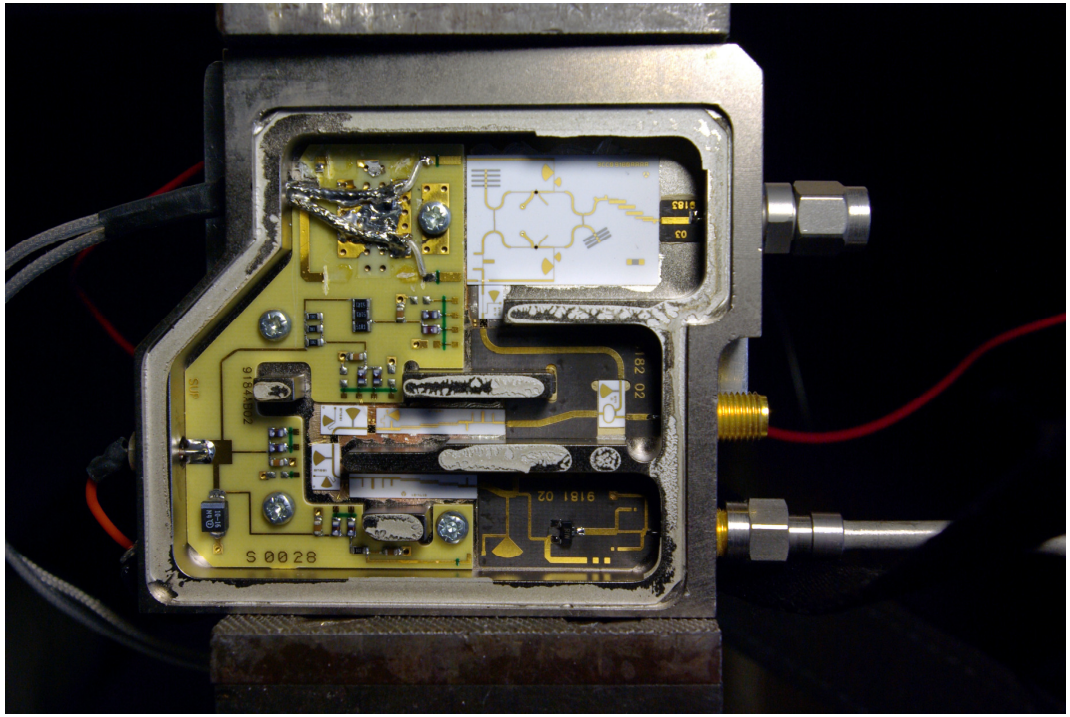
A 24 GHz beacon source using IQ upconversion

Andy Talbot G4JNT

White Box Modules

- Drive is LO/2 to a pair of Subharmonic mixers
  - Internal Doubler for drive at 6GHz
- Quadrature image cancelling mixer at 24GHz
- 90° Hybrid at ~700MHz

- Remove the hybrid and go direct to diodes



A Very Simple Solution

- DC Through diodes just controls level
- ON-OFF with ramping
- Wasteful, throws away the image cancelling capability

Baseband upconvert

- Direct Baseband drive to diodes, I/Q folded spectrum
  - (third method SSB generation)
- Quadrature audio DDS, analogue allpass OPAmps, or DSPIC
- OPAMPs need to present a 50Ω source, but only have to supply <1.5V pk-pk drive. So NE553x opamps and resistors work FB.

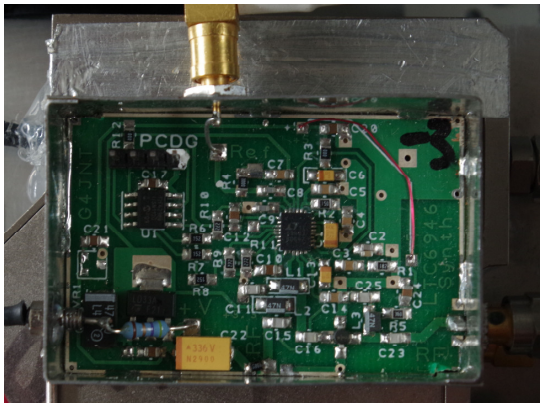
- Need to generate exact centre frequency for LO

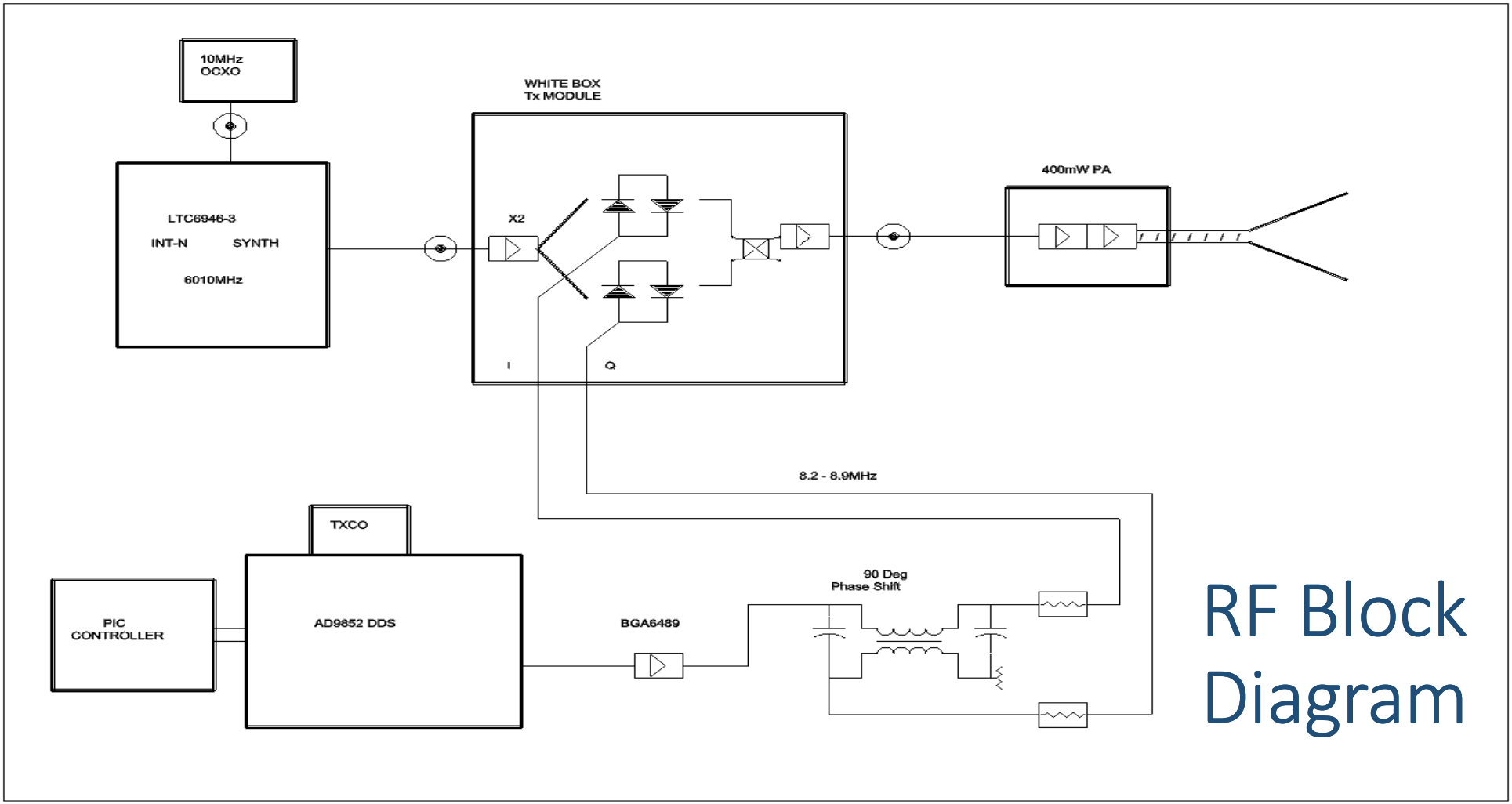
Frequency Setting

- No scope for fiddling with centre frequency using Direct U/C.
- So we must use a Fract-N synth or sit on a wide spaced grid
  - Fract-N at 24GHz is potentially going to be a bit noisy and spurious-ridden
  - And has to generate at 6GHz
- ADF5355 is an off the shelf solution, but as I only had one of those and didn’t want to dedicate it to a beacon, what other options were there?

Low IF With Integer-N synth

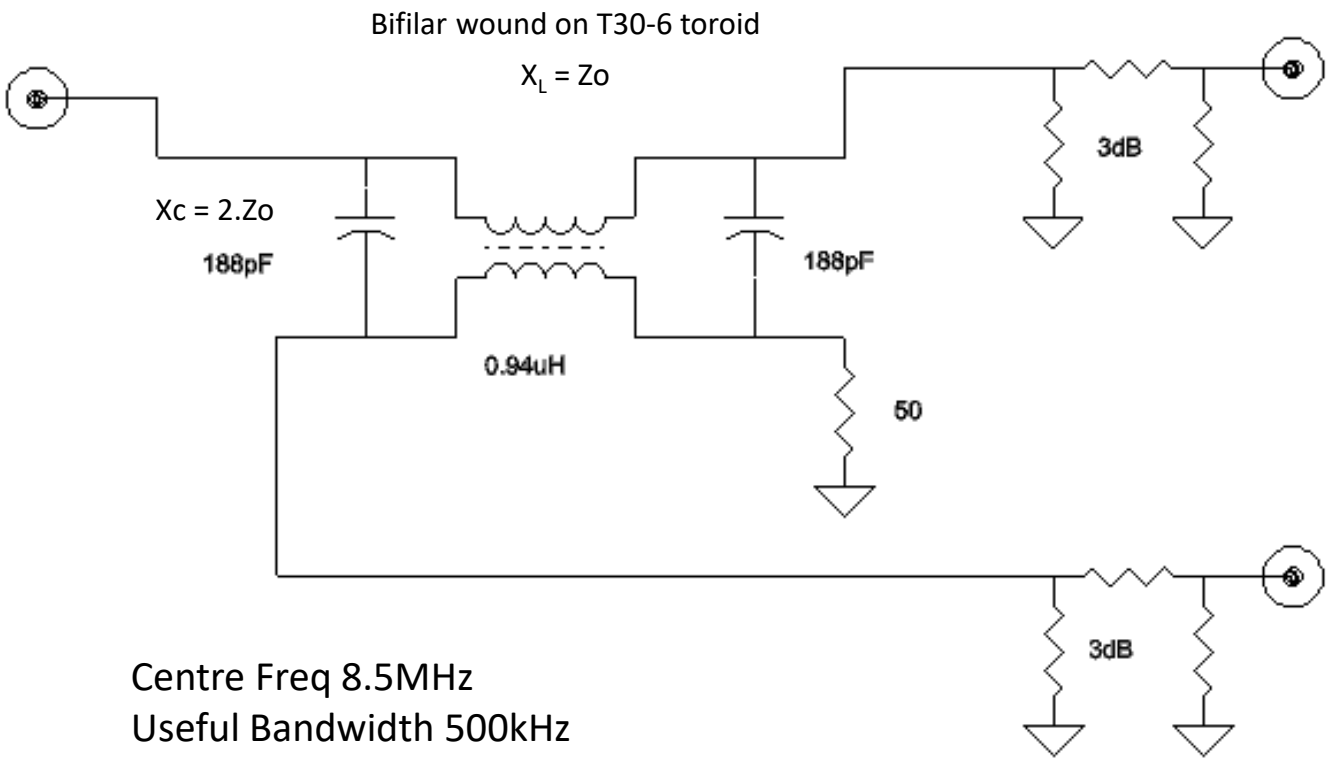
- How about a DDS for full frequency agility, upconverted using image reject.
- Band 24 to 24.05 is amateur primary – so image leakage on the low side is unlikely to be an issue
  - It's not as if there are many users down there !
- Keep the numbers simple – 24040MHz LO,
  - LTC6946-3 Integer-N Synth at 6010MHz with 10MHz OCXO (High F_{comp})
- 8.xx MHz drive from DDS
  - 20MHz TCXO clock for a 'few Hz' accuracy.
- Image < -25dBc at ~24031MHz

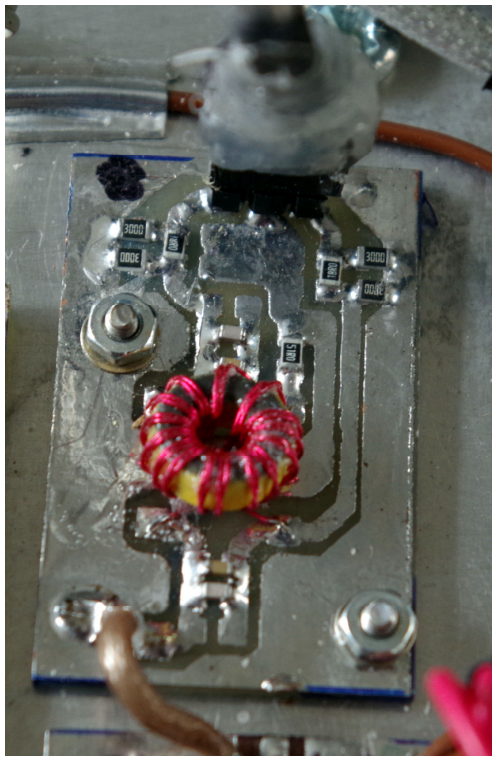




RF Block Diagram

90 Degree Hybrid

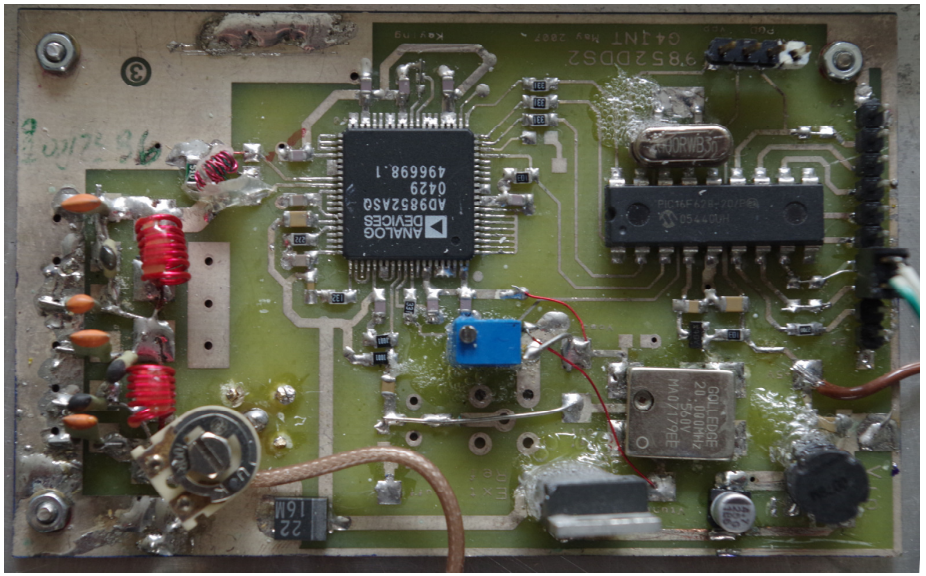




Centre Freq 8.5MHz
Useful Bandwidth 500kHz

DDS Source

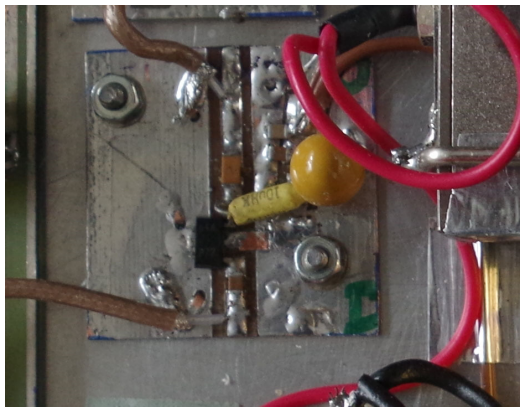
- AD9852 Module already to hand.
- Plenty of PIC firmware for all data modes
- Offers frequency and amplitude variation



- -4dBm output
- Max drive to diodes is around +12dBm each.

Gain Block

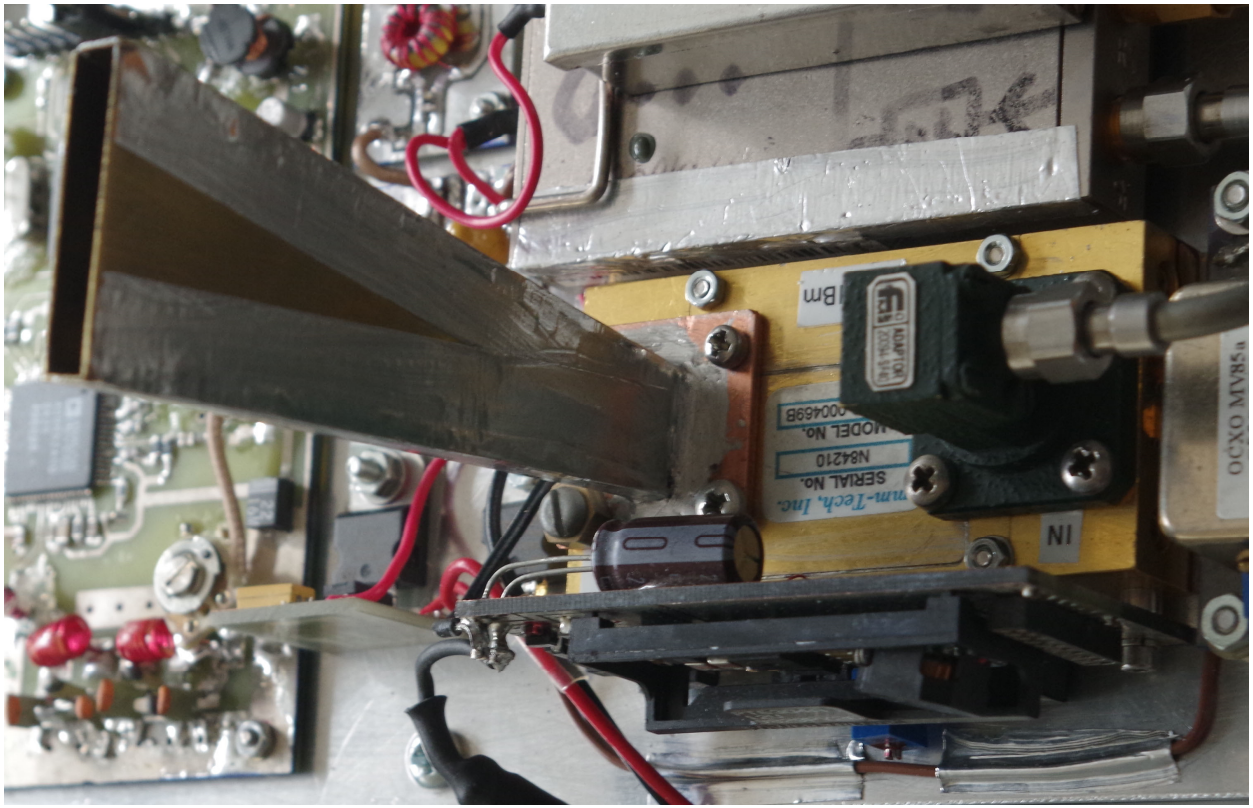
- Diodes need max +12dBm each
- Quad network has -6dB each channel
- So hybrid needs 18 – 19dBm drive



- -4dBm from DDS
- BGA6489 MMIC
- Not intended for this low frequency, but it works!
  - +20dBm P_{1dB}
  - > 23dB gain
- Plenty of gain margin

RF Power Amp

- 400mW (ish) Module from µWave Roundtable
- Self contained SMPSU with 12V input



Power Supply

- All modules apart from PA run from nominal 5V
  - 5.2V for WB converter
- First thoughts, 12V to 5.2V buck converter.
- Couldn’t get it clean enough, as the 5V goes direct to RF circuitry.
- Two linear converters, LM317 for 5.2V and LM7805 supplied from buck converter to 7.7V
  - Good filtering in dedicated screened box with feed-throughs.
- Total current consumption 1.6A at 13V with OCXO stabilised
- 20 Watts of heat generated

Cooling

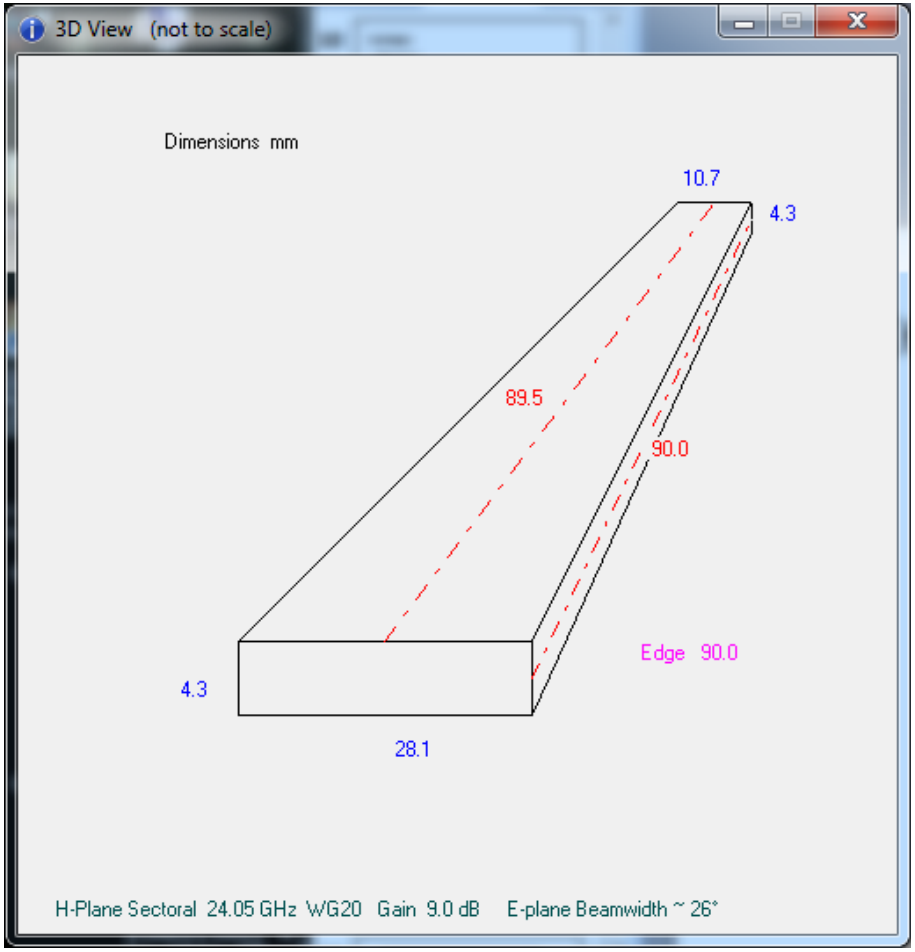
- Traditional solution, metal box with heatsink
  - Waterproofing nightmare
- Plastic box for waterproofing, ~ 20W/K across thickness, insignificant
- All modules mounted on thick Al baseplate to share heat dissipation
- Fan inside rapidly circulates air
- All the box surfaces work as heatsink 0.27m^2
- After several hours in summer temperature indoors, surface of plastic box is about 10 - 15 deg above ambient
- Hottest items inside sit at around 45C

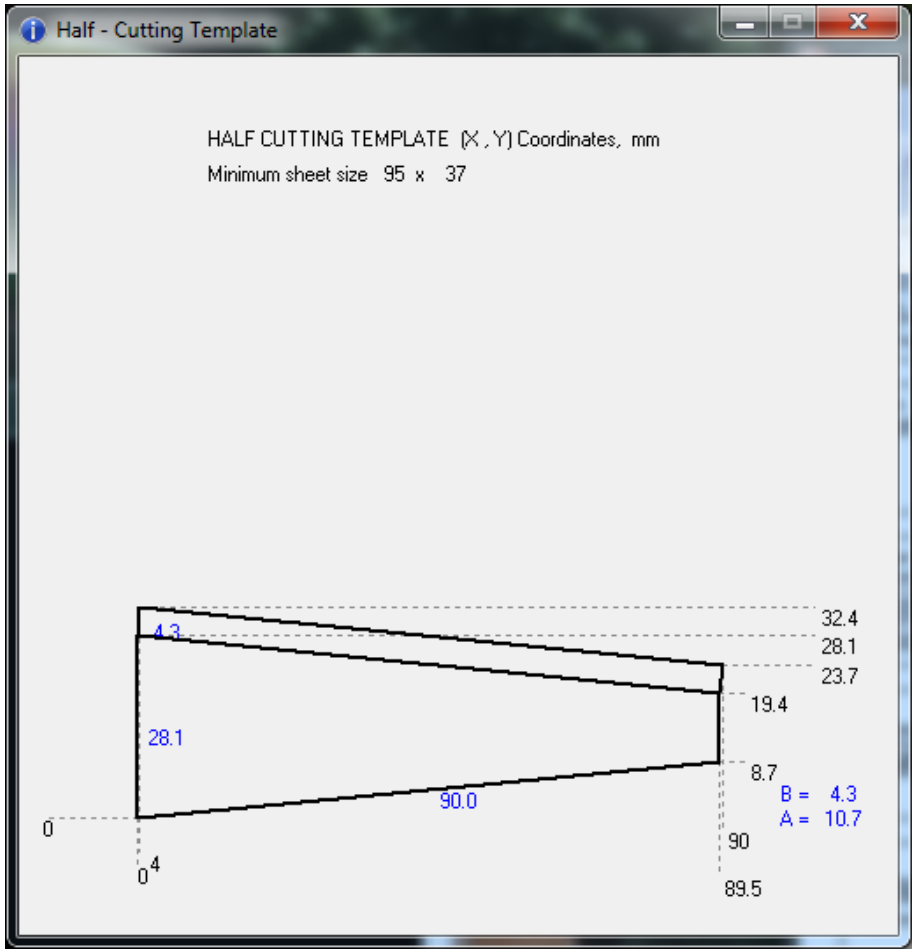
Antenna

- Omni would be nice, but slotted waveguide at 24GHz is not easy.
- H-plane Sectoral Horn is next best compromise
- 9dBi , 20deg vertical beamwidth, wide azimuth

- G8AGN Horn design software
  - Latest ‘JNT version for Windows
  - Gives cutting templates

Antenna


3D View (not to scale)
Dimensions mm
10.7
4.3
89.5
90.0
Edge 90.0
4.3
28.1
H-Plane Sectoral 24.05 GHz WG20 Gain 9.0 dB E-plane Beamwidth ~ 26°

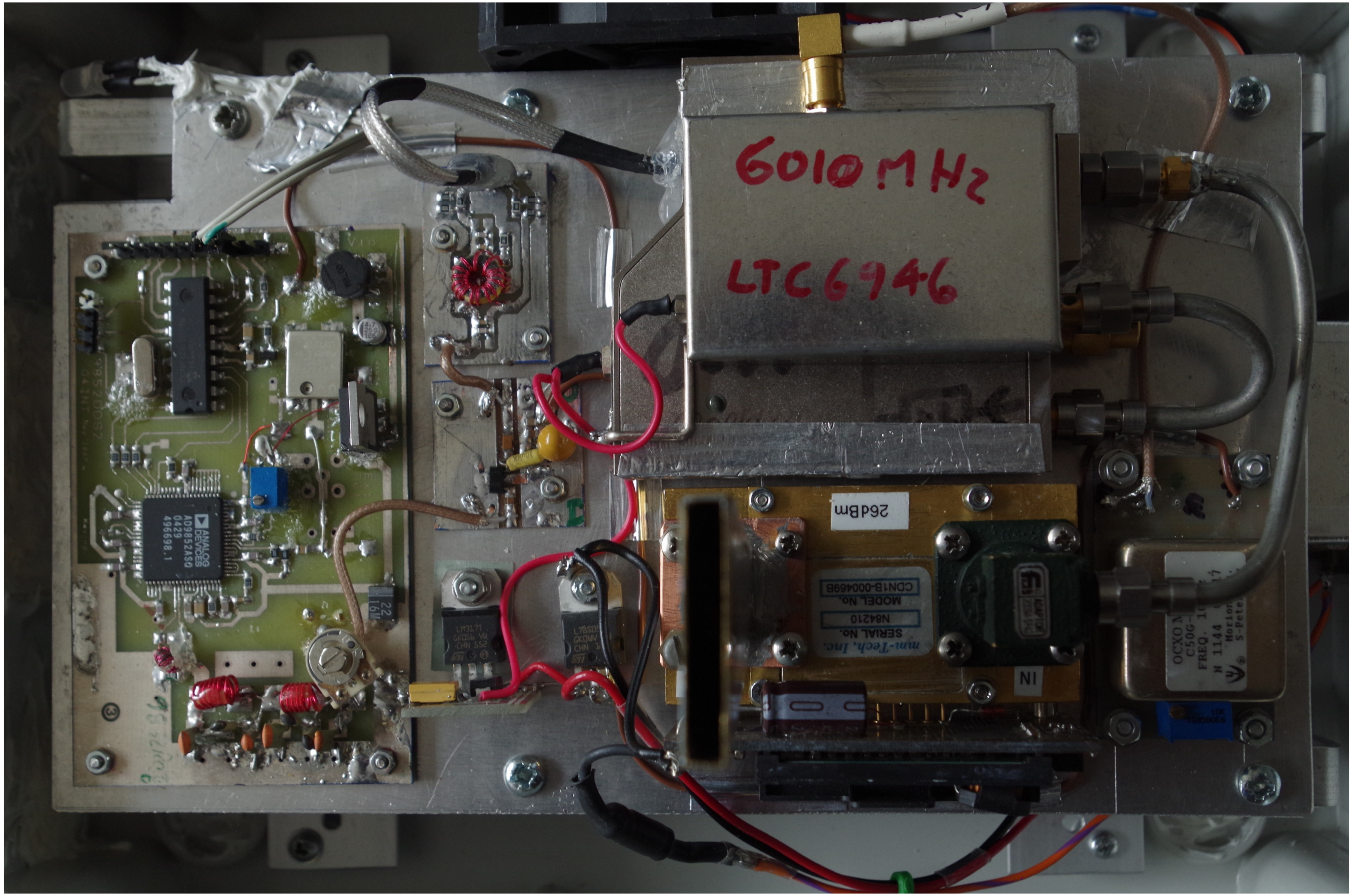

Half - Cutting Template
HALF CUTTING TEMPLATE (X , Y) Coordinates, mm
Minimum sheet size 95 x 37
4.3
32.4
28.1
23.7
19.4
28.1
8.7
B = 4.3
A = 10.7
90.0
0
0
4
90
89.5

Modulation

- As this is a sort of ad-hoc setup-and-drive-out beacon with no GPS …
- For once, and completely contra to normal ‘JNT-think …
- An audio modulation rather than digital mode is called-for
- And just plain CW will never be an option

- Reprogramme the DDS with 3Hz increment every 0.8ms generates a sweep. Reset after 700 steps gives 2100Hz chirp every 0.56s
- And… might as well … a CW ident, using raised-cosine ramp.

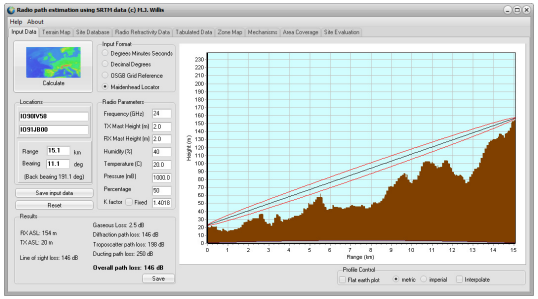
  - Spot the phase noise and AGC pumping


6010 MHz
LTC6946
26dBm

Results

- At 24028.5 MHz Opposite sideband leakage, -25dBc
- At 24048.8 MHz best value -32dBc
- No trimming of I/Q paths; no doubt that could be improved

- Some close-in DDS spurii around -60dBc
  - Changes rapidly with the sweep
- No other spurii from synth
- Mounted on my mast, I can receive it at Cheesefoot Head 5/9



Cheesefoot Head

A view from behind.

02:00
12 Aug 2017