Subcutaneous Transmitters

Presentation for the Institute of Neurology, UCL

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History

The subcutaneous transmitter (SCT) system is the result of a five-year collaboration.

In London: the Institute of Neurology (Matthew Walker and Pi-Shan Chang).

In Boston: Open Source Instruments (Kevan Hashemi, Jim Bensinger, Michael Bradshaw)

The SCT system is designed for:

- continuous EEG recording
- wireless operation beneat skin
- permit animals to move around freely
- eight-week operating life
- automatic seizure detection
- analog bandwidth 160 Hz
- open-source software
- open-source hardware

Seizure-detection developed in rats at ION, London, 2005-2010.

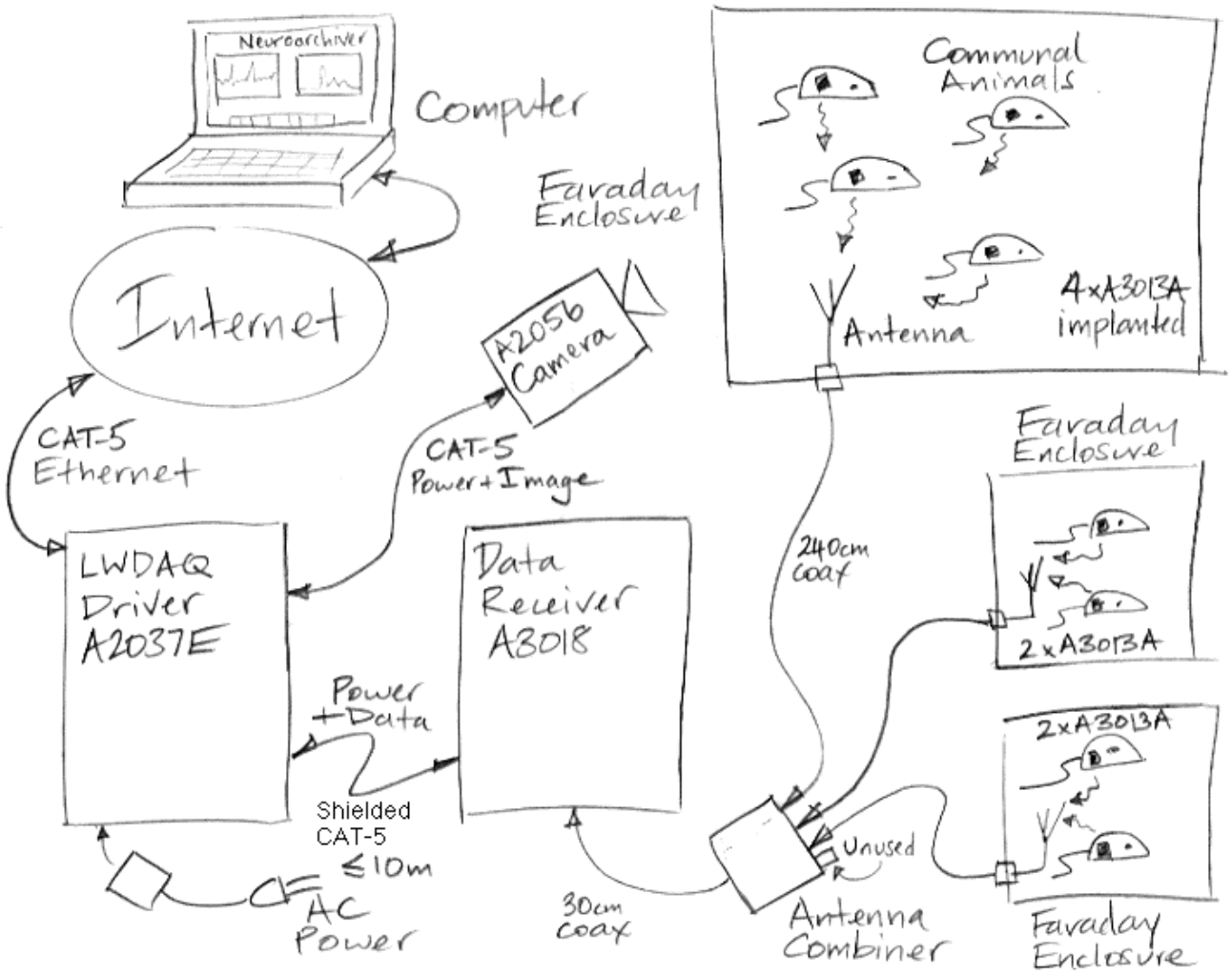
Seizure-detection improved in rats at Harvard Children's Hospital, Boston, 2010.

High-frequency (70-160 Hz) power detection used in rats at ION, London, 2010.

New, smaller transmitter developed for Louise Upton of Oxford University, 2010.

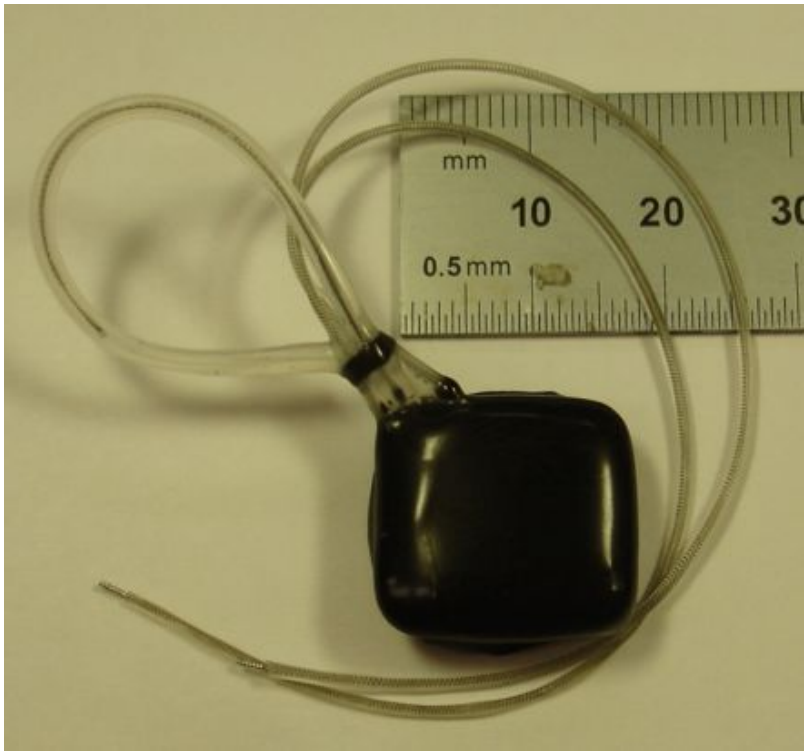
First mice experiments expected at Oxford University in 2011.

Overview


Neuroarchiver
Computer
Internet
Faraday Enclosure
A2056 Camera
CAT-5 Ethernet
CAT-5 Power+Image
LWDAQ Driver A2037E
Data Receiver A3018
Power + Data
Shielded CAT-5
≤10m
AC Power
30cm coax
Antenna Combiner
Unused
240cm coax
Communal Animals
Antenna
4xA3013A implanted
Faraday Enclosure
2xA3013A
2xA3013A
Faraday Enclosure

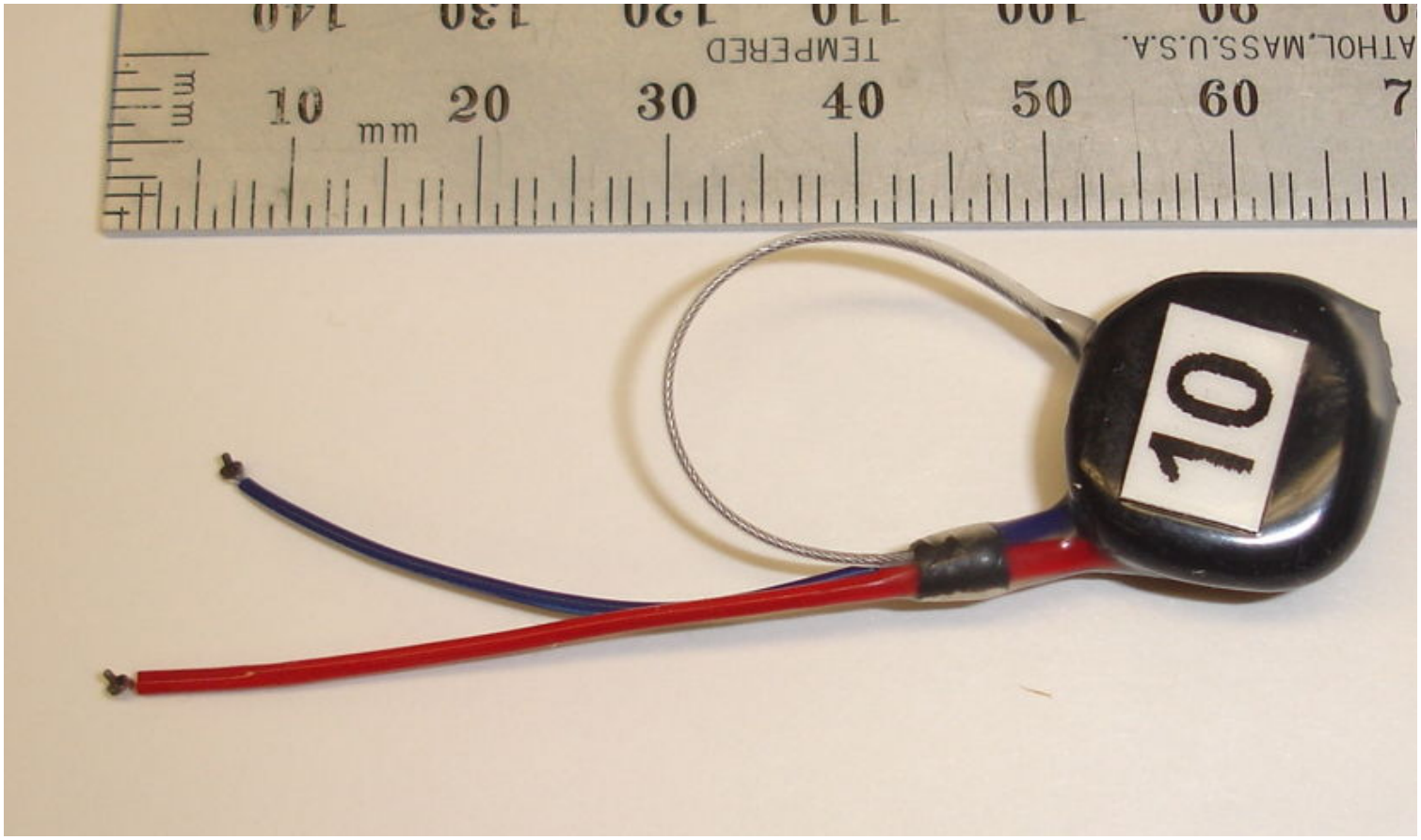
Basic System

Original Rat Transmitter



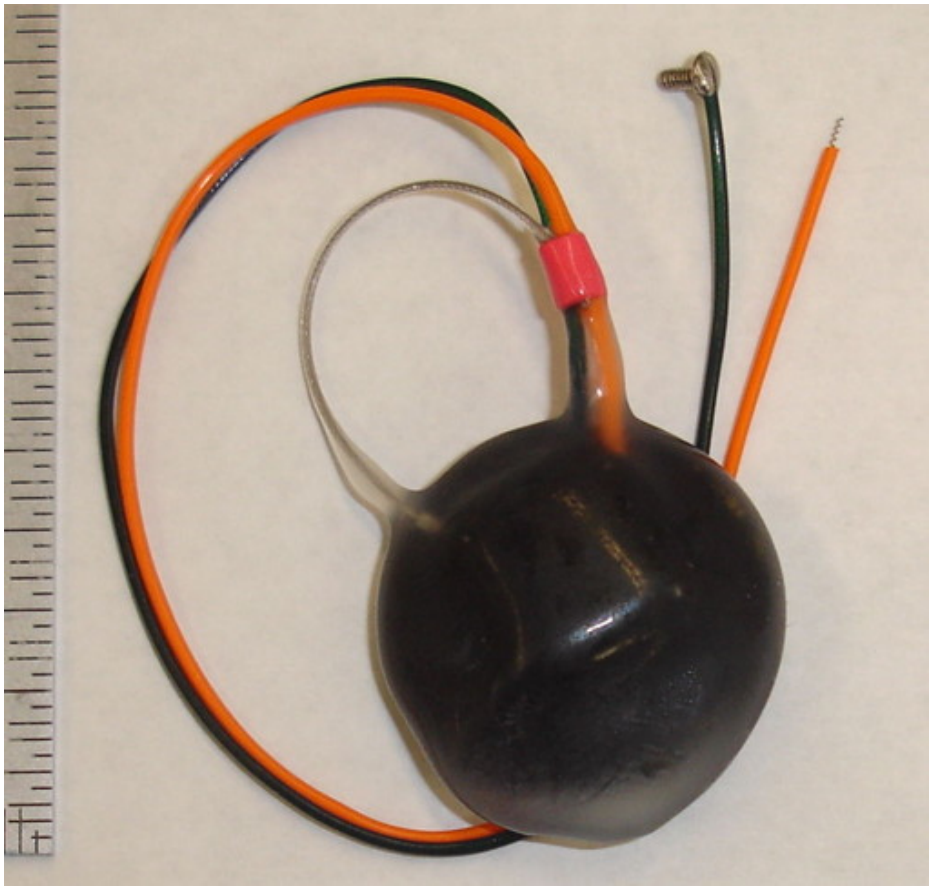
A3013A: Epoxy body coated with silicone, volume 2.4 ml, operating life >8 wks, shelf life 32 wks, sample rate 512 Hz, analog bandwidth 0.2-160 Hz, dynamic range 9 mV, white noise 12 μV, hum <1 μV, 500-μm diameter steel springs coated with silicone, steel screw electrodes, radio-frequency transmission at 910 MHz.

New Mouse Transmitter



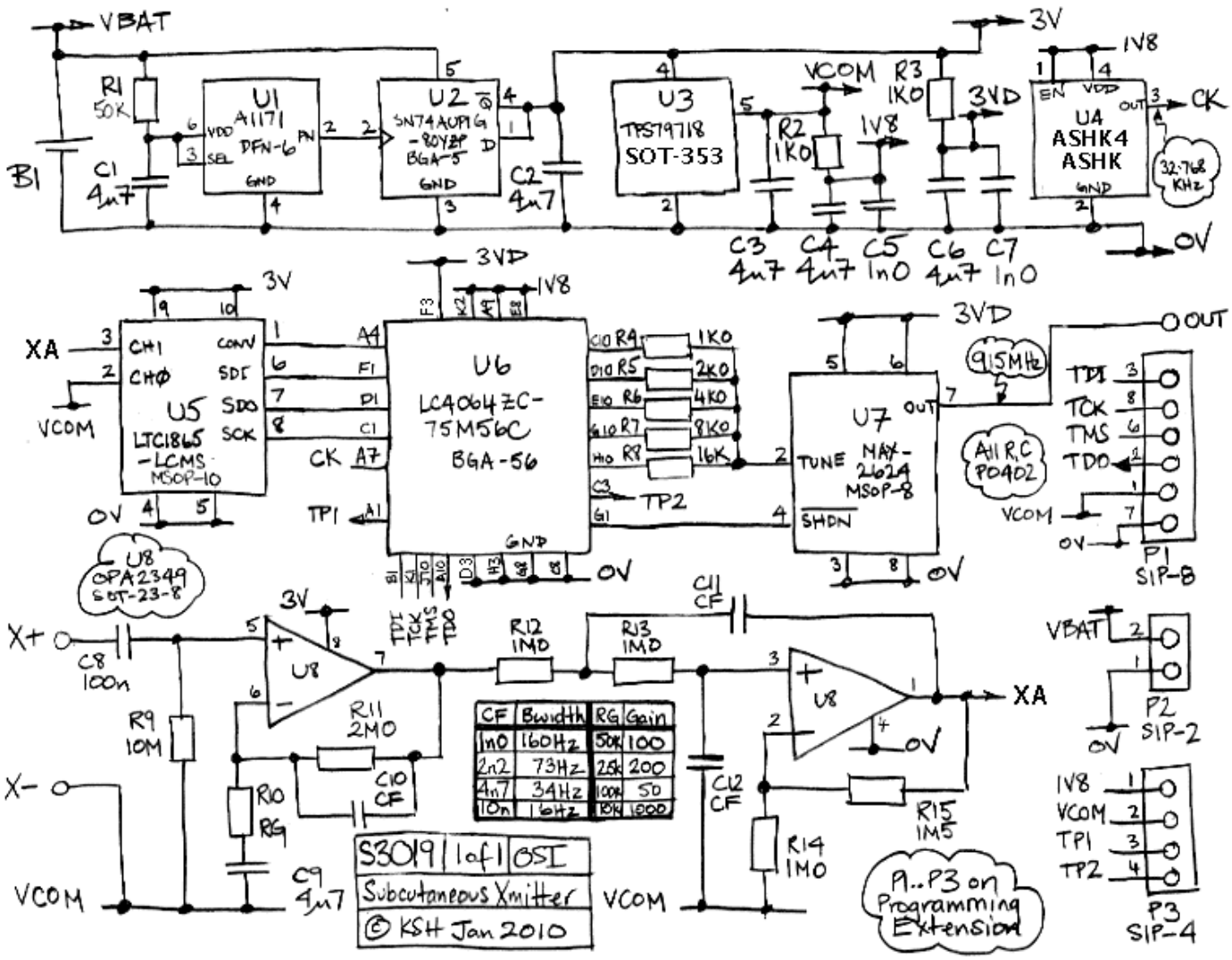
A3019A: Volume 1.0 ml, operating life 4 wks, shelf life 60 wks, sample rate 512 Hz, analog bandwidth 0.7-160 Hz, dynamic range 20 mV, white noise <12 µV, hum <1 µV, 400-µm diameter steel springs coated with silicone, steel screw electrodes, radio-frequency transmission at 910 MHz.

New Rat Transmitter



A3019D: Volume 2.2 ml, operating life 19 wks, shelf life 300 wks, sample rate 512 Hz, analog bandwidth 0.7-160 Hz, dynamic range 20 mV, white noise <12 μV, hum <1 μV, 400-μm diameter steel springs coated with silicone, steel screw electrodes, radio-frequency transmission at 910 MHz.

Transmitter Circuit

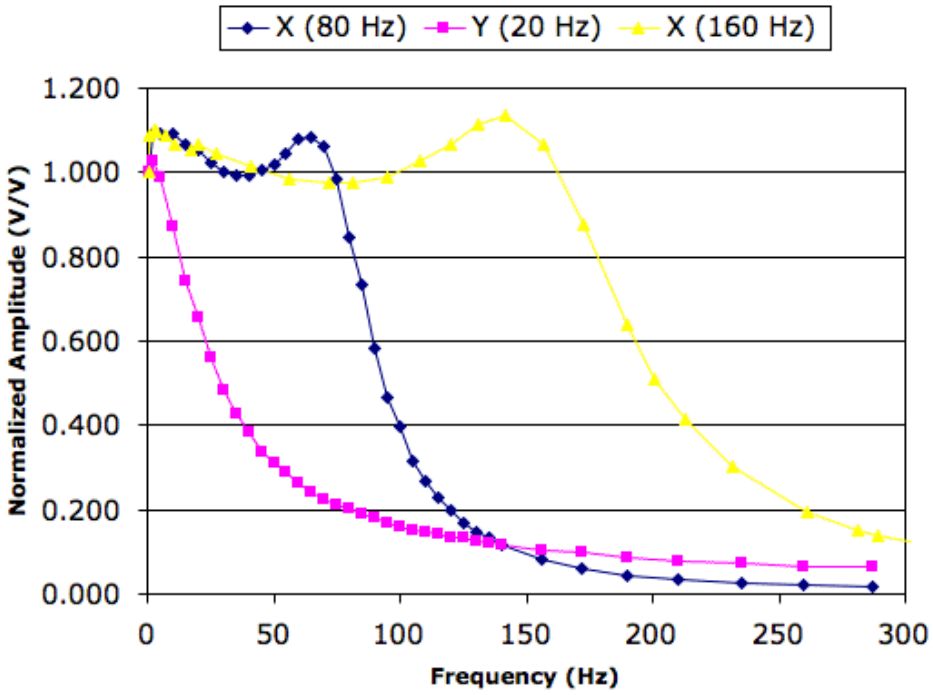


CF	Bwidth	RG	Gain
1n0	160Hz	50K	100
2n2	73Hz	25K	200
4n7	34Hz	100K	50
10n	16Hz	10K	1000

Frequency Response

Anti-aliasing filter for 512 SPS (samples per second):

- three-pole
- 3-db ripple Chebyshev
- cut-off frequency 160 Hz
- 20 dB attenuation at 256 Hz



For different sample frequencies, have different filters.

Radio-Frequency Transmission

- Use 902-928 MHz ISM band (industrial, scientific, medical).
- Each transmitter sample carried in a *message*.
- Message transmission takes 10 μs.
- At 512 messages per second, transmitting for 0.5% of the time.
- Transmitters operate asynchronously and independently.
- Simultaneous transmission from 2 transmitters is a collision
- Avoid sustained collisions with transmissionn scatter

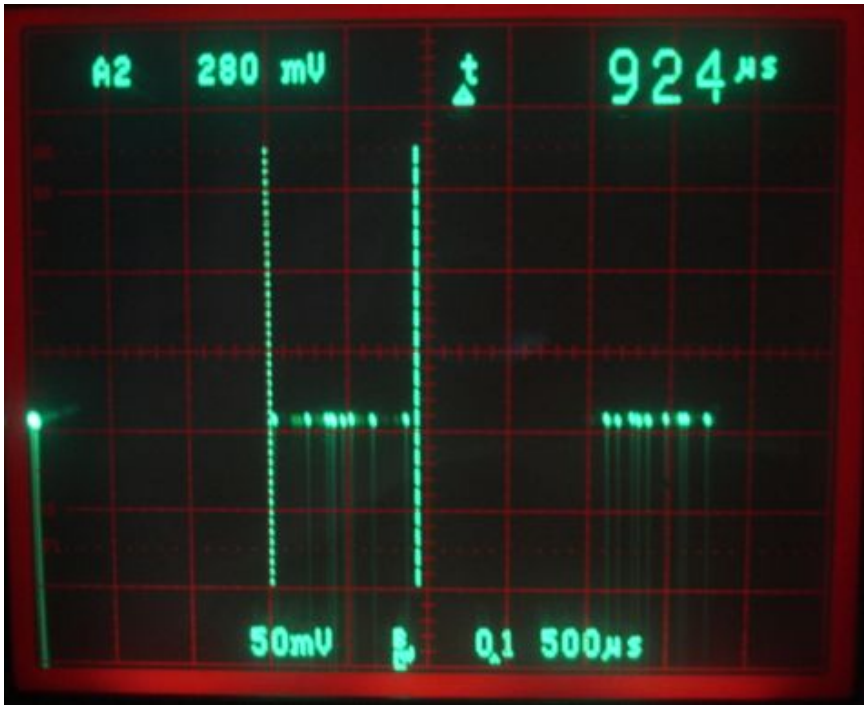


Figure: Transmission Scatter. Pulses are burstes of message bits.

Transmission is *unreliable*, but still effective with >80% of messages.

We hope for *robust* reception, with >80% reception ≥95% of the time.

Message Collisions

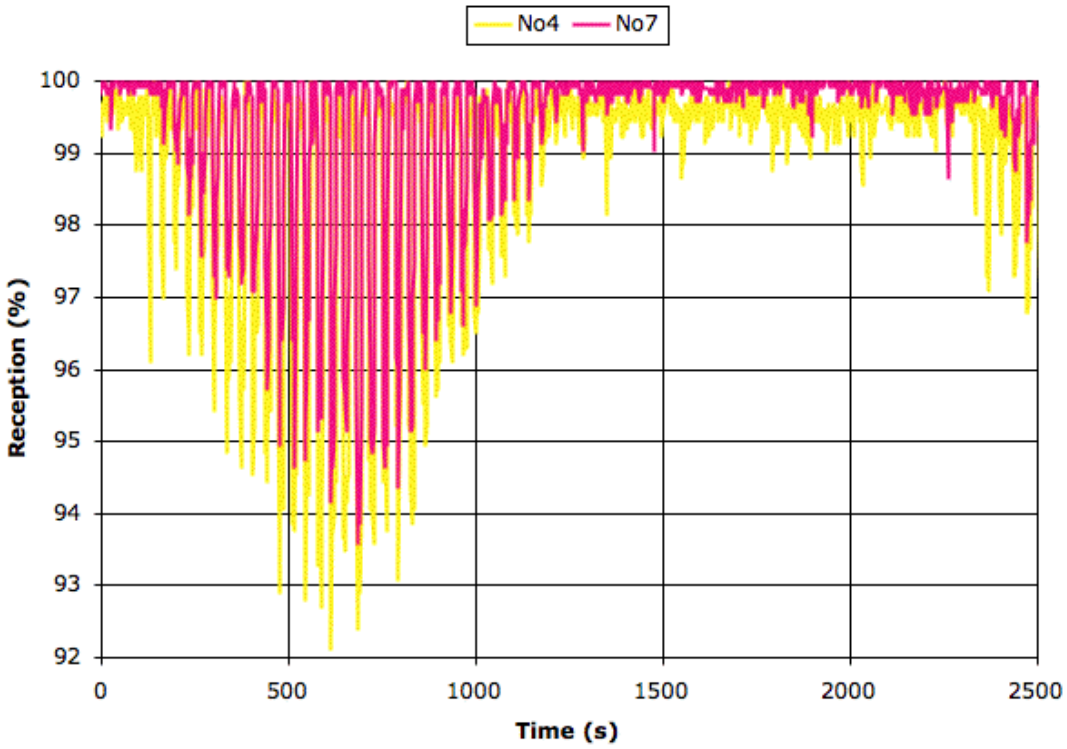


Figure: Cyclic Changes in Message Reception from Two A3013A Transmitters. Transmitter No4 has been running for 6 weeks in a jar of water. Transmitter No7 is new and in air. Average reception from No4 is 98.9% and from No7 is 99.5%..

Interference

Competeing sources of 902-928 MHz power is *interference*.

At range 50 cm, received message power varies by four orders of magnitude with orientation and position.

When signal is weak, strong interference in a city like London will overwhelm messages.

Faraday enclosures shut out 99.9% of interference, and guarantee robust reception.

The FE2B faraday enclosure is 71 cm × 71 cm × 33 cm. Fits two animal cages.

Could make much larger enclosures or single-animal enclosures.

Within a faraday enclosure, are confident of 3-m operating range.

Software

The Neuarchiver records raw data to disk in *archive files* and generates summary data called *characteristics files*.

Seizure Detection

Characteristics files are, by default, text files with numbers in them.
Characteristics file provides basis for seizure-detection.
We use Tcl scripts to detect seizures, but any other programming language is fine.
Seizure detection produces another text file: and *event list*.
The Neuroarchiver can step through the event list to display alleged seizures.

Conclusion

Reception appears to be robust with up to eight animals and one receiver.
Battery life is at least eight weeks with a fresh A3013A.
New rat transmitter has battery life 19 weeks at 512 SPS.
Hope to be using 1.0-ml transmitter in mice in 2011.