan Oort was using Grote Reber's work to show how astronomy at radio wavelengths might increase our knowledge of the Universe. He was also at the meeting where Hendrik van de Hulst predicted that neutral Hydrogen would have a spectral line at 1420 MHz. The search for this signal continued over the following years, with the Dutch efforts hampered by fire, so that Ewen and Purcell (Harvard) claimed the prize in 1951. He described the inauguration of the Dwingeloo dish by Queen Juliana on this very same day, April 17, 60 years previously. Hydrogen Line emissions formed an important part of the subsequent work and culminated in the discovery of the Dwingeloo-1 galaxy in 1994, notable because of its optical obscuration by the gas and dust at the centre of the Milky Way.

Harm Munk described how the CAMRAS team recreated the observations at Dwingeloo which contributed to the first map of the spiral structure of the Milky Way. The project was carried out in conjunction with students and high school pupils and showed how historical observations can still have a significant educational value.

Michiel Klaassen gave an impressive presentation on how, almost single-handed, he disassembled a 9.3m satellite communications dish, shipped it over 2,000 km to Portugal, and then rebuilt it at his own observatory. The project took several years to complete, long enough for the differing stages to be captured on Google Earth images. Two 6-metre sea containers were used to ship the metal work, with the component dragged into the containers using a car and rope passing through a hole drilled through the end wall. Back home in Portugal he struggled with the local planning approval process to build a new concrete foundation, and then had to overcome the absence of a 380V power supply, rendering the elevation motor unable to move the dish up from 0 degrees. A counterweight system has partly solved the problem with 'first light' measurements of maser activity from NML Cygni.

Frans de Jong is another member of the CAMRAS team and reported on observations of M31 and the (originally) unexpected high rotational velocities which gave support to the concept of Dark Matter holding galaxies together when accepted physics insisted they should disintegrate. The hydrogen line theme was continued by Gerhard Stramm with a step-by-step guide to building a 21cm feed horn for less than 20 Euros. The skills needed here are those of woodworking, sheet metal cutting and plumbing, rather than electronics.

Peter East described his work in determining the minimum useful antenna aperture for amateur radio astronomers to detect the strongest pulsars using low-cost receivers based on the RTL2832U SDR. His theoretical evaluation was supported by data from 25-metre instruments provided by Guillermo Gancio and Michiel Klaassen. The conclusion was that amateur detection should be possible with dish sizes exceeding 3m at frequencies around 400 MHz, coupled with careful system design and moderately long (3 hours) observation times.

Jules Marien (Public Observatory Hove, Belgium) explained how antenna pedestals and parabolic reflectors saved from the scrapyard have been used to build a 1420 MHz interferometer. The project has not required a lot of money but has taken a lot of time to complete. There is still a lot to do but the first results have been encouraging with fringes being observed on ever weaker radio sources.

Wolfgang Herrmann (Astropeiler Stockert) was responsible for initiating the EUCARA series of events, starting in 2014 at the Astropeiler Stockert Telescope. He has been particularly active in pulsar research and he described the latest results of observations at 1400 MHz. A total of 95 pulsars have now been observed, including millisecond pulsars and binary systems. His presentation included examples of exotic pulsar phenomena such as mode changing pulsars, nulling pulsars, scintillation and giant pulse observations.

Paul Boven's day job is at ASTRON, as part of the JIVE (Joint Institute for VLBI in Europe) team. He is also a leading contributor to the CAMRAS project and had led the team organising the EUCARA 2016 conference. His concluding presentation reviewed the history of the refurbishment of the original Dwingeloo instrument, which included the removal and rebuilding of the parabolic reflector, and the subsequent work carried out with it. The CAMRAS team are now looking towards replacing the receiver systems to improve the sensitivity, frequency coverage and resistance to RFI. The intention is to make the design available to the wider amateur community via an open hardware license and Paul invited anyone who was interested in supporting this work to contact him.

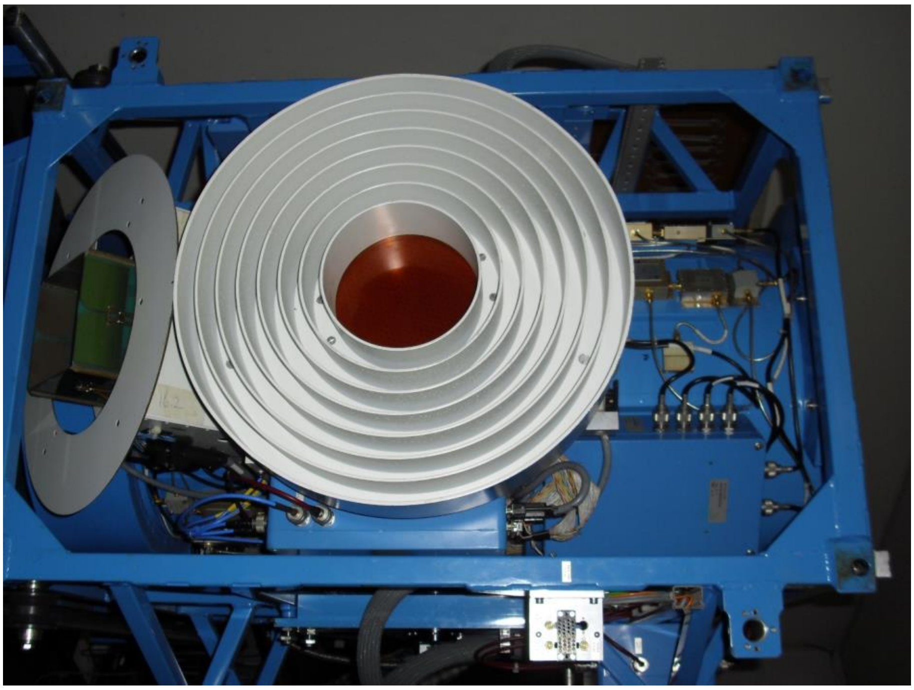
Visit to the Westerbork Synthesis Radio Telescope

The conference was followed by a visit to the WSRT observatory, which is about half an hour's drive from Dwingeloo. This instrument originally consisted of twelve 25-metre dishes mounted in a straight line and was completed in 1970. A further two dishes were added later at a second site approximately 0.5 km away. The instrument is now remotely operated from the ASTRON facility leading to control rooms and offices with eerily clear desks.

(Figure 4 A few of the fixed-position 25 m dishes that form part of the WSRT.
Four other dishes are mounted on railway tracks)

(Figures 5a and 5b Drive and cable management arrangements at each of the dishes)

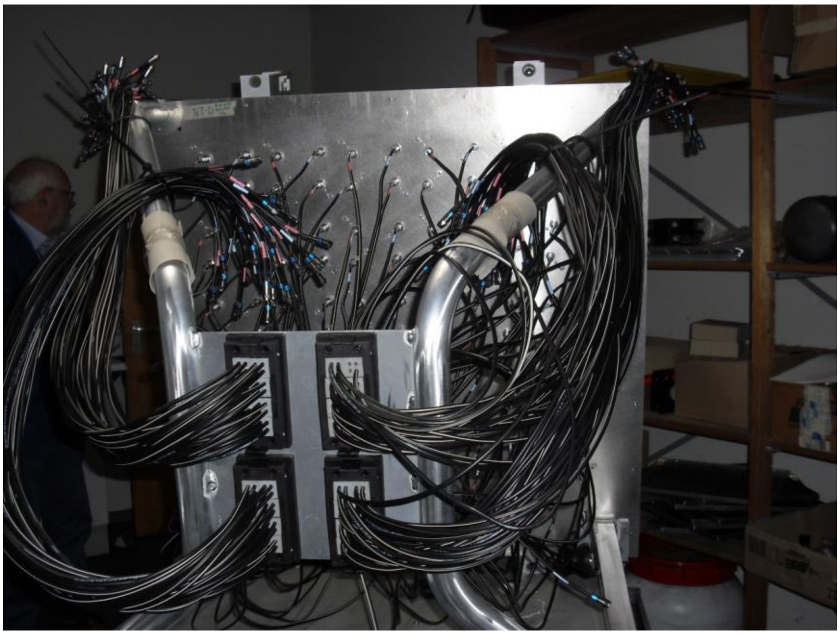
The instrument is in the process of being further upgraded with the APERTIF (APERture Tile In Focus) Focal Plane Arrays which increase the field of view by a factor of 25, allowing surveys to be carried out in a fraction of the time previously needed. Although it has been a wideband instrument in the past, the future WSRT work will focus on deep sky observations of hydrogen emissions, which is very appropriate given the historical connection of The Netherlands with this frequency.



(Figure 6 One of the receiver carousel units removed from the dish focal cabins prior to replacement by an APERTIF unit.)

APERTIF consists of an array of 121 'Vivaldi' (so-called because of their horn shape) or Tapered Slot antennas. These are coupled with Phased Array technology to allow multiple beams to be formed at the same time, providing the increased performance in survey times.

(Figure 7 An APERTIF FPA unit with its 121 Vivaldi antennas.)



(Figure 8 Rear view of the APERTIF array. Unbelievably, the individual coax cables are terminated with 'F' connectors, though obviously expensively engineered brass-body, weather-proof versions.)

Both the Stockert and Dwingeloo instruments are steeped in history, being built as part of Europe's recovery from the horrors of WW2, with the aim of use the technological advances arising from that conflict for the advancement of science. Nowhere is this more apparent than at the WSRT. I was surprised by the number of cars at the entrance to the site and the number of people walking the half mile or so to the observatory proper. The explanation is that the WSRT was deliberately constructed on the site of the notorious Westerbork Transit Camp, where Romani and Dutch Jews (including Anne Frank's family) were interned prior to transportation to Auschwitz and other camps. Ironically partly funded by the Dutch Jewish community to aid refugees fleeing Germany before the war, the camp subsequently saw over 100,000 individuals shipped on to meet a terrible fate. Part of the camp has been retained as a museum and monument to this tragedy, and the dishes and work of the WSRT serve as part of this monument.

(Figure 9 The Camp Commandant's house, part of the memorial museum. A 200-seat auditorium has been included at the rear, all enclosed within this huge glass structure.)

The EUCARA 2016 event was a very enjoyable occasion with a good selection of talks and two very interesting locations. The pre-conference social on the Friday evening and the dinner on the Saturday provided the opportunity to socialise and exchange ideas with like-minded individuals. It is planned to hold a EUCARA 2018 event which will be back at the Astropeiler Stockert Observatory.

May 2016

Amateur Radio-Astronomy project with RTL-SDR radio dongle and Raspberry PI

By Mario Cannistrà

Back in February I published an amateur project for an automated radio astronomy station, based on a Raspberry PI 2/3, for low power consumption and possibly 24/7 continuous operation.

Amateur radio-astronomers built several devices in order to receive, listen and/or display signals from outer space sources, many use custom made radio receivers, others use HAM radio receivers. Recently, various experiments have been done using the cheap RTL-SDR dongles (radio receivers originally meant to listen radio and watch TV on your laptop).

With this project I want to try receiving radio emissions from the Sun or Jupiter and its satellite Io using these RTL-SDR dongles.

I am building an automated radio station, cloud connected like an IoT device that any amateur could easily replicate, joining the project and forming a collaborative, open science effort. Hopefully this would facilitate data collection and dissemination, at least for the community learning benefits. I envision the adoption of this simple system by several amateur radio-astronomers that could form a network of distributed stations running different radio surveys at the same time. 4 other persons already started the same project build: 2 in UK, 1 in USA and 1 in Brasil. Participation is open, free and encouraged.

Requirements and current status of project development:

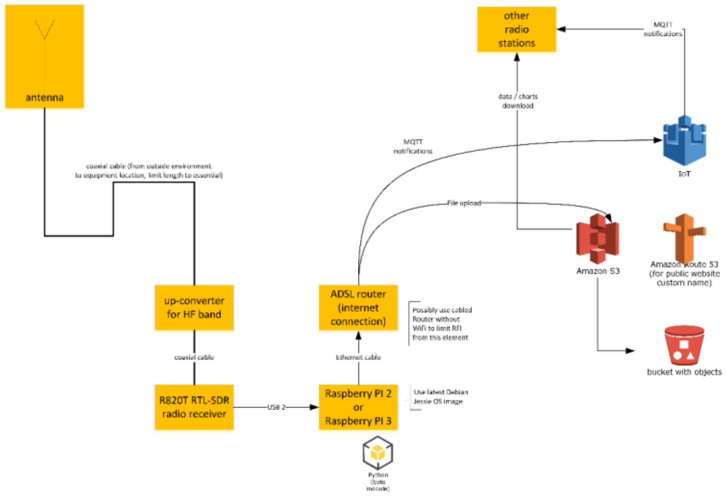
- connect directly the RTL-SDR USB dongle receiver to the R-PI
- do the radio spectrum scan and data writing directly on the R-PI microSD
- produce the spectrum image (waterfall) on-board from that data
- publish on the web the resulting image and/or data sending to the Amazon AWS cloud for centralized storage
- send push notifications (MQTT) to other amateur observers for open science data sharing
- free usage of the publishing system should allow easy access to historical data stored on AWS S3
- the message based notification system should facilitate the integration with other systems and/or further study / processing
- notification messages can already be sent for each new scan produced
- message reception is simple and post-processing tasks could be easily linked to data being made available by another station
- the proposed design should work for most of the usual radio-astronomy frequencies. I will use the recommended 18-24 MHz frequency range, probably the most used one for Jupiter-Io radio storms. Any other frequency range can be used for other experiments such as Sun monitoring on HF.
- Tests are being performed with/without LNA before the dongle receiver. Some surveys could run without LNA, test results will be shared within the community
- RF filters bring significant improvements to the SDR and are currently in build/test phase
- Optimal receiver gain should be determined for the various possible radio surveys (Sun, Jupiter, others)

A specific program has been written to calculate predictions of Jupiter/Io radio storms, based on probability data collected by various scientific projects along the years.

All the programs are constantly evolving thanks to feedbacks received by current users. A new update should be published before end of May.

I added some features/options to rtl_power_fftw (by Klemen Blokar and Andrej Lajovic) in order to leverage faster FFT execution, save data to smaller files in binary format, simplify and speedup spectrogram production. This branch of the program is now Windows compatible for those who want to test this on a PC before buying a Raspberry PI (remind that this will consume less power if you leave it running 24/7…).

The overall project design is the following:



Summary of currently available functionality:

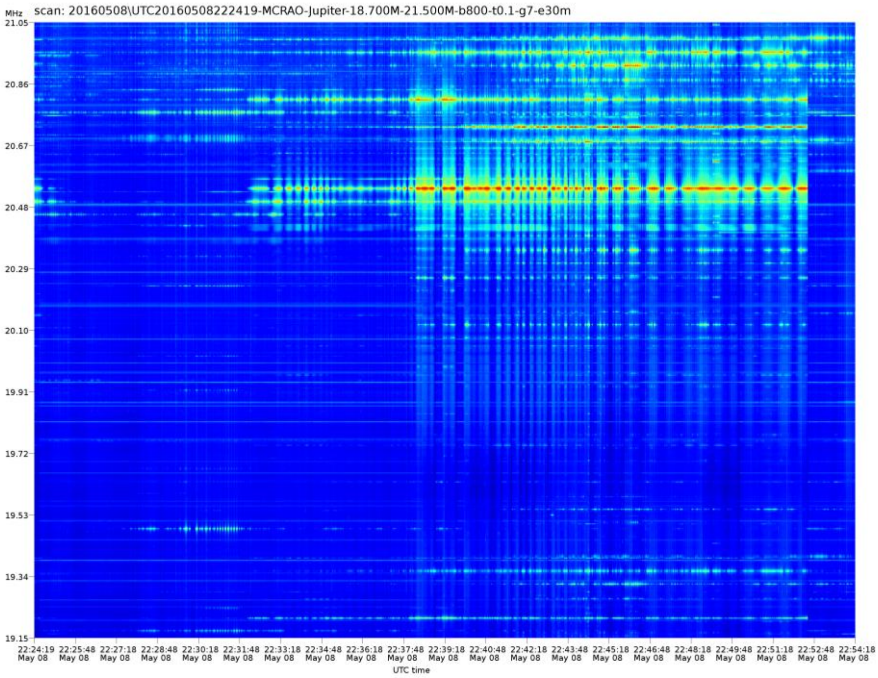
1. Run a radio scan session with various configurable parameters/options:
    a. Run for a number of hours then stop
    b. Run continuously 24/7
    c. Save separate data files with FFT values in binary format and produce a spectrogram every N minutes (suggested scan duration is 30 minutes)
    d. specify ~~center~~centre frequency of the scans performed, for example 22.5 MHz
    e. specify frequency range of the scans around the ~~center~~centre frequency, for example 15 MHz will cover from 15 to 30 MHz
    f. specify integration time (also < 1 sec)
    g. optional: send spectrogram to cloud
    h. optional: send notification message to other radio stations via cloud based MQTT gateway
    i. produce end of session overall chart with minima and maxima of signal strength
2. post process (reprocess) a set of scans collected during a session to produce an overall session spectrogram summarizing hours of radio scans (see below for sample spectrograms)
3. all data is logged in UTC time and NTP time sync is performed both at start of scan session (forced) and automatically by NTP during the normal uptime of Raspberry PI Operating System
4. all spectrogram PNG image files have metadata embedded with all the technical information about how the scan has been performed (center frequency, bandwidth, FFT bins, integration time, etc)
5. metadata of a PNG file can be displayed at any time using one of the programs made for the radio station (catpngmeta.py)
6. run a test session with varying gain for the same tuning ranges in order to determine the best gain for your setup, RFI presence, your geographical position, etc

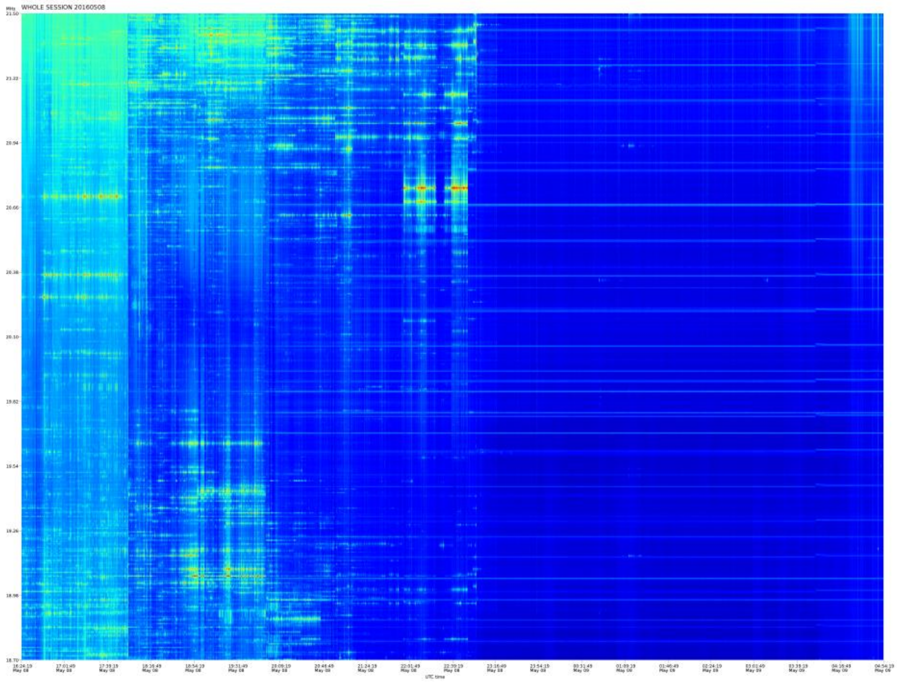
7. specify your geographical position in a configuration file in order to be able to run the Jupiter "visibility"/storm prediction program (jpredict.py)

Some work is going on about tuning the gain and building an RF bandpass filter to improve the output of the dongle receivers. As you can see from the following examples, the dongles are sensitive to out of band emissions and too strong input can show up on several FFT bins. This should be solved adding a bandpass RF filter.

To see an example of the expected benefits, watch this video by Kugellagers Noodle : https://www.youtube.com/watch?v=WDE8ho0uee8

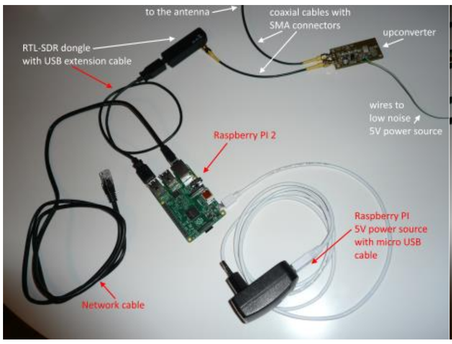
Please see below two example spectrograms: a single scan of 30 minutes and a session overview obtained stitching together about 12.5 hours of FFT data.





Spectrograms produced on the Raspberry PI are stored in separate folders named with session date and can be copied periodically to different storage / PC for post-processing enabled by additional Python programs that are part of this project. Some changes/improvements currently being evaluated are about using an attached/external storage instead of the R-PI microSD. Cloud connection and data publishing are optional but encouraged.

The two following pictures show the main ~~hw~~ hardware components/connections and the importance of RFI shielding with metal case for the R-PI and ferrites on cables:



A dedicated forum has been created where the users can exchange their experiences, ask questions, find documentation updates and receive notifications of new software versions.

Your feedback and ideas are more than welcome. You can get in touch both through the forum (see below) or writing me directly at: mariocannistra@gmail.com

- Links to resources mentioned in this summary: Full project details: https://www.hackster.io/mariocannistra/radio-astronomy-with-rtl-sdr-raspberrypi-and-amazon-aws-iot-45b617
- Dedicated forum: https://groups.google.com/forum/#!forum/ra-rtl-rpi
- Link to new branch of rtl_power_fftw: https://github.com/mariocannistra/rtl-power-fftw
- Link to radio astronomy software suite for this project: https://github.com/mariocannistra/radio-astronomy-fftw
- Link to modified version of rtl_power_fftw: https://github.com/mariocannistra/rtl-power-fftw

Software De-dispersion for RTL SDR Pulsar Data

By Peter East

Introduction

Data files produced by RTL SDR dongles can be folded directly for pulsar detection using software such as rapulsar.exe. Using simple I/Q vector averaging software, the data can be down-sampled by factors of more than 100 prior to folding and/or period search processing to speed up useful data extraction. Ideally, wide band RF data should be de-dispersed to optimise later search and folding processing. De-dispersion is normally carried out by time adjusting data sampled from RF filter banks before combination. This note describes how data already digitised from the RTL SDR can be spectrum analysed or filtered using the FFT algorithm. Two methods are discussed, one summing power with some down-sampling; the second, a 'coherent' method that de-disperses the rtlsdr.exe .bin data file and outputs a .bin-compatible file. Both accurately de-disperses the data offering an improved folded data SNR.

The broadband pulsar noise radiation interacts with free electrons in the interstellar medium, causing lower frequencies to be delayed compared to the higher frequency components.

De-dispersion processing compensates for the delays and is carried out using time shifts of filtered sub-bands followed by recombining to increase the observable pulse power. A basic Gaussian pulse shape approximation shows that the power gain with de-dispersion is minimal for pulsars with band delays smaller than half the pulsar pulse width but is much more important for detectability with larger RF bandwidths. The following table based on simple 4/8-element models illustrates this point.

Dispersion/Pulse Width	Increase in Observed Width	Power Gain dB
0.25	-	0.05
0.5	1.6	0.22
0.75	1.12	0.51
1	1.24	0.88
2	2.0	2.95
4	2.7	5.75

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De-dispersion Processing with an FFT - 'Total Power'

The process considered, accepts RTL SDR .bin files and performs a series of FFTs, then re-organises the data in frequency and delay time, before band-combining and outputting the dispersed data file, suitable for period-folding and SNR integration. The process is depicted in Figure 1.

A four-point FFT is shown for clarity although the number of points N determines the data down-sampling ratio.

The delay blocks are clocked at N times the input data clock period tf and the delays are given in numbers of FFT blocks by, nTDM/N/N/tf, where n = 0 to N-1 representing the FFT frequency bins, and TDM is the dispersion measure time calculated for the whole received RF bandwidth. For example, for a 2MHz data bandwidth, TDM in µs, the real time delays for a four-channel RF filter bank are, 0, TDM/4, TDM/2 and 3TDM/4, and for a 4-point FFT, the delays in terms of FFT blocks (2µs) are , 0, TDM/4/2, TDM/2/2 and 3TDM/4/2.

Continuing this 2MHz data example, for N-point FFTs, the bin delays in FFT blocks, becomes, 2nTDM/N/N, which, obviously imposes a limit on the FFT size, given the RF dispersion time. In fact, above a certain size, increasing FFT length does not significantly improve the pulse compression but may impact on computation time.

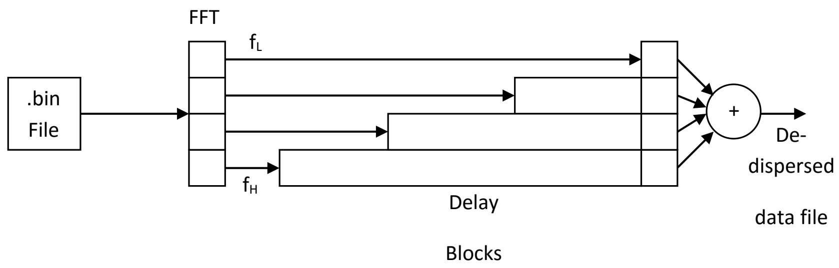

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Figure 1 De-dispersion Principle

The software process comprises 3 sections:

i. Calculate pulsar pulse dispersion time from the RF and pulsar Dispersion Measure,

ii. Calculate FFT frequency bin-required delays in terms of FFT data blocks (= N x input data clock).

iii. Place values in the delay array.

i. Read N I/Q data pairs.

ii. Perform N-point FFT.

iii. Re-order FFT data to compensate for the RTL zero-IF aliasing.

iv. Repeat sequence 2.

3. Data de-dispersion and output

i. Place FFT bin amplitude data in a 4096xN array addressed offset by the each required bin delays as calculated in the delay array.

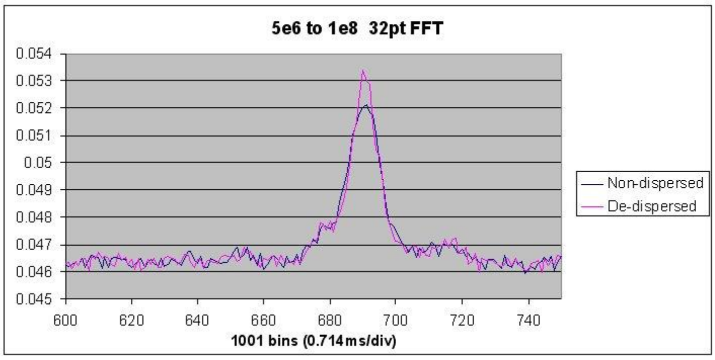
ii. Once the array is filled, sum time-aligned FFT data and place in the output file.

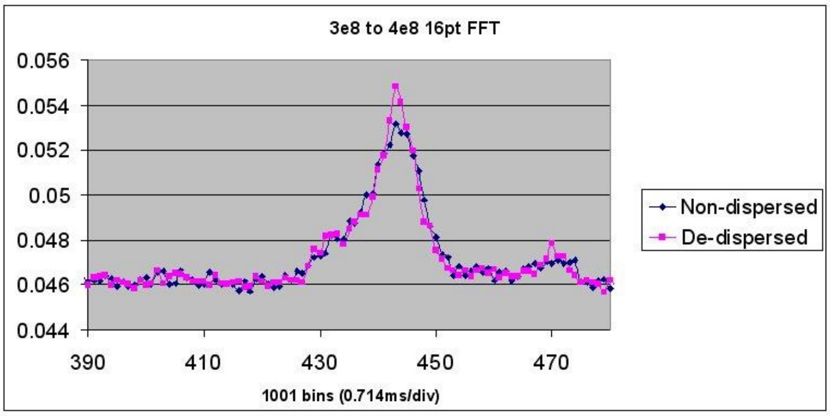
iii. Continue to fill a second identical array and on roll-over, refill the first array from the start.

iv. Once the second array is filled, sum time-aligned FFT data and place floating point data in the output text file.

v. Repeat step iii to end of file.

Figures 3 and 4 show the results of software FFT de-dispersion of 100MB blocks from the start and end of the Pulsar B0329 data file, dump2000a.bin, recorded by M Klaassen using an RTL2832U SDR receiver tuned to 419MHz behind the Dwingeloo 25m radio telescope on 14/01/2016. The file contained 400M samples and the figure labels define the data used. Both figures show the results of data folding using 1001 bins to show fine detail.





The software process again comprises 3 sections and outputs a binary file in the rtlsdr.exe format, slightly smaller in size due to the incomplete delayed records being rejected. The file is time-synchronised with the non-dispersed input file for easy comparison.

Calculate pulsar pulse dispersion time from the RF and pulsar Dispersion Measure,

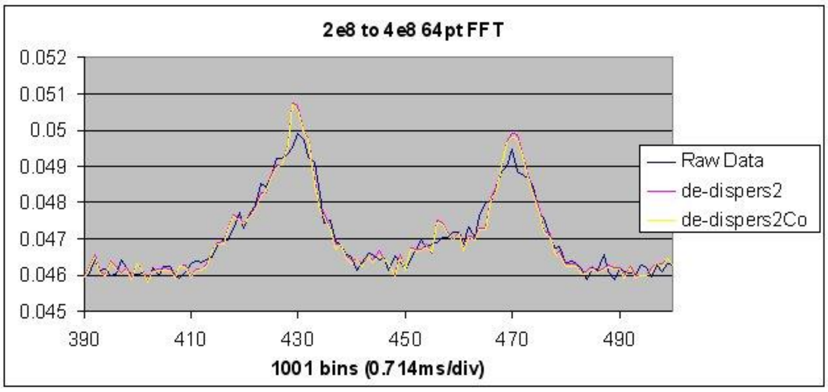
Calculate FFT frequency bin-required delays in terms of FFT data blocks (= N x input data clock).

c. Place values in the delay array.

2. Data-in and calculations
   a. Read N I/Q data pairs
   b. Perform N-point FFT
   c. Re-order FFT data to compensate for the RTL zero-IF aliasing
   d. Repeat sequence 2
3. Data de-dispersion and output
   a. Place FFT bin I and Q data in a 4096x2N array addressed offset by the each required bin delays as calculated in the delay array
   b. Once the array is filled, access time-aligned FFT data, re-alias spectrum data, take inverse FFT and place as unsigned characters in the output .bin file
   c. Continue to fill a second identical array and on roll-over, refill the first array from the start
   d. Repeat steps b – c to end of file

i. Place FFT bin I and Q data in a 4096x2N array addressed offset by the each required bin delays as calculated in the delay array.

central 200MB part of the Pulsar B0329 data file, dump2000a.bin. As before, the original file data is shown in the blue trace. Total power (de-dispers2 software) is shown in magenta and overlaid in yellow is the coherent de-dispersion result (de-dispers2Co software). The only obvious difference is a slight DC offset, probably due to floating-point FFT rounding when converted to integer/binary.



The presence of two pulses in this record appears to be a real pulse position jump in the pulsar data. It is interesting to note that both are similarly compressed in the de-dispersion process.

Even for B0329, where the dispersion/half-height pulse width ratio is about unity a sharpening of the pulse is evident coupled with a small noticeable SNR enhancement consistently, in separate sections of the raw data file. As well as SNR improvement, de-dispersion offers a better indication of pulse shape and variations over time.

Early experiments on 1420MHz Vela data were inconclusive although significant improvement can be expected at lower RF frequencies where the much larger DM can cause dispersion equivalent to multiple pulse widths.

Since both de-dispersion methods appear to produce similar results after synchronous integration, the chosen software is a personal choice. The total power version requires a modified rapulsar.exe tool to cope with text file output from de-dispers2 but does offer some data compression dependent upon the FFT length chosen. The 'coherent' version may be preferred as it outputs an accurately de-dispersed input-compatible file (from rtlsdr.exe) useful for driving other custom software directly, such as rapulsar2.exe.

This exercise has shown that post-processing of raw pulsar data to de-disperse the pulsar signals can give a useful enhancement of SNR and improve observability and detectability.

Software Tools - (http://www.y1pwe.co.uk/RAProgs/de-disperscv2.zip)

De-dispersion Tool

Format: de-dispers2 <infile> <outfile> <clock rate (MHz) <fft points> <RF centre(MHz)>

<dispersion measure(DM)>

Accepts rtlsdr .bin files, takes N-point FFT, de-aliases data, de-disperses frequency components in time, sums aligned FFT bin powers, ready for folding by rapulsar2_avg2 using output down-sampled clock rate. Outputs a text file of dispersion corrected power data at the initial clock rate, reduced by a factor equal to the number of FFT points. Negative DM used for odd sideband in superhet receivers.

Format: rapulsar2_avg2 <infile> <outfile> <clock rate (MHz)> <No. of output data points> < pulsar period(ms)>

Accepts de-dispers2 .txt files, applies averaging and folding algorithm in blocks. Outputs text file of folded average. Also accepts pdetect2 output .txt files.

Format: de-dispers2Co <infile> <outfile> <clock rate (MHz) <fft points> <RF centre(MHz)> <dispersion measure(DM)>

Accepts rtlsdr .bin files, takes N-point FFT, de-aliases frequency data, de-disperses frequency components in time, re-aliases data, takes inverse FFT, outputs binary data in rtlsdr.exe format ready for folding by rapulsar2. Outputs a .bin file of dispersion corrected sampled data at the initial clock rate, slightly smaller in size due to incomplete delayed sets, but still in time synchronism with the input file. Negative DM used for odd sideband in superhet receivers.

Format: filetrim <infile> <outfile> <Start Bytes> <End Bytes>

Accepts .bin files, cuts command number 'Start Bytes' from front and command number 'End Bytes' from beginning and end of the input file respectively and outputs a binary file of rtlsdr .bin-compatible data.