All Your Modems Are Belong To Us

Talk Outline

- The origin of an SDR modem
- Commercial digital chipsets are no fun
- High altitude balloon telemetry
- Modem performance
- FSK internals in port to C
- Use in a FreeDV mode
- Live images from HABs

Why was this modem written?

- Project HORUS was using a commercial FSK chipset for telemetry
- Telemetry sent by ~50 baud RTTY
- Modem unreliable, especially during descent

Closed chipsets

- Closed ‘modem on a chip’ radios are popular
- ISM band modem chips are common in low power wireless devices
- Popular for HAB telemetry
- Can’t be improved
- Locked down around patents

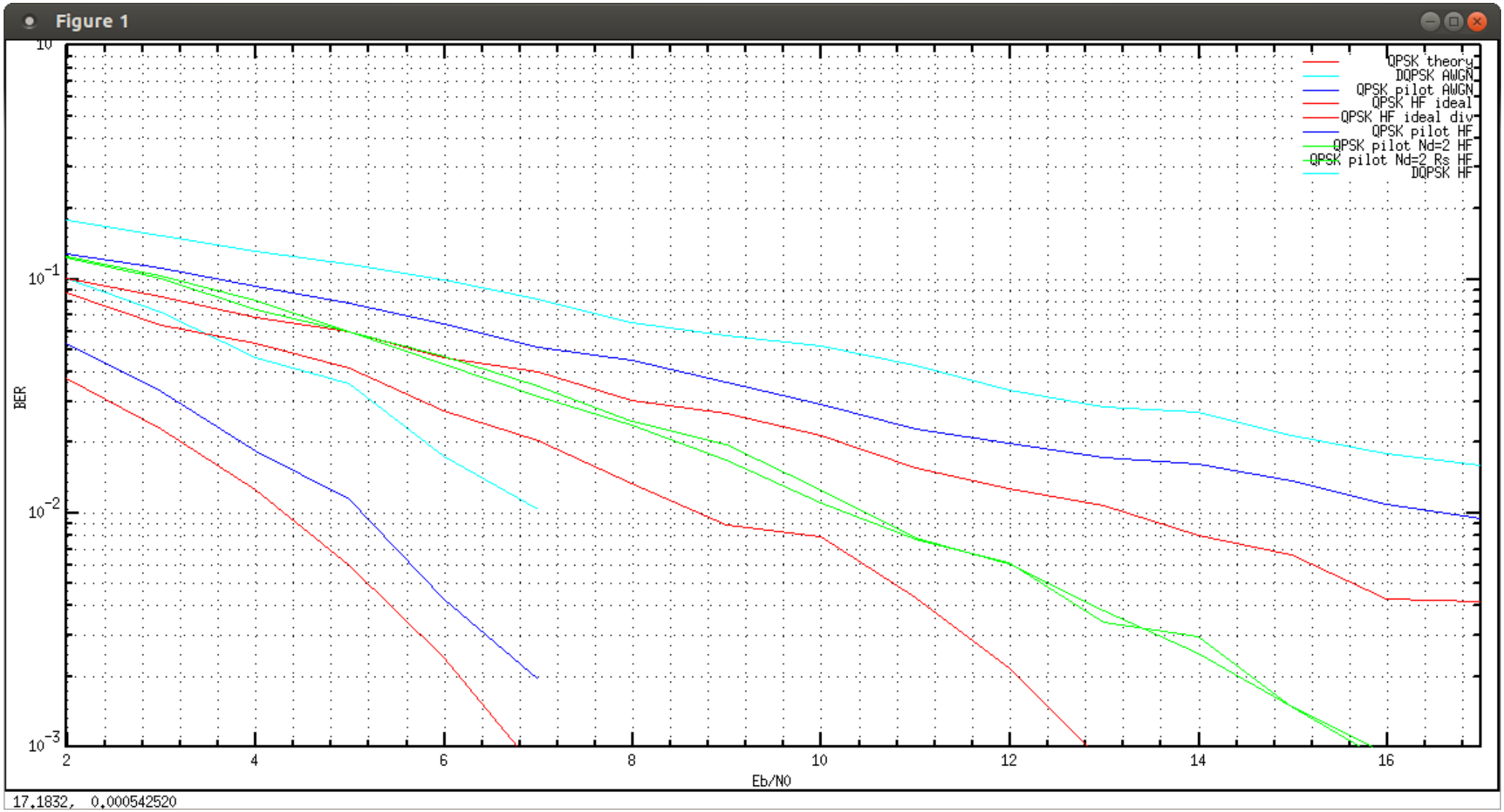
Enter David

- David Rowe, VK5DGR, known for FreeDV and Codec2 work, saw this situation in project HORUS
- Decided to do something about it!
- Threw together an FSK demodulator in 3 days in Octave
- ~10dB better performance than modem chipset!

Eb/N0

- SNR is carrier power over noise power in some noise bandwidth
- Instead of SNR, Eb/N0 is often used for digital systems
- Eb is the energy per bit, N0 is the noise density
- SNR of 1 bit/second in 1 Hz of noise bandwidth
- Eb/N0 can compare modem performance, even with different bitrates and bandwidth

Eb/N0 vs BER of various modems



FSK Eb/N0

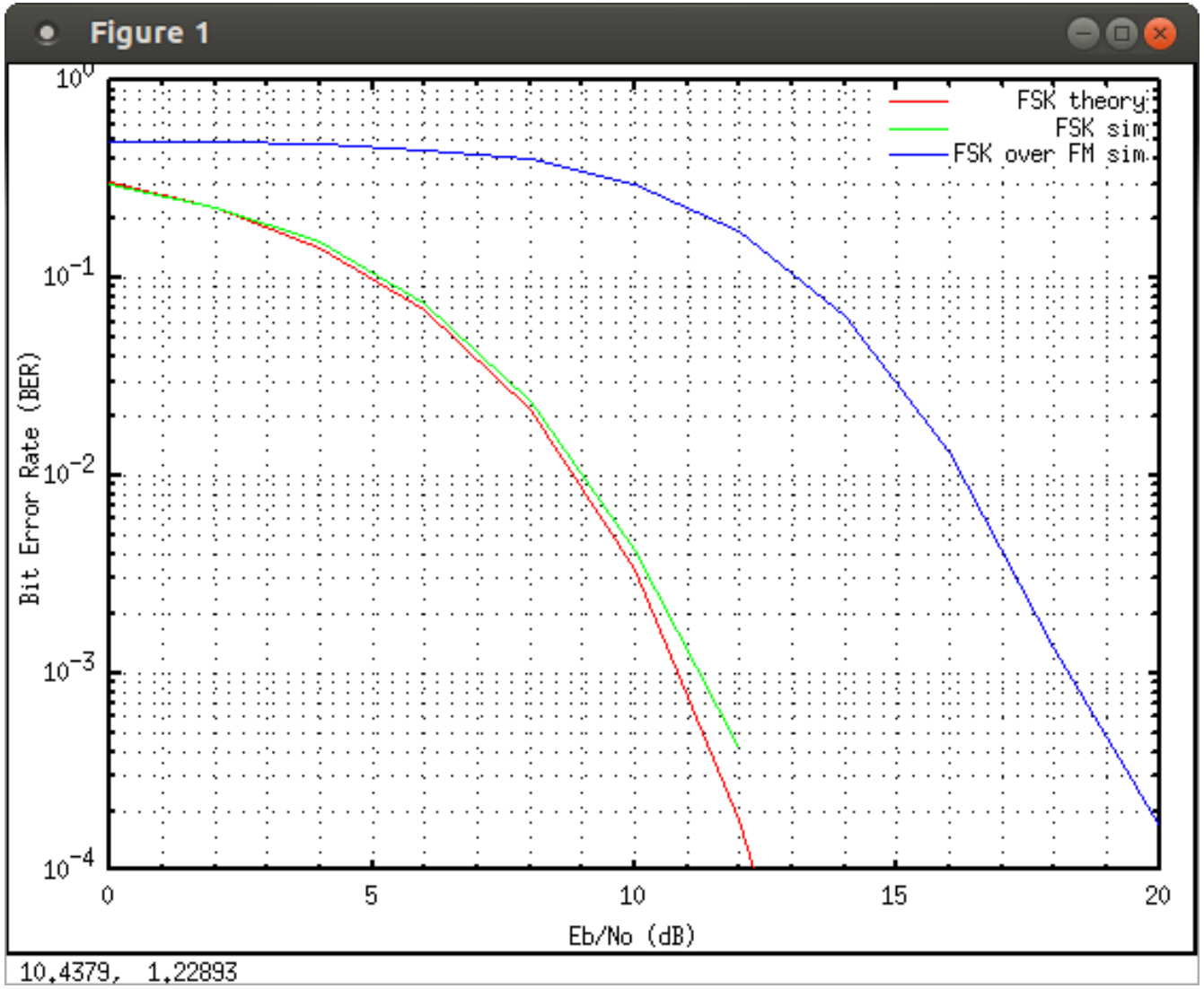
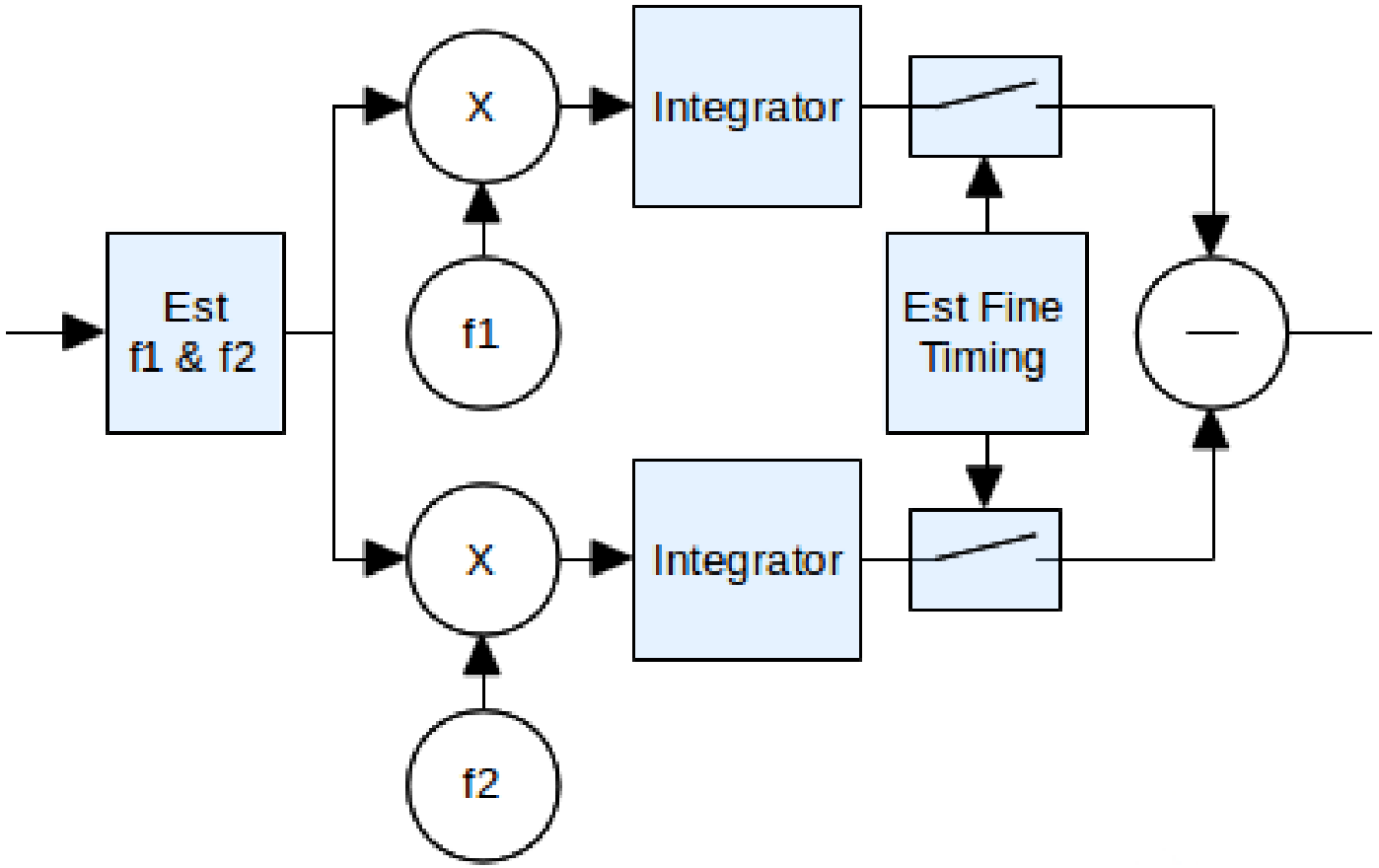


Figure 1
FSK theory
FSK sim
FSK over FM sim
Bit Error Rate (BER)
Eb/No (dB)
10^0
10^-1
10^-2
10^-3
10^-4
0
5
10
15
20
10.4379, 1.22893

FSK Demodulator Design



FSK Modem Design

- Fairly straightforward noncoherent FSK modem
- For each symbol tone, incoming samples are mixed to baseband for that tone and integrated over for a sample period
- Timing and frequency estimation also done, not shown on diagram
- Very close to noncoherent FSK theoretical performance for a fairly simple modem

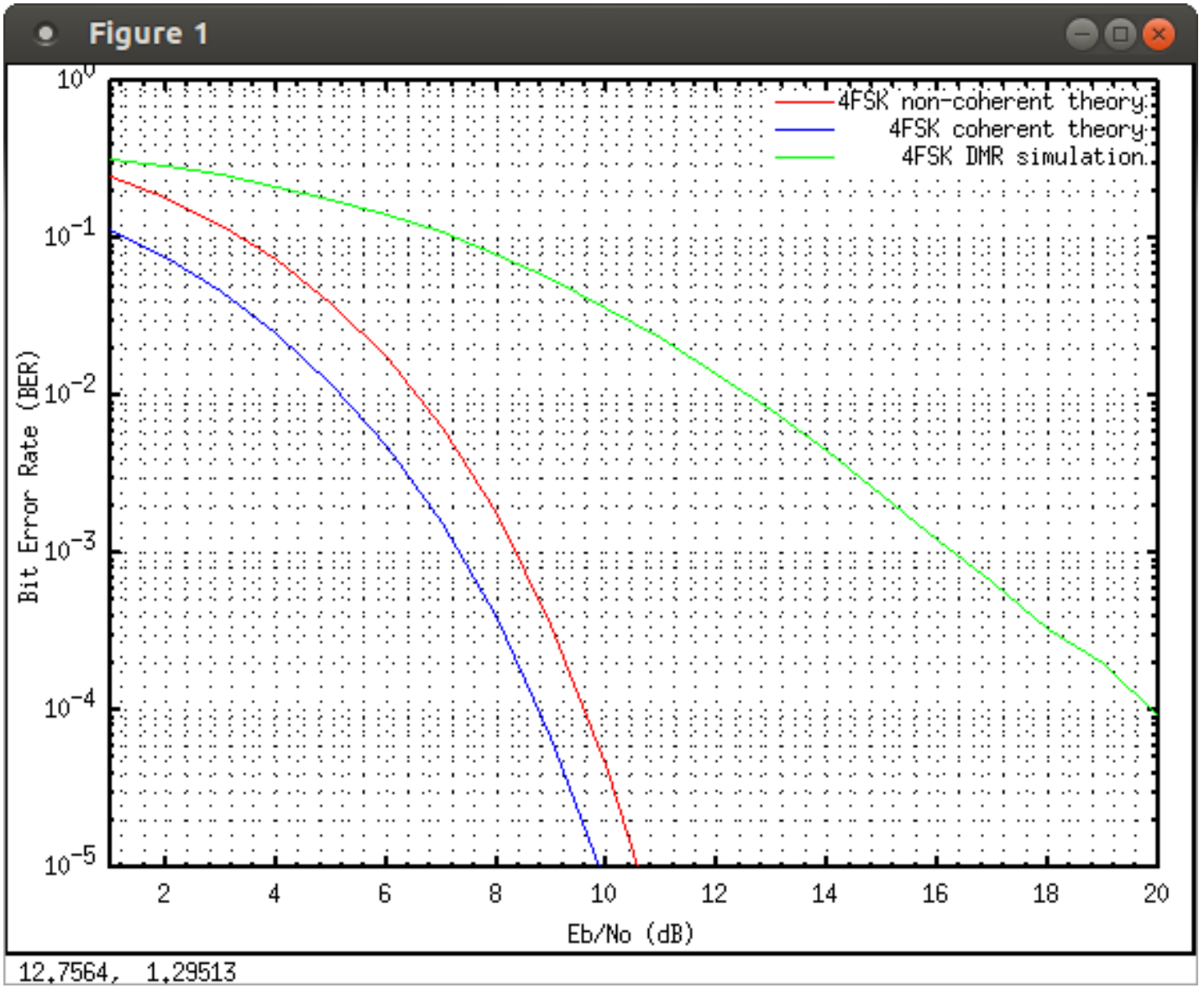
Port to C

- I ported the FSK modem from Octave to C in early 2016
- C port allowed for higher bit rate applications, such as a new FreeDV mode and live balloon images
- The ‘meat’ of the modem is about 500 lines of C
- C port still uses floating point, no fixed port yet

A new FreeDV mode

- In our simulations, the DMR modem preforms about 6-7 dB worse than theoretically possible for noncoherent 4FSK
- This is probably down to the use of an analog FM frontend FSK and heavy symbol filtering

DMR vs Theory



A new FreeDV mode

- After porting FSK to C, I was contracted by David Rowe to develop a few new FreeDV modes
- FreeDV 2400A built on the FSK modem
- Uses Codec2 1300 mode, same as FreeDV 1600
- 4FSK, 1200 symbols/sec modem, 4800Hz bandwidth
- 96 bits per frame – 52 for voice, 16 for sync word, and 20 left over for ‘protocol’

A new FreeDV mode

- Where is it now?
- 2400A can be used from the FreeDV API
- Intended to be shipped with the SM2000, but SM2000 work is stalled right now

Wenet

- Had a great modem sitting around – what else can we do with it?
- Balloon downlink has nearly 30db more link budget than needed for 100 baud telemetry
- Can we send images from the balloon in flight?

Project Horus
www.projecthorus.org

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Wenet

- Developed by Mark Jessop VK5QI and David Rowe VK5DGR
- Built on the SSDV project – sending images via ISM radios
- Modem and FSK layers replaced

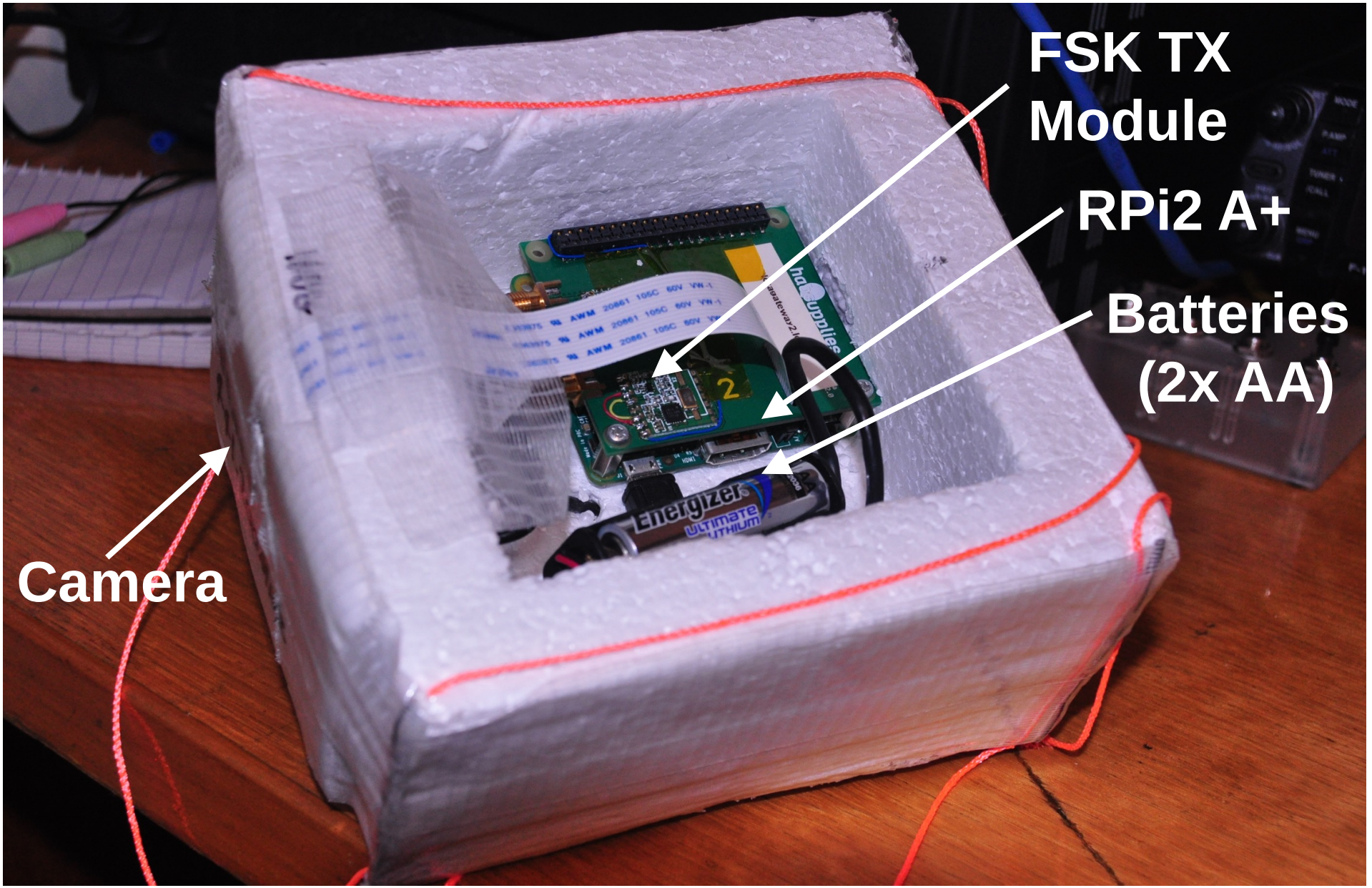
Wenet – Motivations

- Camera payloads common on HABs
- Images usually only recovered after landing
- Live images are nicer feedback than just a dot on the map

Wenet – The Setup

- Raspberry Pi+Camera in balloon payload
- 115kbps FSK transmitter (using modem-on-chip)
- LDPC FEC used on image packets, developed by Bill Cowley VK5DSP
- Our SDR FSK modem used on RX end
- Images passed through SSDV after packet extraction and FEC

Wenet – The setup




Lat: -35.08212 Lon: 139.05938 Alt: 32067m (32067m) Speed: H 125.9 kph V 5.4 m/s
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Credits

- David Rowe, VK5DGR – Codec2 and FreeDV
- Mark Jessop, VK5QI – Project Horus and much of the SSDV side of wenet
- Bill Cowly VK5DSP – LDPC used in Wenet

Questions?