

Spectrograph Hardware



Richard Flagg, Radio Jove Meeting, July 2, 2014, NRAO Green Bank

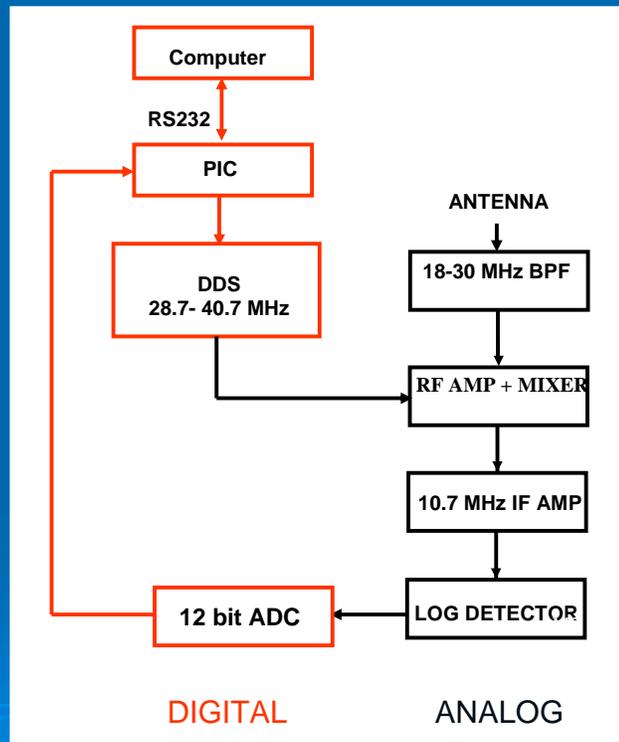
Hardware capable of producing spectrograms is evolving rapidly.

We have already talked a bit about a couple of receiver types – the direct conversion receiver and the superheterodyne. We have seen a little detail of the FSX spectrograph, a super het design whose local oscillator is digitally controlled.

We are clearly in a transition time – many new receiver designs are primarily digital – called SDRs or software defined radios. SDRs perform many of the functions of reception, demodulation, and display in software. If you know how to do digital signal processing its easier to write a few lines of computer code than to take out a bag of parts and a soldering iron to modify what your radio can do.

FSX Spectrograph

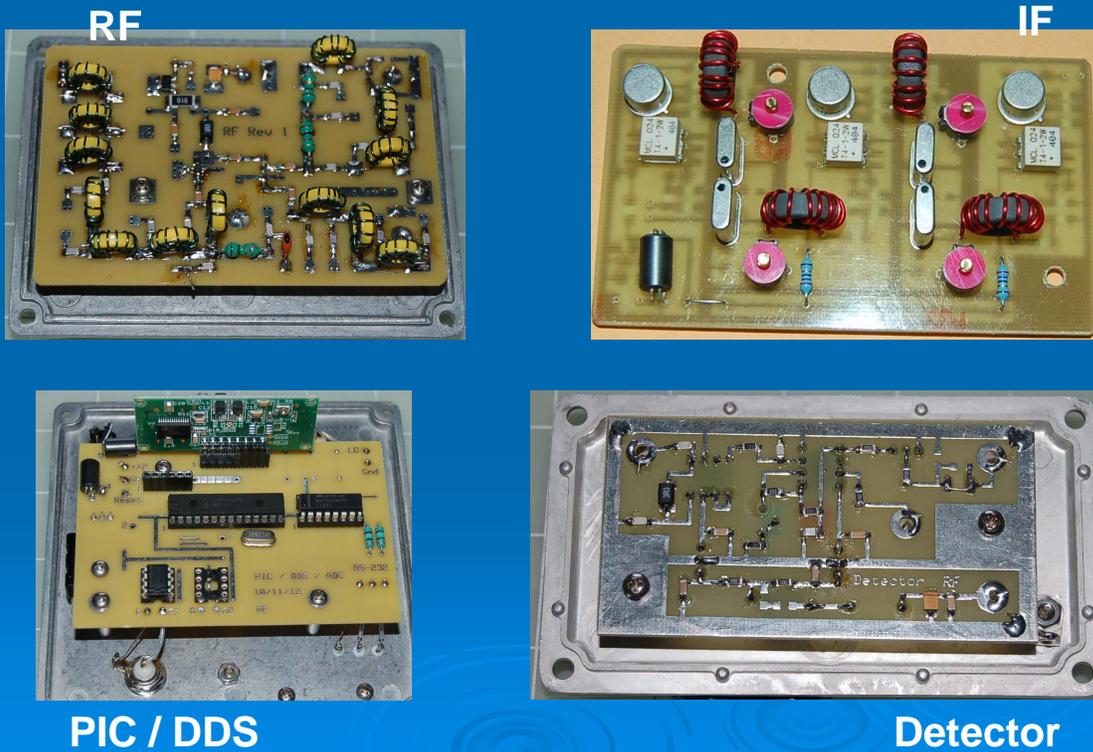
18-30 MHz
30 kHz IF BW
2000 channels/sec



Before plunging into SDRs let's take another quick look at the FSX spectrograph which uses analog hardware under control of a microprocessor. The functions of amplification, filtering and detection are carried out using analog devices – ICs, transistors, resistors, inductors and capacitors.

The analog output of the detector is digitized and processed in software to generate the display.

FSX Spectrograph



Here we see the guts of an FSX spectrograph -the various modules with lots of discrete parts within diecast boxes to keep digital noise out of the analog portions of the instrument. Lots of band shaping and filtering – particularly in the RF module.

Into the Future



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Digital



Analog

The ultimate software defined radio would incorporate a low noise, high speed, analog to digital converter connected directly to the antenna. Amplification, filtering, detection, processing, analysis and display would all be performed in software.

We aren't there yet but that is clearly the direction technology is taking us.

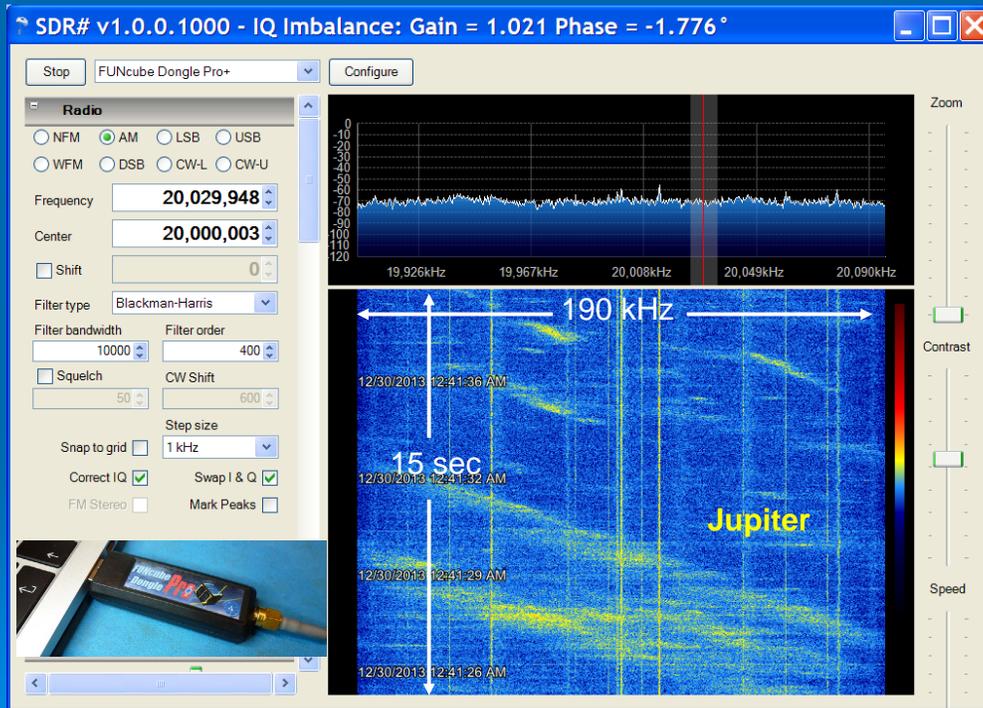
One day in the not too distant future some predict that the soldering iron will be replaced by the keyboard and the analog circuit wizards will take their place alongside the dinosaur in the history books.

Software Defined Radios

- Softrock (190 kHz wide spectrum)
- Funcube Dongle Pro+ (190 kHz wide spectrum)
- SDR-IQ (190 kHz wide spectrum)
- SDR-14 (up to 30 MHz wide spectrum)
- RTLSDR Dongle (2.4 MHz spectrum)
- RASDR

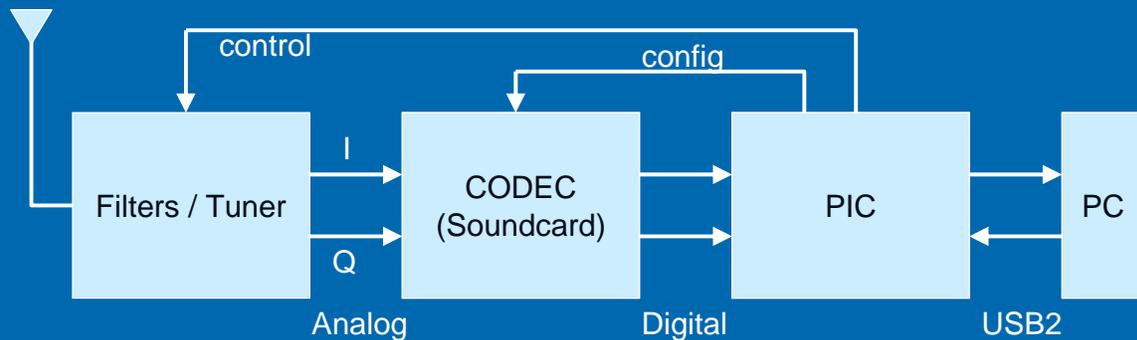
There are currently several software defined radios that fall into an affordable price range and that have more or less useful radio astronomy applications. You see a list of a few of these. Of course all have a hardware component but the software is becoming more and more important.

FUNcube Dongle Pro+



The FUNcube Dongle Pro + was developed by AMSAT-UK as part of an educational satellite program. It is about the same size as a USB thumbdrive. The dongle has an antenna connector on one end and a USB connector on the other end. No knobs, no switches. It can receive between 150 kHz and 1.9 GHz and generates a spectrum 190 kHz wide. The recommended software is called SDR#. The yellow emissions you see on the spectrogram are from a Jupiter storm received at WCCRO using a low gain log periodic antenna. A few of the vertical lines are stations but several are internally generated spurs. A 10 dB gain preamp in front of the FUNcube would make the galactic background strong enough to cover up many of these low level internally generated signals. Most of the FSX spectra you have seen are up 100 times wider in frequency coverage - just to put this waterfall display in perspective. Cost for the FUN cube dongle – about \$200.

Inside the Funcube Pro+ Dongle



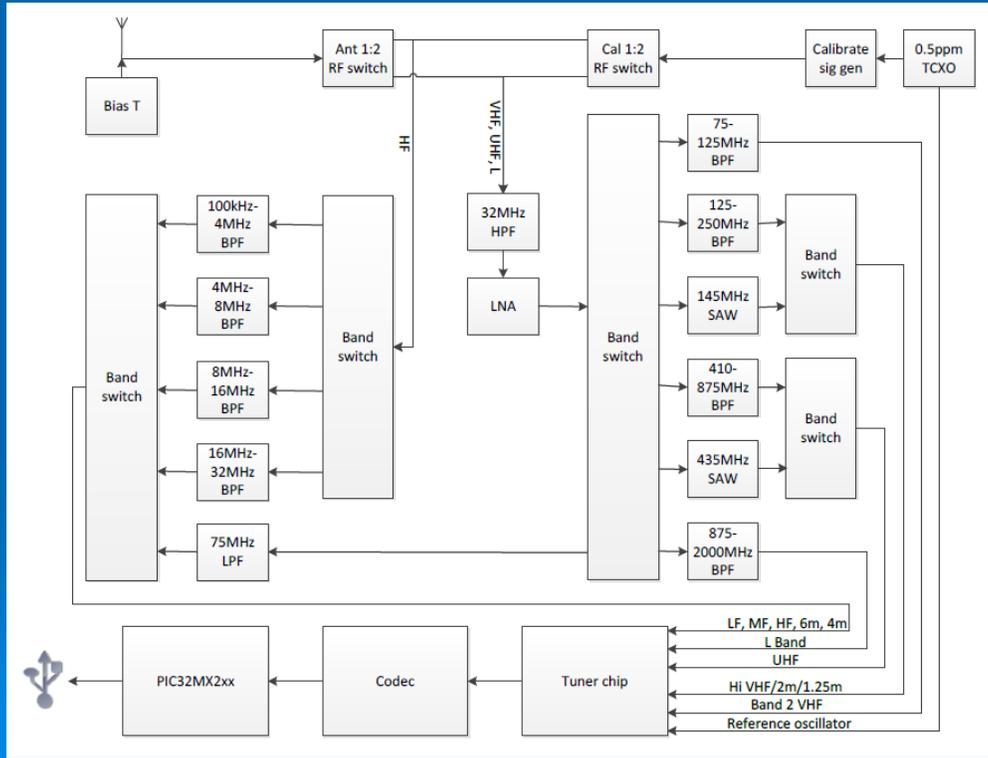
150kHz – 240 MHz
420 MHz -1.9 GHz

192 kS/s rate

NF = 2.5 - 5.5 dB

The Funcube dongle comprises three integrated circuits: a digitally controlled tuner, an analog to digital converter and a microprocessor. It covers an impressive tuning range and has a low noise figure.

Funcube Pro+ Dongle Filtering

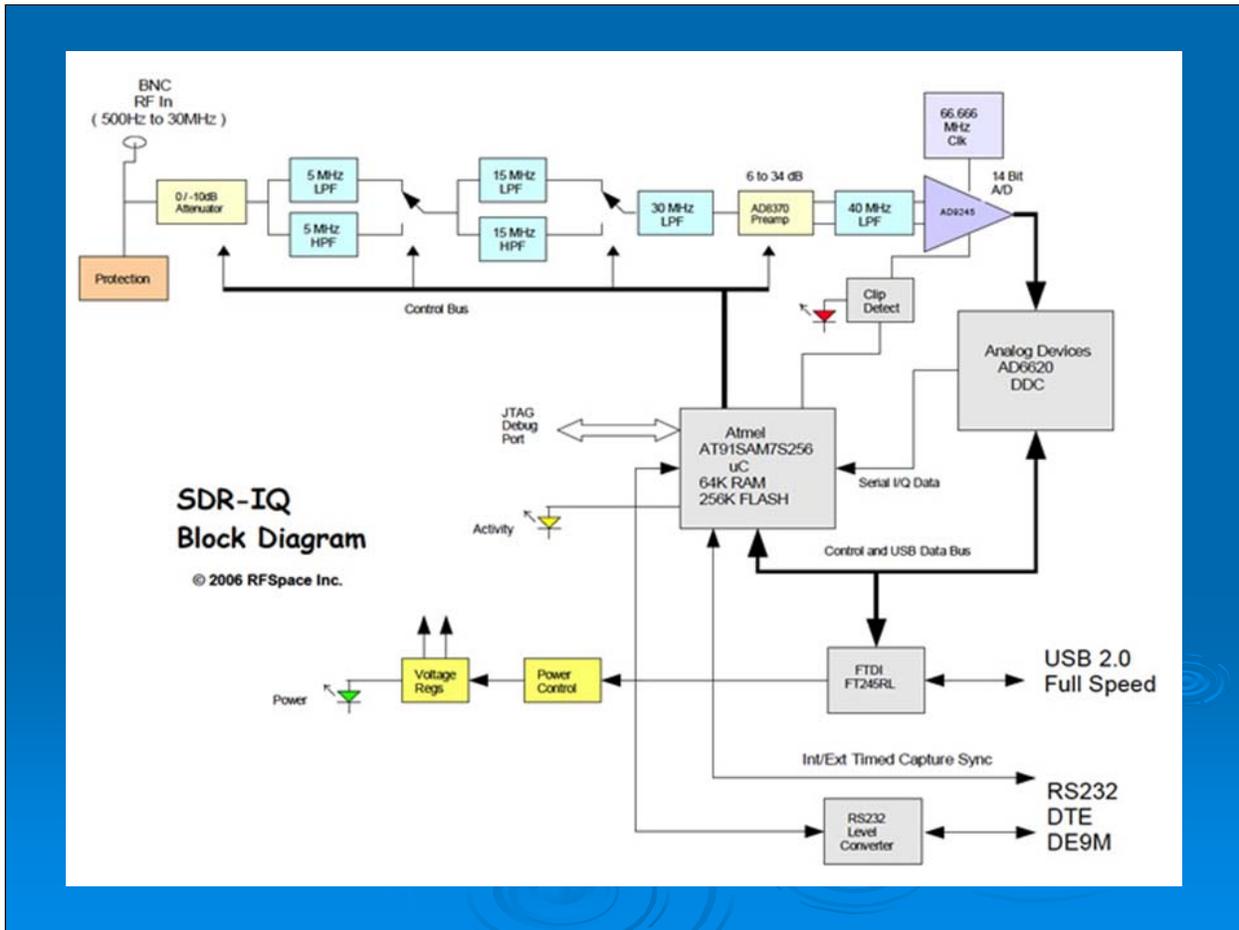


In order to operate in the crowded HF part of the spectrum the FUNcube dongle pro + employs extensive filtering in front of the digital tuner.

SDR-IQ

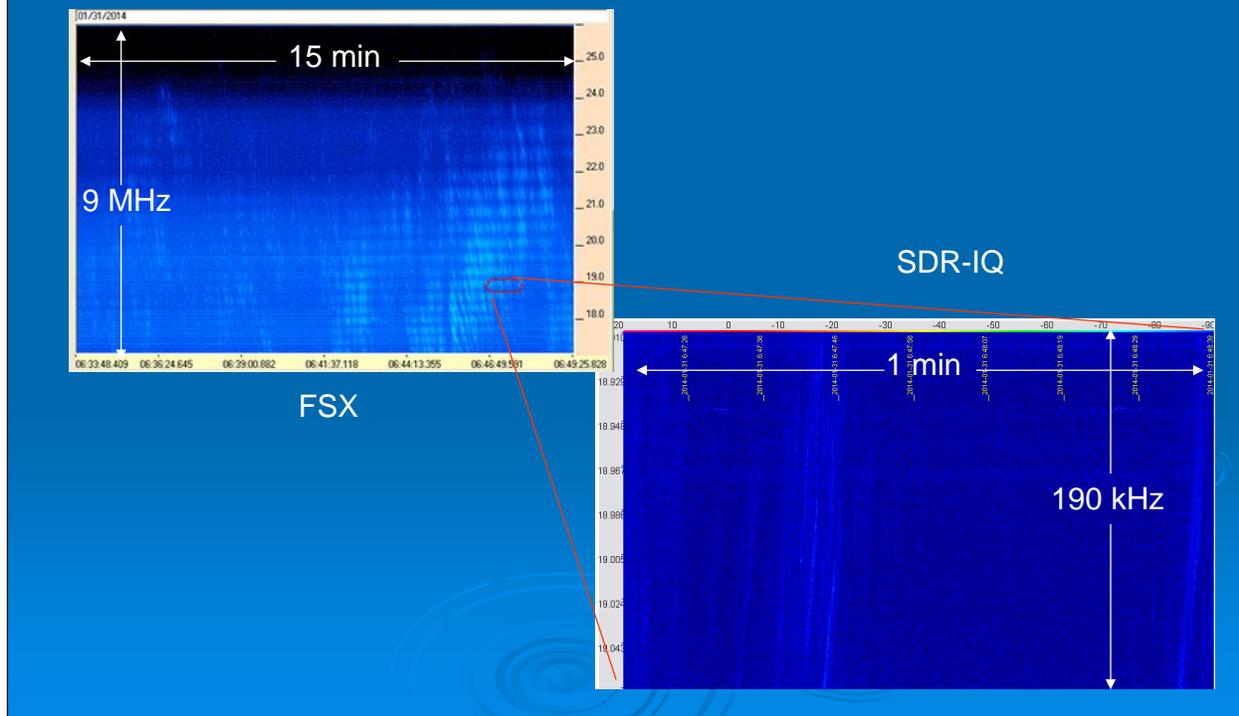


Another SDR is the SDR-IQ made by RF Space and selling for \$525.



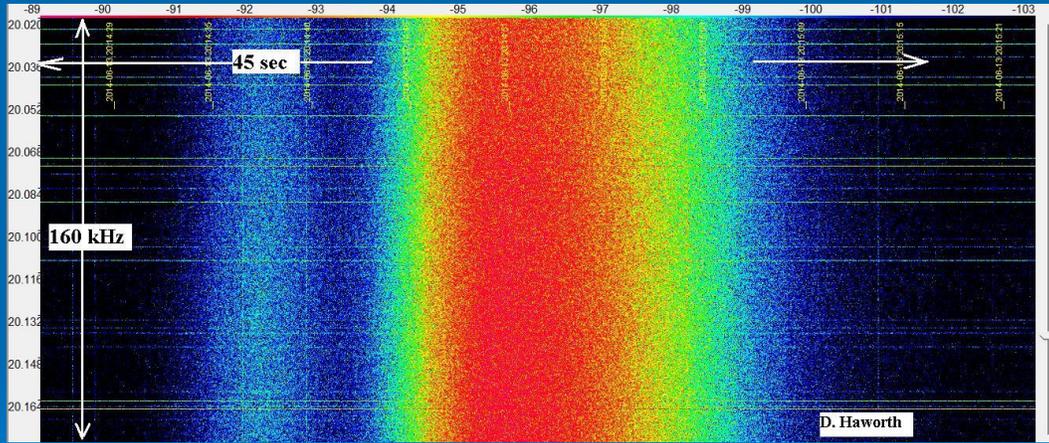
The SDR-IQ tunes from 500 Hz to 30 MHz and like the FUNcube dongle it can generate a spectrum display 190 kHz wide. The SDR-IQ incorporates front end filtering and develops 14 bit digital data at a 66 MS/sec rate. The digital data from the ADC is processed into I and Q format using a direct digital converter (DDC). The I and Q data is then sent to the PC for processing using a USB 2.0 interface.

FSX and SDR-IQ (Tom Ashcraft)



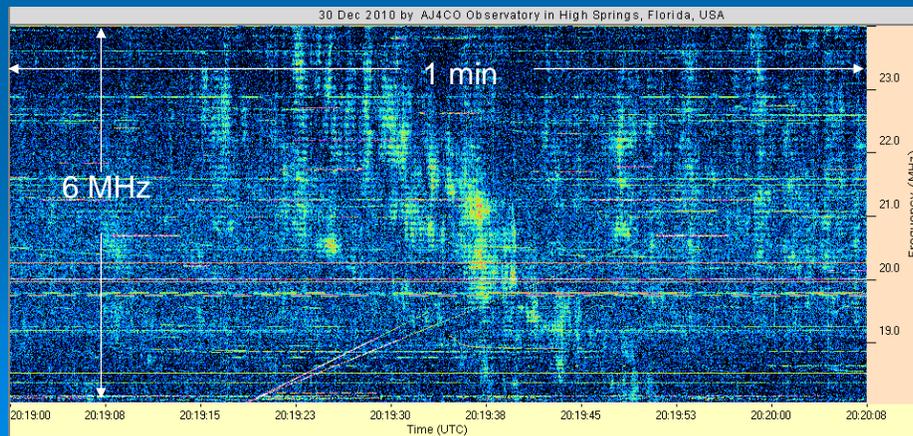
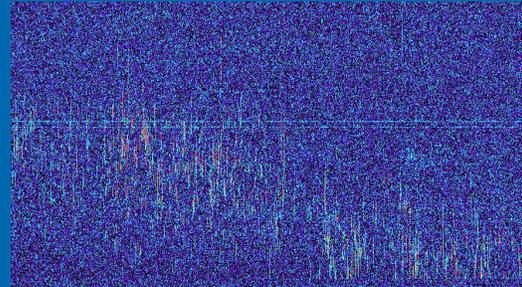
Here we see a portion of a Jovian storm received by Tom Ashcraft using both an FSX and SDR-IQ. Faraday bands and modulation lanes are seen in the FSX spectrogram which covers 17 to 26 MHz over 15 minutes. We see a 1 minute spectrogram from the SDR-IQ which was tuned to 18.5 MHz. The comparison between spectrograms is a bit confused as the FSX vertical scale of frequency goes upward from low to high frequencies while the SDR spectrum goes upward from high to low frequencies – making everything appear to drift backwards.

SDR-IQ Solar Burst (David Haworth)



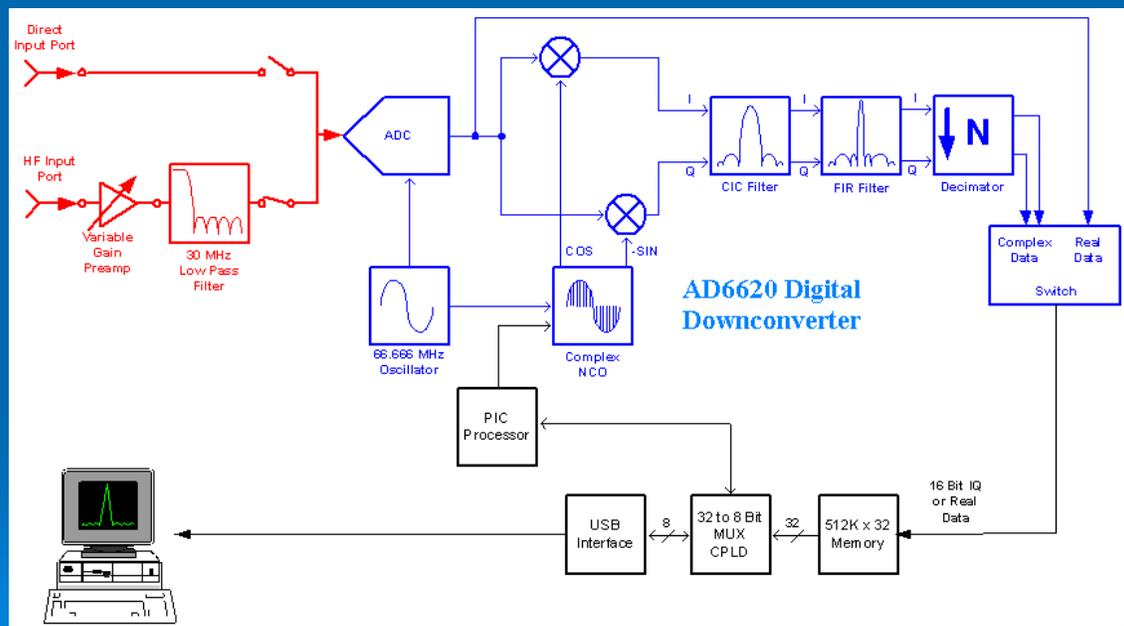
Here we see a strong solar burst received by David Haworth.

SDR-14



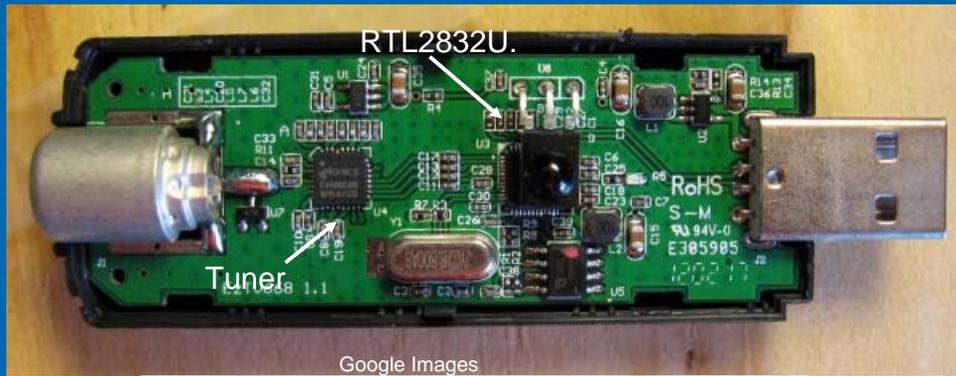
The SDR-14 by RFSpace is no longer in production but is occasionally seen on e-bay in the one thousand dollar range. This instrument can cover a wider frequency range than the FSX and runs with Spectravue software by Moetronix, or RSS software by Jim Sky. The new NETSDR is a 16 bit machine that goes for about \$1500 and has higher digitizing rates, a wider bandwidth, and ethernet capability.

SDR-14 Block Diagram



The SDR-14 uses a 66 Msample/sec ADC and generates I and Q data allowing wide spectral displays – more than 10 MHz wide. This makes the SDR-14 generally comparable to the FSX series of spectrographs. However, I would add that some users of both instruments have reported that the FSX machines are superior in signal handling capabilities and are less susceptible to overload.

The RTL-SDR



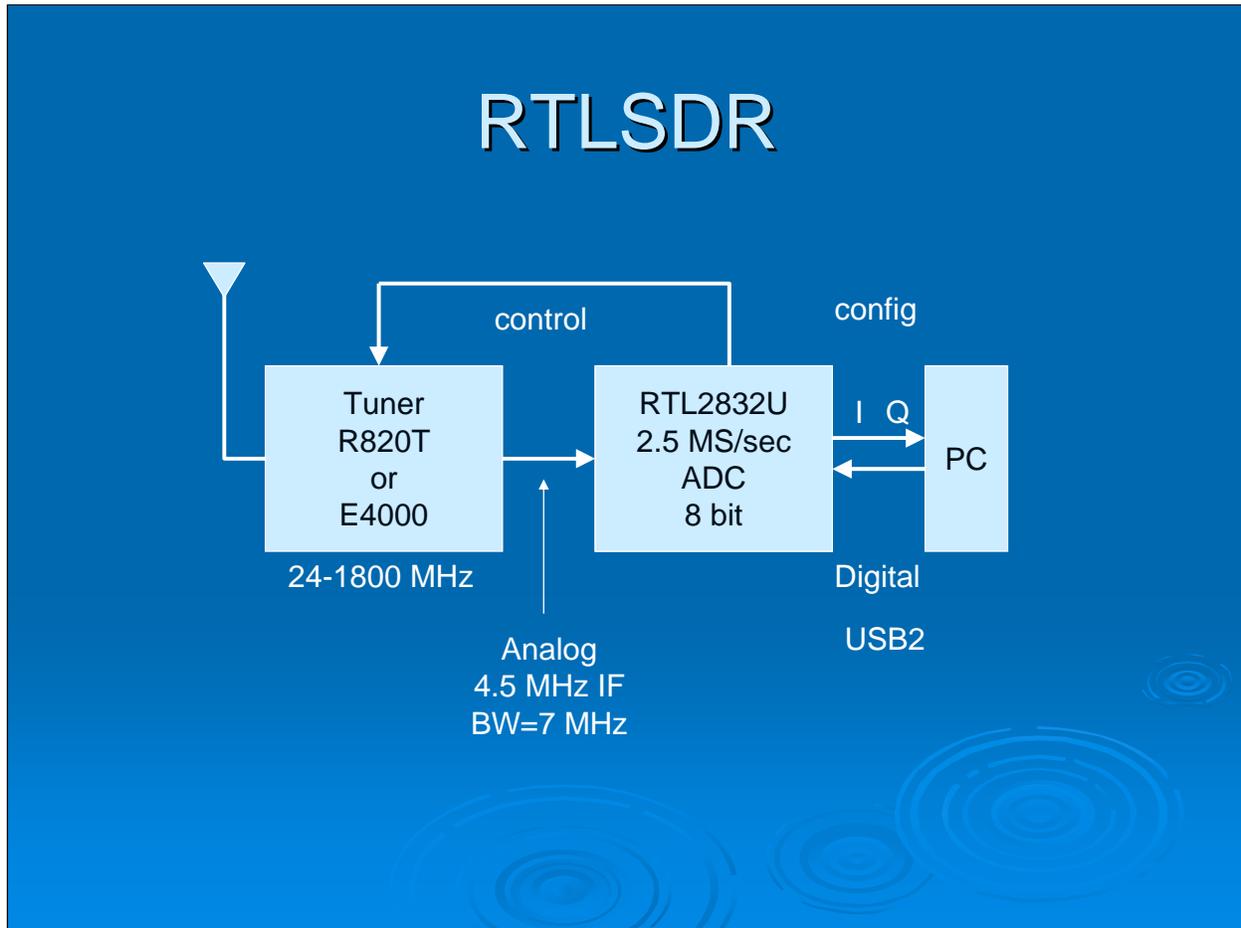
Antenna in

24-1800 MHz



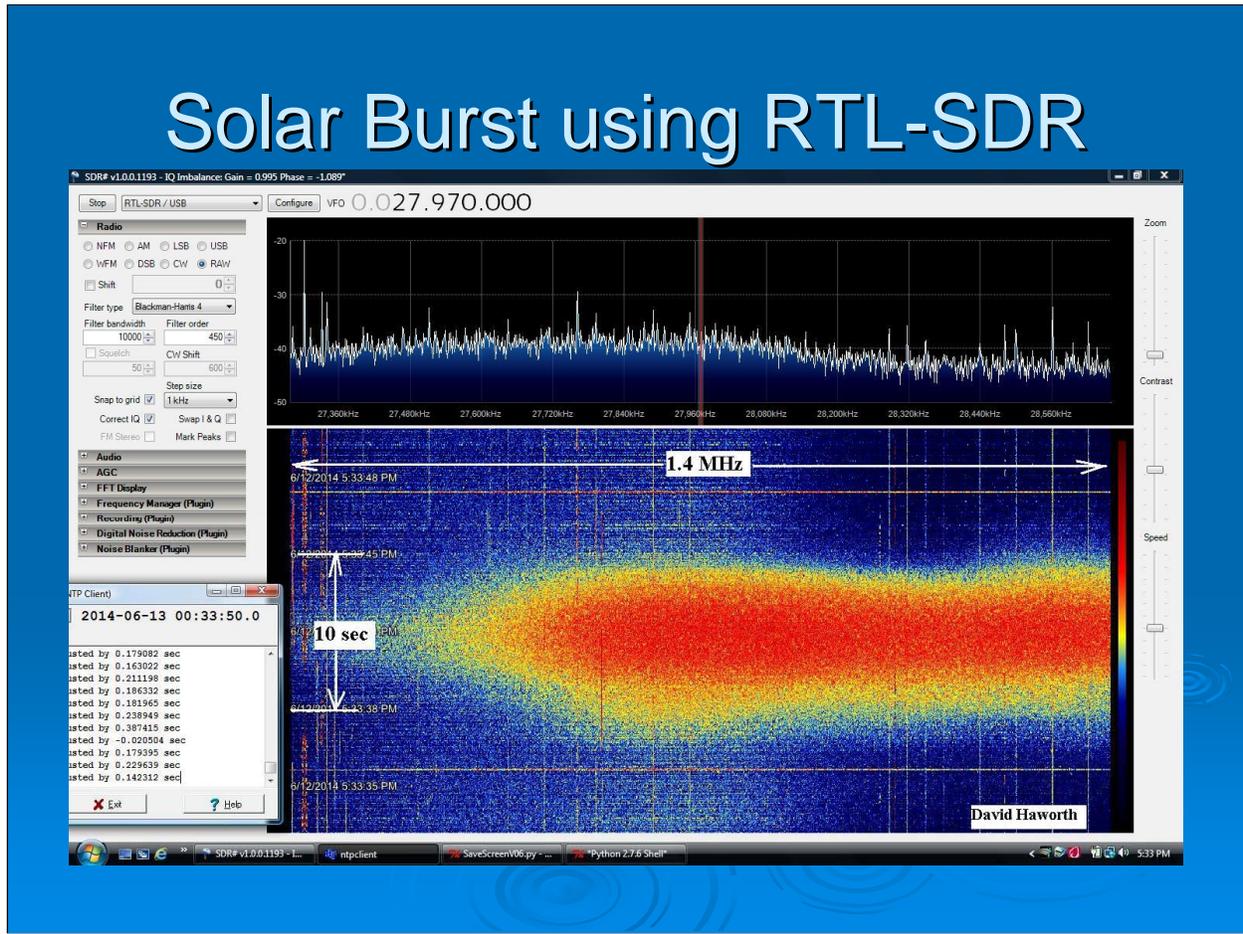
USB out

The RTLSDR Dongle is hardware based on DVB-T technology (Digital Video Broadcasting – Terrestrial), specifically the Realtek RTL2832U. This dongle hardware is capable of supporting software generating spectrograms 2.5 MHz in bandwidth. Thus the RTL-SDRs could yield interesting spectrograms of Jupiter and the sun – wider than the 200 kHz of the soundcard types like the FUNcube dongle Pro + but much less than the sweep range of the SDR-14 and FSX machines.



The RTL-SDRs lower frequency limit seems to be 24 MHz (dependent on the tuner chip). While this is fine for solar work, unfortunately 24MHz is just a bit high for most Jupiter reception. An upconverter will allow reception at lower frequencies.

Solar Burst using RTL-SDR



David Haworth captured this solar burst using an RTL-SDR and a scanner antenna at 28 MHz. No upconverter needed. Notice all the constant frequency (vertical) lines in the display. It's likely that many of these are generated internally in the RTL unit.

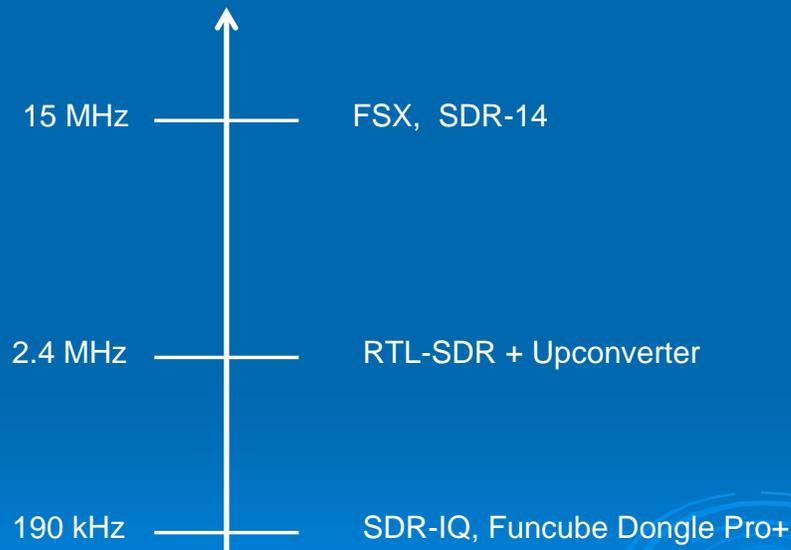
HF Coverage



Inexpensive options are available to obtain HF coverage with the basic RTL-SDR. A separate upconverter that can be added in front of a standard RTL-SDR for about \$40, although putting it in a well shielded metal box is recommended and adds a few more dollars to the price.

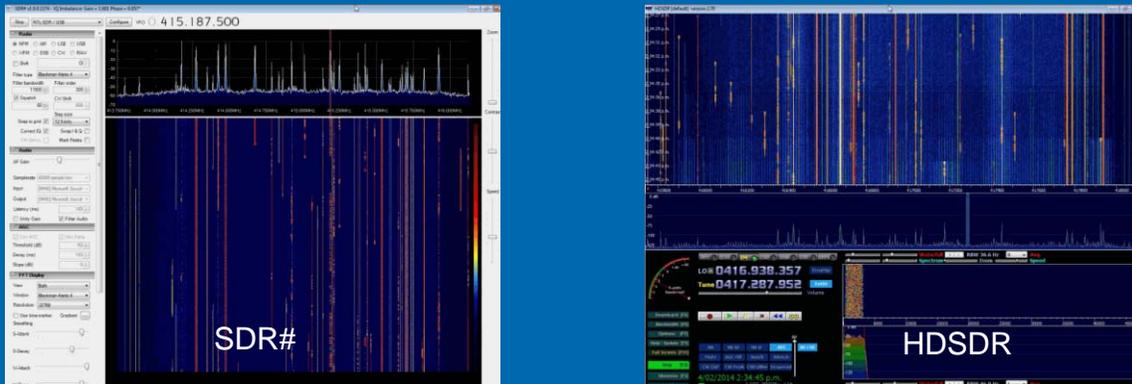
The Soft66RTL packages both an HF upconverter and RTL-SDR together and then there is a kit for \$32. All of these may be adequate for listening to shortwave stations but as far as doing radio astronomy it may be a different story. Key to doing Jupiter radio astronomy with any of these devices is the available software.

Maximum Useful HF Spectrograph Range



In conclusion, you see a summary of the different spectrographs vs their maximum HF frequency range. By this I mean how much spectrum you can view above the ionospheric cutoff of around 15 MHz. The SDR-IQ and Funcube allow a 190 kHz wide display, the RTL type are good for 2.4 MHz. With no upconverter they work above 24 MHz. The SDR-14 and FSX machines can each cover about 15 MHz giving the best overall view of the spectrum.

SDR Software



Several software packages for Windows, Mac and Linux

<http://www.rtl-sdr.com>

There are several software packages available for SDRs. Most allow demodulation of different signal types and provide waterfall displays. However, these programs are generally not optimized for radio astronomy. I won't try to add anything about the RASDR software which you have heard about during the SARA portion of this meeting. Jim Sky is the author of Radio-Sky Spectrograph which we have used for years with the FSX spectrograph. Jim will tell us about RSS and its expanding capabilities.

Spectrograph Software

Jim Sky, Radio Jove Meeting, July 2, 2014, NRAO Green Bank