KA9Q-Radio Update & Demo

Phil Karn, KA9Q, March 2024

- karn@ka9q.net
- https://github.com/ka9q/ka9q-radio
- https://github.com/fventuri/ka9q-web (G0ORX web sdr)

What is ka9q-radio?

- A *multichannel, IP multicast* software defined receiver and related tools
- Fast convolution on general purpose computing hardware providing *hundreds* of independent channels
  - NO FPGAs! Not even a GPU. Just x86-64 or ARM vector instructions
  - A Pi4 can handle 20 Ms/s, e.g., a single VHF/UHF band
  - A Pi5 can handle 64.8 Ms/s, i.e., all of LF/MF/HF
  - A midrange x86-64 can handle 129.6 Ms/s: LF/MF/HF/6m

Fast convolution in a nutshell

(“Convolution” == filtering)

- Related to, but distinct from, polyphase filter bank
- Take fast Fourier transform (FFT) of A/D data blocks
  - *Expensive, but shared by all receiver channels*
- Select frequency bins containing the desired channel
  - # bins determines output sample rate & CPU load
- Multiply by the desired passband filter response
- Take inverse Fourier transform (IFFT) back to time domain
- Perform fine frequency correction (±1/2 bin)
- Glossing over math details, it’s almost this simple!

KA9Q-radio

global parameter selection for RX888 MKii

- Choose sample rate (64.8 MHz)
  - “clean” value for Si5351 clock synthesizer
  - sufficiently high Nyquist limit for LF/MF/HF
- Choose frame duration/rate (20 ms/50 Hz)
  - preferred frame rate of free Opus audio codec
  - acceptable latency & FFT loading

- Choose FFT overlap (1/5, 80% new, 20% old)
  - sets max filter impulse response = 20% * 20 ms = 4 ms
  - sets FFT bin size = 50 Hz * 4/5 = 40 Hz
- All parameters set FFT block size
  - RX888 Mkii: 20 ms * 64.8 MHz * 5/4 = 1,620,000 = $2^5 3^4 5^4$
  - Airspy R2: 20 ms * 20 MHz * 5/4 = 500,000 = $2^5 5^6$

radiod

- The core of ka9q-radio is the radio daemon, *radiod*
  - the core of radiod is MIT's *FFTW3* package ("fastest Fourier transform in the west")
- Managed by Linux system control daemon, *systemd*
- Reads configuration from /etc/radio/
  - specify front end, static channels, defaults for dynamic channels
  - moving toward dynamic configuration - much simpler!
- Reads/controls local front end via USB
- Streams output via RTP/UDP/IP Multicast
- Listens for commands & responds on separate multicast channel
- Dynamic channels created/deleted on command

Demodulators in ka9q-radio

1. linear

- AM, SSB, IQ, CW, etc
- Optional PLL for carrier tracking (e.g., synchronous AM, carrier squelch)
- Configurable AGC parameters: target output level, threshold, hang time, gain recovery rate, manual gain
- Noise density estimator - used to set AGC threshold, calculate SNR
  - harder than you might think. noise is, well, noisy.

Demodulators in ka9q-radio

2. FM

- FM is flat down to DC
- PM follows FM demod with 1-pole de-emphasis filter
- Dual hysteresis squelch: channel SNR + amplitude variance
  - Settable squelch thresholds, time delay (tail blanking)
- Experimental threshold extension (popcorn blanking)
- Measures SNR, frequency offset, deviation,

Demodulators in ka9q-radio

3. WFM

- FM broadcast stereo (working)
- RDS/SCA (incomplete)

Demodulators in ka9q-radio

4. Spectrum

- New “pseudo demodulator” producing power spectrum for waterfall, signal sensing and identification, etc
- User specifies bin size, spacing, integration time
- Sends power data on status channel - is this the right thing?
- G0ORX’s new ‘ka9q-web’ server
- 400 MHz radiosonde search and identification (VK5QI)

Sample *radiod* configuration

```
# Sample configuration file for radiod
[global]
hardware = rx888
status = hf.local
ttl = 1
# defaults for dynamically created channels
data = hf-pcm.local
samprate = 12k
mode = usb

[rx888]
device = "rx888" # required
description = "g5rv on rx888 @ ka9q"
gain = 20 # dB max
calibrate = -0.1734e-6
samprate = 64m8

[WSPR]
data = wspr-pcm.local
mode = usb
low = 1300
high = 1700
samprate = 12k # required by wsprd
# Bottom of 200 Hz WSPR segments on each band. Center is 1500 Hz higher
freq = "1m836600 3m568600 3m592600 5m287200 5m364700 7m038600 10m138700 13m553900 14m095600 18m104600 21m094600 24m924600 28m124600"
agc = no   # disable AGC
gain = 60  # dB
```

Caption

Supported front ends

- AMSAT UK Funcube dongle
- RTL-SDR
- Airspy R2: 20 Ms/s (~9 MHz) with 24-1700 MHz tuner
- Airspy HF+:
- RX-888 Mk ii
  - LTC 2208 16-bit A/D direct HF sampling at 130 Ms/s max
- SDRPlay (K4VZ fork)
- sig_gen: synthetic front end with signal & noise generator, including WWV simulator

Frontend/radiod merge

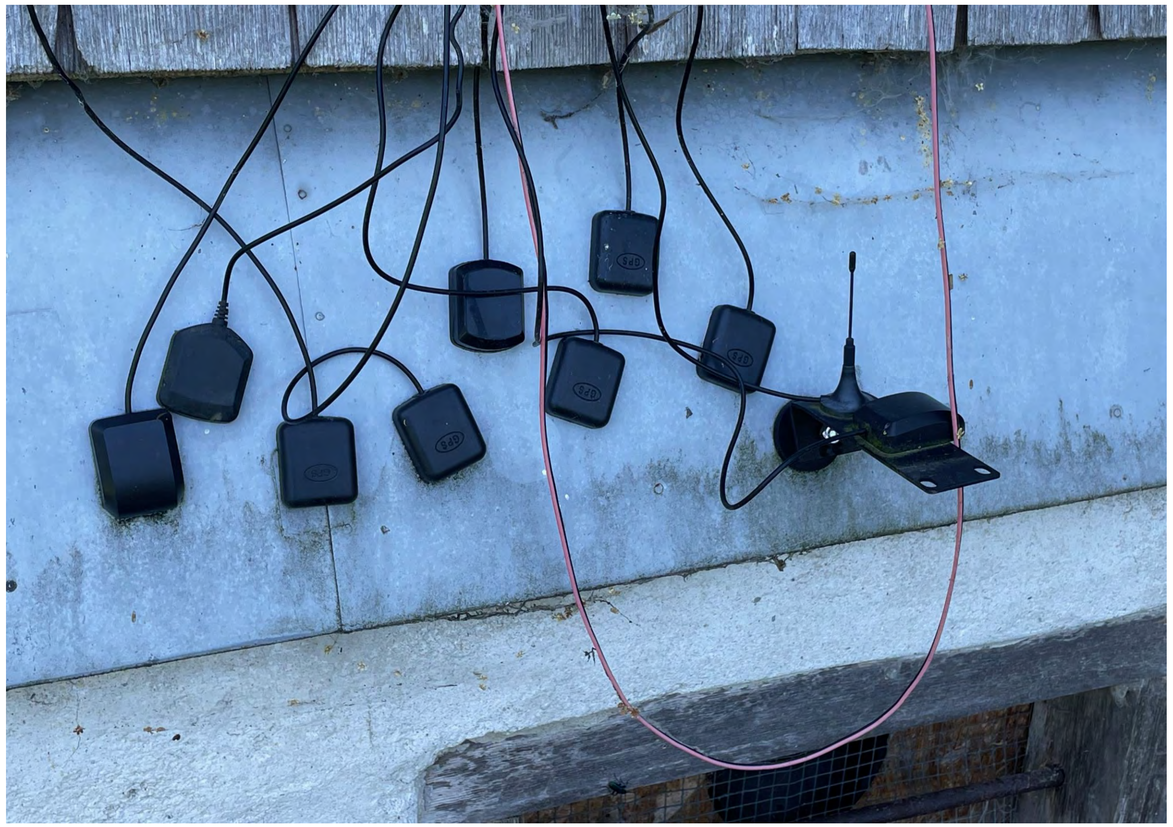
main architectural change in past year

- Handlers now directly linked into radiod
- Much faster & simpler
- Multicast wasn’t that useful here anyway, as opposed to control/status/output
- Lesson: moving fast A/D data is harder than processing it!

Some current uses of ka9q-radio

- Local NBFM monitoring and recording
- WSPR, FT8/FT4, Packet/APRS
  - now replacing stacks of KiwiSDRs in wsprdaemon network
- HamSCI: WSPR and WWV/H Doppler measurements
- Band server feeding Web SDR server (experimental)
- Radiosonde (and amateur balloon) scanning & decoding

- Behind OE9GHV’s shack…



Caption

Linking ka9q-radio to applications

- monitor - interactive listening to multiple channels
- pcmcat - pipe a stream
- pcmrecord - record streams as .wav files
- pcmspawn - invoke a command on each new stream
- control - interactive control of a single channel
- tune - create/control channels from command line

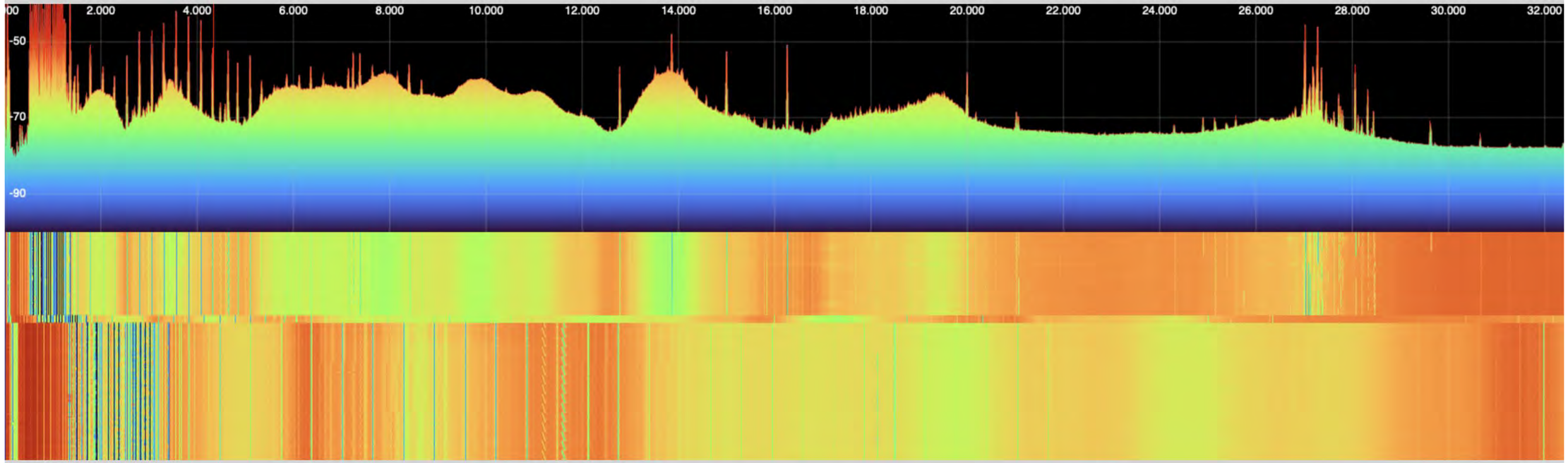
My ongoing work

- Simplify configuration using zeroconf service discovery
  - ‘control’ now browses for receivers and/or channels
- monitor, pcmcat, pcmrecord, etc will get metadata from status channel
  - RTP SSRC and payload type are too heavily overloaded!
- Simplify generation of FFTW3 “wisdom” on first run
- Proof-of-concept for multi-input repeater
- Voting receiver for networked FM repeaters, e.g., PAPA System

Help wanted…

- Graphical user interfaces for individual channels
  - John, G0ORX's "ka9q-web"
- Lots more applications!
  - digital data decoders & loggers: HFDL, DRM, eLoran, etc, etc.
  - my FT-8, FT-4 and WSPR skimmers
  - K1RA's QRA-skimmer

G0ORX Web SDR + ka9q-radio



Range ^ | Range + | Color Map | 4338000 | Set Frequency | Freq - | Freq + | Step: 1KHz | Mode: USB | Zoom In | Zoom Out | Start Audio

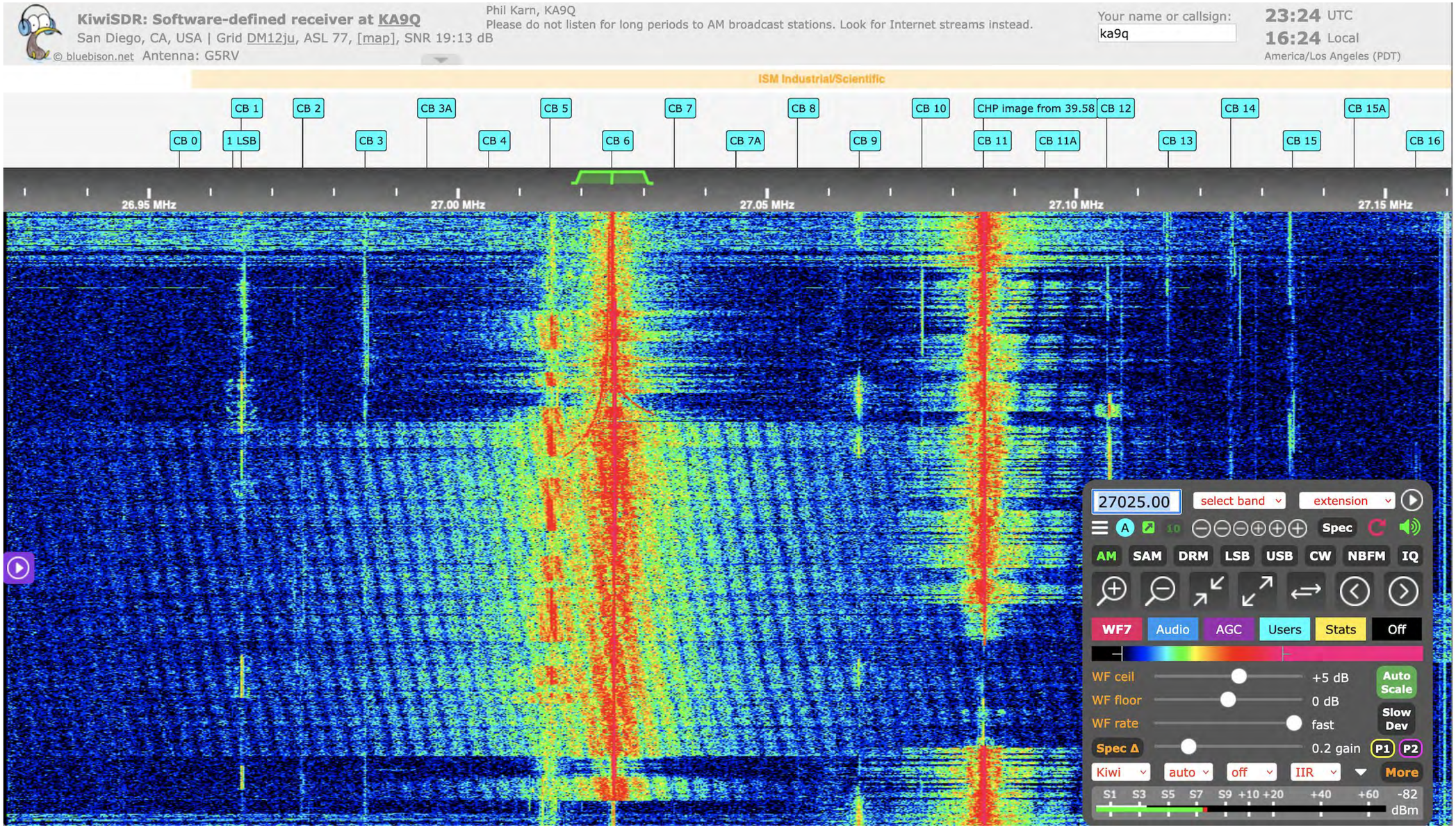
Range v | Range - | Band: Select Band | Zoom Center

Samples=1620 Hz/sample=20000

- Use mouse to click to a frequency.
- Use mouse wheel to increment/decrement frequency by Step amount.
- Enter frequency in Hz and hit Return or press **Set Frequency**.

Web Server by John Melton, G0ORX (https://github.com/g0orx/ka9q-radio)
ka9q-radio by Phil Karn, KA9Q (https://github.com/ka9q/ka9q-radio)
Onion Web Framework by David Moreno (https://github.com/davidmoreno/onion)
Spectrum/Waterfall Display by Jeppe Ledet-Pedersen (https://github.com/jledet/waterfall)

One fine day on 27 MHz…



Demo

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