A Contemporary LF/MF Ham Station

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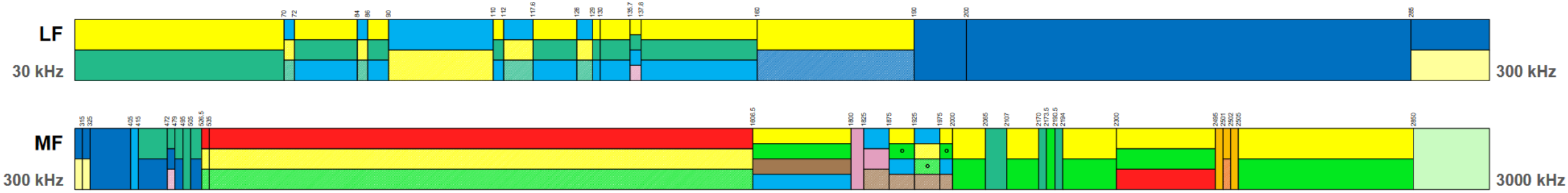
Presentation outline

- My motivation for building an LF/MF station
- Introduction to VK6MJM
  - LF emphasis for brevity
- Station technology overview
- Some first results
- Future directions
  - Including science

LF and MF amateur bands

136 kHz
(2200 m)
1 watt EIRP



475 kHz
(630 m)
5 watt EIRP

1850 kHz
(160 m)

ACMA

Motivation: why LF/MF, why remote?

- Interesting technology, e.g.
  - Antennas: only just beyond lumped-element circuits
  - Signalling: experiments with information transfer at very low SNR
- LF/MF propagation and radio science
  - LF propagation often characterized by VLF (waveguide) or MF/HF (ray) models
  - Lots of history, but also new tools for improved probing and modelling
- VK6 fell into a void in world LF transmitting and receiving coverage
  - Significant omission for propagation studies
  - No LF broadcasting in AU; VLF military transmitter at North West Cape (NWC, 19.8 kHz)
- Big (transmit) antennas → go rural/remote
  - Physically big antennas, but often < 0.01 wavelength electrically
  - Remote stations allow more hams to operate efficient LF transmit antennas and low-RFI receivers…but are by no means the only approach
  - VK6MJM antenna is comparable in size to many ham towers / wires

Amateur LF/MF in 2025

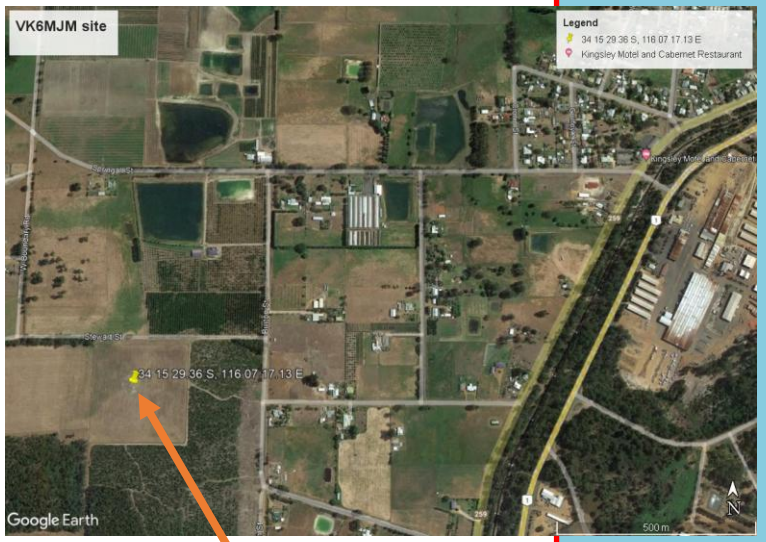
- Still experimenters' ham bands, requiring more than a credit card** to succeed
- Probing anomalous propagation (aka "very rare DX") beyond previous limits
  - e.g. JT-mode signalling such as FST4(W) beacon and QSO modes
- More commercial T/R equipment now available
  - e.g. Kenwood, Flex, Elecraft, ANAN, Hermes Lite, … transceivers produce ~ 0 dBm drive, with good receivers
- Good receive antennas to buy or construct
  - Active and passive loops (large and small), active arrays, new ways of building classic designs (e.g. DSP), ….
- Efficient power amplifiers (Class D/E switching) "easy" to homebrew
  - Antenna current is cheap – fewer efficiency imperatives
- Better and easier metrology readily available
  - Better test equipment for home building, antenna tuning, transmission monitoring, ….
- Good software tools
  - Cheap or free computational electromagnetics (EZNEC etc.)
  - Remote Desktop for station operation (AnyDesk, TeamViewer, ….OtherStuffForCommonFolk)
  - Custom station software not essential if hardware is selected/built appropriately

*** credit card strongly recommended*

VK6MJM: a re-born NDB

- 22.5 m (74’) umbrella-loaded live-mast antenna
  - Electrically very short:
  - 13° @ 475 kHz → 0.8 Ω radiation resistance (R_r)
  - 3.7° @ 136 kHz → R_r = 0.07 Ω
- Self-resonant (λ/4) frequency of antenna = 1795 kHz
  - Essentially 160 m amateur band!
- Ground radial field of unknown extent – originally 30 x 22.5 m radials ?
- Good quality steel shack – about 3.5 x 3.5 m (10’ x 10’)
  - Wall-mounted air-conditioner, workbench, 240 V mains power
- Antenna coupler (“tuner”) near mast
  - New, homebrew IoT-controller coupler commissioned last week
- T/R operation via internet and remote desktop

VK6MJM location

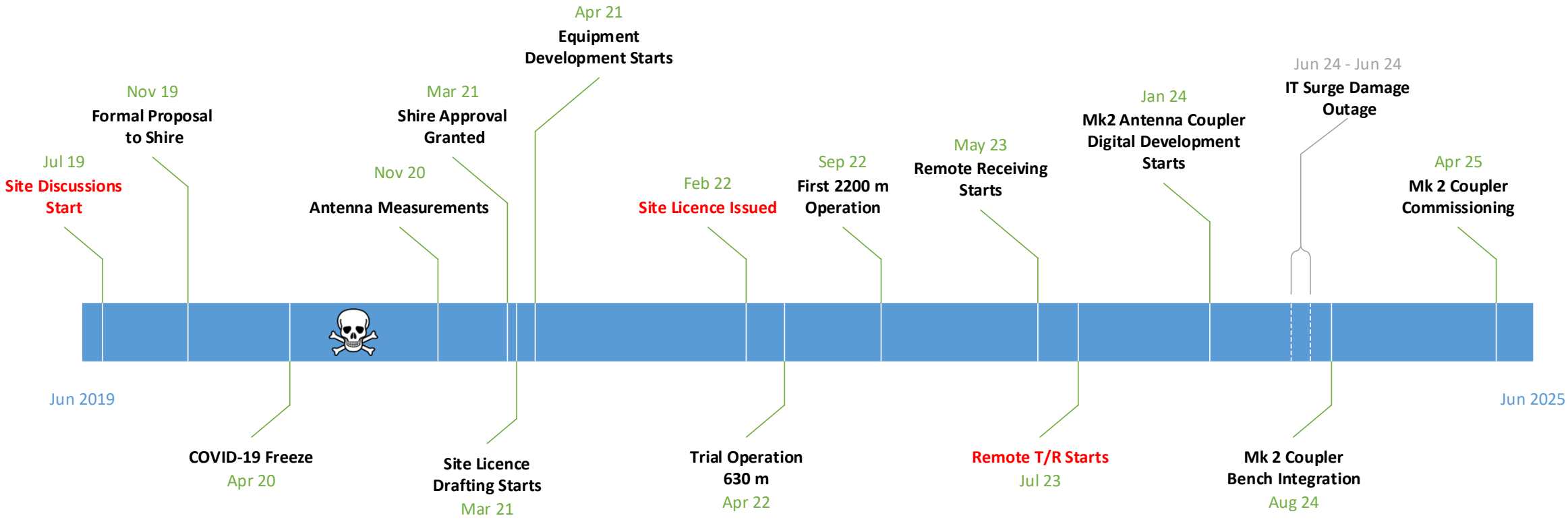


VK6MJM

WA ~ 4 x Texas in area ☺

***Manjimup**: About 3.5 hours drive from Perth*

6 years of VK6MJM

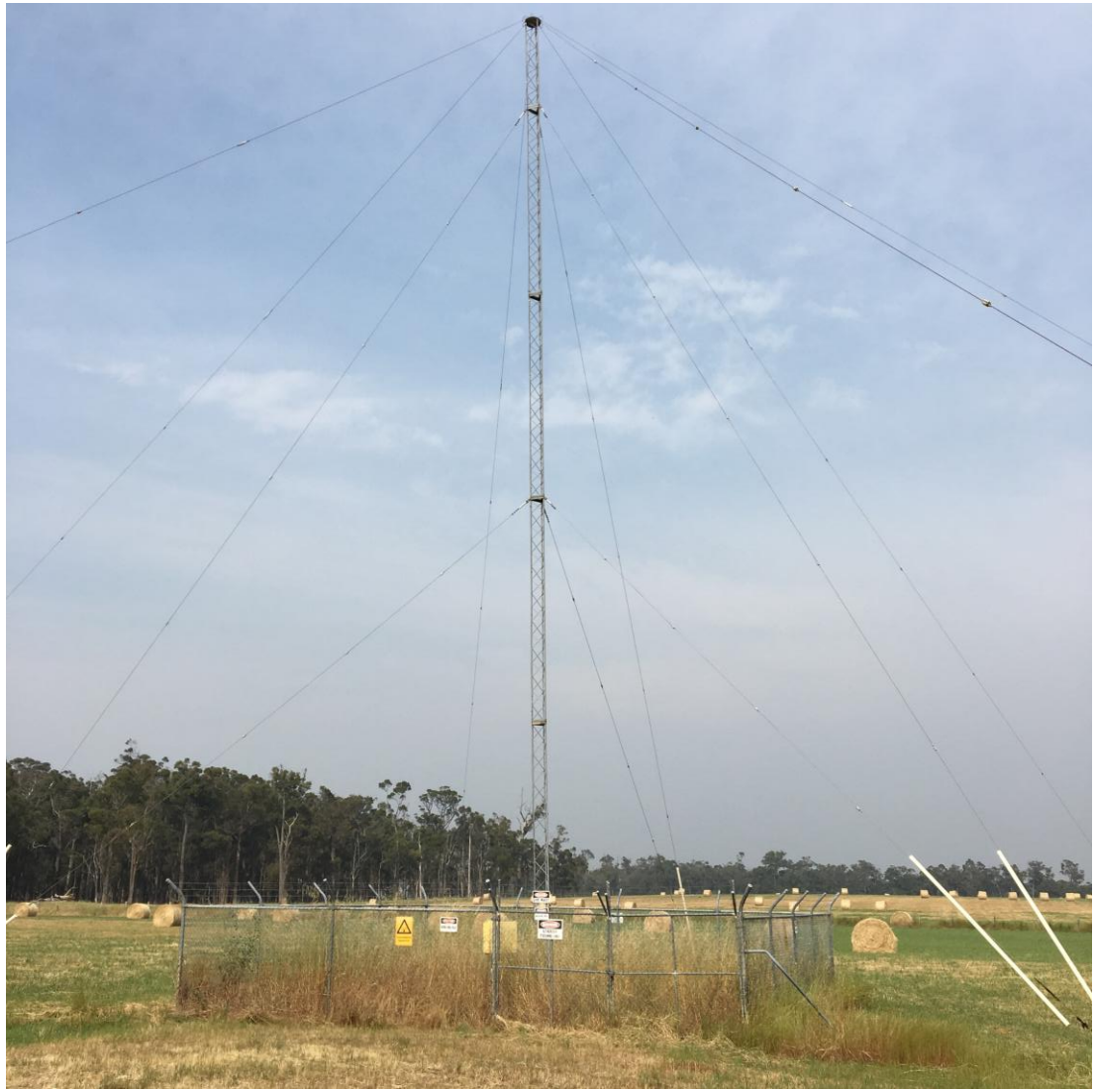


”Shire” ≈ rural county

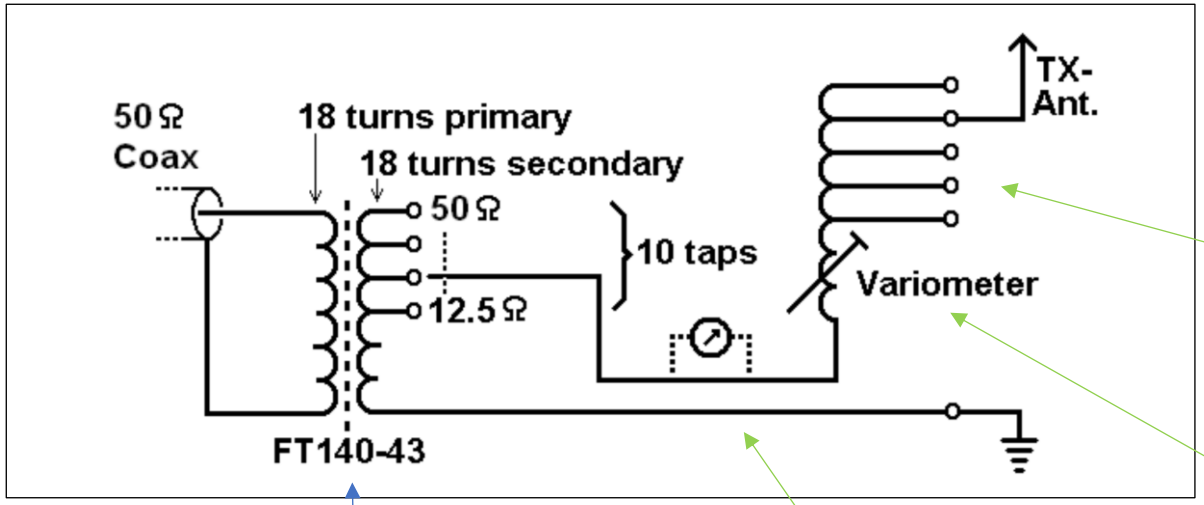
Some initial VK6MJM design decisions

- Both transmit (legal limit) and receive operation at LF/MF
  - Mains power, site RFI minimization, use of transceiver, …
- Year-round operation
  - Shack air-conditioning, efficient thermal control, diligent site maintenance, …
- Capable of long-duration digital, as well as other, modes
  - Local PC for high-fidelity signalling, transceiver TCXO, …
- Internet-based remote control
  - Remote desktop for easy and extensible operation, autonomous local safety systems, …
- Emphasis on radio technology development, but system choices consistent with (eventual) integrated software solution
  - Commercial hardware with control/monitor apps and drivers, W11 operating system
- Relatively fast-track development
  - Re-invent as few wheels as possible
  - Reliable “installable prototype” hardware, with functional documentation

Antenna views



LF/MF antenna coupler – typical form



Large “loading” coil to resonate with short antenna’s capacitance (2.3 mH at 136 kHz)

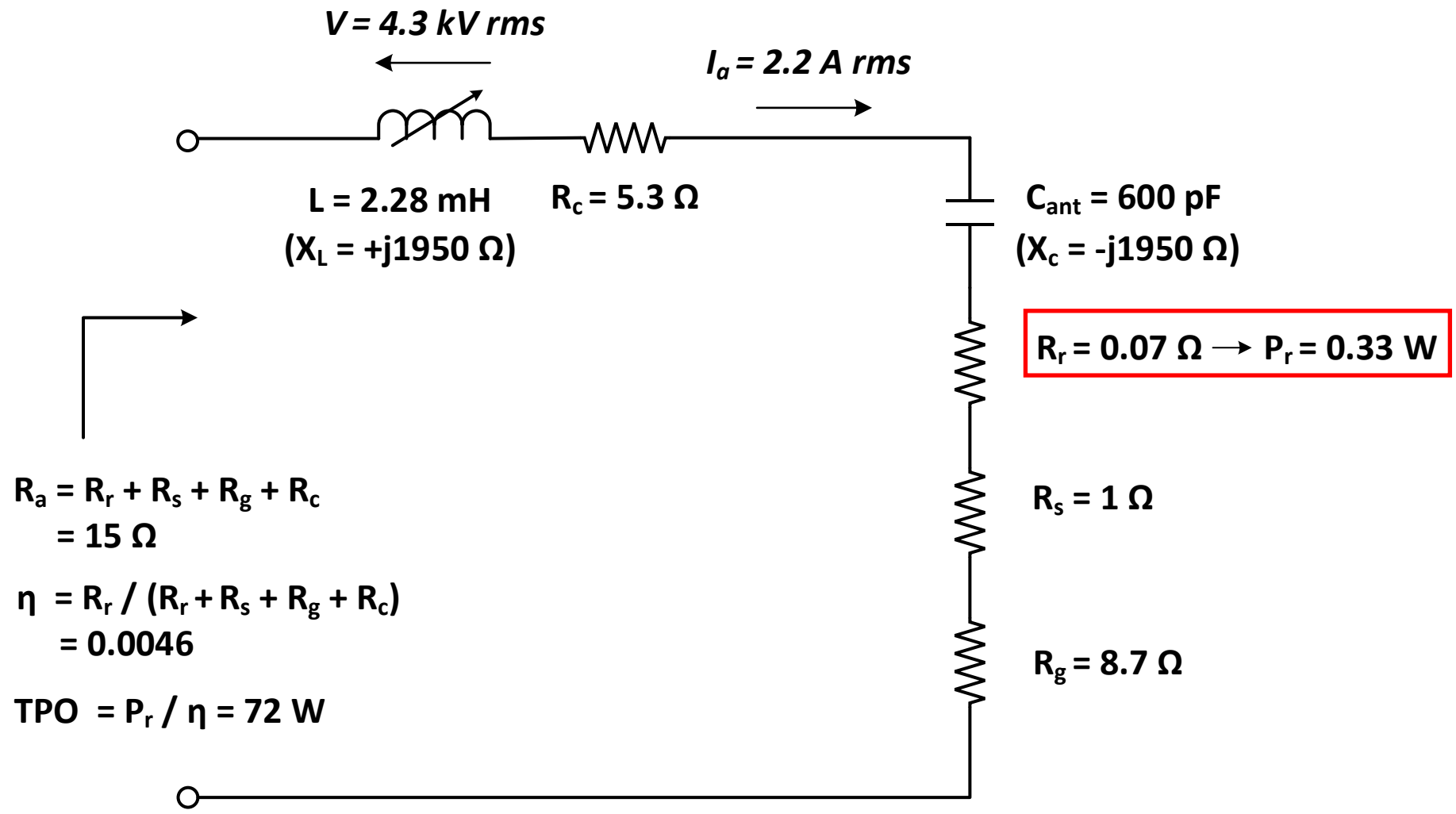
Variable inductance for fine tuning resonant frequency

Tapped impedance matching transformer: resonant resistance → 50 ohm feeder

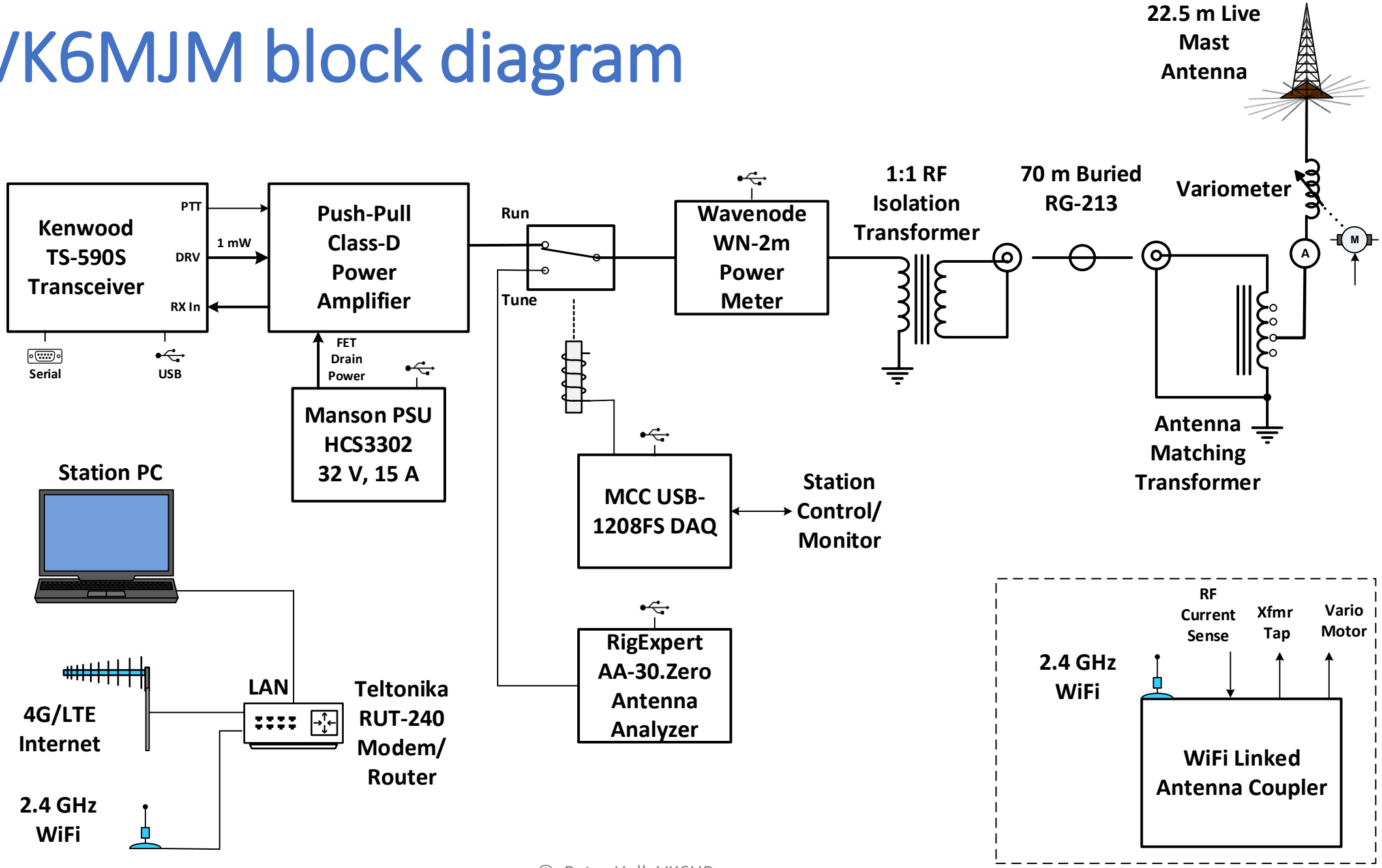
RF ammeter

(DL4YHF diagram)

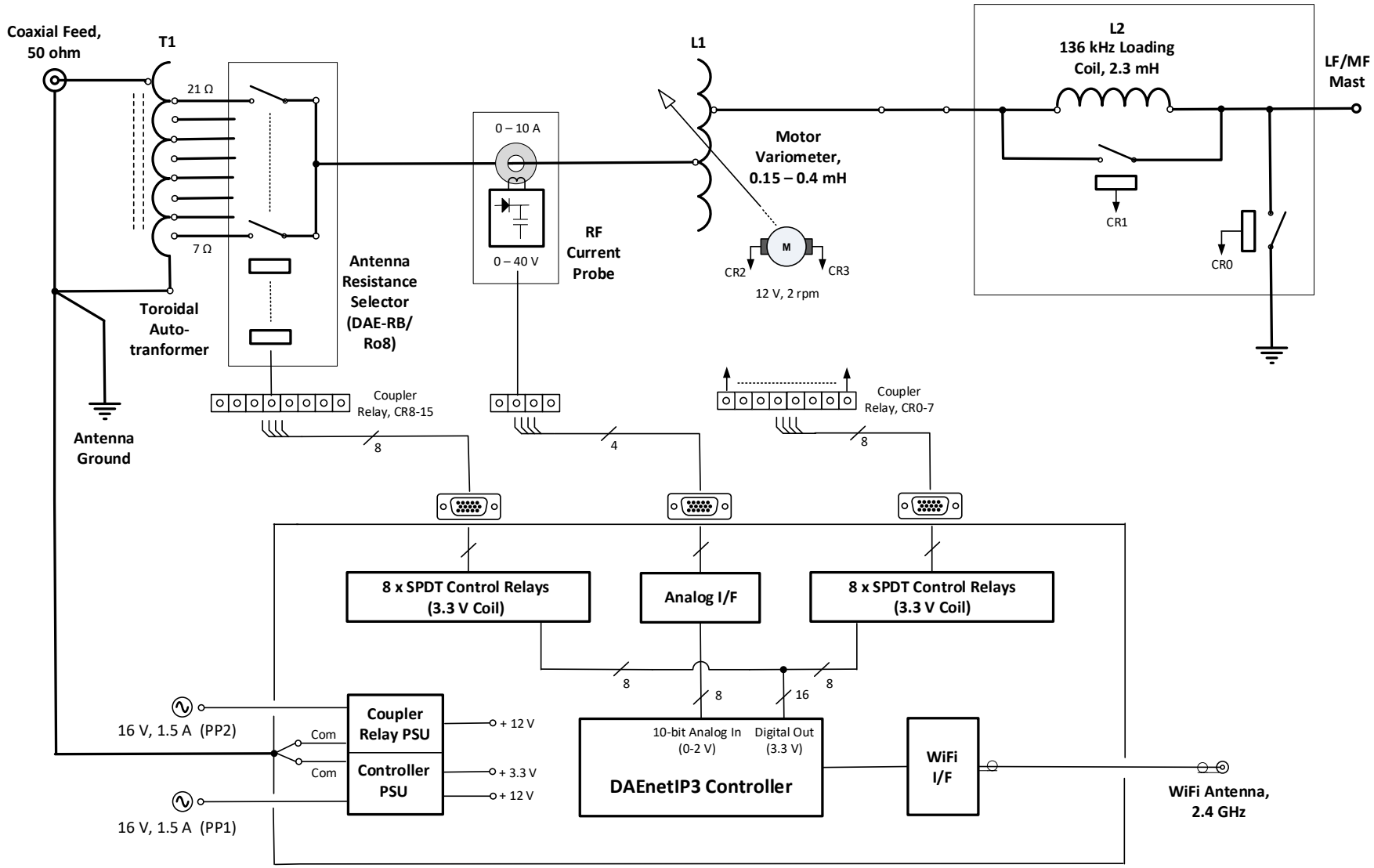
VK6MJM at 136 kHz, 1 W EIRP



VK6MJM block diagram



New Remote (IoT) Antenna Coupler

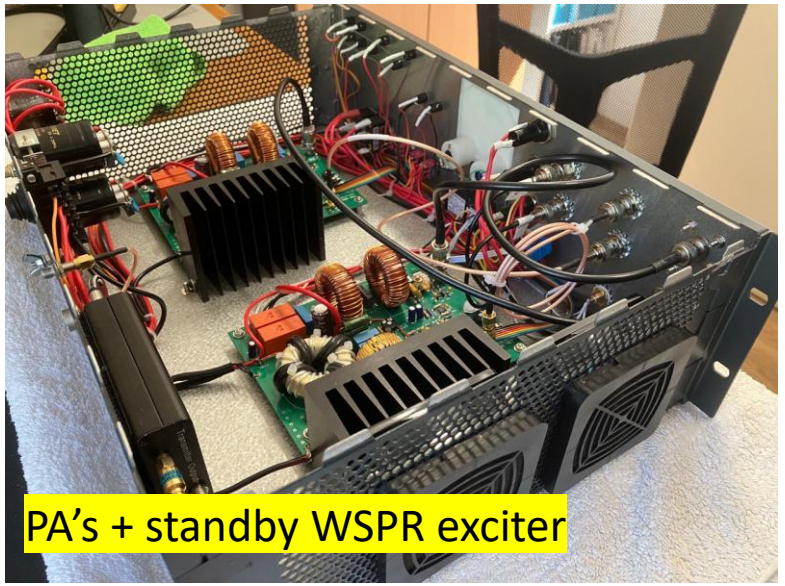


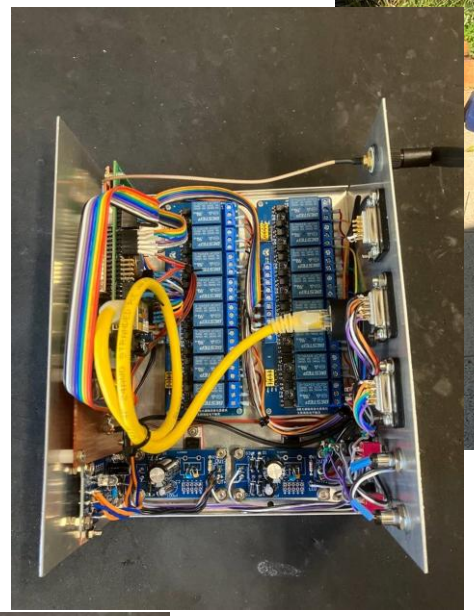
Highlights:

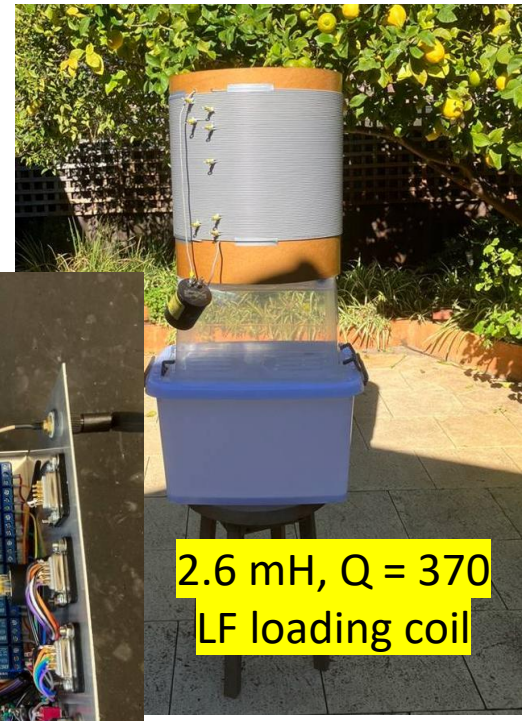
1. Galvanically isolated coupler control
2. Flexible and extensible
3. Both R and X tuning
4. Good EMC from both culprit/victim directions

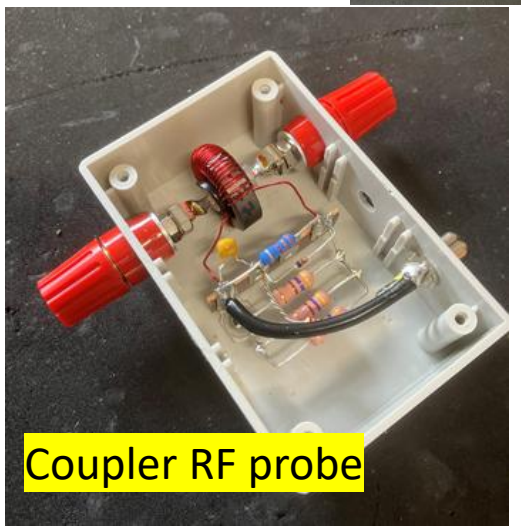
Hardware snapshots


Rack (with TS-590S)


PA's + standby WSPR exciter

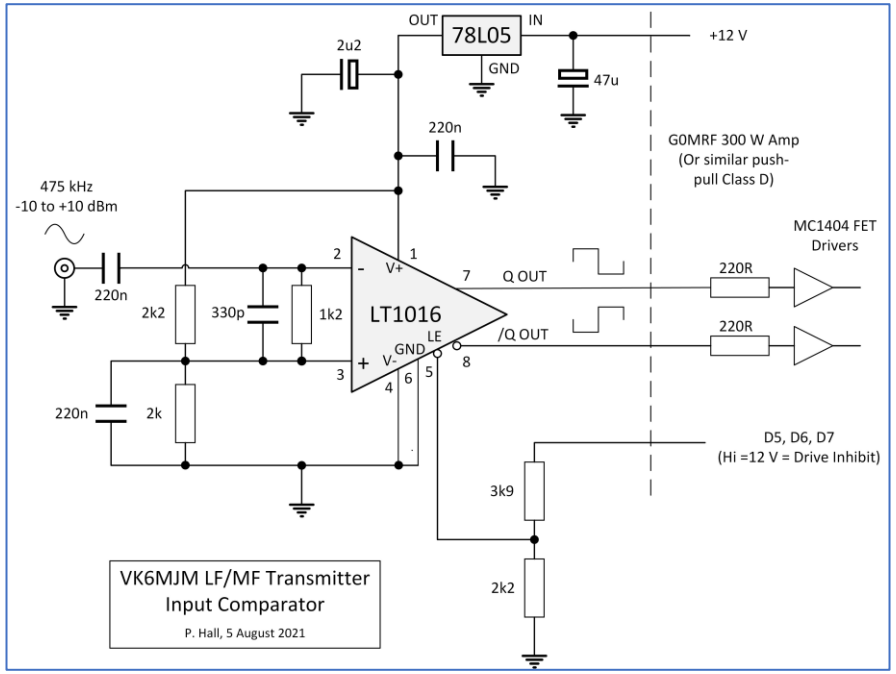



2.6 mH, Q = 370
LF loading coil

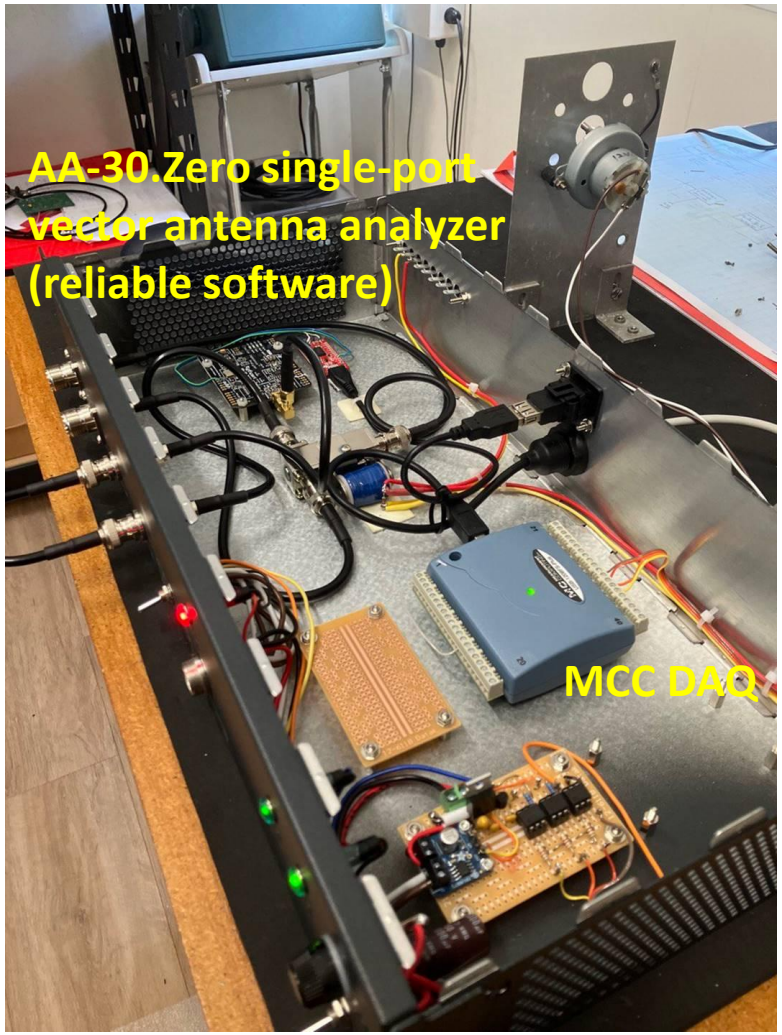

Coupler RF probe

WiFi coupler controller

More hardware

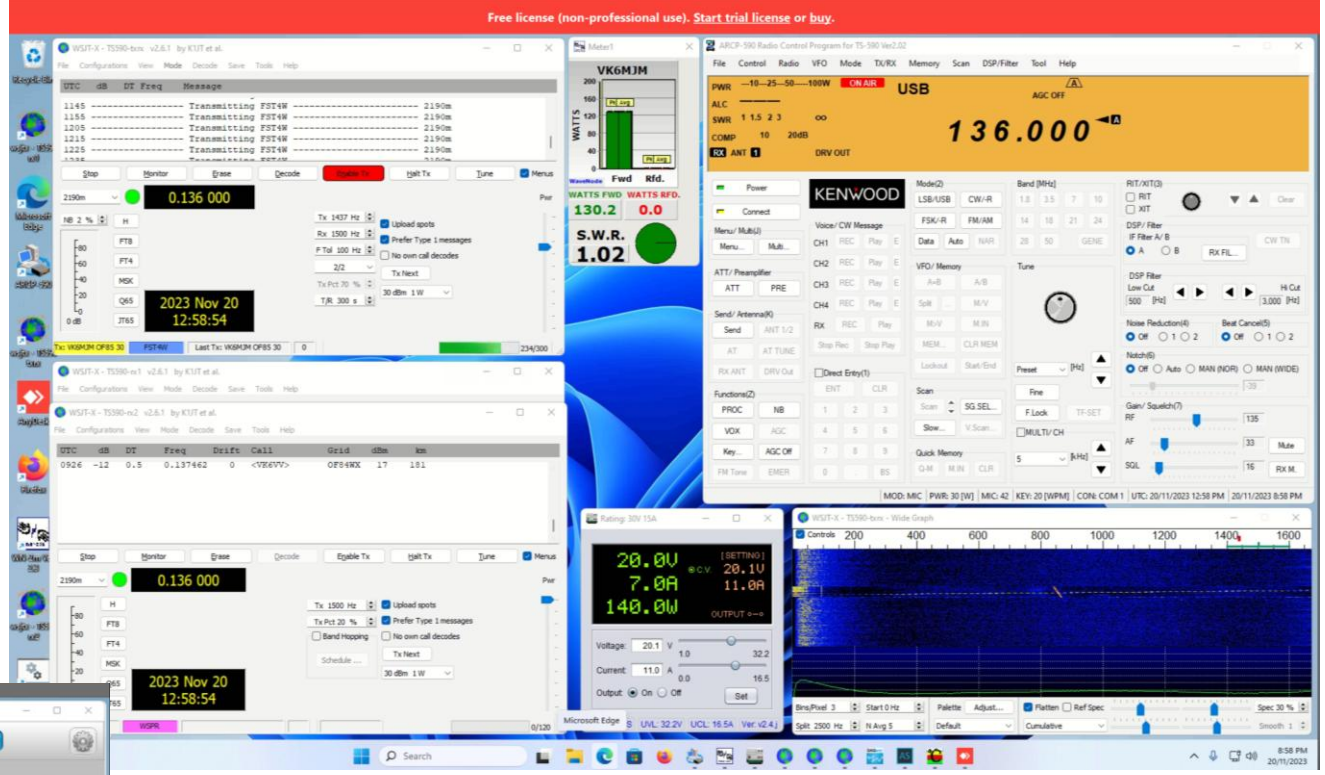


Fast, low-jitter (phase noise) comparator (direct signal frequency input)

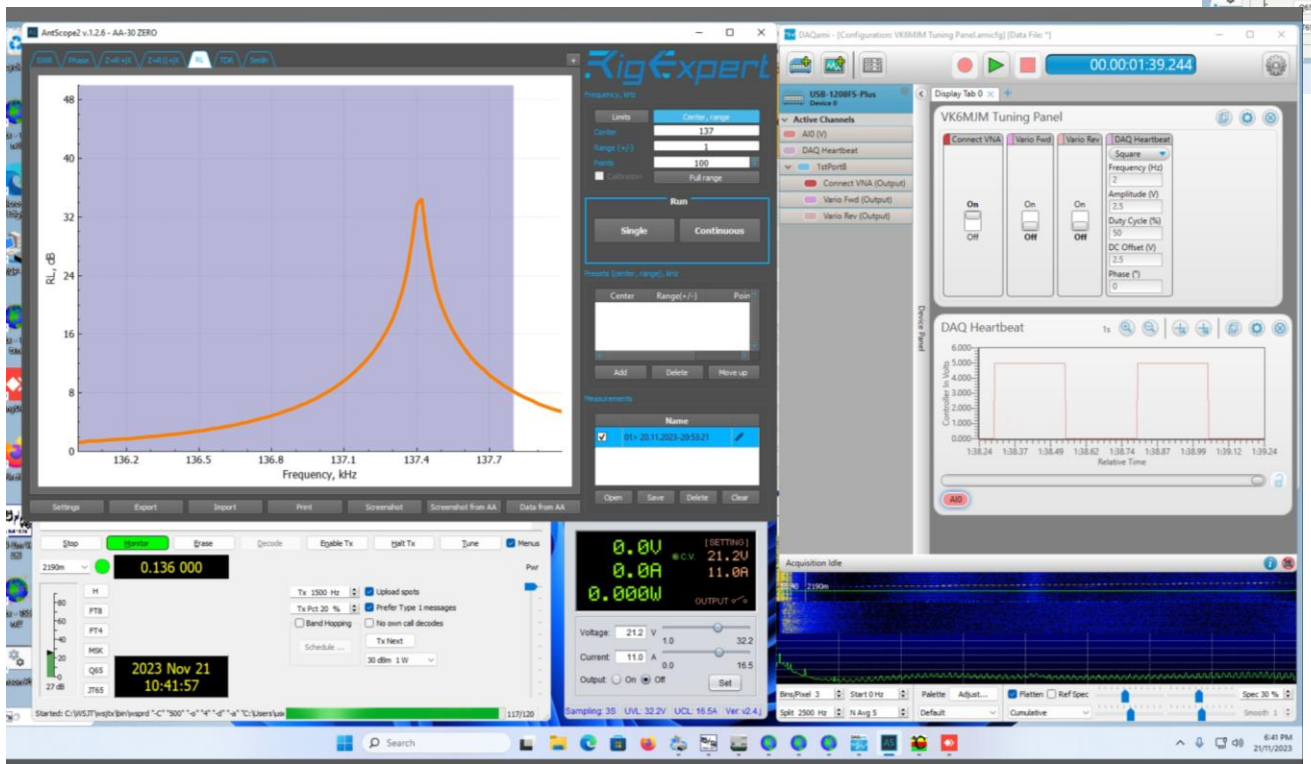


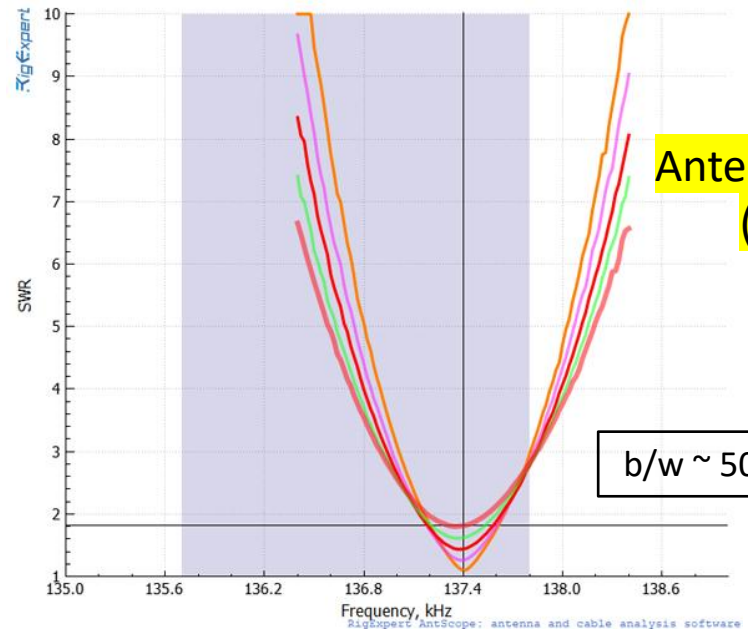
Remote screens (v1)

"Run"



"Tune"





Antenna tuning curves (new coupler)

b/w ~ 500 Hz

Results to March, 2025

- WSPR 2, FST4W-300, FST4W-900 transmissions
  - New coupler removes previous key-down time limit
- Antenna currents around modelled values
- 475 kHz field strength @ 1 km ~ 80% of expected value (1 dB)
- Oceania → North America 136 kHz one-way digital record
  - Repeated many times with KM5SW using FST4W-300; extended to 16,823 km with SWLEM3
  - Hard-won spot with KL7L (Wasilla, AK)
- Very new FST4W-900 spots by KPH, W1CK, K6VZK
- Best 475 kHz (WSPR) spot by KL7KY (Talkeetna, AK)
- DL7NN, R2BM, R7LP, UA4AAV, JA1NQI, JA1RWI, JH1OFX, G3SDG, … received on 136 kHz – frequent repeats in most cases
- Formed overview of seasonal propagation trends
- Encouraged other VK6 amateurs to try LF/MF

Selected STEM topics

- Propagation studies
  - LF/MF skywave: when, where and how? Correlation with key physical indicators?
  - Trans-equatorial vs mid-latitude path behaviour
  - Importance of path spatial/time variation, and choice of signalling mode
  - Simultaneous multi-mode studies (need a linear PA)
  - Data visualization (WSPR Live)
- Non-linear power amplifier design
  - Improved Class D or E designs
  - Better characterization of stray reactances (esp. magnetic components)
  - Better understanding of load matching on C/N ratio
- Communications systems operating near the theoretical limit
  - E_b/N_0 characterizations
  - How do JT-mode FEC systems stack up in practice?
    - Especially when “robust” error rates are set in decoding software

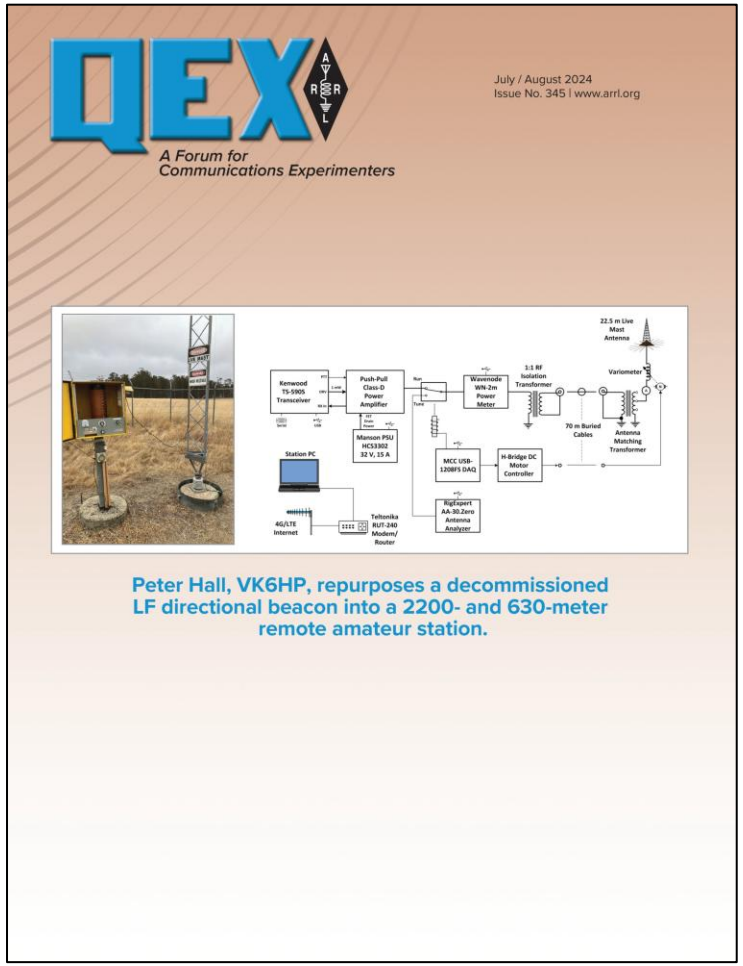
Future VK6MJM directions

- Directional receive antenna(s)
  - Beverage, loop, ….
- More integrated software, better documentation
  - Easier, safer operation by more people
- More bands and modes
  - Incl. 160 m + HF phone
- More STEM education
  - Uni projects, ham education, high school science, …
- More serious (and systematic) propagation studies
- LF/MF linear amplifier: simultaneous signalling modes
  - e.g multiple JT modes for path studies
- Other non-commercial uses of site
  - e.g. Kiwi SDR

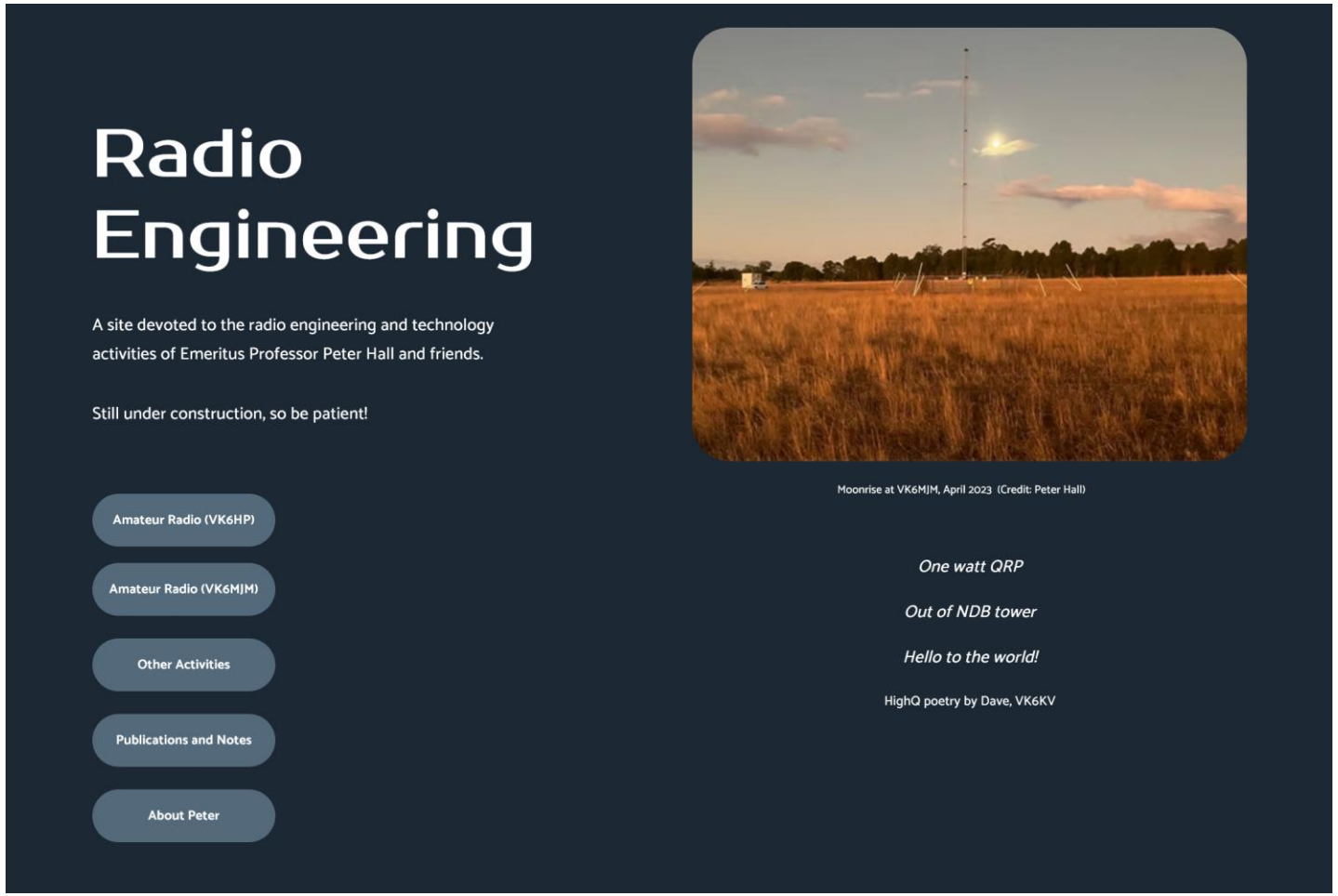
Closing thoughts

- VK6MJM is an unusual ham station, with a projected 5-10 year lifetime
- There is considerable scope for fun, engineering, science and education
  - Only minimally responsible to external stakeholders!
- VK6 location fills a void in the distribution of Global LF ham stations
- VK6MJM is particularly competitive on 136 kHz
  - RFI-quiet location; antenna efficiency allows EIRP limit to be reached easily
- New-generation LF/MF is a sandpit for electronics, antenna, propagation, edge-of-envelope communications, and IT/networking projects
  - And probably much else

Further VK6MJM reading



QEX, Jul/Aug 2024, pp. 9 -13



https://highqradio.com/

Starter LF references (selected)

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2. Antennas by N6LF, Rudy Severns (N6LF), https://www.antennasbyn6lf.com/
3. G0MRF Projects, David Bowman (G0MRF), https://g0mrf.com/
4. NDB antennas, John R Pinks, https://nautelnav.com/content/user_files/2023/05/NDB-ANTENNAS-Pinks-Jan-2012.pdf
5. Radio Antenna Engineering, Edmund A Laport, https://www.e-booksdirectory.com/details.php?ebook=1156 *(an old, but good, reference for LF antennas)*
6. Understanding LF Propagation, Alan Melia (G3YNK),in https://rsgb.org/main/files/2012/10/Understanding_LF_and_HF_propagation.pdf