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.

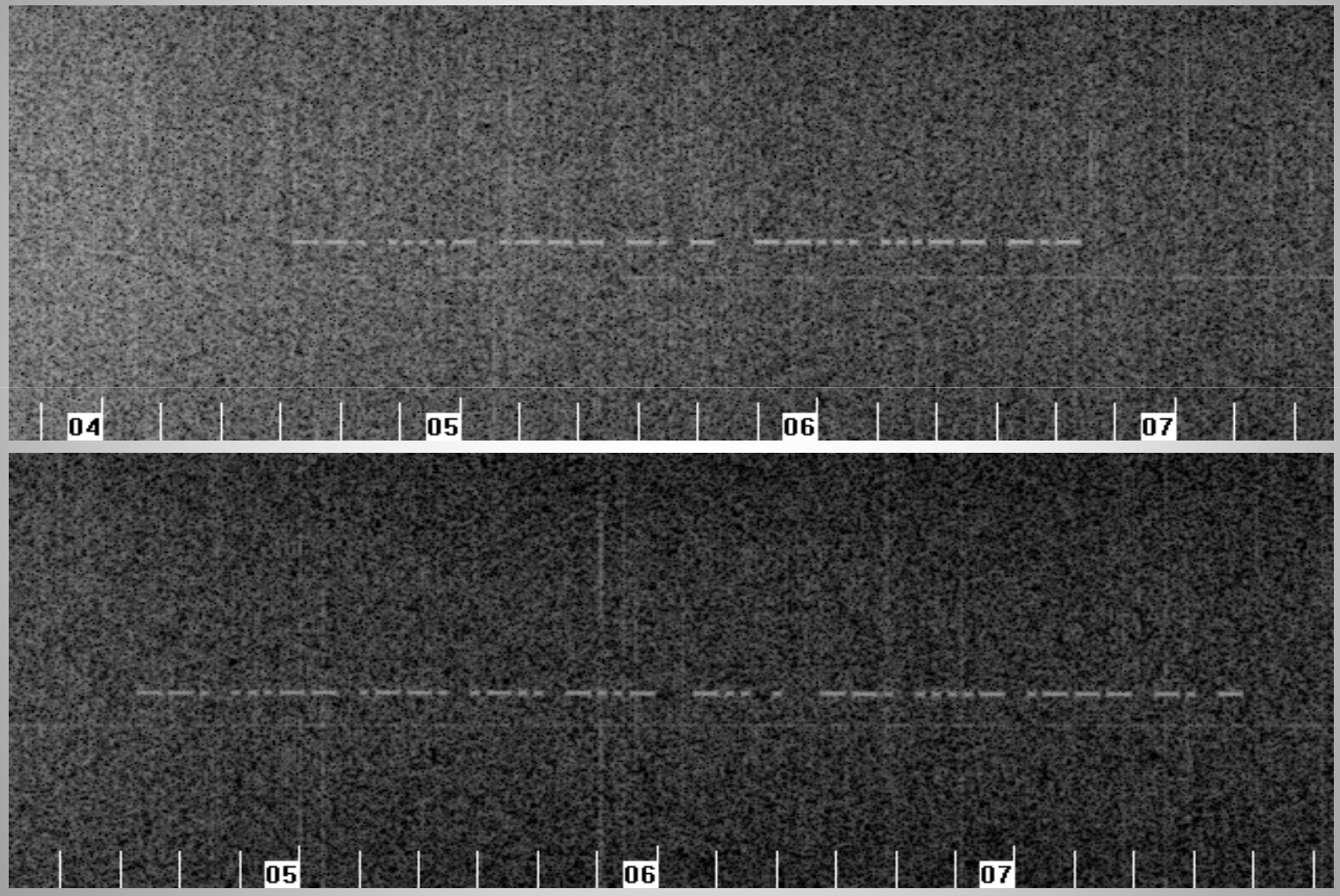
A Bit more History

- ... 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

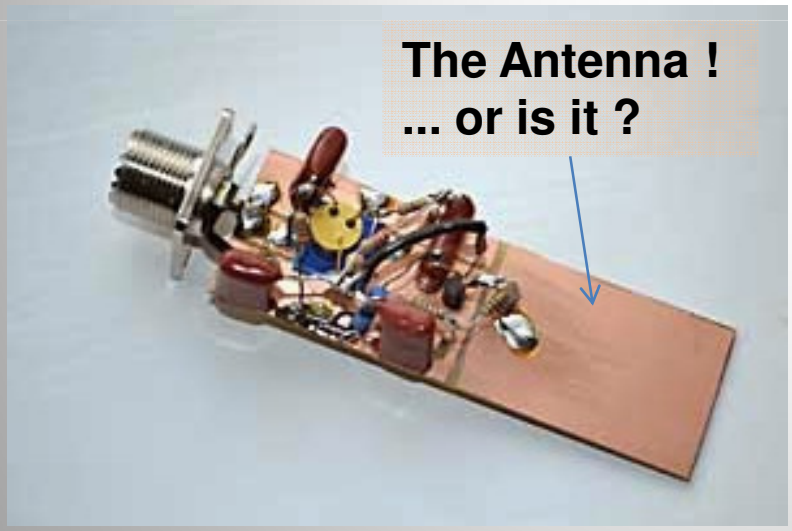
The Licence Allows :

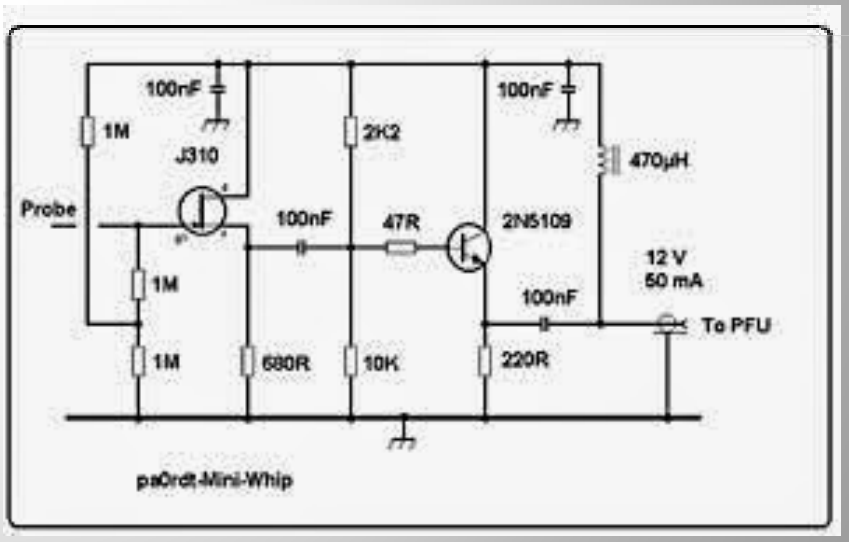
- 135.7 to 137.8kHz 2100Hz
  - 1 watt ERP (you'll be lucky ☺)
- 472 to 479kHz 7000Hz
  - 5 watts EIRP (perhaps, if you work hard at it)
- No restrictions on modulation type,
  - Although voice isn't used

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.

PA0RDT Mini-Whip





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^{th} power law of size / radiation resistance
  - Very inefficient if small

    3m diameter, 2 turns of 8mm copper tubing at 73kHz

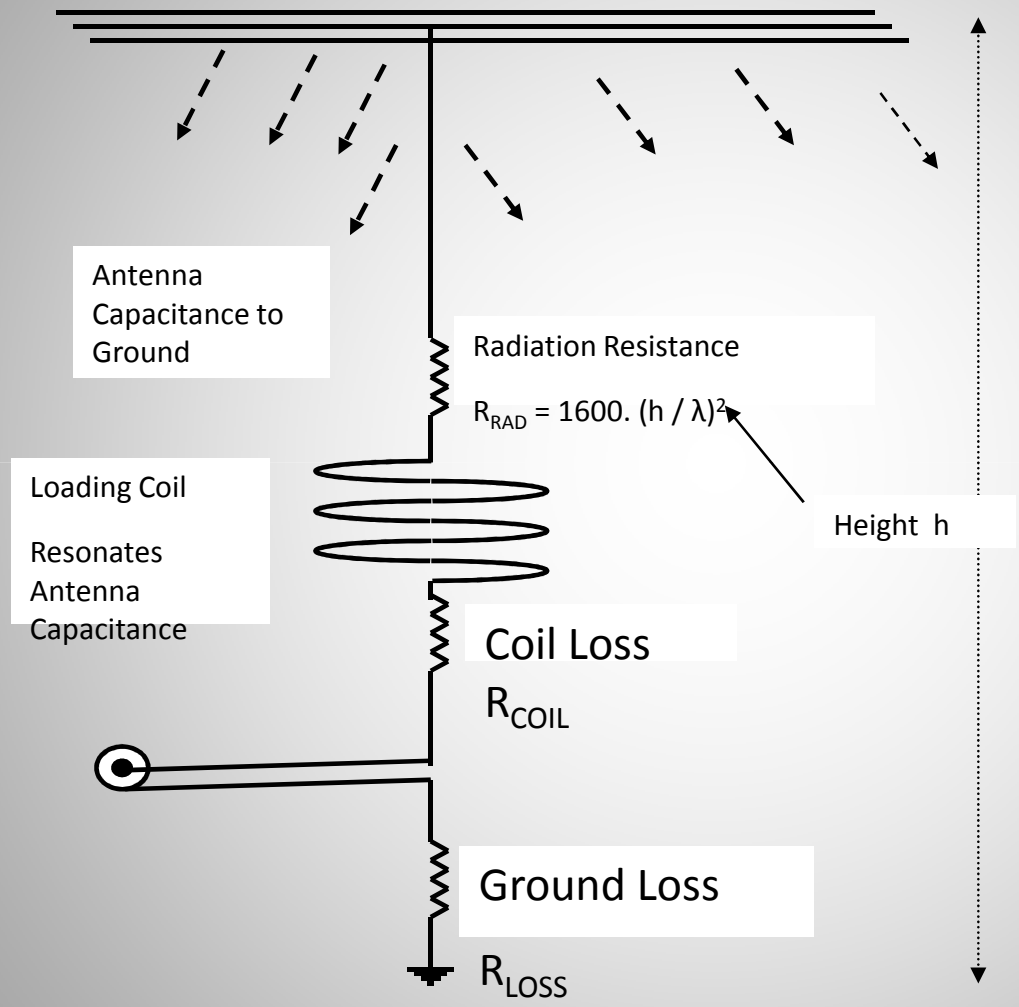
    -63dB Gain !!!!!!!

    500Hz bandwidth

Vertical

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

Vertical Antenna theory



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)
- Rrad = $1600x(7/2200)^2 = 0.016\Omega$

Loading Coil

- C_{ANT} is typically 7pF / metre of the <u>total</u> 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 = 5.2mH

Use Wheeler to estimate

$$L(nH) = (D.N)^2 / (0{\cdot}46\ D + Length) \quad [mm]$$

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

Monopole Radiation Factor	3			Alter figures in BLUE only
Frequency	137	kHz		
Eff. Height	7	m		
Capacitance	260	pF		
Total resistance	150	ohms		
Power input	700	Watts		
I_{rf}	2.2	A		
Fract lambda	0.0032			
Rrad	0.0164	ohms		
Loading Coil	5190.7	uH		
Efficiency	-39.6	dB		
EIRP	0.229	W	=	-6.4 dBW
			=	23.6 dBm
Voltage on Antenna	9652	V (RMS)		

- 'JNT System Parameters

Monopole Radiation Factor	3			Alter figures in BLUE only
Frequency	476	kHz		
Eff. Height	7	m		
Capacitance	260	pF		
Total resistance	35	ohms		
Power input	300	Watts		
I_{rf}	2.9	A		
Fract lambda	0.0111			
Rrad	0.1977	ohms		
Loading Coil	430.0	uH		
Efficiency	-22.5	dB		
EIRP	5.083	W	=	7.1 dBW
			=	37.1 dBm
Voltage on Antenna	3765	V (RMS)		

- Not so bad at 475kHz
  - 300 W legal limit

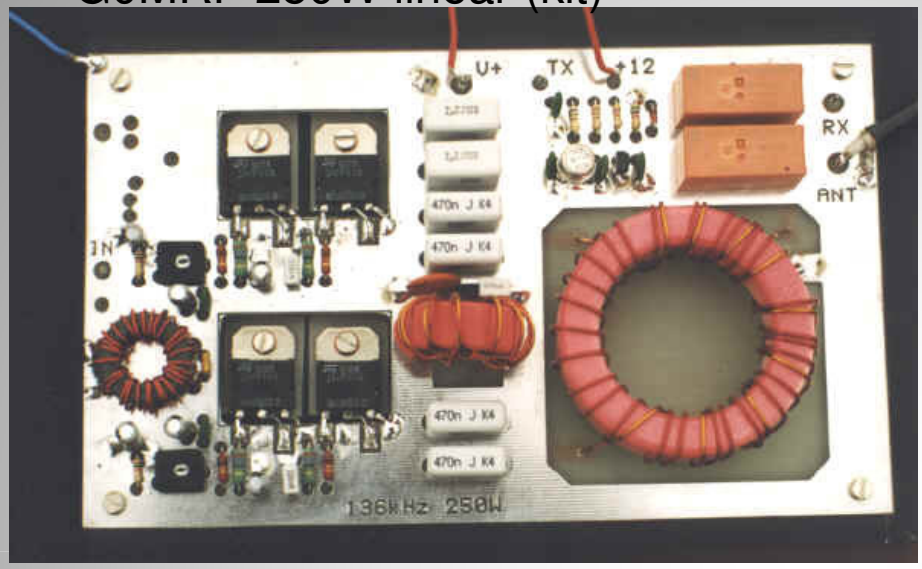
Transmitters

- 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

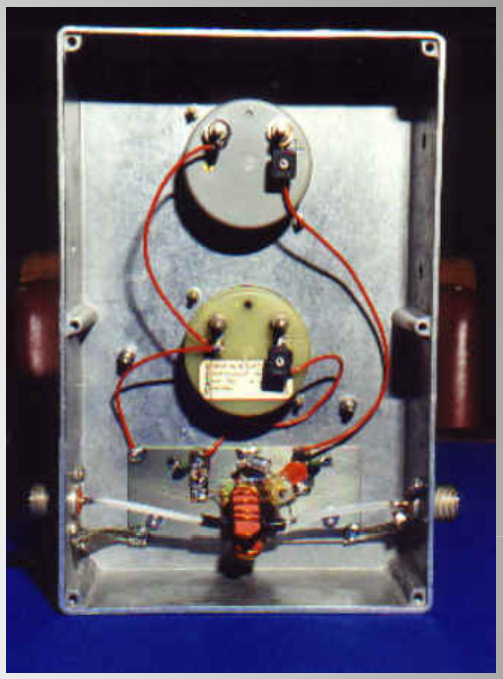
Power Amps

- 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

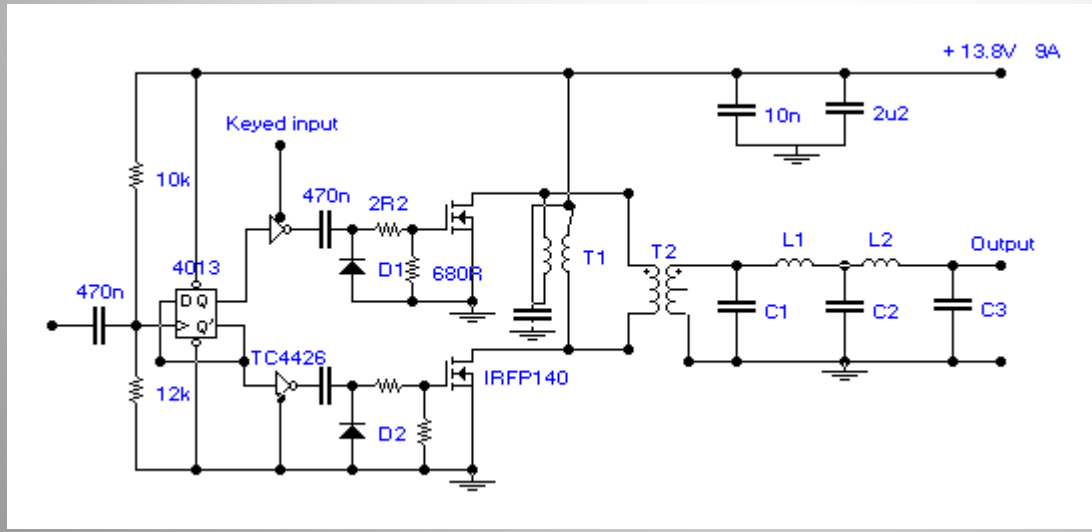
G0MRF 250W linear (kit)



LF SWR Bridge

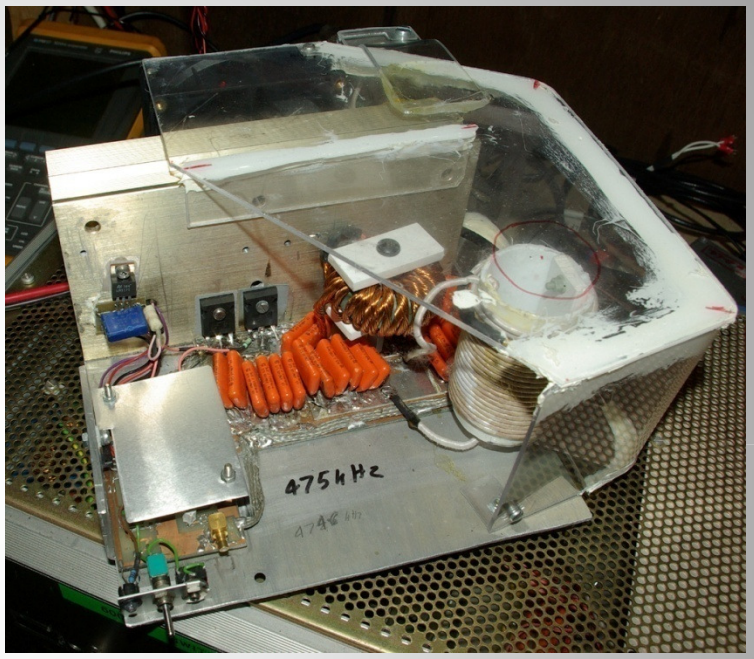


100W Class-D (Switching) Amp



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:
    - dBW (EIRP) = 65.8 + P_{RX} (dBm) + 20.LOG(D / (F . A))

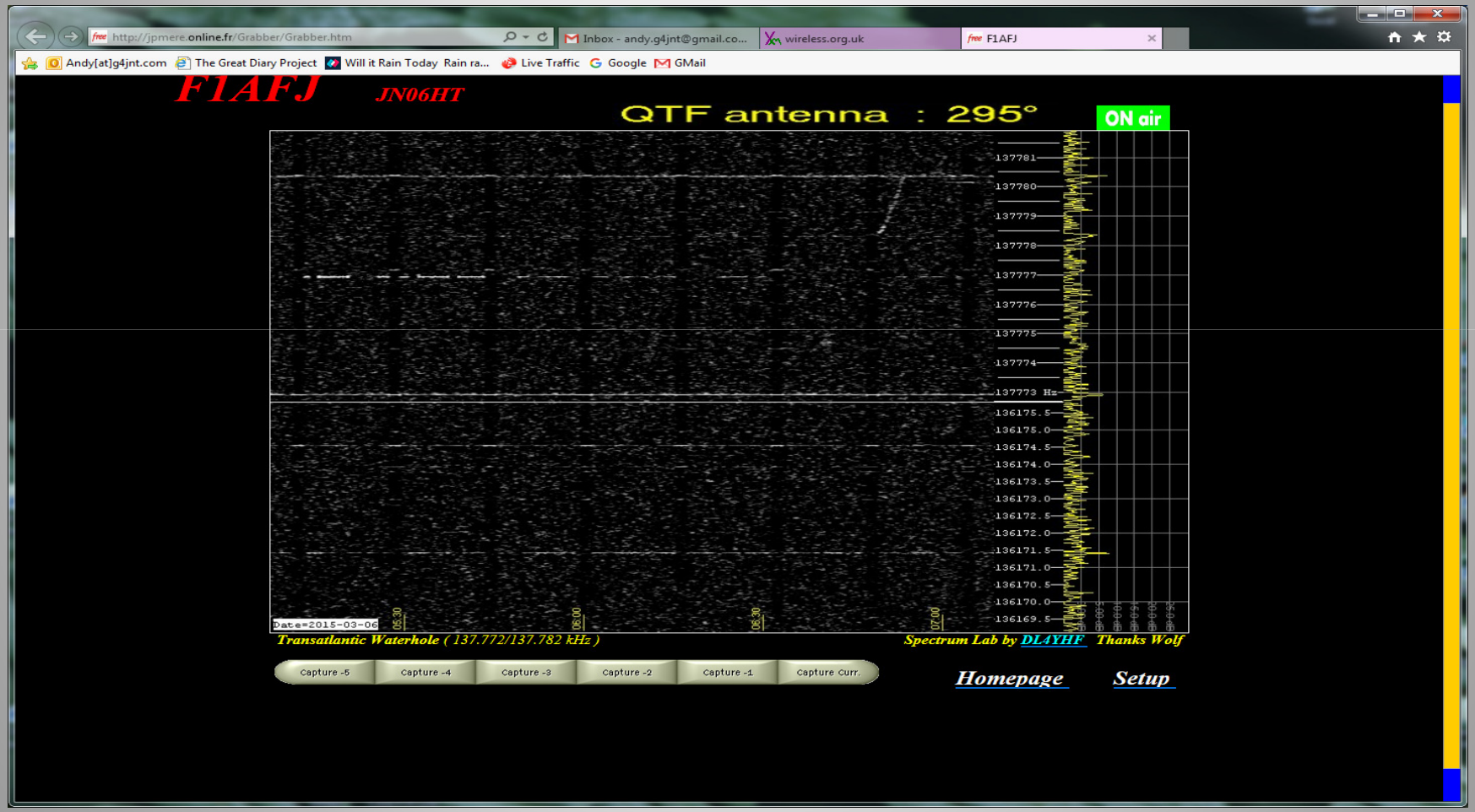
      (km, MHz, m^2 , Rx is 50Ω R_{IN})

- 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


http://jpmere.online.fr/Grabber/Grabber.htm
Inbox - andy.g4jnt@gmail.co...
wireless.org.uk
F1AFJ
Andy[at]g4jnt.com
The Great Diary Project
Will it Rain Today Rain ra...
Live Traffic
Google
GMail
F1AFJ
JN06HT
QTF antenna : 295°
ON air
137781
137780
137779
137778
137777
137776
137775
137774
137773 Hz
136175.5
136175.0
136174.5
136174.0
136173.5
136173.0
136172.5
136172.0
136171.5
136171.0
136170.5
136170.0
136169.5
Date=2015-03-06
05:30
06:00
06:30
07:00
Transatlantic Waterhole (137.772/137.782 kHz)
Spectrum Lab by DL4YHF Thanks Wolf
Capture -5
Capture -4
Capture -3
Capture -2
Capture -1
Capture Curr.
Homepage
Setup

Overnight WSPR operation

Timestamp	Call	MHz	SNR	Drift	Loc	Pwr	Reporter	Loc	km	az
WSPR 2										
2016-02-21 07:50	G4JNT	0.137474	-10	0	IO90iv	0.2	G3XKR	IO70ux	210	274
2016-02-21 07:40	G4JNT	0.137474	-28	0	IO90iv	0.2	PI4THT	JO32kf	583	72
2016-02-21 06:52	G4JNT	0.137474	-23	0	IO90iv	0.2	DF6MK	JN68ik	1042	100
2016-02-20 20:04	G4JNT	0.137474	-27	0	IO90iv	0.2	DF6NM	JN59nj	899	96
2016-02-20 19:18	G4JNT	0.137474	-20	0	IO90iv	0.2	G6AVK	JO01ho	155	59
2016-02-20 09:54	G4JNT	0.137474	-3	0	IO90iv	0.2	G3XIZ	IO92ub	147	28
2016-02-20 08:16	G4JNT	0.137474	+19	0	IO90iv	0.2	F6CNI	JN19qb	391	120
2016-02-20 07:14	G4JNT	0.137474	-17	0	IO90iv	0.2	DF2JP	JO31hh	554	82
2016-02-20 06:24	G4JNT	0.137474	-18	0	IO90iv	0.2	2E0ILY	IO82qv	240	338
2016-02-20 05:48	G4JNT	0.137474	-13	0	IO90iv	0.2	G0HWW	JO02if	203	42
2016-02-20 05:04	G4JNT	0.137474	-27	0	IO90iv	0.2	DL6OW	JO31kk	572	81
2016-02-20 02:22	G4JNT	0.137474	-26	0	IO90iv	0.2	DK7FC	JN49ik	730	99
2016-02-19 22:48	G4JNT	0.137475	-22	0	IO90iv	0.2	PA7EY	JO22jj	451	66
2016-02-19 21:02	G4JNT	0.137474	-10	0	IO90iv	0.2	M0DSZ	IO82ls	241	331
2016-02-19 20:46	G4JNT	0.137475	-25	0	IO90iv	0.2	GW4NOS	IO81gp	172	300
WSPR 15										
2016-02-21 07:00	G8IMR	0.137607	-17	0	IO90iv	0.2	2E0ILY	IO82qv	240	338
2016-02-21 05:15	G8IMR	0.137607	-35	0	IO90iv	0.2	DL6OW	JO31kk	572	81
2016-02-21 05:15	G8IMR	0.137607	-33	0	IO90iv	0.2	SM2DJK	KP03au	1908	33
2016-02-20 22:46	G8IMR	0.137607	-29	0	IO90iv	0.2	DF6NM	JN59nj	899	96
2016-02-20 22:46	G8IMR	0.137607	-11	0	IO90iv	0.2	G3XKR	IO70ux	210	274
2016-02-20 09:16	G8IMR	0.137607	-23	0	IO90iv	0.2	PA7EY	JO22jj	451	66
2016-02-20 06:30	G8IMR	0.137606	-5	0	IO90iv	0.2	G3XDV	IO91vt	127	36
2016-02-20 06:30	G8IMR	0.137607	-20	0	IO90iv	0.2	DF2JP	JO31hh	554	82
2016-02-20 06:30	G8IMR	0.137607	-29	0	IO90iv	0.2	DK7FC	JN49ik	730	99
2016-02-20 01:00	G8IMR	0.137607	-23	0	IO90iv	0.2	G6AVK	JO01ho	155	59

WSPR on 475kHz

As heard by PI4THT

•	2016-02-16 04:06	G8HUH	0.475650	-13	0	IO81mg	1	PI4THT JO32kf 685 km 77 deg
•	2016-02-15 22:36	DH0PAZ	0.475674	-15	4	JO30nm	0.2	PI4THT JO32kf 191 355
•	2016-02-15 22:24	F1AFJ	0.475704	-18	0	JN06ht	1	PI4THT JO32kf 752 34
•	2016-02-15 21:32	PA3ABK/2	0.475740	+4	0	JO21it	0.5	PI4THT JO32kf 155 72
•	2016-02-15 21:26	PA3GHJ	0.475725	-26	0	JO22gb	50	PI4THT JO32kf 160 82
•	2016-02-15 21:20	DK6NI	0.475733	-9	0	JN59ln	0.1	PI4THT JO32kf 412 318
•	2016-02-15 21:00	IW4DXW	0.475796	-17	0	JN64bw	0.5	PI4THT JO32kf 897 336
•	2016-02-15 20:24	G7NKS	0.475700	-10	0	IO92ub	0.05	PI4THT JO32kf 489 85
•	2016-02-15 20:02	DL6TY	0.475670	+3	0	JO44lo	1	PI4THT JO32kf 298 208
•	2016-02-15 19:30	DK6XY	0.475718	-15	0	JO53jv	0.2	PI4THT JO32kf 321 236
•	2016-02-15 17:50	DK7FC	0.475683	+6	0	JN49ik	1	PI4THT JO32kf 336 338
•	2016-02-15 17:46	PA0A	0.475731	+5	0	JO33de	2	PI4THT JO32kf 114 160
•	2016-02-15 16:54	DK2DB	0.475642	-18	0	JN48fw	0.5	PI4THT JO32kf 383 344
•	2016-02-15 16:32	F6GEX	0.475767	-27	0	IN97na	0.5	PI4THT JO32kf 804 41
•	2016-02-15 16:20	DJ0ABR	0.475665	-19	1	JN68nt	0.2	PI4THT JO32kf 582 313
•	2016-02-15 16:16	DL2WB	0.475778	-24	0	JN39qh	0.2	PI4THT JO32kf 326 354
•	2016-02-15 16:14	DD2UJ	0.475618	-17	-4	JO61wc	0.2	PI4THT JO32kf 498 287
•	2016-02-15 15:54	LA3EQ	0.475776	-25	0	JO28xj	1	PI4THT JO32kf 688 175
•	2016-02-15 15:52	DH5RAE	0.475755	-16	0	JN68qv	0.5	PI4THT JO32kf 590 311
•	2016-02-15 14:54	G3XIZ	0.475621	-15	0	IO92ub	0.05	PI4THT JO32kf 489 85
•	2016-02-15 13:18	DL6II	0.475711	-4	0	JO30nx	0.5	PI4THT JO32kf 140 353
•	2016-02-15 13:10	DF2JP	0.475623	-17	0	JO31hh	1	PI4THT JO32kf 103 9

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