241 GHz
- a new challenge

Roger Ray G8CUB
Chris Whitmarsh G0FDZ

What is the 241 GHz band?

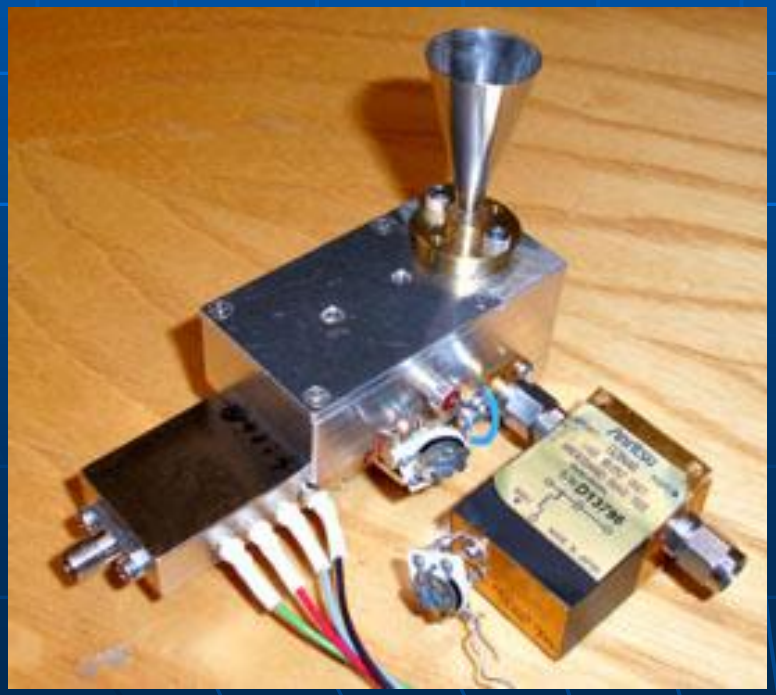
The 241 GHz band is the highest frequency allocated to UK licensees where we have 9 GHz of spectrum available to use

241000-248000	Secondary	Secondary (satellite)	400W (26 dBW)
248000-250000	Primary	Primary (satellite)	400W (26 dBW)

Note that the section from 248 – 250 GHz is Primary status. The Secondary segment from 241 to 248 GHz is shared with the Radio Astronomy and Radiolocation services !

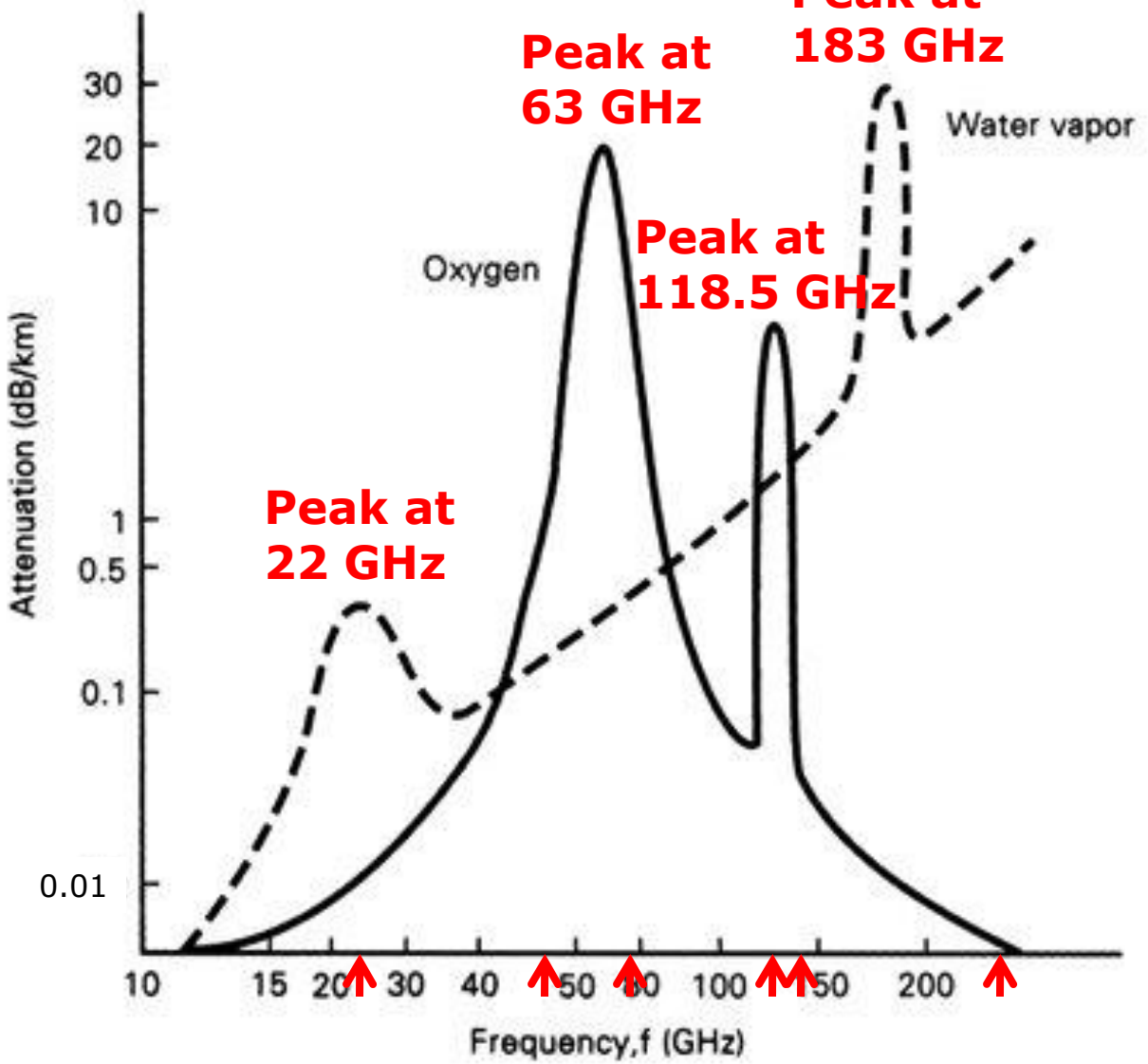
241 GHz - 1.2mm

- Much more difficult than 134 GHz
- A lot of test gear stops working at < 200GHz
- Waveguide very small WR-03 – 1 or 0.9 mm hole
- High gain antennas required – very directional



Propagation at 241 GHz

- Propagation – virtually nothing is known in any detail, of propagation at this frequency although it is obviously very much 'line of sight'
- Free space loss over 1km is around 140dB
- Just like lower millimetre wave frequencies, atmospheric water vapour gives extra path loss, but there is no nearby 'peak' unlike some other bands
- Oxygen losses are however very low at less than 0.01 dB per km.
- The FCC publish a useful document on millimetre wave propagation



Water and oxygen losses at millimetre waveband frequencies

Amateur bands

When is the best time to operate on 241 GHz

- Just like other millimetre wave bands where water vapour adds to the path loss, the best time is when the dew point is low.
- This normally means that the temperature is coldest.
- The usual tools and software can be used to determine dew point and measure relative humidity
- Brian WA1ZMS operating on this band in a very low temperature, told me that he nearly lost his toes due to frostbite!

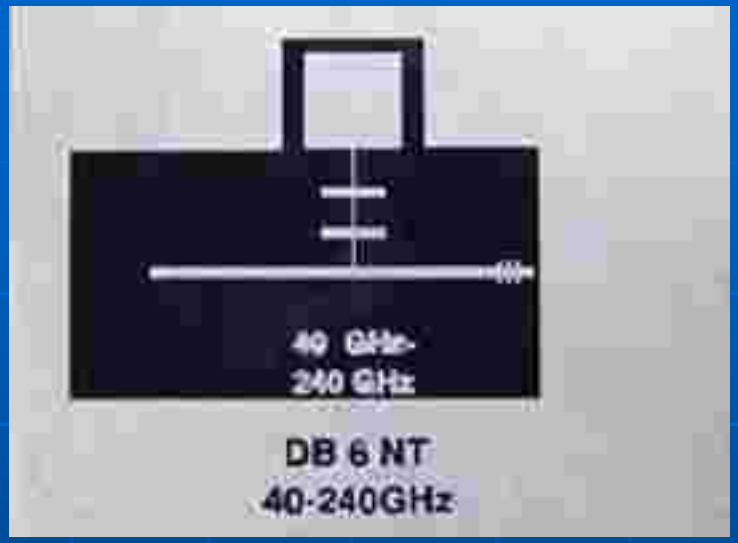
241 GHz equipment choices

- A DB6NT sub-harmonic mixer design is available but is very inefficient as it uses the 10th harmonic of a 24 GHz LO frequency for the mixer
- The RF output likely to be very low – probably <10 µW at best !!
- LO frequency accuracy is paramount, stability is extreme so a PLL 11.45 GHz low noise source for the LO is essential
- CW is the probably the easiest mode to use at this frequency to eliminate transmit mixer conversion losses. The mixer is used only on receive.
- Mixer can be used only on receive and a separate TX used (also good for test source)

241 GHz equipment choices

- Very few designs available – mainly DB6NT and DL2AM – boards available from Khune
- RF output will be very low – probably <1 µW at best !!
- Chris G0FDZ used drive at 34 GHz as the 7th harmonic for the mixer instead of the 10th harmonic
- Roger G8CUB tried using 80 GHz LO drive but insufficient LO power was the problem
- CW is the probably the easiest mode to use at this frequency and A1A CW can be achieved by using a PIN switch to key the 11 GHz drive on the transmit frequency.
- Alternative is to use FSK if the LO permits
- Some form of crude sidetone very desirable !

241 GHz equipment choices



WR28 (WG22) IP
1mm WG OP
DUBUS 1.2009
241 GHz Transverter
DL2AM

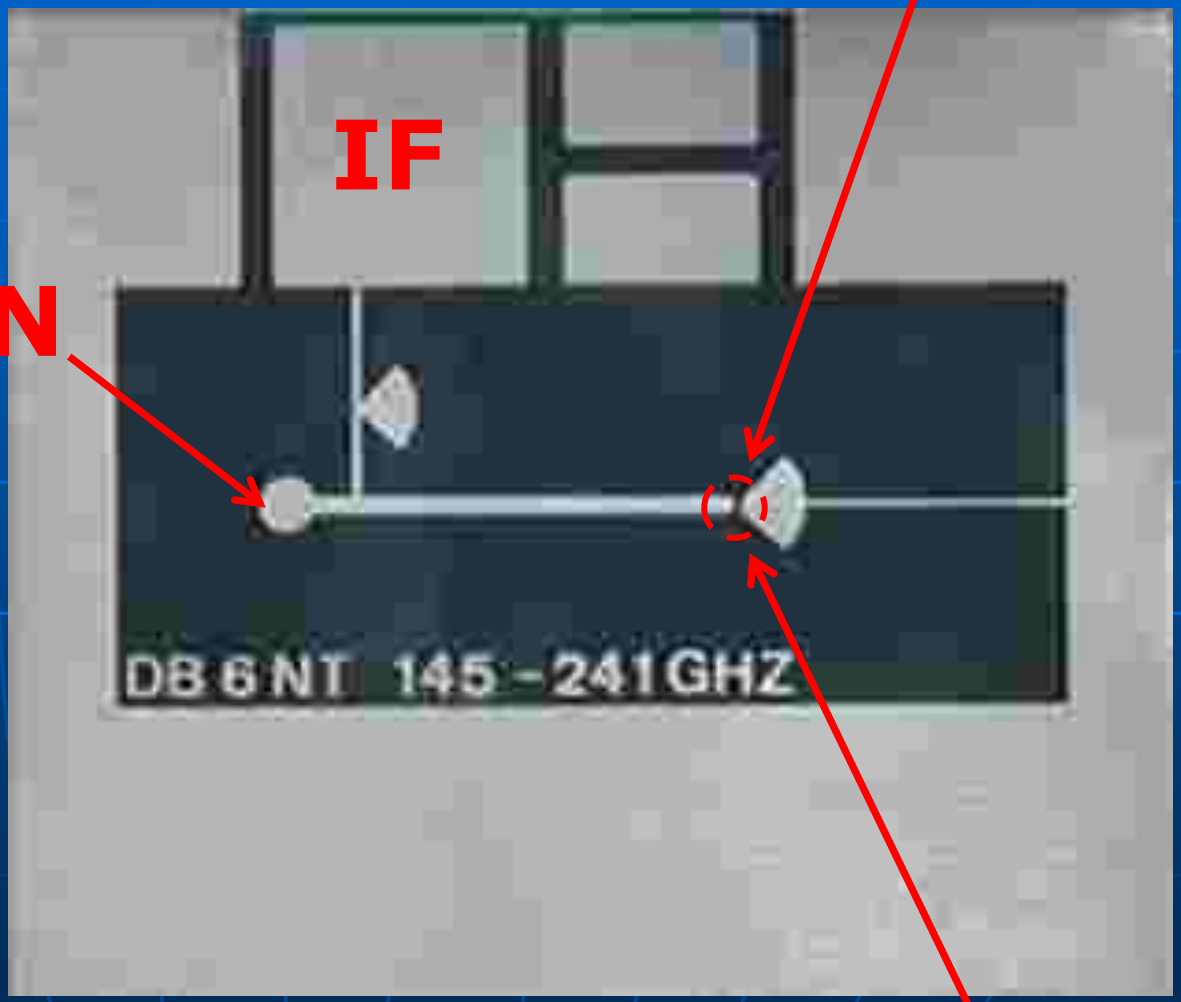
3mm WG IP
1mm WG OP
DUBUS 1.2009
241 GHz Transverter
DL2AM

Aluminium block available from DL2AM for these boards

241 GHz equipment choices

DUBUS 2.94
241 GHz
transverter
DB6NT

Mixer board same as the 145 GHz version but has different ground plane on other side



241 GHz Antennas

- Extremely hard to find suitable antennas for this frequency
- Small horns for lower frequencies do work and give useful gain
- Small conical horns can be made using icing nozzles and do work well
- Dishes made for lower frequencies such as the Procom 145GHz dish works OK and gives useful gain at 241 GHz
- Other 250 or 300 mm dishes are available but often very costly
- Any dish larger than 300 mm is likely to be very difficult to align – beamwidth is a fraction of a degree !

241GHz Mixer diodes

- DB6NT mixer board for 241 GHz available from Khune Electronics

- Choice of Diode:
- HSCH-9101 RX
- DBES105A RX + CW TX
- Care as static discharges destroys diodes very quickly!

- Diode can either be glued with silver epoxy or soldered with indium solder

241 GHz Testing

- A steady tripod is ESSENTIAL
- We found that just moving the tripod a couple of inches to one side or the other from boresight resulted in loss or severe reduction of signal
- A useful device was a tripod dolly that enabled the tripod to be easily moved around but could be braked when required
- Leave plenty of time for LO warm-up to enable previous use frequency accuracy to be maintained.
- Frequency was normally within a few ten's of kHz once LO warmed up and stabilised.
- CW T9 signal able to be held in 2.7kHz BW for a couple of minutes before retuning is needed

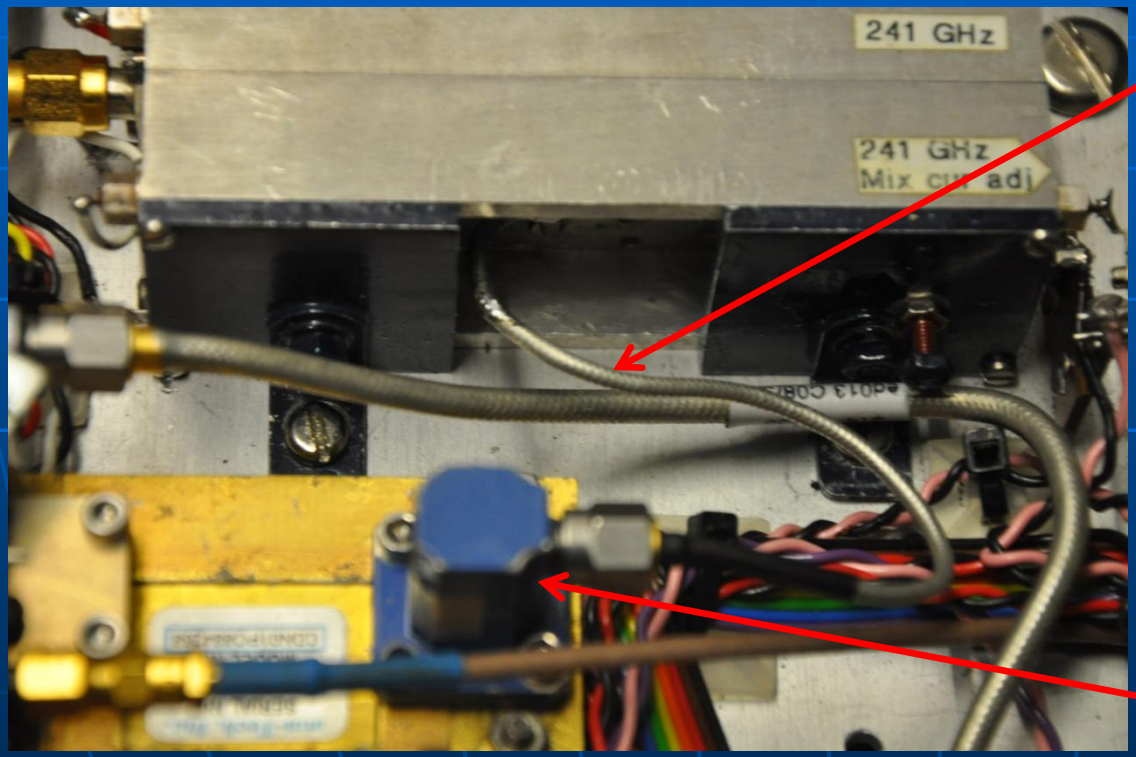
241 GHz Test Equipment

- Basically there is nothing readily available !
- For frequency measurement - best to measure at 11GHz and calculate
- There are external mixers for spectrum analysers – but very expensive indeed
- Power measurement – best is to estimate using lower frequency power sensors as guide
- The most useful and readily available tool is round hole waveguide acting as a high pass filter
- The output signals from transmitters and tests sources can therefore be verified as actually being on 241 GHz and not a lower frequency

241 GHz early G0FDZ mixer

Chris G0FDZ's early system using a DB6NT mixer employing the 10th harmonic before extensive modification to use the 7th harmonic

241 GHz G0FDZ mixer using 34 GHz LO injection



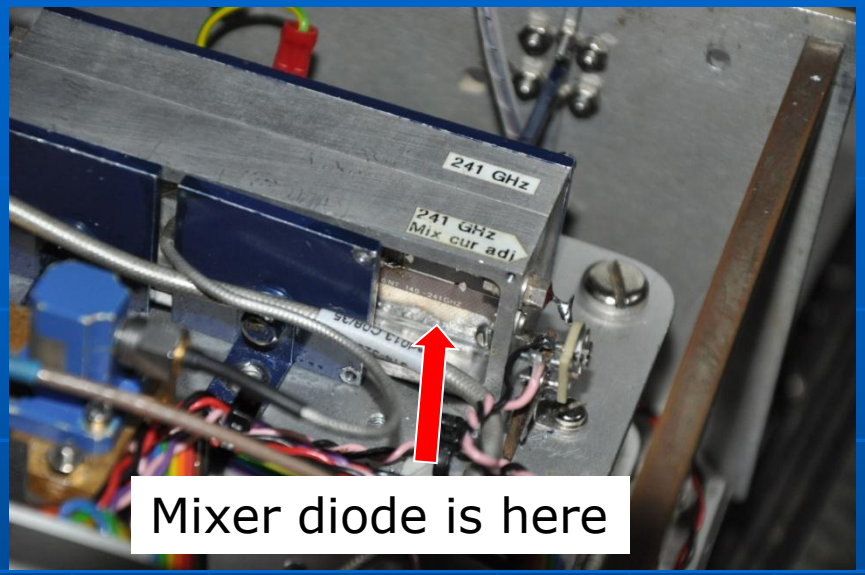
New LO injection arrangement using 085 semi rigid to feed direct to the mixer board.

34GHz LO signal filtered by the WG to K type transition

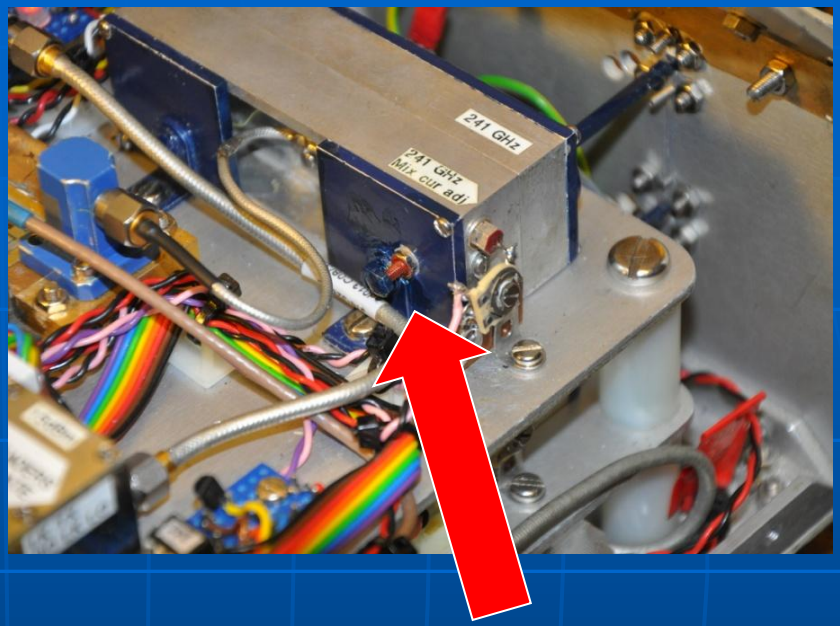
241 GHz G0FDZ mixer using 34 GHz LO injection

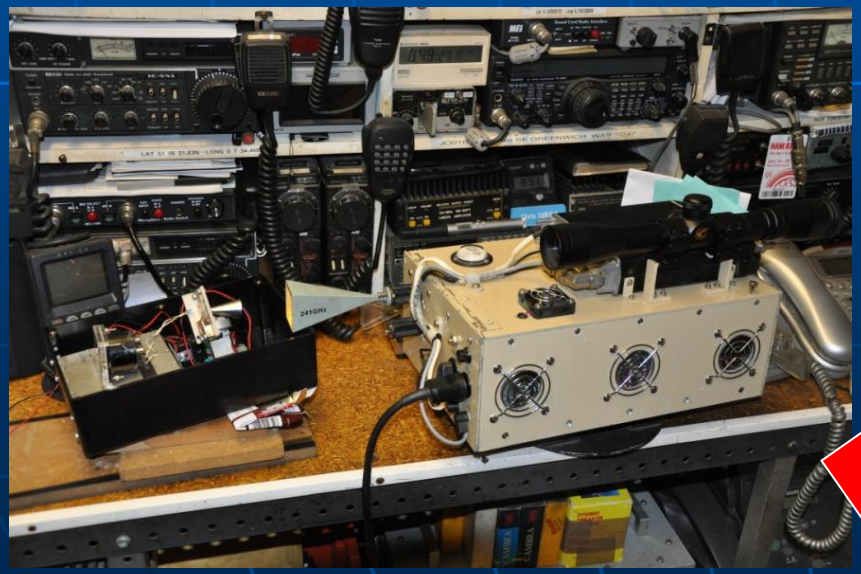
Initial testing after changing to 34 GHz LO injection revealed problems with the trough waveguide filter machined into the mixer block

241 GHz G0FDZ mixer mods



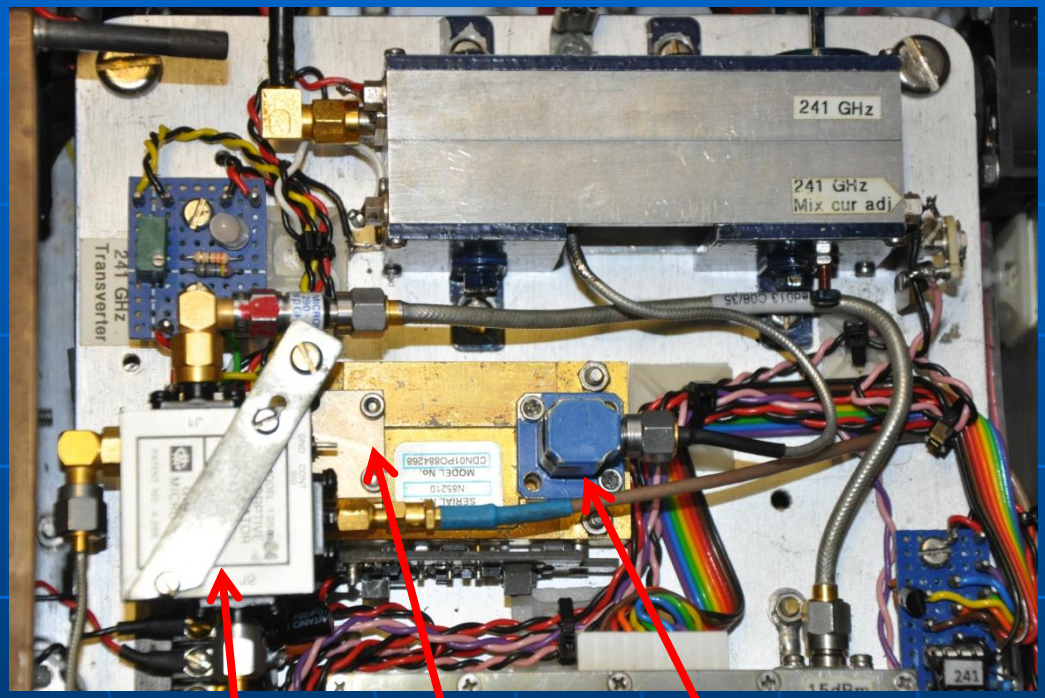
Mixer diode is here





It was found that there was little RF emanating from the waveguide hole and therefore a back screw was required to be fitted. This was made from a filed down M2.5 screw and is nearly touching the diode.
Testing the system afterwards on the shack bench.

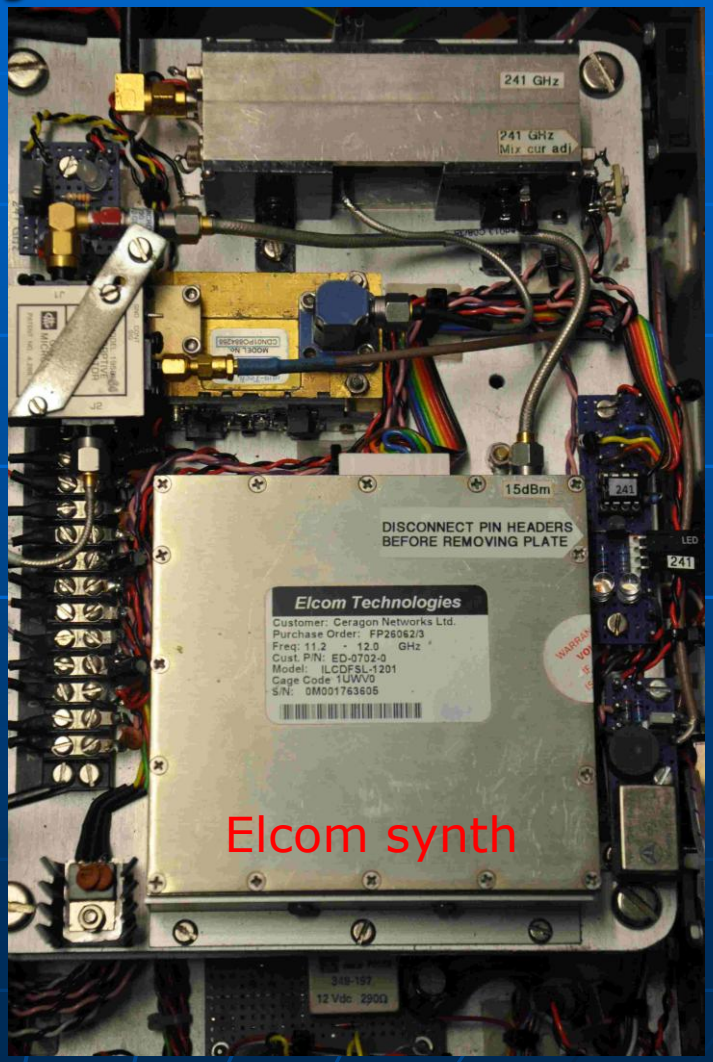
241 GHz G0FDZ mixer using 34 GHz LO injection



PIN switch for keying

Tripler and Gold amplifier output 34 GHz

WG to K type transition



Elcom Synthesiser – a good choice for the LO

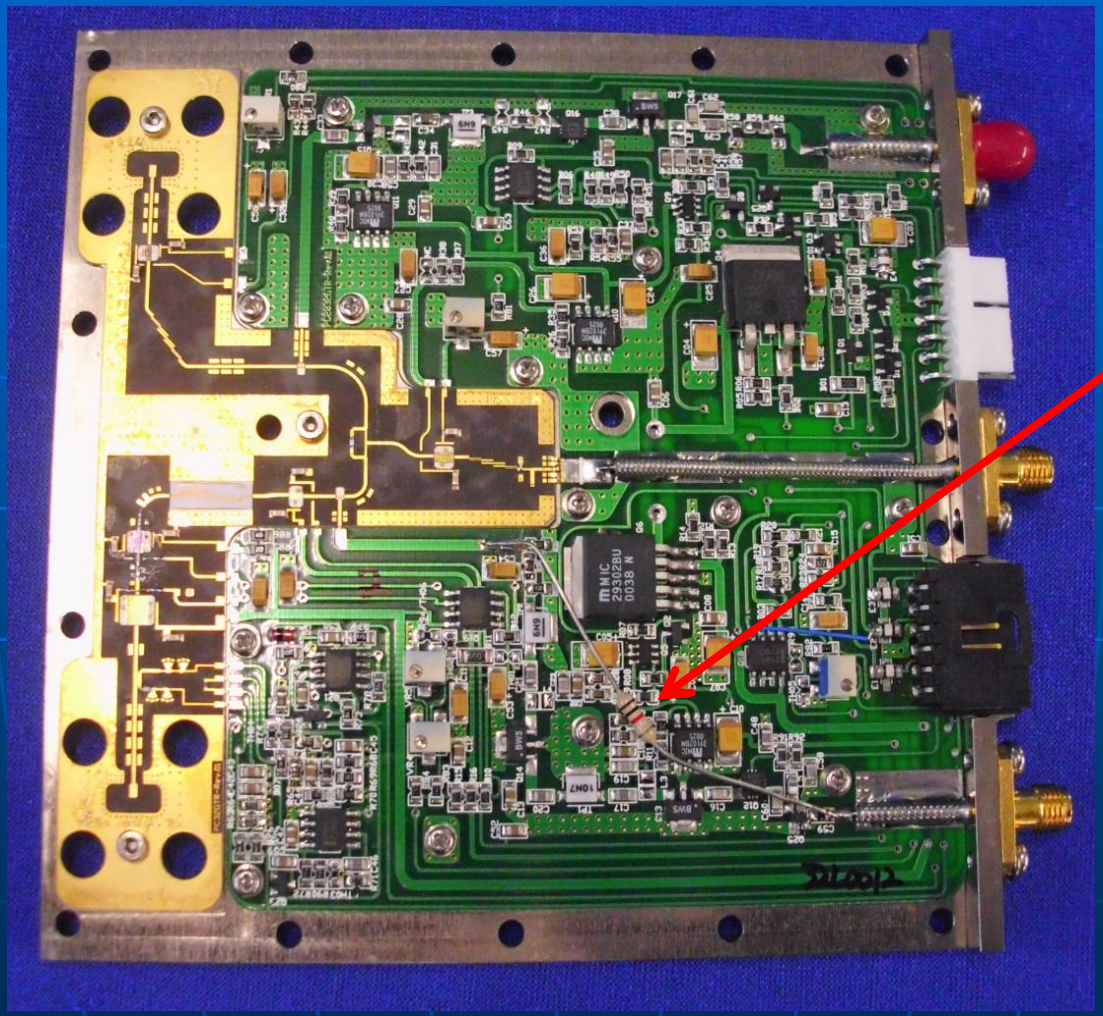
241GHz

10.575 – 11.400 GHz	3.333M step
11.200 – 12.000 GHz	3.333M step
12.200 – 12.950 GHz	3.333M step
12.650 – 13.350 GHz	5M step

Elcom Synthesisers

- Complete robust block
- Simple to program
- Stable frequency after 30 mins warm up from cold
- Low cost
- Multiple frequencies (LO and TX frequencies)
- Possible to GPS lock
- Limited frequency step hence use of ‘strange’ IF’s)
- T9 note at 241 GHz

Broadern Module



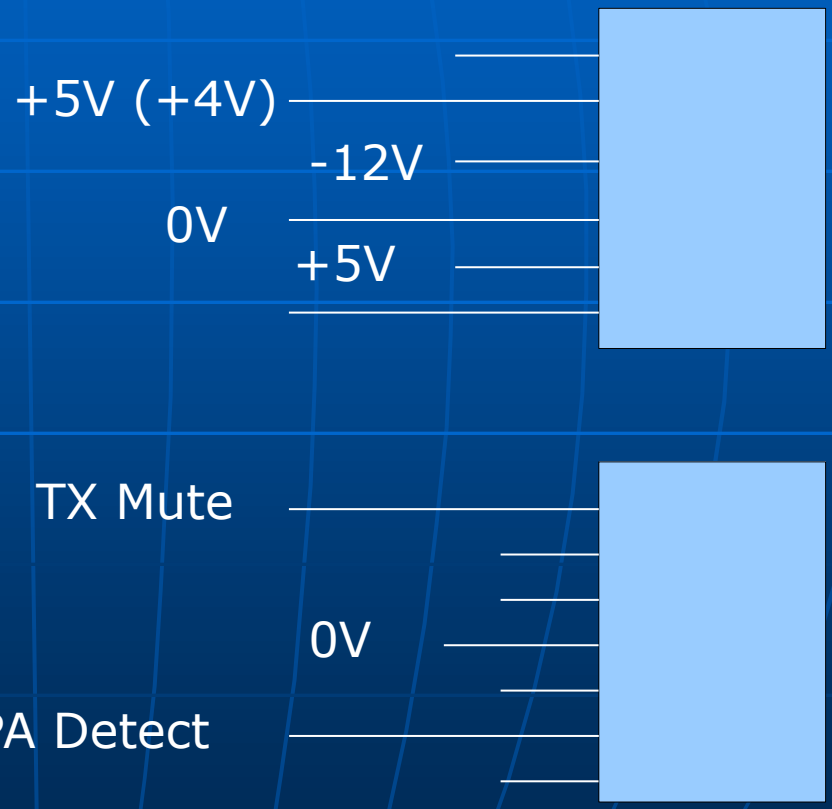
X3 Multiplier / Amplifier

- Broadern ED-0296-2

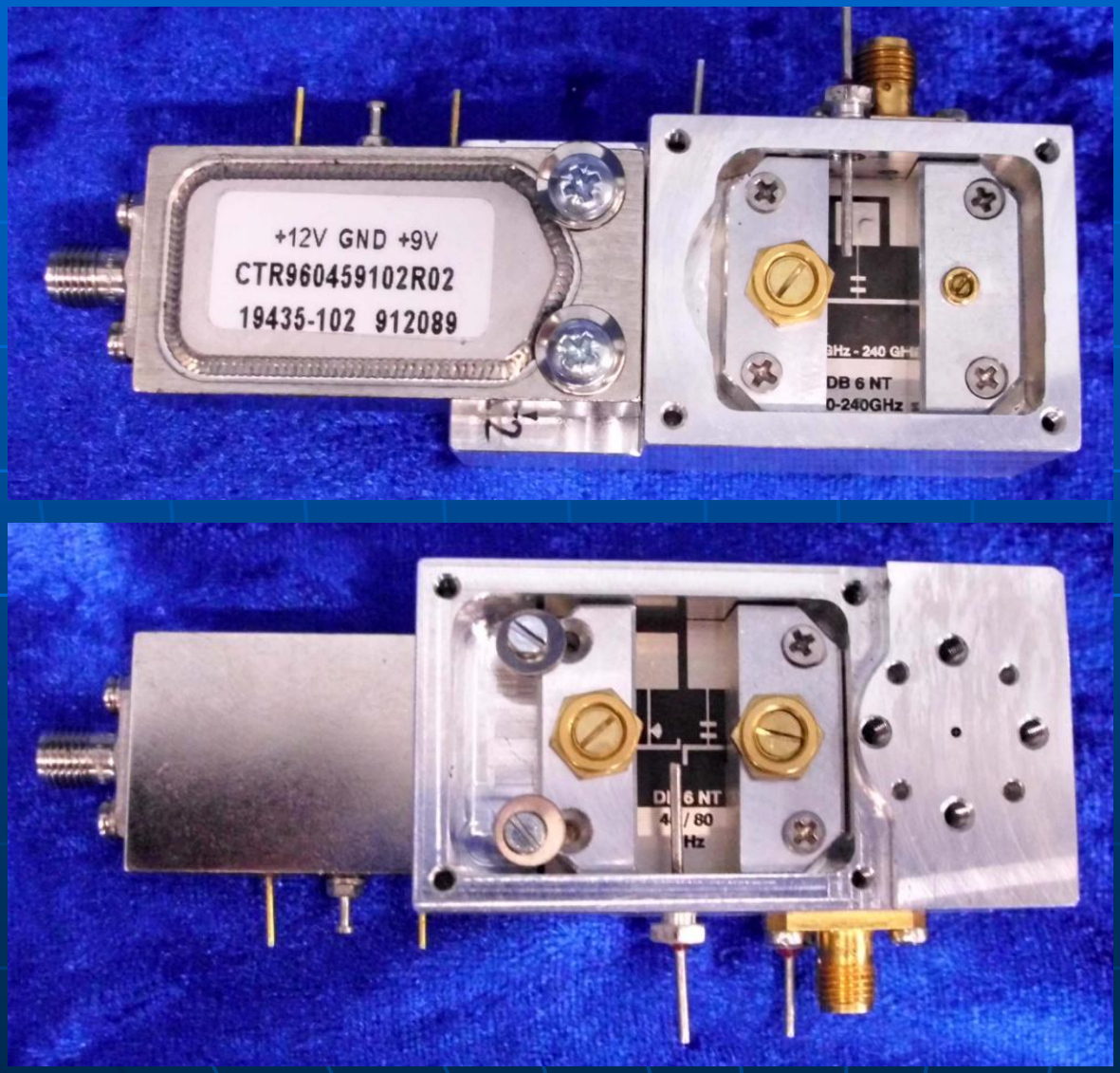
I A	dBm	Det V
.85	+20	2.6
.87	+22	2.7
.90	+24	2.9
.95	+26	3.1
1.0	+28	3.3

Control 0 – 1.5V

Drive +3dBm

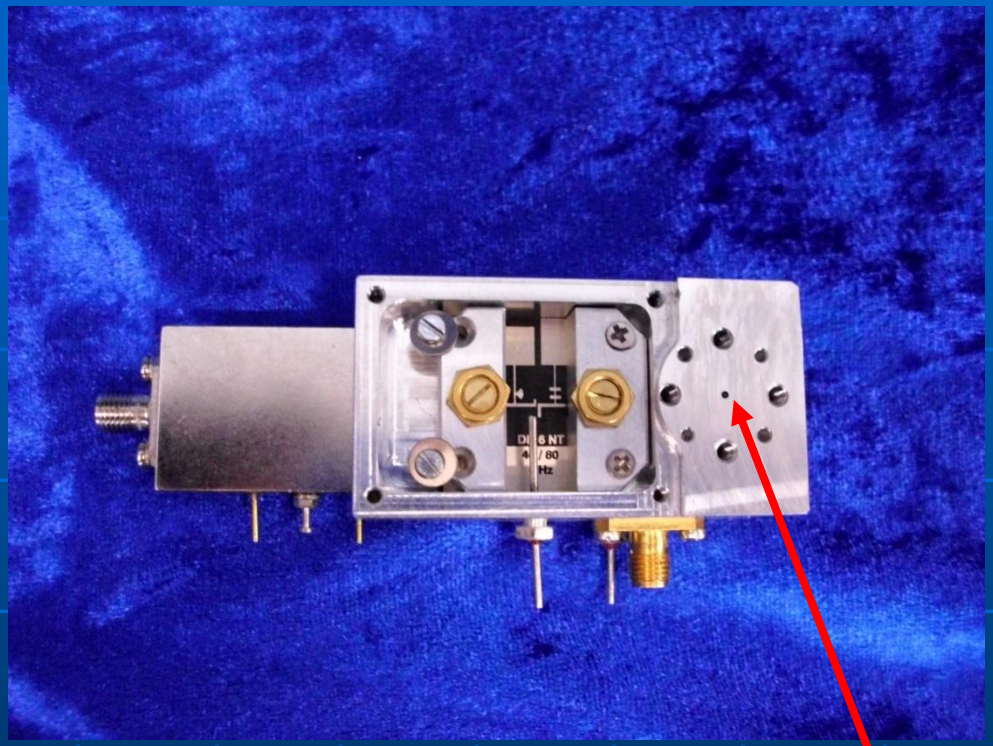


241 GHz G8CUB receive mixer



This mixer is based on the DL2AM design and uses an aluminium block with a 1mm waveguide hole. It is designed to accommodate a CMA382400AUP module for 40 GHz.

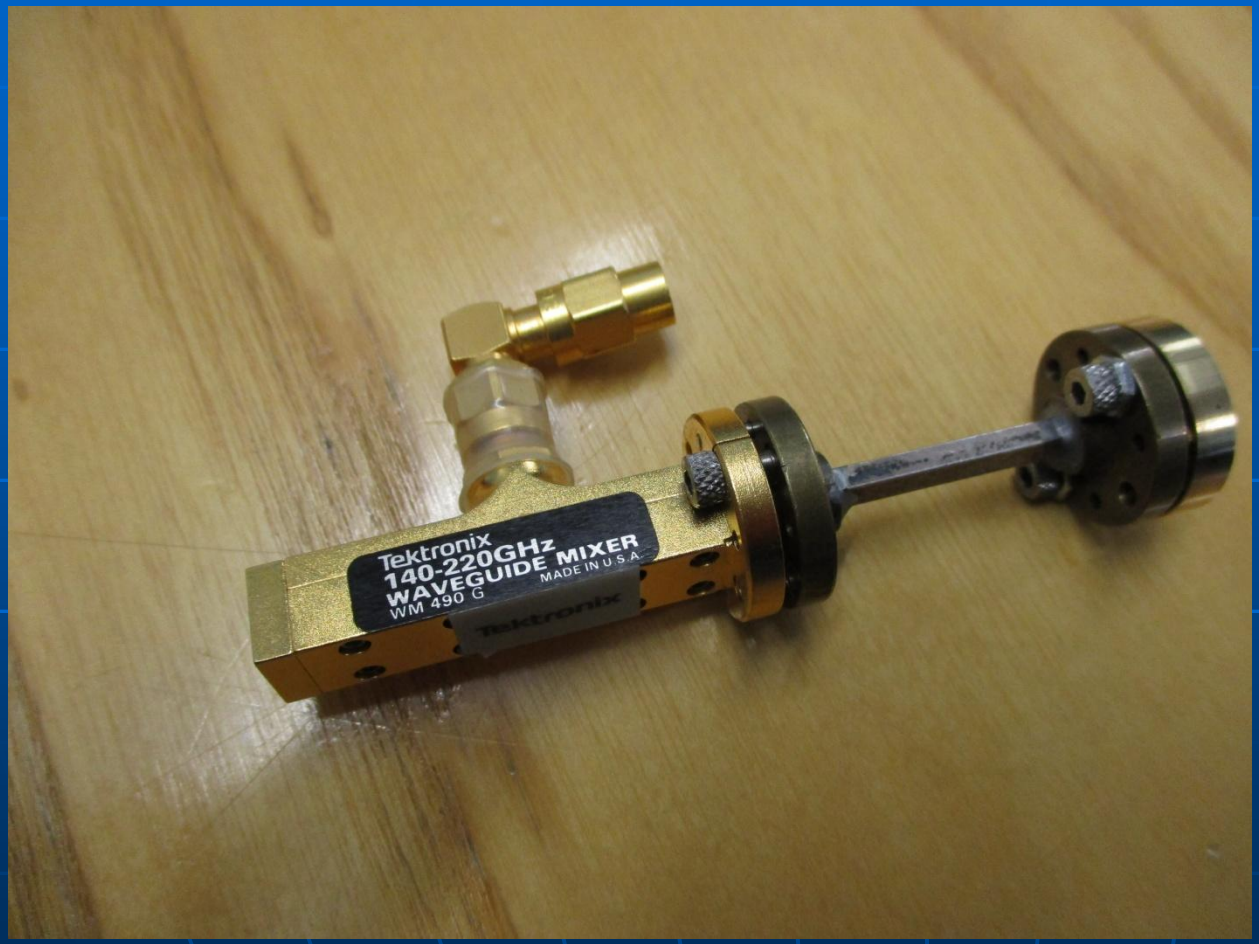
241 GHz - 1.2mm



Circular waveguide 1.0mm

The 241 GHz mixer

241 GHz Tektronix WM490G Mixer



This mixer is used for receive only and driven from a 16 GHz LO source (x15)

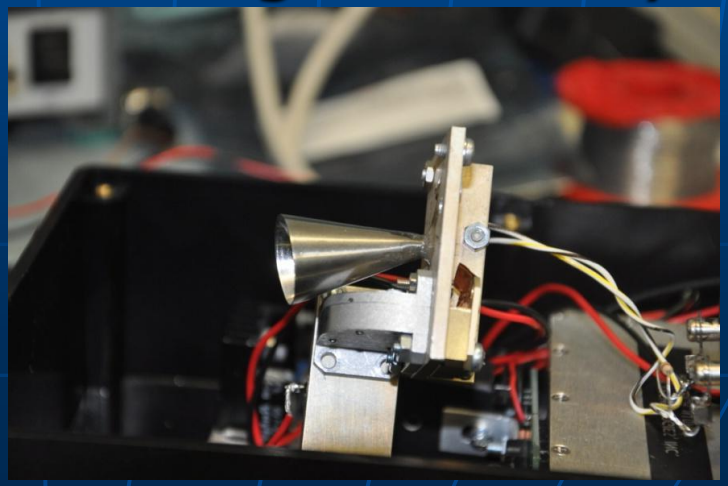
Requires DC bias return !

Normal use – conversion loss 60dB at 220 GHz

Using 241 GHz signal sources

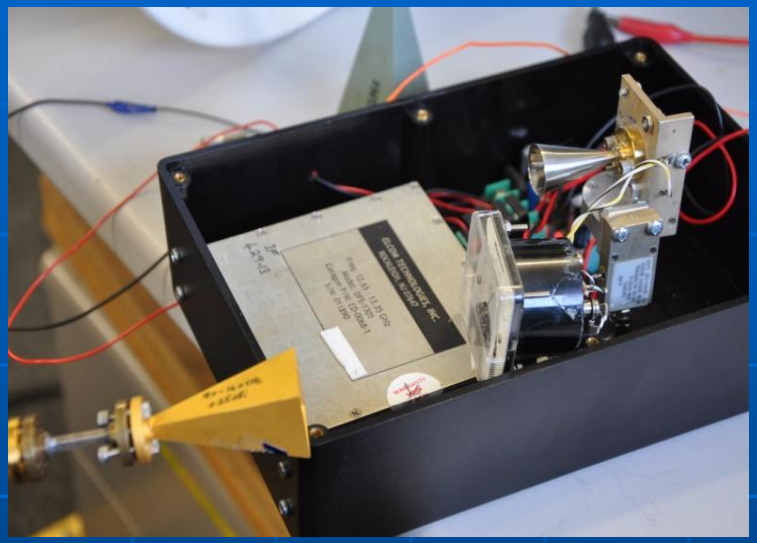
- Some form of local signal source is essential
- Useful for initial checking and then optimisation of both receiver and antenna.
- If antenna is removable can then double as transmitter with large antenna
- Very useful if CW keying is fitted
- Comprises an Elcom source and x3 multiplier giving 50mW then direct multiplier to 241 (output through 1mm waveguide hole)

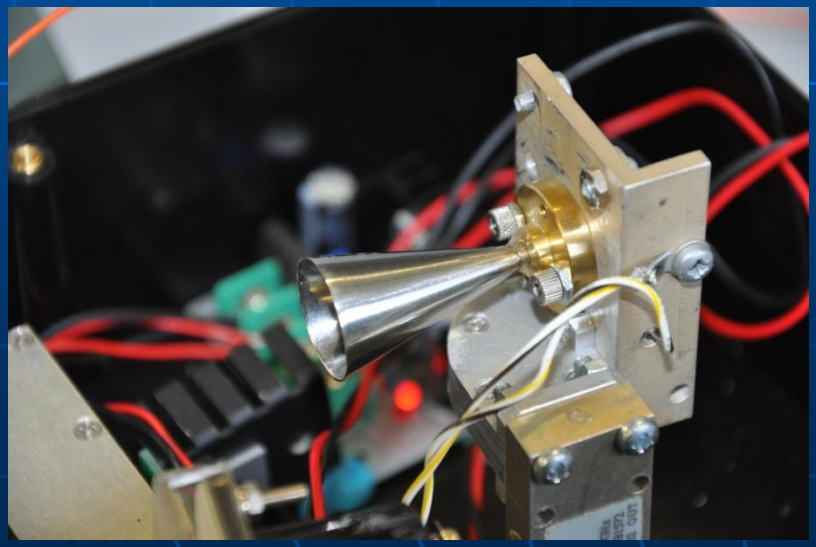
10pW signal source with conical horn antenna



241 GHz testing using signal sources

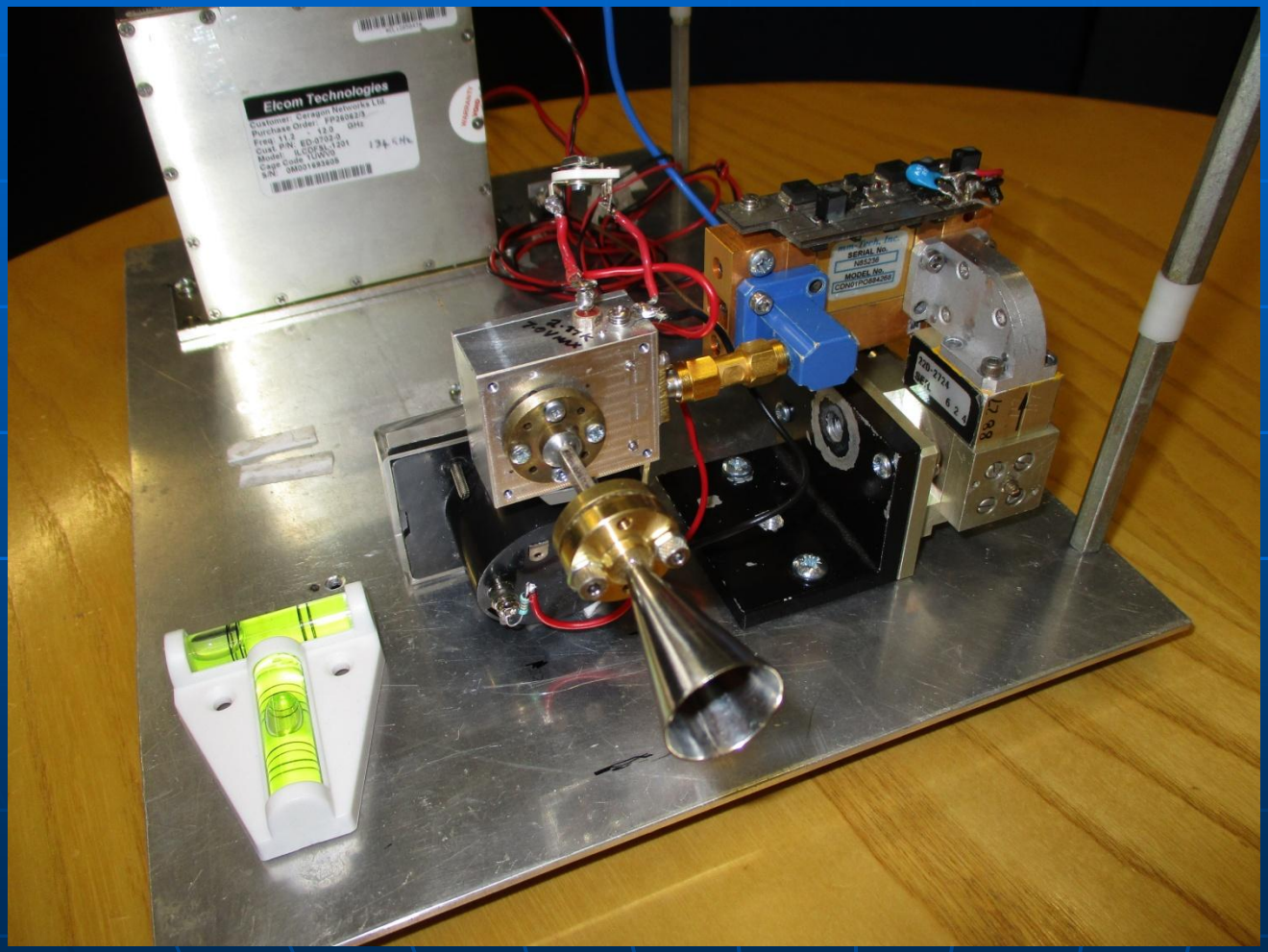
Standard gain horn fitted to mixer for testing low power source





Use of removable conical horn on low power source

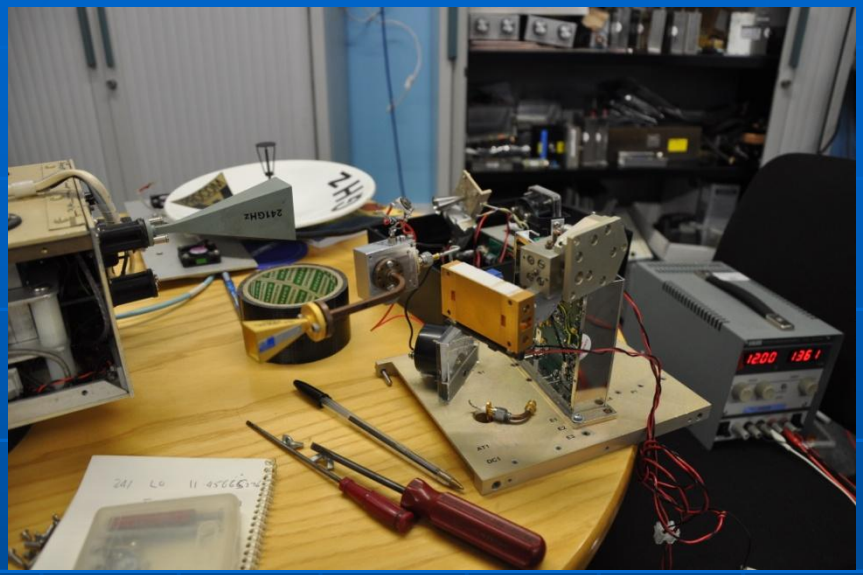
241 GHz High Power Tx

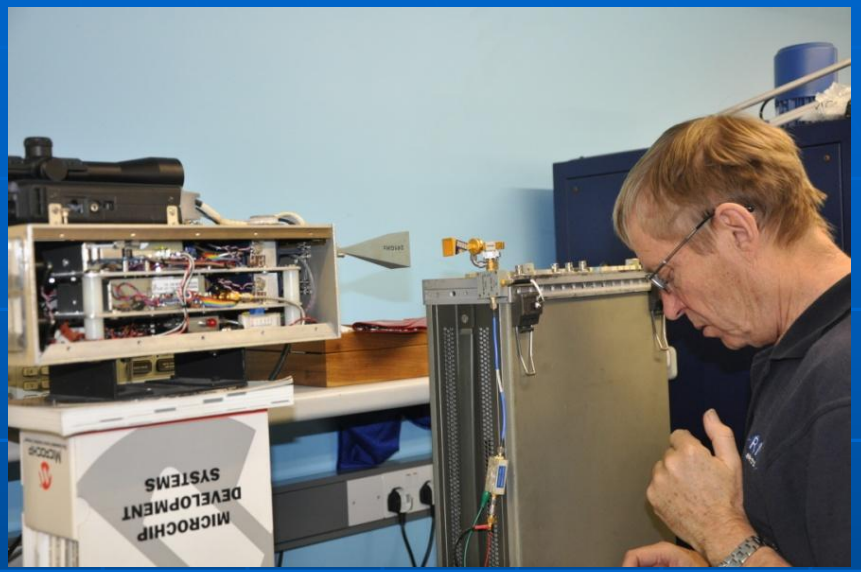


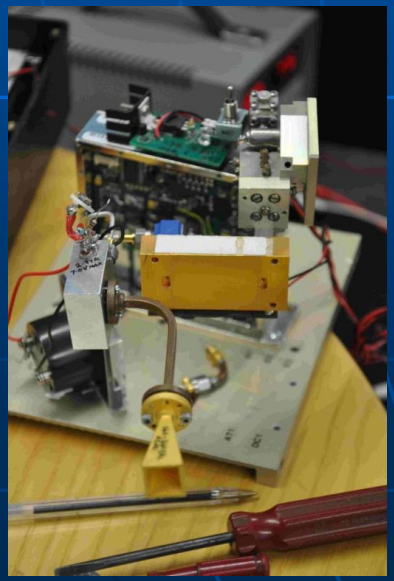
1uW maximum

x21 total
11.47666GHz
x3 Amplifier
50mW
x7 DBES105A

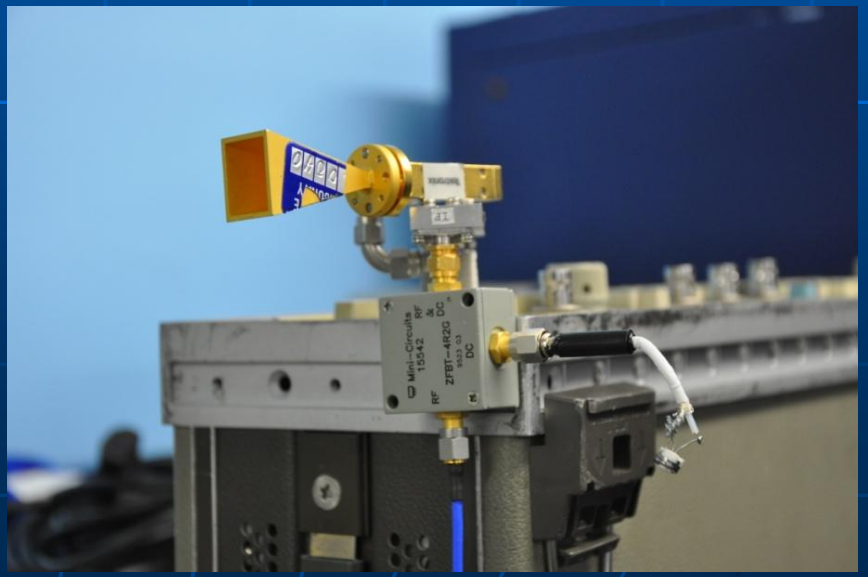
241 GHz testing over distance





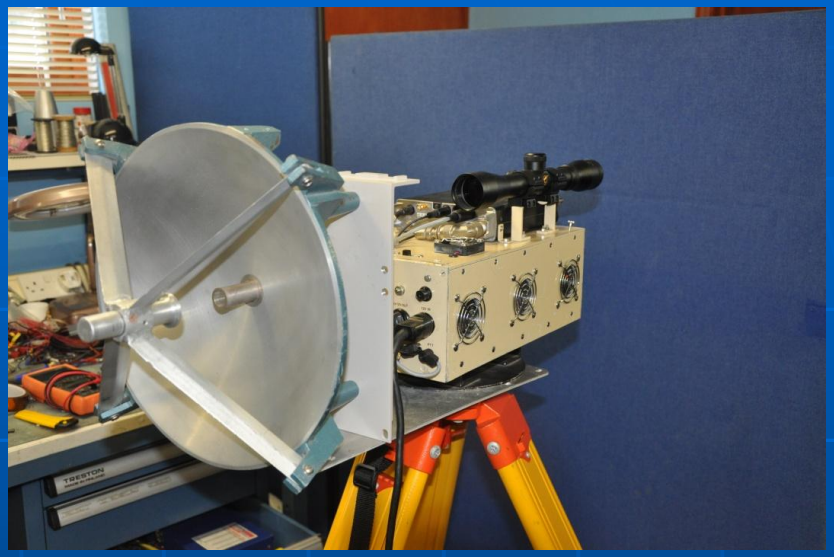


Using the higher power source we tested the systems over several metres to optimise the mixer and check antennas



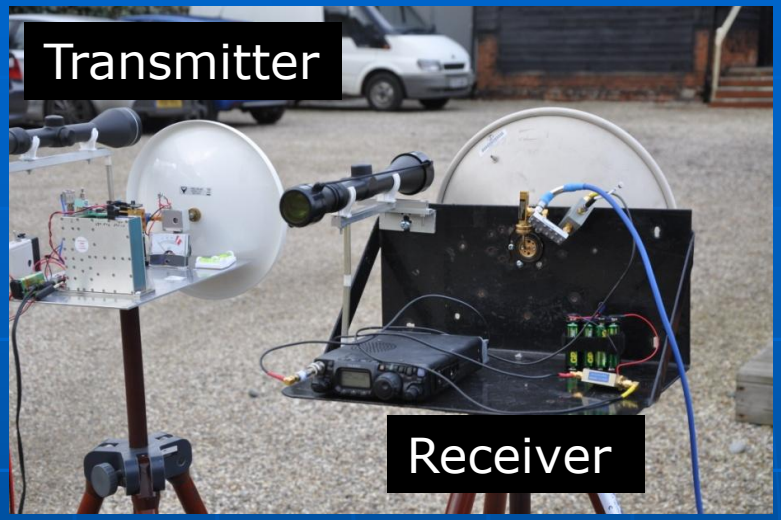
241 GHz testing before first QSO

Testing over 10 metres to check cassegrain dish performance and receiver sensitivity

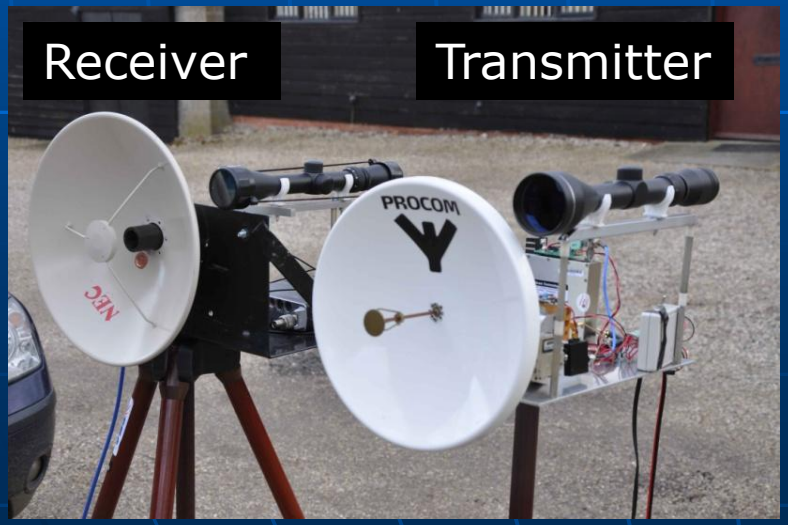


241 GHz first UK QSO over 30M

G0FDZ End



G8CUB End



G8CUB End

G0FDZ End

241 GHz Using the correct harmonic

- Using harmonic mixers for receiver LO's and multiplier diodes for transmitters can give rise to doubts as to what harmonic is selected.
- Use of calculator to determine the IF if a lower harmonic than required is mistakenly selected
- Only the correct combination of harmonics will give the required IF
- Use of adjustable LO – move LO 1kHz up and then retune test signal which should be higher by the multiplication factor e.g. 11GHz x21 should result in the signal being found 21kHz higher

Waveguide as HPF

- Fco (GHZ) = 150/a

Where a = longest dimension in mm

- Fco (GHZ) = 176/d

Where d = diameter in mm

1.0mm round hole gives cut off at 176 GHz

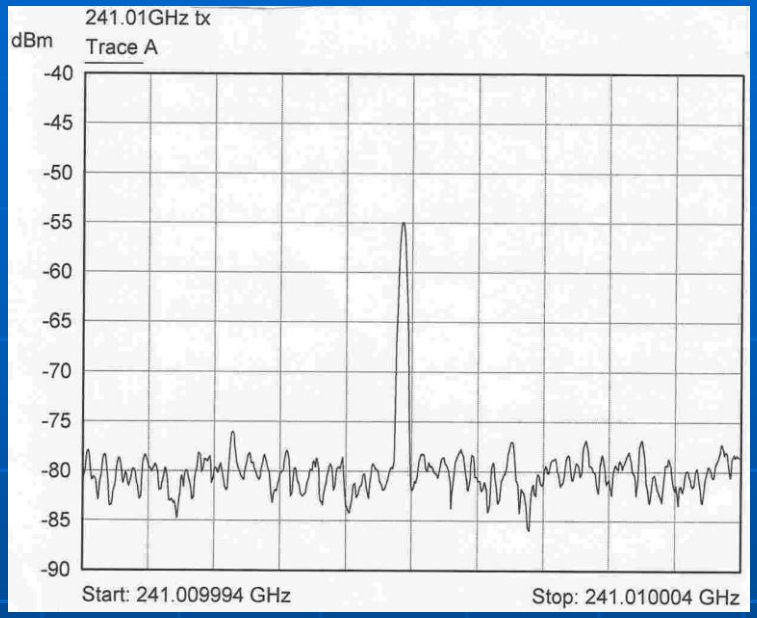
WR03 gives cut off at 173 GHz

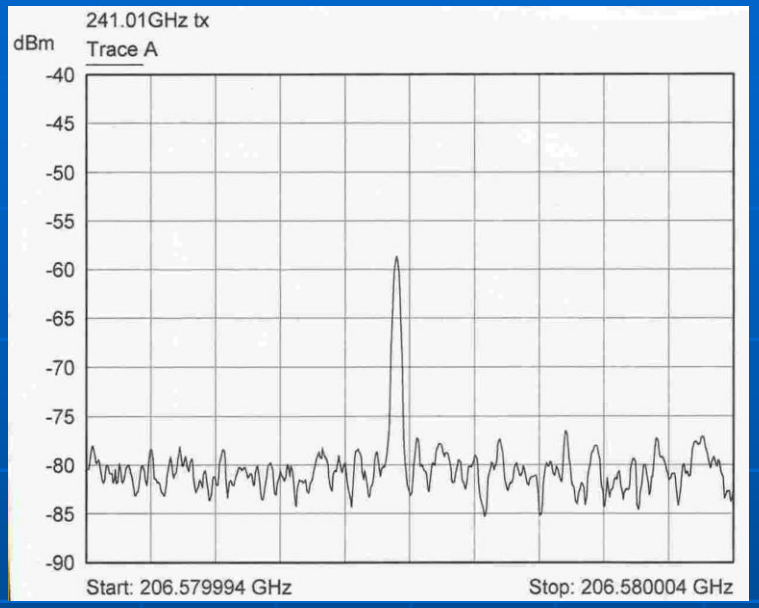
WR03 is extremely difficult to obtain from UK suppliers

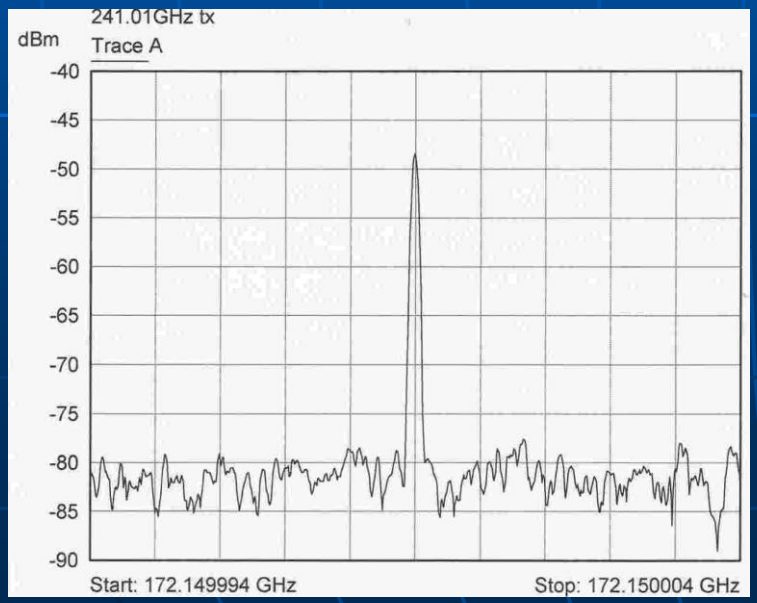
Waveguide as HPF

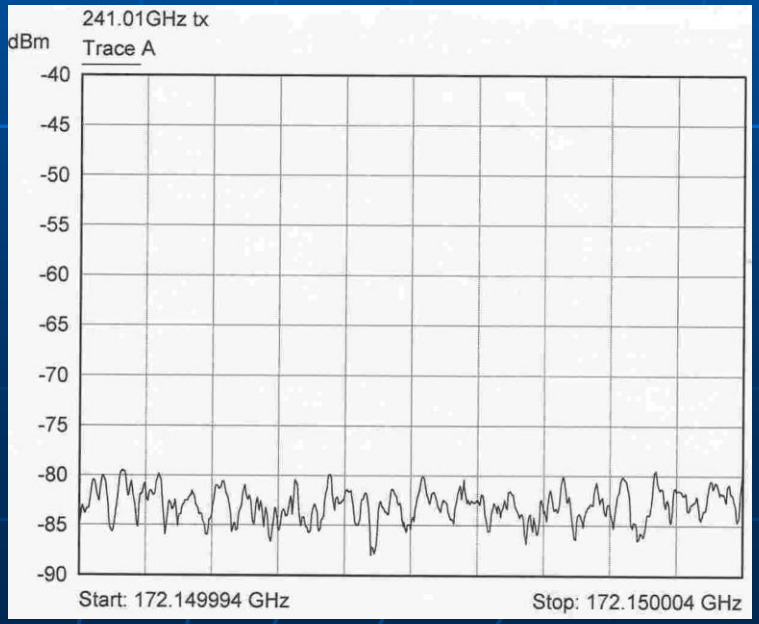
- WR-03
- 225 to 325 GHz - Cut off at 173 GHz
- Inside dimensions 0.86 x 0.43 mm

Waveguide as HPF









Waveguide as HPF

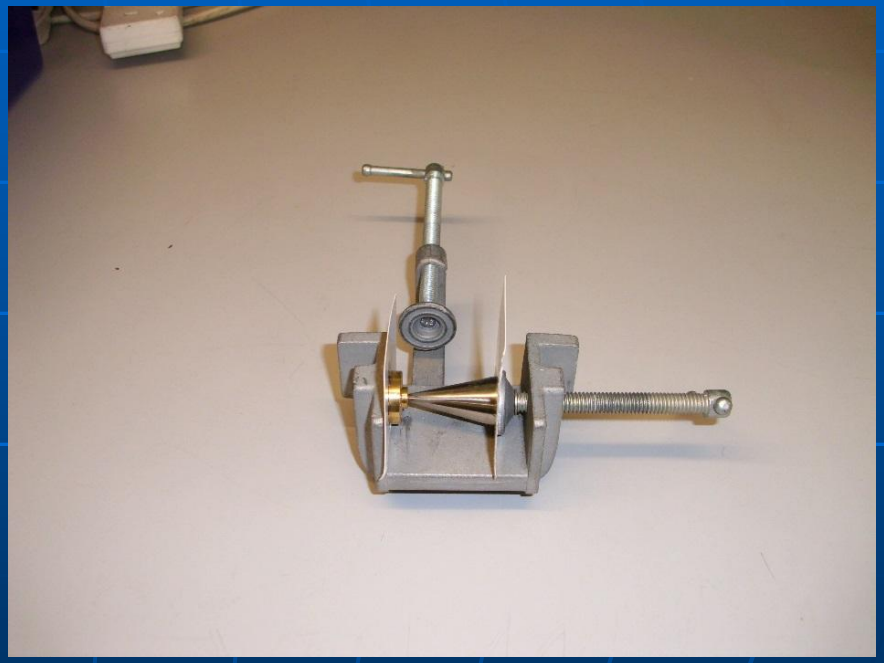
- The waveguide hole must be smooth as any roughness can cause severe attenuation
- Suggestions have included using 0.8 mm reamers to ensure hole is correct size!
- Polishing the hole with ‘Brasso’ is very difficult

Waveguide as HPF

- With Chris G0FDZ's system the hole at 0.8mm did not pass any 241 GHz
- It was found that drilling out to 1mm solved the problem
- Probably the optimum size is 0.9mm but the hole must be totally smooth

241 GHz Test Antenna

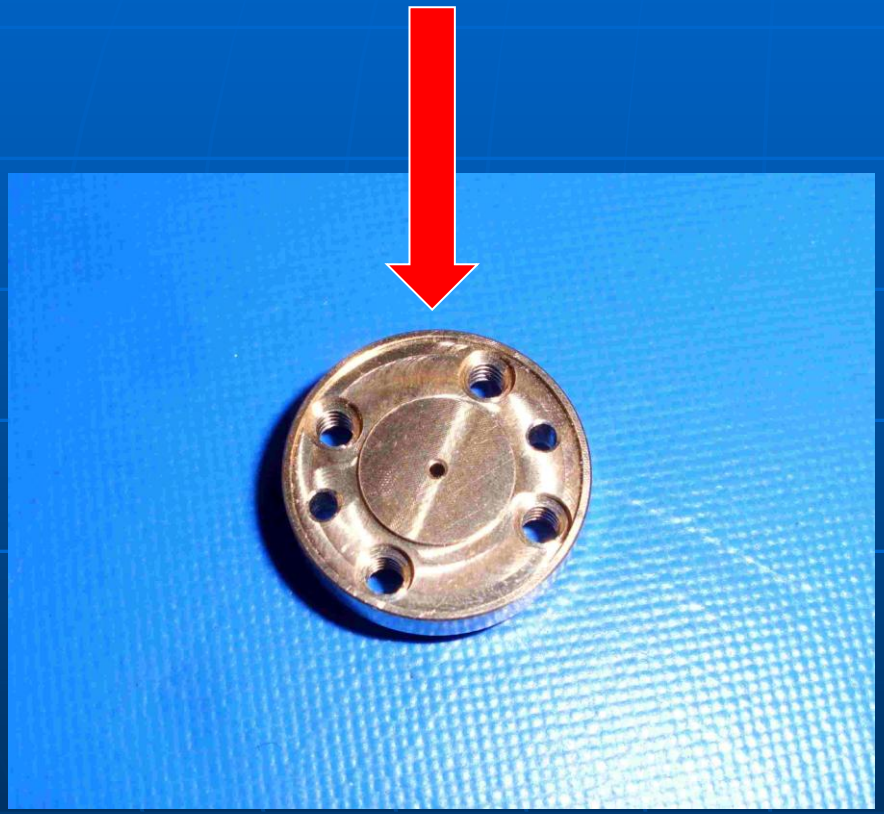
- Making a conical Horn Antenna from an icing nozzle



Made with a standard UG blank flange drilled with a 1mm hole.
Horn was just as good as a standard gain horn and much cheaper !!

241 GHz Test Antenna

- 1 mm hole in standard blank UG flange



241 GHz - 1.2mm
Where do we go from here ?

- Basically we need improve on power and have milliwatts available instead of microwatts
- We need to use higher gain antennas and have the ability to point them with accuracy
- To achieve the ability to use higher gain antennas requires much more skill than we have at the moment –maybe we need to start using azimuth/elevation micrometer drives on our tripods !
- Some really cold weather would help too !!

We both look forward to working you on 241 GHz !!

Roger Ray G8CUB
Chris Whitmarsh G0FDZ