Long distance FT8 contacts on the 2 meter band with the ADALM-Pluto (PlutoSDR)

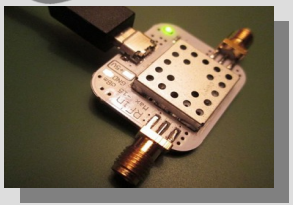
The ADALM-Pluto SDR transceiver was used together with some external hardware to make long distance FT8 contacts in the amateur radio 2 meter band.

WSJT-X, QRadioLink and a GNU radio DSP flowgraph drove the PlutoSDR.

Despite the minimal cost of the hardware and the modest technical specifications, and with the help of good tropospheric propagation conditions, successful contacts were made up to distances of 350 to 880 km.

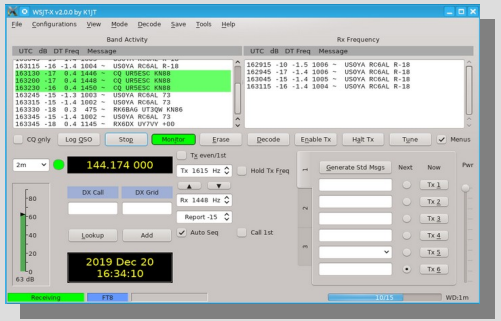
The hardware

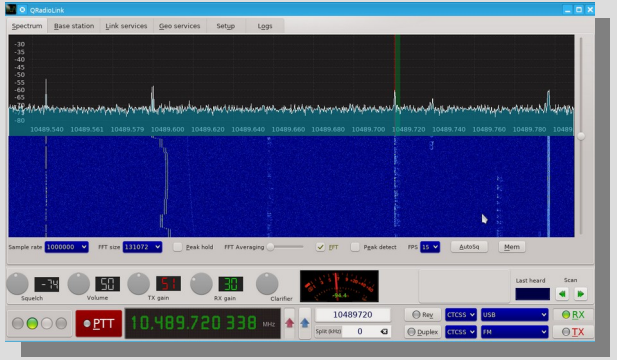
- ADALM-Pluto (PlutoSDR) – core
- USB controlled relay board
- LNA (40 dB gain, 0.8 dB noise figure)
- Tunable helical band-pass filters
- SPDT RF switch, 0.2 dB insertion loss
- 60 W Linear power amplifier, driven with 1 mW input
- 4/5 element Yagi-Uda antenna, 144/432 MHz



The software

- 100% Free Software
- Debian GNU/Linux OS
- WSJT-X by Joe Taylor K1JT
- Pulseaudio (Linux audio layer)
- QRadioLink (GUI, VOX, relay activation control)
- GNU radio SSB transceiver flowgraph (C++)
- Gr-osmosdr (common API for multiple hardware)
- SoapyPlutoSDR (SoapySDR backend)





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Equipment and software settings

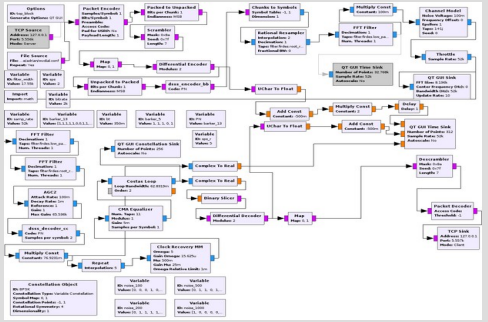
- Internal receiver gain of the ADALM-Pluto SDR reduced to minimum
- ADALM-Pluto output power set from QRadioLink to achieve 20 Watts at the antenna port (continuous monitoring of RF power and SWR)
- Device sample rate was 1 Msps (input and output)
- Audio sample rate to Pulseaudio was 8000 samples/second
- Pulseaudio internal remixing to 48000 samples/second
- 90% TX gain setting in WSJT-X
- Relay switching delays 5 milliseconds at TX activation and deactivation

Software architecture

- GNU radio DSP flowgraph implemented in C++ for performance and usability reasons
- Graphical user interface of QRadioLink written with the Qt 5 API, major UI elements borrowed from Gqrx (FFT display, frequency control)
- Audio mixer talks to Alsa audio layer via the Qt audio / Pulseaudio API
- Configurable audio level VOX PTT control implemented in QRadioLink, no manual intervention needed to switch TX/RX.
- Relay control via USB implemented in QRadioLink, up to 8 configurable relays supported, automatic TX/RX RF path switching, PA activation, LNA deactivation

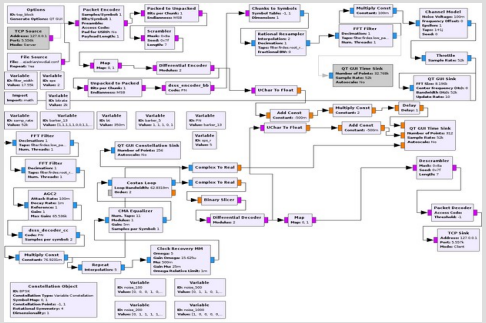
GNU radio SSB TX flowgraph

- Floating point audio source at 8000 samples/sec (from Pulseaudio)
- AGC block
- Rail block (clipping of overdriven AGC peaks)
- Audio low-pass filter, standard SSB bandwidth, configurable
- Float to complex transition
- Filter for desired sideband
- Configurable baseband gain block
- Resampler block to 1 Msps
- Complex rotator block (shift signal away from 0 Hz)



GNU radio SSB RX flowgraph

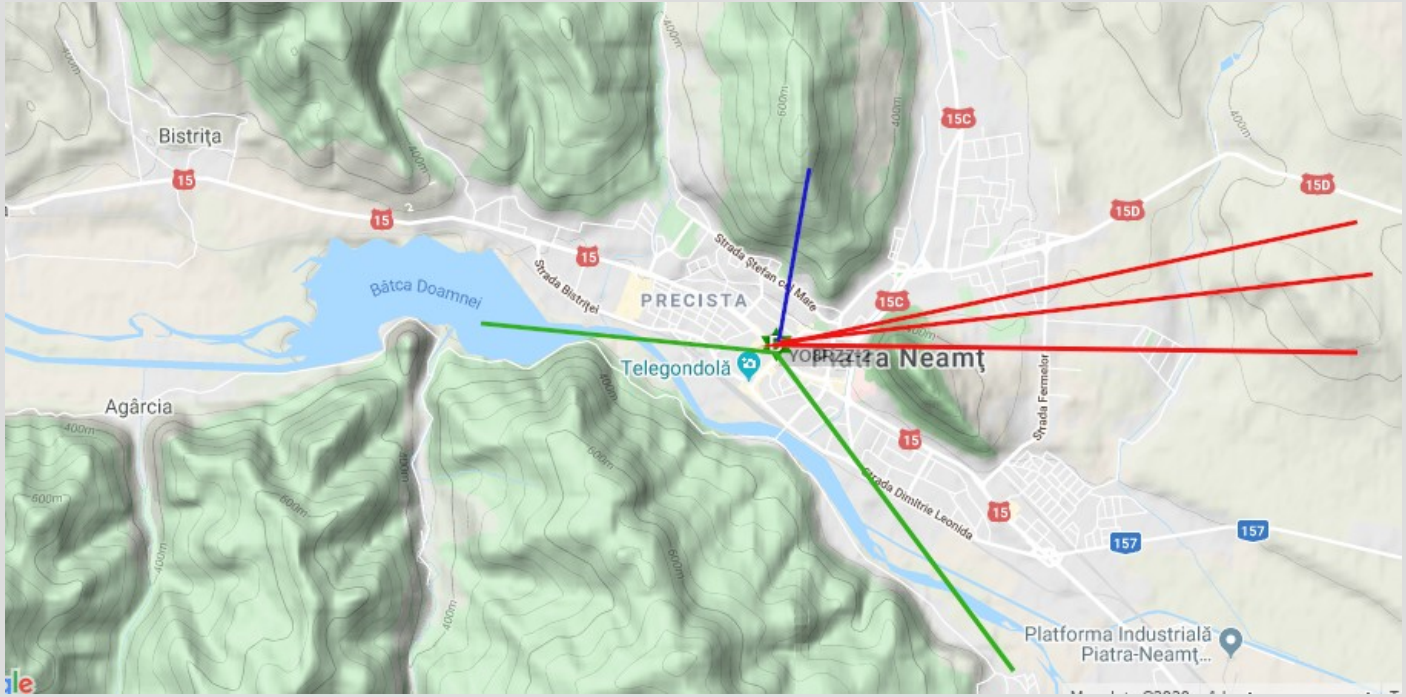
- Complex rotator block (shift signal to baseband)
- Resampler from 1 Msps to 8000 samples / second
- IF gain block
- Filter for desired sideband, bandwidth configurable
- Squelch block
- AGC block
- Complex to real transition block
- Rail block
- RX level measurement probe blocks
- Floating point audio sink block (to Pulseaudio)



Weather and QTH conditions

- 20th of December 2019, 16 – 22 UTC time
- Unusually warm weather the whole previous weak, mid-day temperatures up to 17 degrees Celsius
- Incoming cold weather front, light fog at dusk
- Relatively stable tropospheric ducting towards North-East, East, South-East
- Antenna HAAT 20 meters, fixed orientation towards North, contacts towards 90 degrees, vertical polarization, surrounded by mountains
- Contacts made with wrong antenna polarization (vertical) suggest relatively strong tropo propagation conditions

Map of QTH area



Red lines indicate direction of contacts, blue line is antenna orientation

Results

- 6 FT8 contacts to Ukraine made in 2 hour interval with 20 Watt power

```
2019-12-20,18:03:00,2019-12-20,18:04:00,UT7EW,KN78,144.174930,FT8,-10,-22,20 W
2019-12-20,18:13:45,2019-12-20,18:15:30,UT3HG,KN79,144.175282,FT8,-09,-05,20 W
2019-12-20,18:25:06,2019-12-20,18:30:00,US4IEK,KN87,144.174926,FT8,-09,-08,20 W
2019-12-20,18:41:30,2019-12-20,18:42:30,UT7EW,KN78,144.174924,FT8,-04,-16,20 W
2019-12-20,18:43:30,2019-12-20,18:45:30,UY5YA,KN77,144.174924,FT8,-13,-13,20 W
2019-12-20,19:47:15,2019-12-20,19:49:45,UR5ESC,KN88,144.175562,FT8,-14,-22,20 W
```

- Maximum distance completed QSO 880 km to Donetsk, Ukraine
- Farthest station heard RC6AL, 1024 km, Rostov on Don, Russia

Latency impact

- FT8 mode is 2 slot TDM, synchronized on UTC clock
- Large latency can cause late transmission, bleeding into next timeslot
- DSP has more latency, caused by time required to execute instructions by CPU
- Buffers add latency
- QRadioLink audio mixer buffer adds 120 millisecond delay
- Pulseaudio buffers add 40 milliseconds delay
- GNU radio has internal buffers too, usually automatic size
- SoapyPlutoSDR and libusb / IIO transfer buffers add latency
- Total latency 220 – 350 milliseconds, guard time important
- FT8 possible, FT4 not tried

Notes

- ADALM-Pluto is not factory designed to operate on the 144 MHz band
- FT8 has continuous amplitude, is linear amplifier really necessary?
- FT8 signals were not expected and were found by accident while visually inspecting the spectrum, FFT display is very useful
- No previous experience with WSJT-X, some operator errors made during QSOs
- LNA was found to have too much gain and easily overloaded by close in-band transmitters, replaced later with PGA-103+
- Lack of prior testing of FT8 lead to frantic setting adjustment during QSO period, many opportunities to make contact missed

Thanks

- Analog Devices for making an affordable and very capable device
- Joe Taylor K1JT for WSJT-X
- The GNU radio developers and community
- Maitland Bottoms AA4HS for maintaining Debian GNU radio packages
- Alexandru Csete OZ9AEC for making Gqrx free software