Operating at LF and MF

The Experimenters’ Bands

137kHz and 475kHz

Andy Talbot   G4JNT / G8IMR
A Bit of History

• In 1996 We got an allocation at 73kHz, with up to 1 Watt ERP allowed

• 14 Feb 1997, G3LDO and G3XDV had a “QSO” over 200 metres across a car park
  – but that’s a capacitor!!!!

• ... so I started playing, first with a loop antenna, then a vertical, running 180 Watts from two Maplin audio amps in bridge.
A Bit more History

• ... And got 3km. This was a new record! Soon extended to 8km.

• Then to 99.6km with G3YGF driving around with a portable receiver. All one-way so far
  – People were getting interested, others came on the band.
  – First “DX” Two way, G4JNT/G3LDO 57km 23 Aug 1997

• Then G3PLX came along and changed the rules completely
Going Narrow

• With a Motorola 56002 (DSP kit of that era) he made a narrow band spectrum analyser, showing a waterfall in bandwidths of milli-Hz
• I wrote software to send 40s dot length CW
• He received this at 393km
• SlowCW (now called QRSS) was born
  – They said “It isn’t real amateur radio ...” they were wrong, of course.
31 July / 1 August 1997
Meanwhile – other stuff happened

- The Internet was new, and we set up one of the first user groups / reflectors. Exchanging ideas, and setting up skeds.
- Soundcards had arrived in PCs, and Richard Horne (a bird watcher) had written ‘SpectroGram’ audio waterfall display and monitoring software. QRSS for all.
Tech Moves On

- **VE2IQ** *Coherent* –
  - Error Corrected BPSK at 10 Bits/s
  - Dedicated hardware digitiser
- **Soundcard software appeared**
  - *WOLF* by KK7KA, 10BPS BPSK with better error correction
  - That and QRSS, first Transatlantic crossing on 73kHz by G0MRF et al.
  - 1kW Transmitter and vertical antenna using a church tower.
Rapid Progress

• The LF reflector was new, we’d never experienced such an effective real time exchange of ideas before.

• Everyone began to accept progress

• Old Decca transmitters appeared surplus, several stations got 1kW signals

• DX became the norm, although the UK was the only country that could transmit on 73kHz
A New Band, and another

• The success on 73kHz spurred the authorities to give us a new allocation at 137kHz
  – Most of Europe, but unfortunately not the US
  – PCs, data modes and techniques continued improving, WSPR appeared.

• A few years later, marine use of 500kHz stopped and we got NoVs to play there.
  – I ran a 100 Watt CW / PSK31 Beacon for over a year.

• Replaced with a worldwide 475kHz allocation,
  – Firstly by NoV, then incorporated in the new licence
The Licence Allows:

• 135.7 to 137.8kHz 2100Hz
  – 1 watt ERP (you’ll be lucky 😊)

• 472 to 479kHz 7000Hz
  – 5 watts EIRP (perhaps, if you work hard at it)

• No restrictions on modulation type,
  • Although voice isn’t used
Equipment

• Receiving - is dead-easy
  – Just about any general coverage amateur transceiver will go down to 470kHz at full spec.
  – Most cover 137kHz, although sensitivity may roll off
  – Any SDR that can do MF/HF will go down that far
  – Atmospheric noise is high, so noise figure is unimportant
  – Small RX antenna is OK. Tuneable loop is perfect

• For some advanced modes, frequency stability can be MORE critical than for microwaves.
PAORDT
Mini-Whip

The Antenna!  ... or is it?
Large receiving Loop (G0API)

- Made from Waveguide 17
- Has also been used for transmitting (at low power)
Antennas for Transmit

• Electrically small at 2.2km wavelength so:
  – Inefficient
  – Low bandwidth / narrowband
  – Need to be **BIG**

• But trade off against each other
  – The *Chu* limit
Antenna Types

• Loops
  – Convenient, easy to resonate (good caps)
  – 4\textsuperscript{th} power law of size / radiation resistance
  – Very inefficient if small
    3m diameter, 2 turns of 8mm copper tubing at 73kHz
    -63dB Gain !!!!!!!!
    500Hz bandwidth
Vertical

- Easier to build
  - But you need one of these
    >>
  - (73 kHz)
Vertical Antenna theory

\[ R_{RAD} = 1600 \left( \frac{h}{\lambda} \right)^2 \]

- Antenna Capacitance to Ground
- Loading Coil
  - Resonates Antenna Capacitance
- Radiation Resistance
  \( R_{RAD} \)
- Ground Loss
  \( R_{LOSS} \)
- Coil Loss
  \( R_{COIL} \)
- Height \( h \)
Top Hat

• Current tapers in a vertical to zero at the ends
  – A large capacitive top load keeps current in the vertical section almost constant

• 7 metre high Tee antenna at 137kHZ, with a big top hat, so $Heff. = 7m$ (near enough)

• $R_{rad} = 1600 \times \left(\frac{7}{2200}\right)^2 = 0.016\Omega$
Loading Coil

- $C_{\text{ANT}}$ is typically 7pF / metre of the total wire used, but with a much lower contribution from bunched parallel wires in top hats.

My system is 260pF. Loading coil has to resonate this, $L = 5.2\text{mH}$

Use Wheeler to estimate

$$L(\text{nH}) = \frac{(D.N)^2}{(0.46 \cdot D + \text{Length})} \quad [\text{mm}]$$

Eg. 150 turns, 300mm diameter, 250mm long. Wound on a fermentation bin.
G3LDO and G3XDV with their 73kHz loading coils in 1997
Grounding and radials

- Short antennas - The E-field dominates
  - Terminate that as losslessly as possible
    - Proximity Effect with nearby lossy materials
  - Radials, will be electrically short
  - Run under the top hat, and as far out as the antenna is high.

Lots of wire, ground rods, connect to utilities

Use everything possible, do whatever you can.
Losses

• Loading Coil
  – Skin Depth of wire
  – typical coil $R_L$ 6–20Ω at 137kHz,
  – so dominated by :

• Ground Resistance
  – Who knows! Measure it...
  – 130 - 180Ω at 137kHz. Lower with bigger antenna. Gain is more than height squared

• Weather dependent, PROXIMITY EFFECT
So - an inefficient antenna

- Loss = $R_{RAD}$ (16mΩ) / All losses (12Ω + 100 Ω)  
  = 0.00014 = -38dB  
  (and yes, the 10.LOG form is correct)

For 1W ERP we’re going to need ~ 6kW of RF

Double the height needs less than 1.5kW
Several stations use 10m antennas with 1kW
The Smell of Burning Plastic
- JNT System Parameters

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<td>Voltage on Antenna</td>
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- Not so bad at 475kHz
  - 300 W legal limit
Transmitters

- Very little commercial equipment – you generally have to **BUILD** stuff!
- Signal source
  - Kits, several DDS sources
  - Crystal osc. Divider. Mix two crystals
  - Few transverter designs, linear modes not used very much, although that may increase.
  - Some transceivers can do a few mW
Power Amps

• Switching Designs using MOSFETS are popular
  – Efficient (elec. bills)
  – Devices are cheap, FETs cost pennies
  – Easy with SMPSU components
  – BUT Constant Envelope Only: CW / MFSK Modes

• Linear with cheap MOSFETs is also easy
G0MRF 250W linear (kit)

100W Class-D (Switching) Amp

LF SWR Bridge

http://www.g0mrf.com
Two Big Ones

700W 137kHz Class D
400W 475kHz Class E

And a smaller one.  40W linear
80kHz – 2MHz
Test Equipment

• Field Strength
  – Loop in air with calibrated receiver:
    • $\text{dBW (EIRP)} = 65.8 + P_{RX} \text{ (dBm)} + 20 \cdot \log(D / (F \cdot A))$
      (km, MHz, m$^2$, Rx is $50\Omega R_{IN}$)

• Antenna Matching
  – Voltage / Current bridge (or SWR bridge)
  – Phase Meter – tuning is sharp, need zero X
  – Or VNWA
Operating

• Plenty of hand keyed on-off stuff on 475kHz
• Some on 137kHz, especially at weekends.
  – But unless you have a high power Tx, expect to only work local UK and perhaps Europeans
• QRSS is very popular
• Use Skeds and the LF reflectors
• WSPRIng 15 minute cycle introduced for LF, 9dB more sensitive
• Listen to SAQ special events on 17.2kHz
Grabbers
## Overnight WSPR operation

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WSPR on 475kHz
As heard by PI4THT

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Other Modes

• JT9, a new mode in the WSJT-X suite is gaining in popularity and allows real time QSOs
• Wolf 10 B/s BPSK (needs linear Tx)
• EbNaut ultra slow coherent BPSK, needs GPS or Rubidium stability