Sub-Millimetre waves Operating above 275 GHz

Under your NOV

Written by Chris Whitmarsh G0FDZ
and presented by Roger Ray G8CUB

Radio spectrum

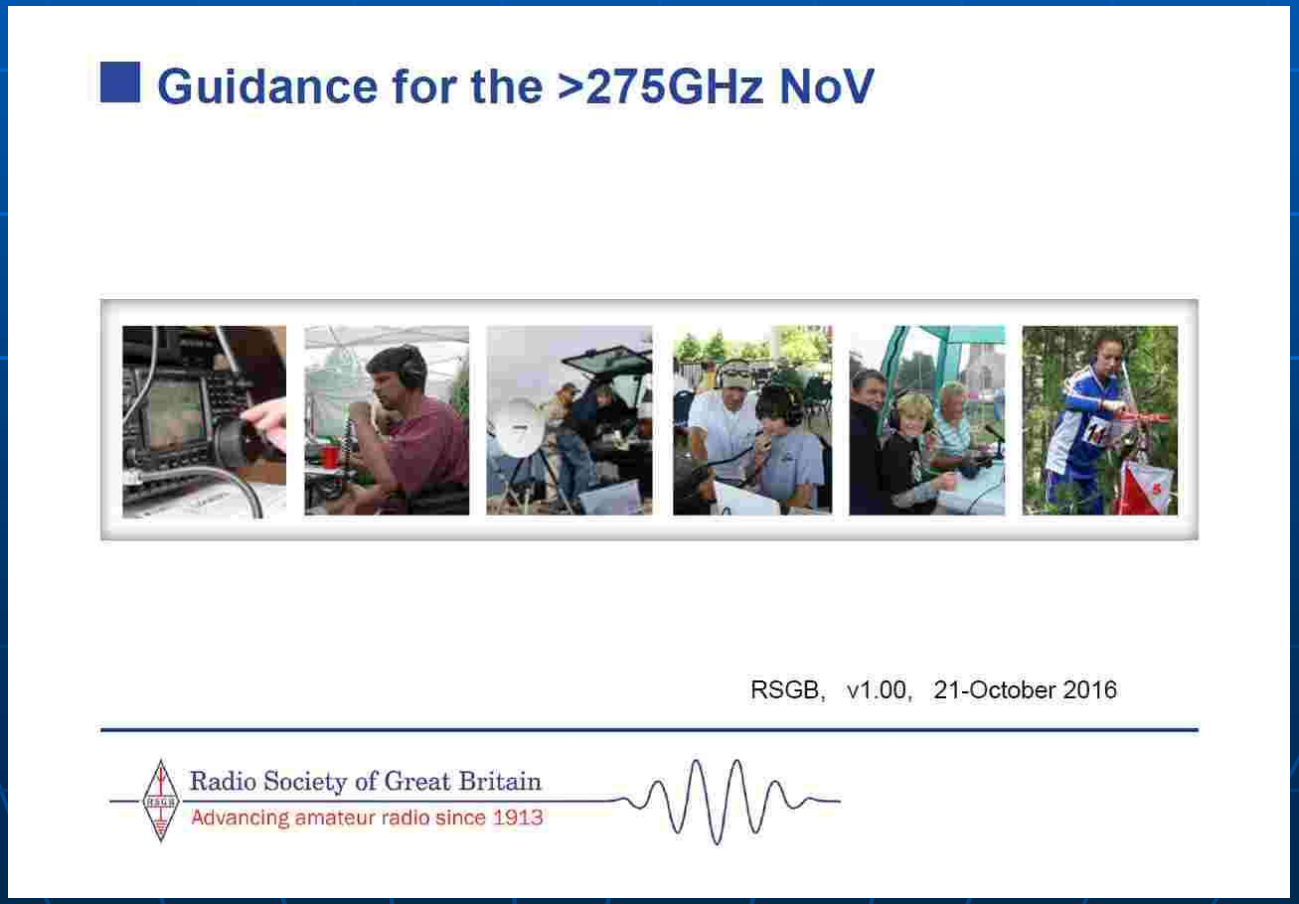
- Although the radio spectrum officially ends at 275 GHz but there is a vast area available for experimental use above this frequency and this is called the THz area
- It is likely that industry will find many uses for this area within 10 years
- Ofcom are interested in promoting research in this area now

NOV

- Anyone who has a full licence can apply to the RSGB for an NOV which is FOC
- The RSGB is only acting as an agent for OFCOM so you do not have to be a member to obtain an NOV
- Apart from personal info you just need to state the NGR/postcode of the sites that you intends to operate from.
- The reply from the RSGB for the NOV is very quick and you are then ready to go

NOV

- You will certainly need to download and read the guidelines document/booklet before any operation as there are frequency bands and locations that will need to be avoided.



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WIRELESS TELEGRAPHY ACT 2006

VARIATION OF AN AMATEUR RADIO (FULL) LICENCE FOR THE PURPOSE OF USING FREQUENCIES ABOVE 275 GHz

1) Introduction

Ofcom, in exercise of the power conferred by Schedule 1, paragraph 6 of the Wireless Telegraphy Act 2006 (as amended - "the Act"), hereby varies the Amateur Radio Full Licence identified below ("the Licence"), in accordance with Schedule 1, paragraph 7 of the Act, as detailed below.

Name of Licensee:	**Mr Christopher Whitmarsh**
Licence reference:	**1-8498-49329**
Licensee's main station address:	**35 Dorchester Avenue**
	Bexley
	Kent
Postcode:	**DA5 3AH**
Licensee's call sign:	**G0FDZ**
Operational location 1	**Main station address as above**
Operational location 2	**RN Electronics CM13 1UT**
Operational location 3	**Higham 1 TQ723716**
Operational location 4	**Higham 2 TQ 722727**
Operational location 5	**Higham 3 TQ717739**
Operational location 6	**Brentwood 1 TQ 634964**
Date of issue of this Variation:	**24 October 2016**
Date of expiry of this Variation:	**24 October 2019**

2) Purpose

The purpose of this variation is to authorise the licensee to authorise the use of the Radio Equipment on frequencies at and above 275 GHz.

3) General

(a) Terms and expressions defined in the Licence shall have the same meaning herein except where otherwise stated or the context requires otherwise.

(b) This Variation shall be read as an integral part of the Licence and the additional terms contained herein shall apply in respect of the Station.

(c) This Variation shall remain in force unless

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- the Variation expires (that is to say that it passes the Date of Expiry given above) or
- Ofcom revokes the licence or
- Ofcom further varies the Licence, such that the effect of this Variation is altered or cancelled or
- the licensee surrenders the licence or
- the licensee requests Ofcom further to vary the licence such that the effect of this Variation is altered or cancelled

(d) This Variation forms part of the Licence and must be attached to the Licence.

(e) This Variation replaces and supersedes any other Variation issued to vary the Licence for the purpose stated in 'Purpose', above.

(f) This variation does not grant any authorisation on its own. It has effect only when read together with the Licence, which it varies.

4) Variation

Subject to the terms and conditions of this variation, the Licence is varied such that the Radio Equipment may be operated on any frequency or frequencies in the Authorised Band or the Restricted Band.

5) Terms and conditions

a) Ofcom may vary the licence to alter the frequencies available in the Authorised Band or the Restricted Band if any of these are needed for terrestrial use.

b) The Radio Equipment may be used only at the Main Station Address or at an operational location specified above

c) The maximum transmitter output power must not exceed 100milliwatts

d) In complying with Clause 7(3) and Clause 7(5) of the Licence, the licensee must, in particular, ensure that the use of the Radio Equipment does not cause undue interference to any use made of wireless telegraphy by radio astronomy sites.

e) When transmitting in the Restricted Band, the Radio Equipment must not be used within 20 kilometres of any of the seven locations and NGRs listed below:

i) Cambridge, TL 39400 54000
ii) Chilbolton, Hants SU 37900 38500
iii) Darnhall, Cheshire SJ 64275 62265
iv) Defford, Worcestershire SO 90200 44700
v) Jodrell Bank, Cheshire SJ 79650 70950
vi) Knockin, Shropshire SJ 32855 21880
vii) Pickmere, Cheshire SJ 70404 76945

6) Interpretation

a) "the Station" means the station identified in Section 1 of this variation and any apparatus for wireless telegraphy associated with it.

b) "the Licence" means the licence identified in Section 1 of this variation.

c) "the Authorised Band" means any frequency at or above 275 GHz, excluding any frequency or frequencies in the Restricted Band or in any of the following bands:
275-286 GHz, 296-306 GHz, 313-356 GHz, 361-365 GHz, 369-392 GHz, 397-399 GHz, 409-411 GHz, 416-434 GHz, 439-467 GHz, 477-502 GHz,

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523-527 GHz, 538-581 GHz, 611-630 GHz, 634-654 GHz, 657-692 GHz, 713-718 GHz, 729-733 GHz, 750-754 GHz, 771-776 GHz, 823-846 GHz, 850-854 GHz, 857-862 GHz, 866-882 GHz, 905-928 GHz, 951-956 GHz, 968-973 GHz and 985-990 GHz

d) "the Restricted Band" means and frequency or frequencies in the following bands:
275-323 GHz, 327-371 GHz, 388-424 GHz, 426-442 GHz, 453-510 GHz, 623-711 GHz, 795-909 GHz and 926-945 GHz

Issued by Ofcom:
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2a Southwark Bridge Road
London, SE1 9HA
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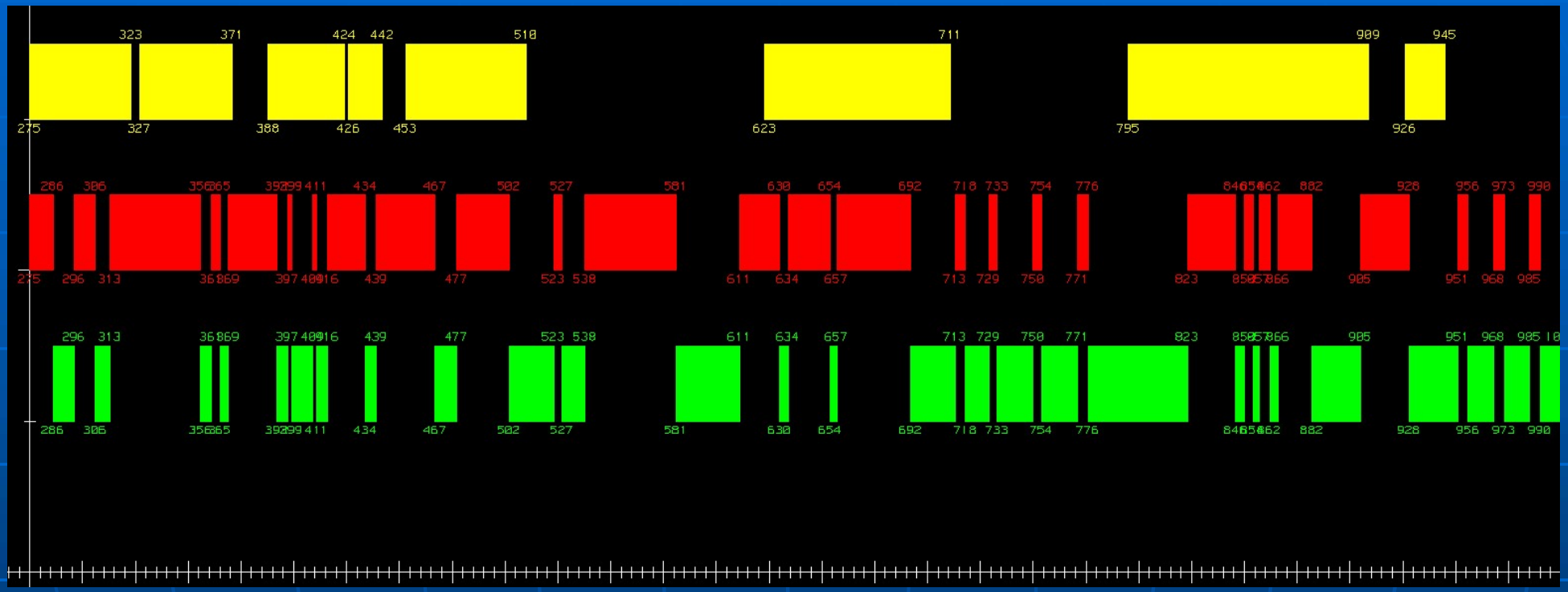
Fax. +44 (0)20 7981 3235
spectrum.licensing@ofcom.org.uk

NOV

- The new NoV enables access to the Terahertz frequencies in the range 275 - 3000 GHz subject to various conditions
- The NoV applies to this entire range and refers to
- ‘the Authorised band’ – Clause 6c
- ‘the Restricted band’ – Clause 6d several radio astronomy sites

The bands above 275 GHz

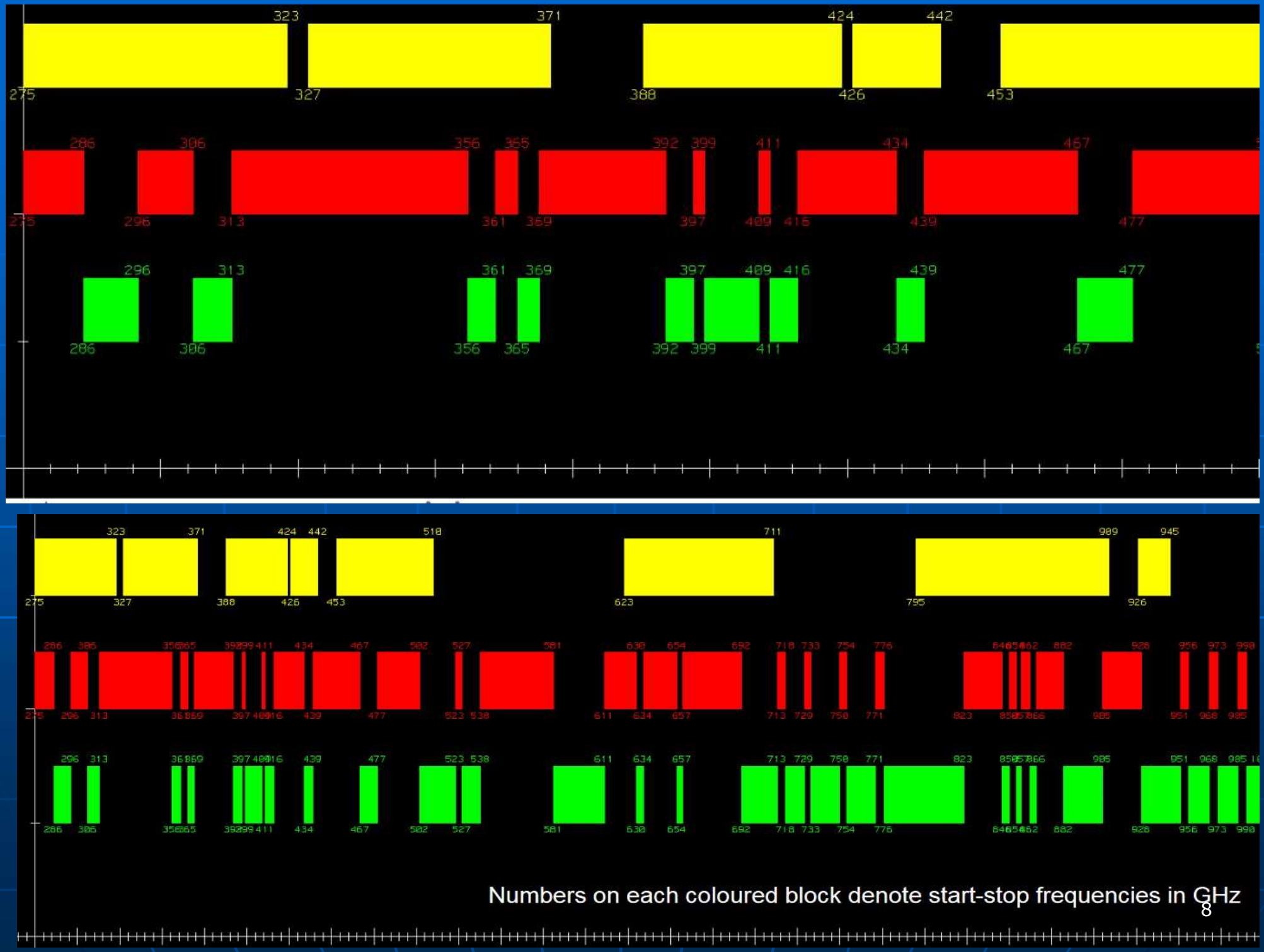


For the 275-1000GHz range, the coloured plot below illustrates:-

- **Red:** Authorised Band ranges where transmissions are **NOT** permitted

Restricted Band ranges - applicable to radio astronomy sites, as per 5e)

- **Green:** Potential Frequencies within the Authorised Band (subject to potential 20km radii)


Numbers on each coloured block denote start-stop frequencies in GHz

The Restricted band

- The Restricted Band relates to frequencies and sites associated with radio astronomy telescopes
- However from 1 to 3 THz a much less reduced set of restrictions apply

Radio astronomy sites

- Therefore no operation within 20km of specified astronomy observatory (yellow bands)
- A list of the sites that apply is given in the NOV but they are mainly in Cambridgeshire and the Midlands
- Note that the red frequencies still apply

The radio astronomy service is the likely sharer of these frequencies

Pickmere, Knochin, Darnhall, Jodrell Bank

Despite these restrictions we actually have “loads of room”

Propagation

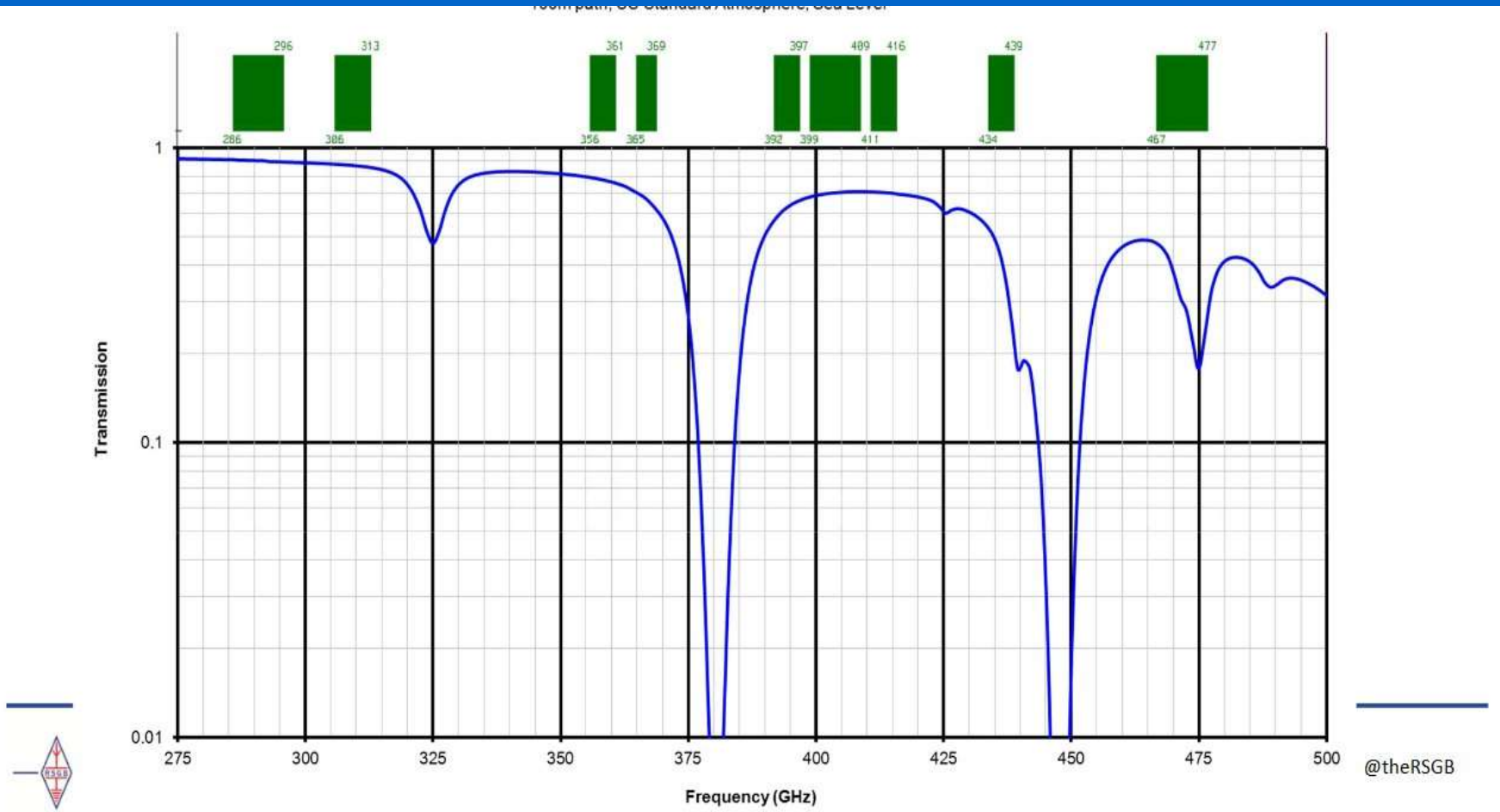
- Like many new THz frequencies there is little known about propagation at these frequencies
- The ITU have issued a request for studies in order for these frequencies to be used in the future for communications
- Even over a few hundred metres range and up to 1.2 kms we have experienced fading of up to 6dB
- As expected the free space path losses are high and are worse with water vapour

  (>> 1dB per km)

Propagation

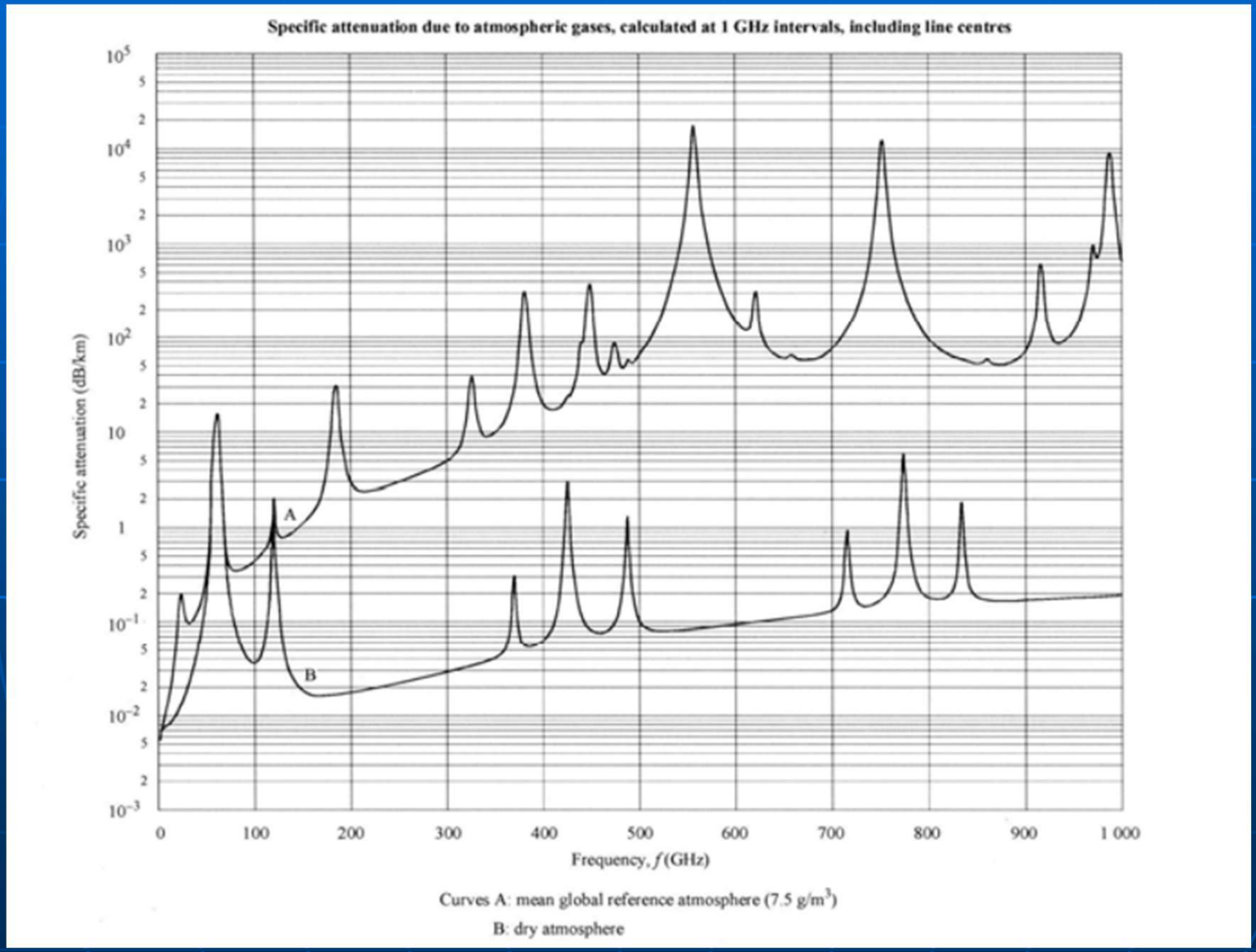
- Green shows potential bands for 275-500 GHz vs atmospheric losses
- • Note some high loss frequencies (due water resonances etc) BUT some potentially useful holes
- We are sure that Barry's Weatherbox should cover some of these frequencies such as 288 GHz but will need extra programming to cover higher frequencies
- Luckily the ITU database extends to 1000 GHz

Propagation



Although the oxygen losses are low @ 288 there is still up to 4dB extra path loss per km due to water vapour

Propagation



Power Restriction

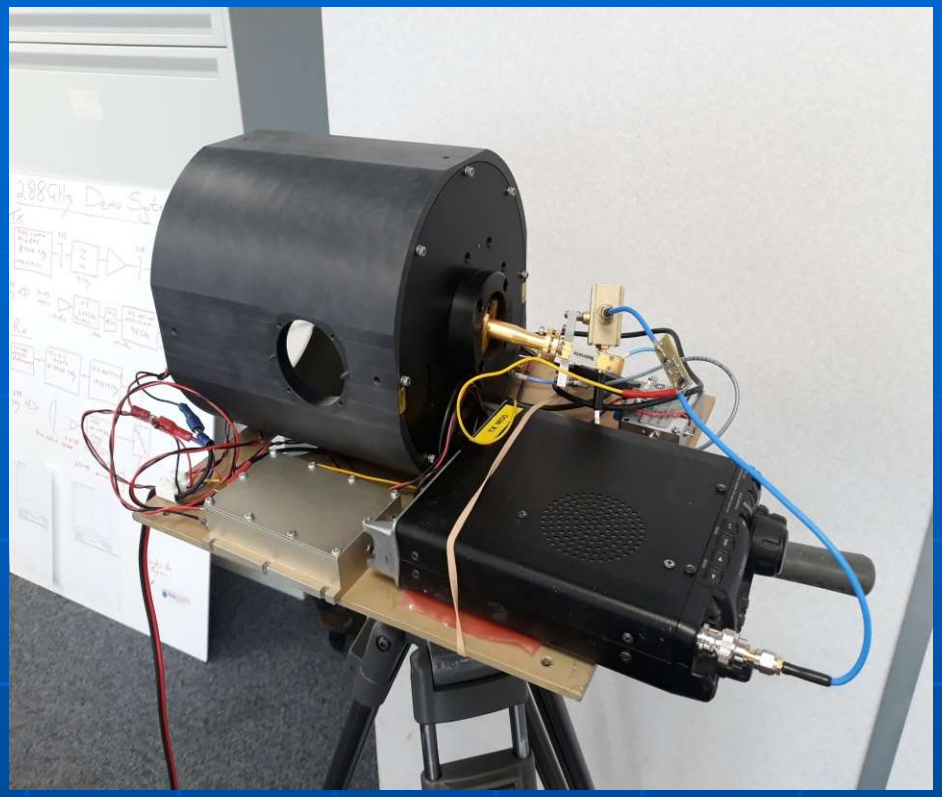
- The NOV TX power limit is 100mW.
- In practice source powers are much lower, LNAs and PAs are rare, so innovation and collaboration are encouraged

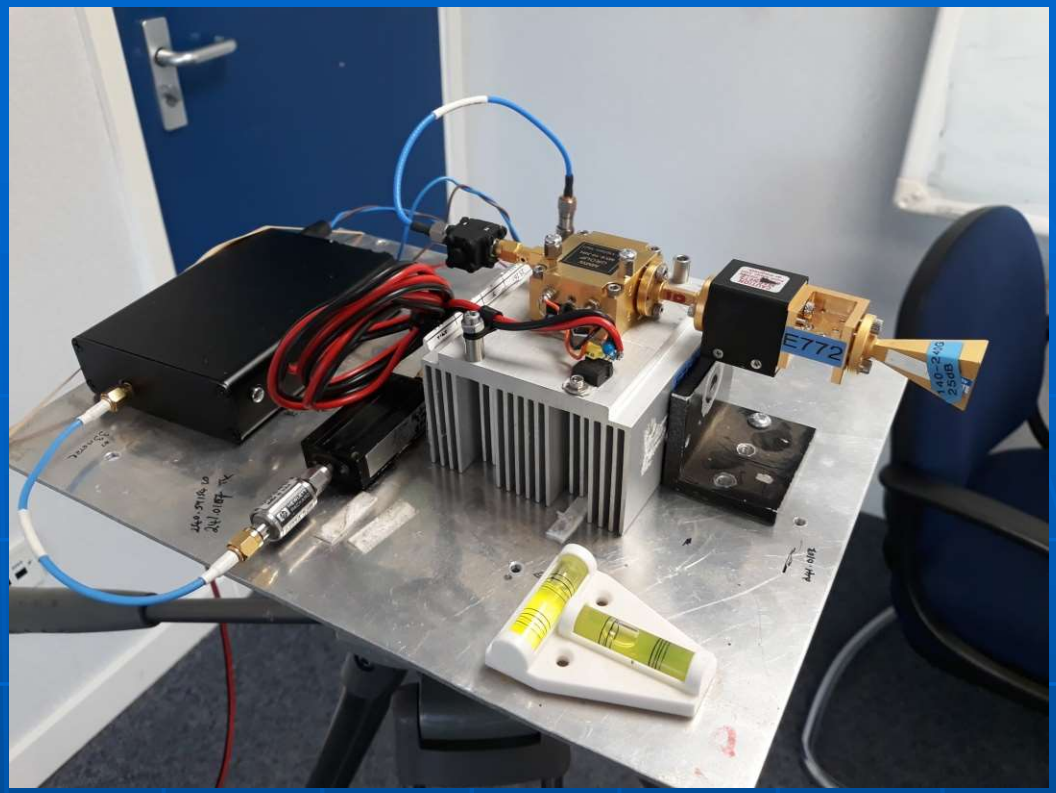
World-wide status

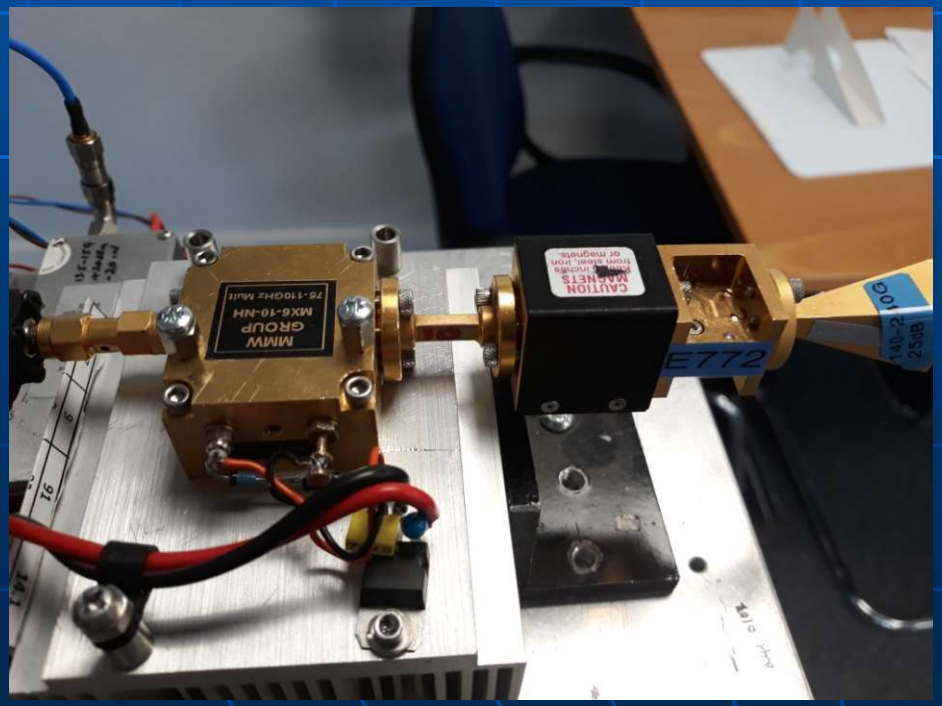
- The following countries have seen activity above 275GHz

- UK
- USA
- Germany
- Australia

UK



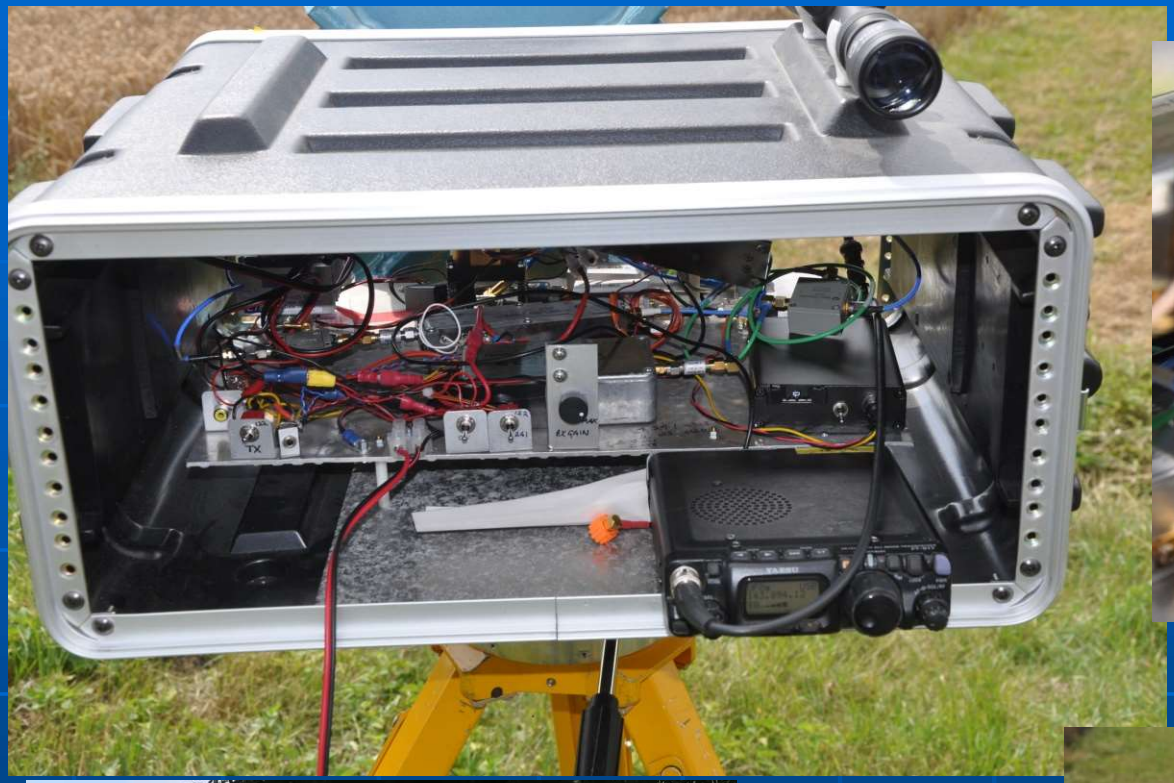


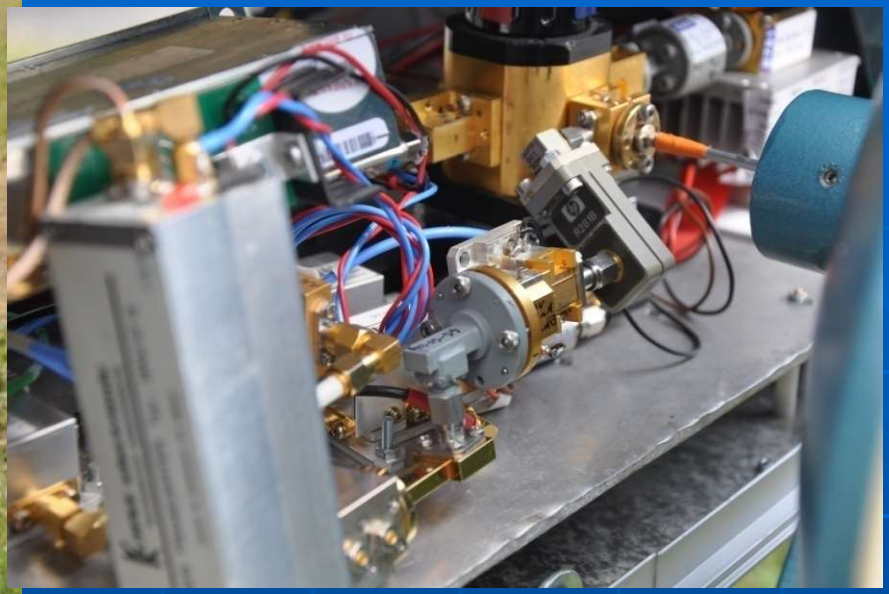


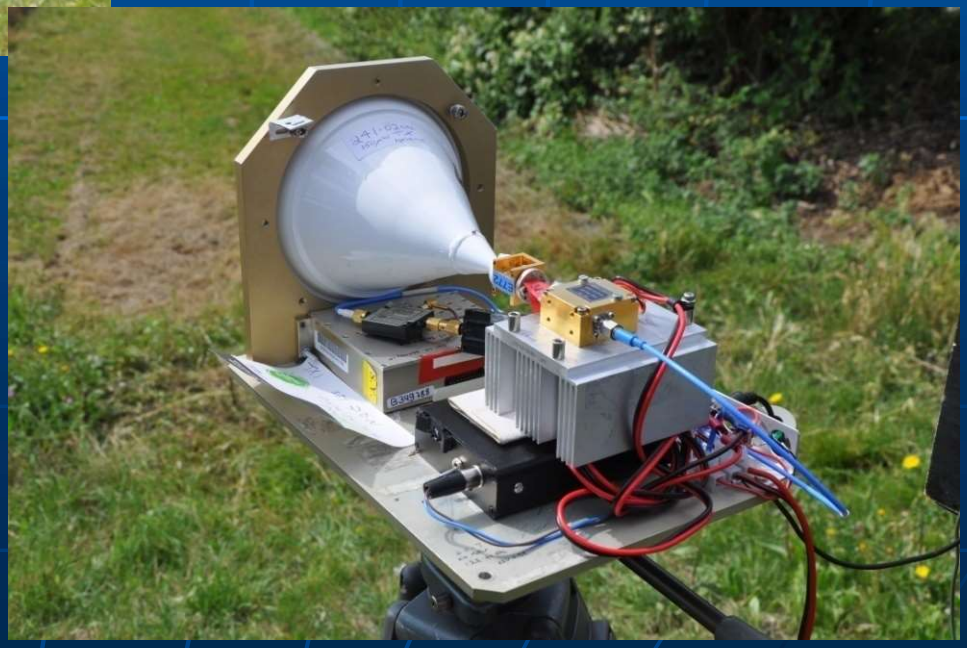
Early G8CUB equipment for 288 GHz

Note the (quasi-optical) lens horn antenna

Equipment

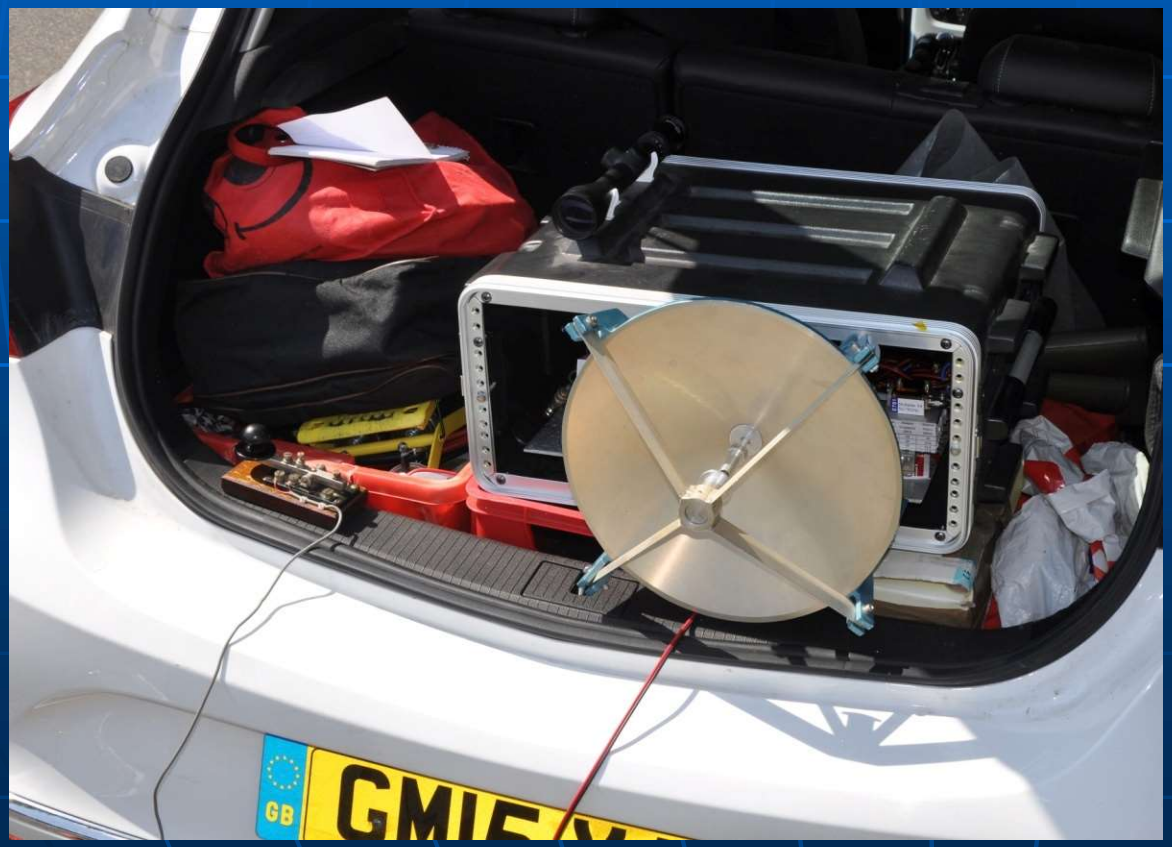


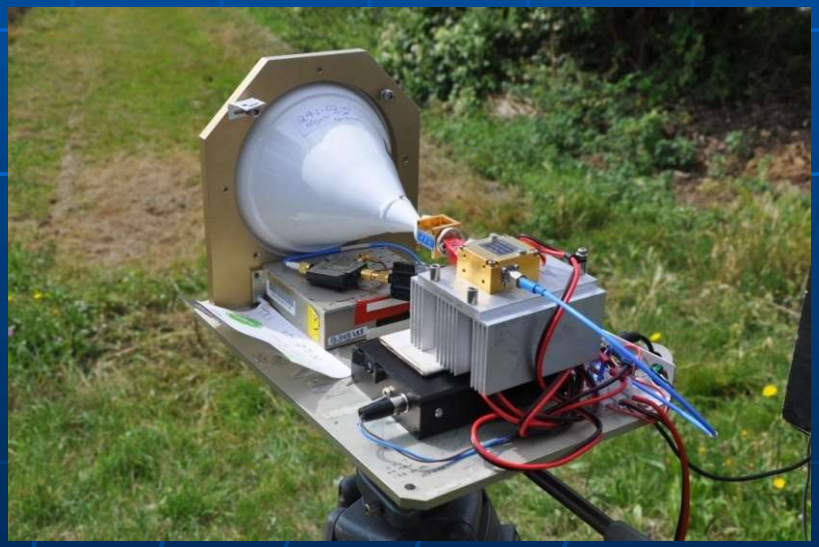




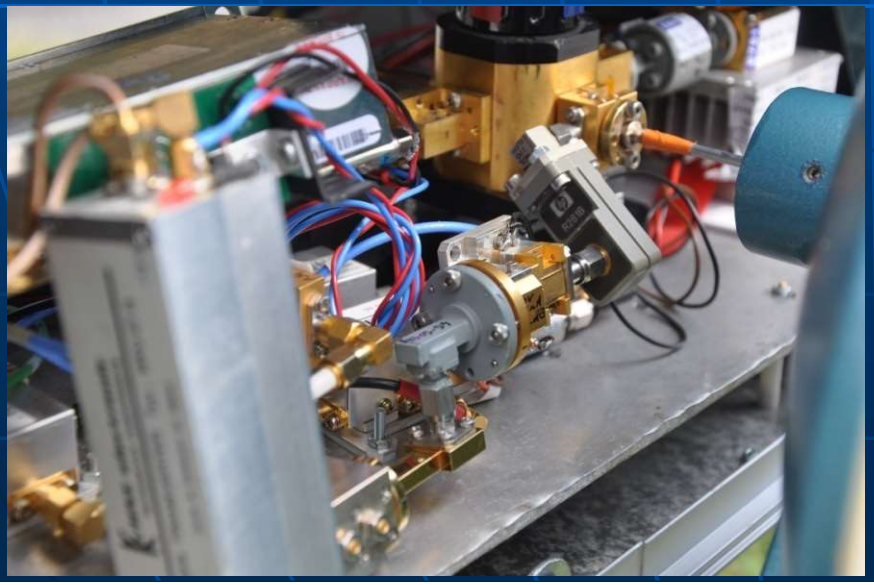
First UK contact at 288 GHz – 1mm

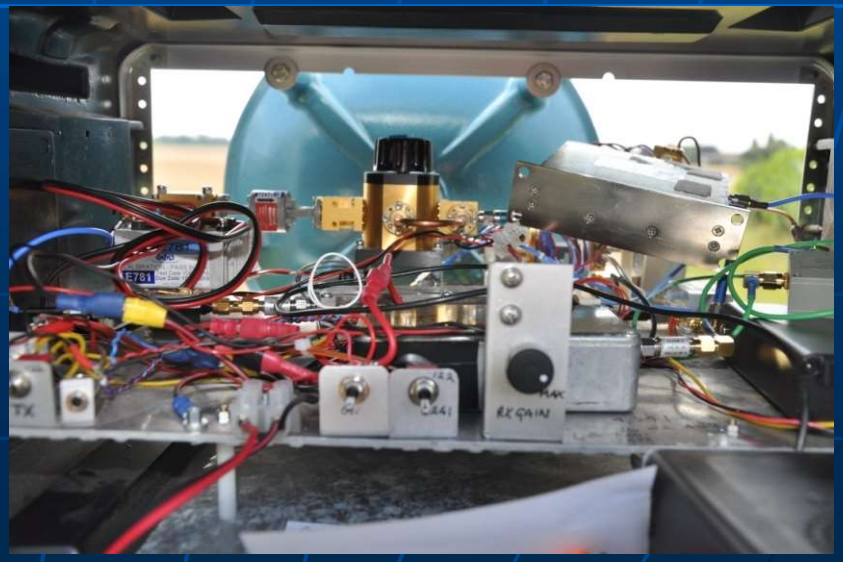
- On the 2nd August 2019 Roger G8CUB/P worked Chris G0FDZ/P on CW over a 175 m path for the first UK two-way contact





First UK contact at 288 GHz – 1mm





Testing over 500 m +

G0FDZ/P receiving Roger G8CUB/P's signal over 650 m for a 2 way contact

Alternative receive system ready for comparison over the 650 m path

Testing over 500 m +

Testing

G0FDZ/P receiving Roger G8CUB/P's signal over 1.2 kms

System ready for the first 2 way contact

Testing over 1.246 kms

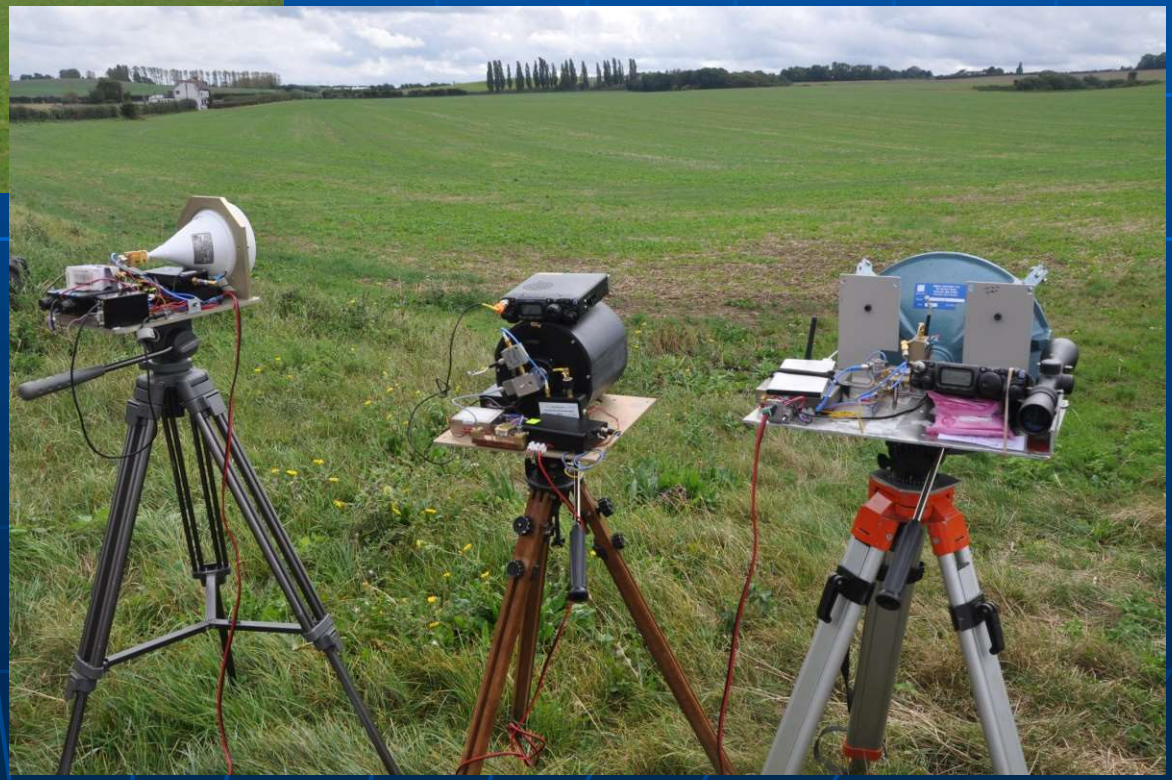
G8CUB/P ready for receiving G0FDZ/P over 1246 m

Low noise receiver with 12” cassegrain dish

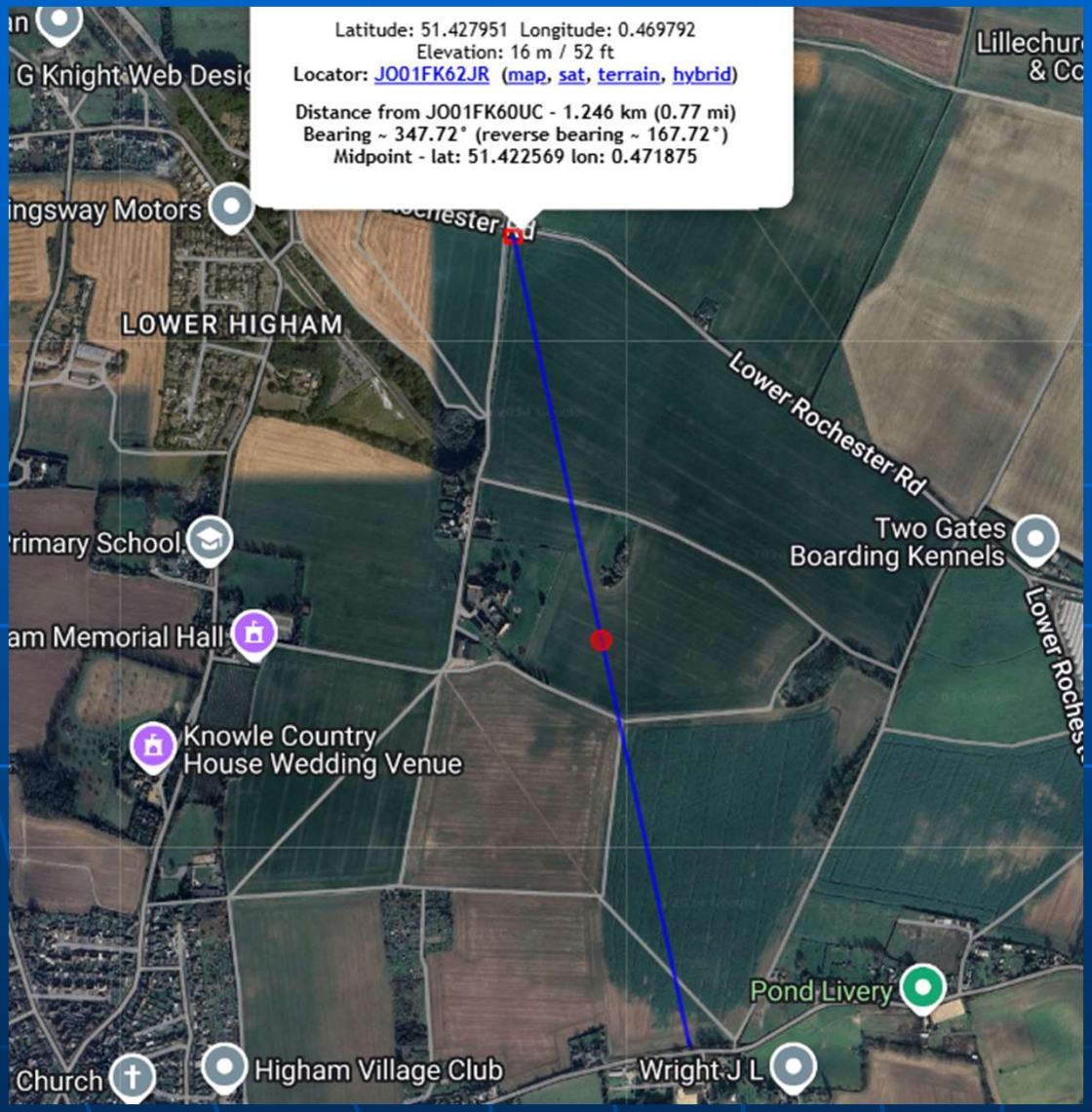
1.246 kms QSO at 288 GHz – 1mm

G8CUB/P located in JO01FK60UC (photo taken though telescopic lens)

G0FDZ/P located in JO01FK62JR



1.246 kms QSO at 288 GHz



G8CUB/P located in JO01FK60UC
Sent report 599

G0FDZ/P located in JO01FK62JR
Sent report 319

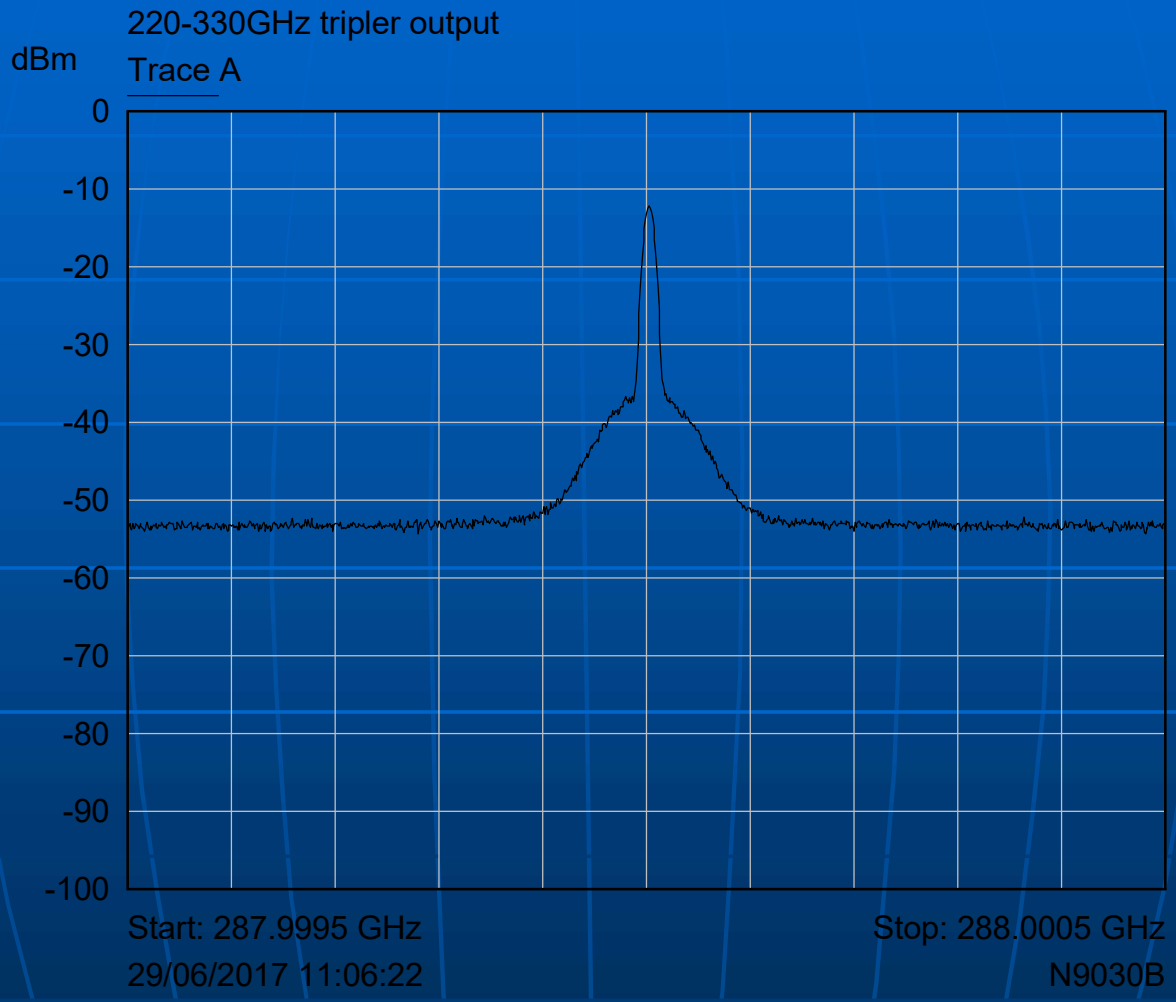
Path Loss 143.5 + 8.5 = 152dB
Dew point +15C

12th September 2019

288GHz Equipment

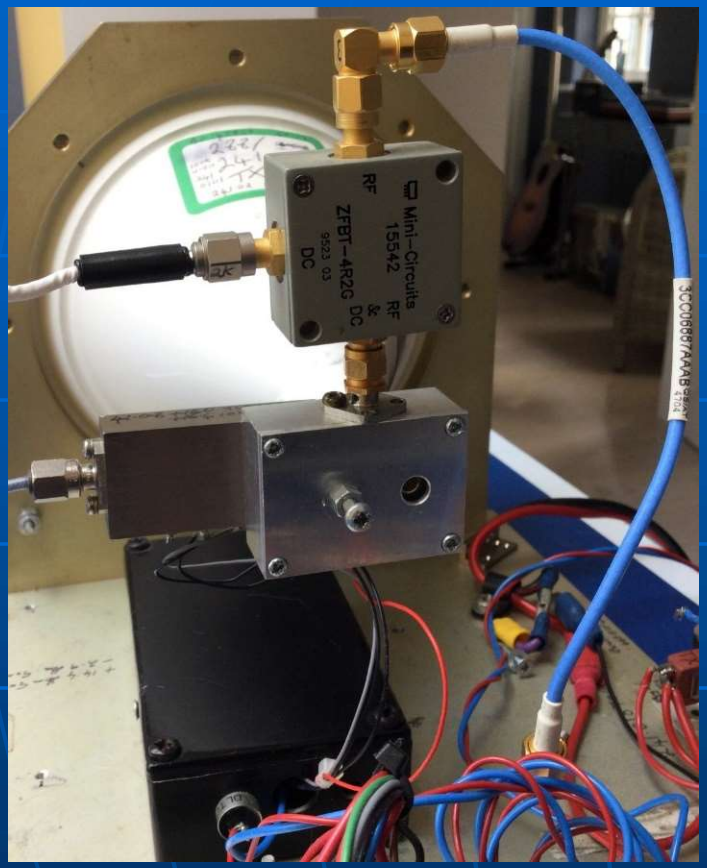
Tripler 220-330GHz, here 241GHz CMA to 40G, x2 80GHz
Output ~100uW @ 241GHz (for 288 32-96-288)

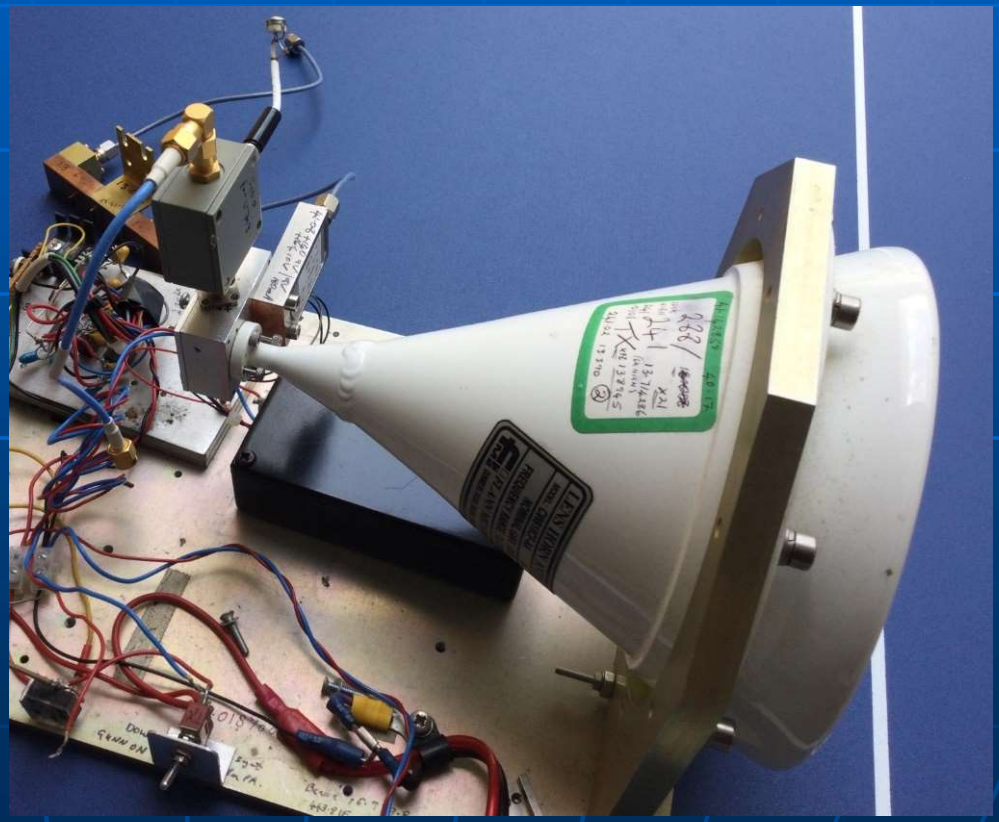
288GHz Equipment



16GHz x6 mult. +9dBm @ 96GHz, then x3 to 288GHz

288GHz Equipment





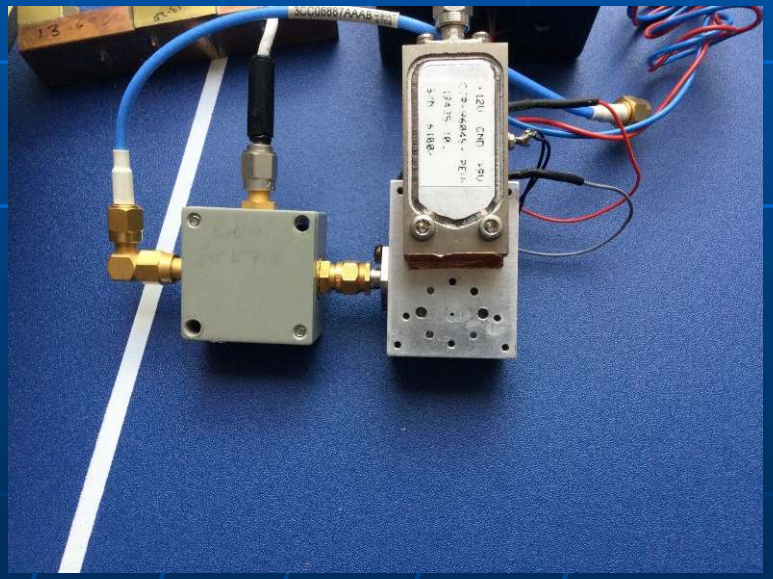
Receive x18 241GHz, x21 288GHz

288GHz Equipment

Receiver can operate on both 241 & 288GHz.

288GHz (x21)
288.000 – 0.432,3 = 287.5677
13.693,7 x3 = 41.081,1G
Harmonic mixer x7 to receive 288.000

241GHz (x18)
241.02 – 0.432 = 240.588
13.366 x3 = 40.098G
Harmonic mixer x6 to receive 241.02



288GHz Equipment

Sub-harmonic mixer used at 241 GHz with 432 MHz IF will work at 288 GHz with 47 GHz IF.
Possibility to make dual band 241/288 GHz transverter..
SSB signal using mixing already received at 7 km on 241 GHz.
Potential for aligning / QSO on 241 then switching to 288 GHz


wr-3.5 in/out


Wr-08 LO port

USA

USA

- US amateurs are allocated bands in both the Authorised and Restricted areas subject to non interference to radio astronomy and earth exploration satellites
- The allocation is anywhere except 275-323, 327-371, 388-424, 426-442, 453-510, 623-711, 795-909 and 926-945 GHz and on earth exploration satellite downlinks
- In the restricted band the rules are much less demanding

US amateurs have used two bands at 322 & 403 GHz

- 322 GHz 1.4 kms WA1ZMS/4 (FM07ji) - W4WWQ/4 (FM07ji) 4-Mar-2003*21-Dec-2004* **using WB equipment and FM**
- 320 GHz 0.5 kms WA201ZMS/4 (FM07ji) - W4WWQ/4 (FM07ji) 1-Mar-2002*/2 GHz
- 320 GHz 0.05 kms W2SZ (FM07ji) - WA4RTS (FM07ji) 15-Dec-2001

- 403 GHz 1.42 kms *WA1ZMS/4 (FM07ji) - W4WWQ/4 (FM07ji) 21-Dec-2004* **using WB equipment and FM**

- 403 GHz 0.52 kms WA1ZMS/4 (FM07ji) - W4WWQ/4 (FM07ji) 11-Apr-2003

Brian WA1ZMS 403GHz

Germany

DB6NT 411 GHz system

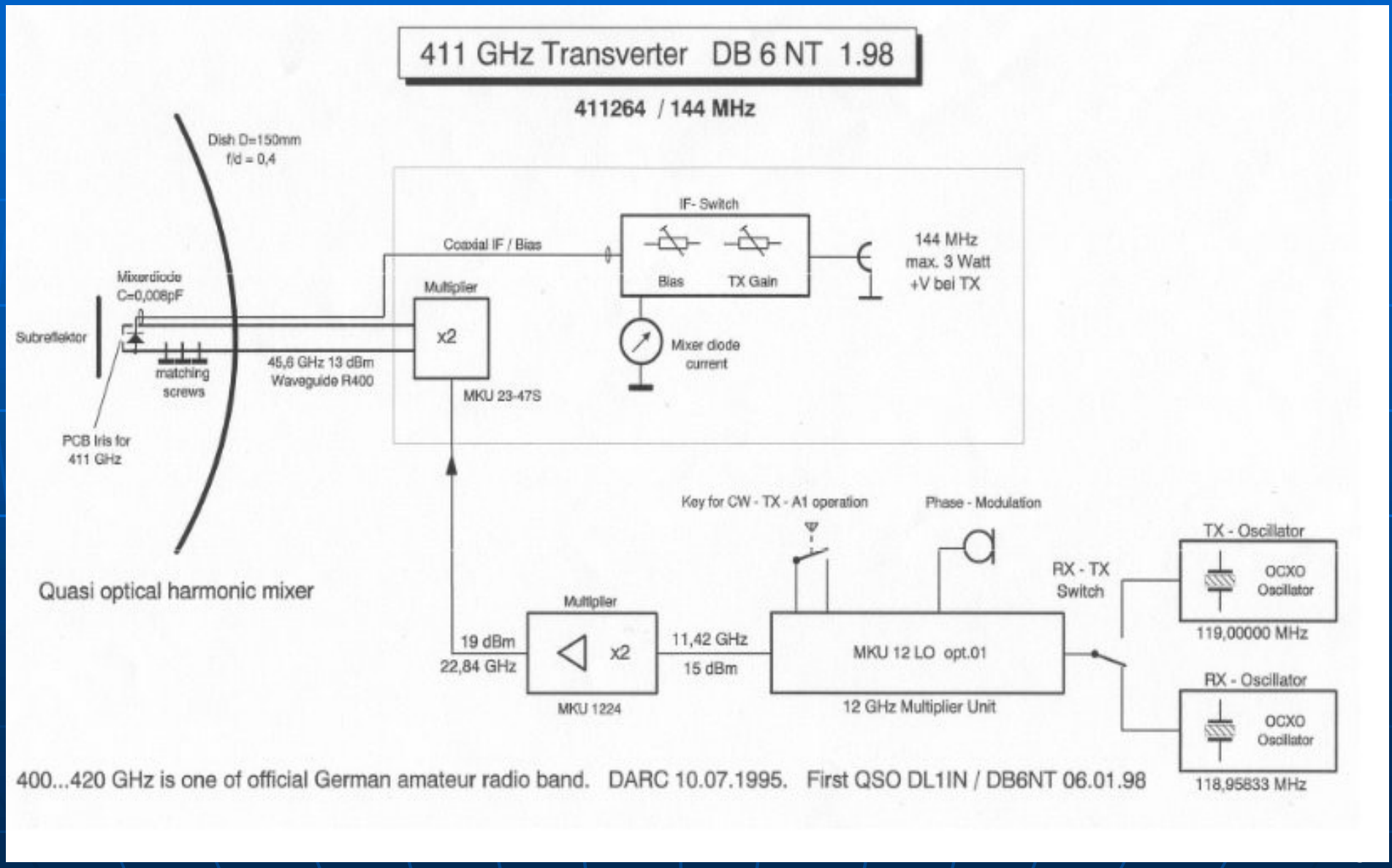
- It is thought that the first amateur sub-millimetre QSO took place on 6th January 1998 when DB6NT worked DJ1JN over 5 metres (0.005 km) using SSB on 411 GHz

DB6NT 411 GHz system

DB6NT 411 GHz system

- It appears that German amateurs have bands allocated and includes the frequency ranges
- 444 – 453 GHz, 510 – 546 GHz, 711 – 730 GHz, 909 – 926 GHz, 945 – 951 GHz and frequencies above 956 GHz can be used by the amateur radio service.

DB6NT 411 GHz system



DB6NT 411 GHz system

DB6NT 411 GHz system

- This system uses a dish ‘feed’ where the mixer diode is at the end of the ‘dish feed’.
- This is for several reasons but one reason to eliminate waveguide losses which can be severe.
- The waveguide actually carries the LO signal to the mixer. The system uses a 45.84 GHz which is the sub harmonic the of the actual LO

DB6NT 411 GHz system

- The antenna is a 150mm paraboloid which I probably the largest that can be handled
- The gain is approx. 58dB and the beam width is approx. 0.19 degrees
- The IF is 144MHz and the transverter needs 3 Watts of drive

DB6NT 411 GHz system

DB6NT 411 GHz system

- The system uses a 11.42 GHz source from a MKU 12 GHz for the LO
- This is followed by two x2 multipliers
- The final frequency is 45.68 GHz and the optical harmonic mixer uses the 9^{th} harmonic
- The MKU source uses special 110MHz crystals
- The two crystals are switched to give transmit and receive frequencies

DB6NT 411 GHz system

- The system was designed and built in the late 90's
- We consider that DB6NT's 411 GHz system to be a giant leap for amateur radio sub-millimetre developments

DB6NT 725 GHz system

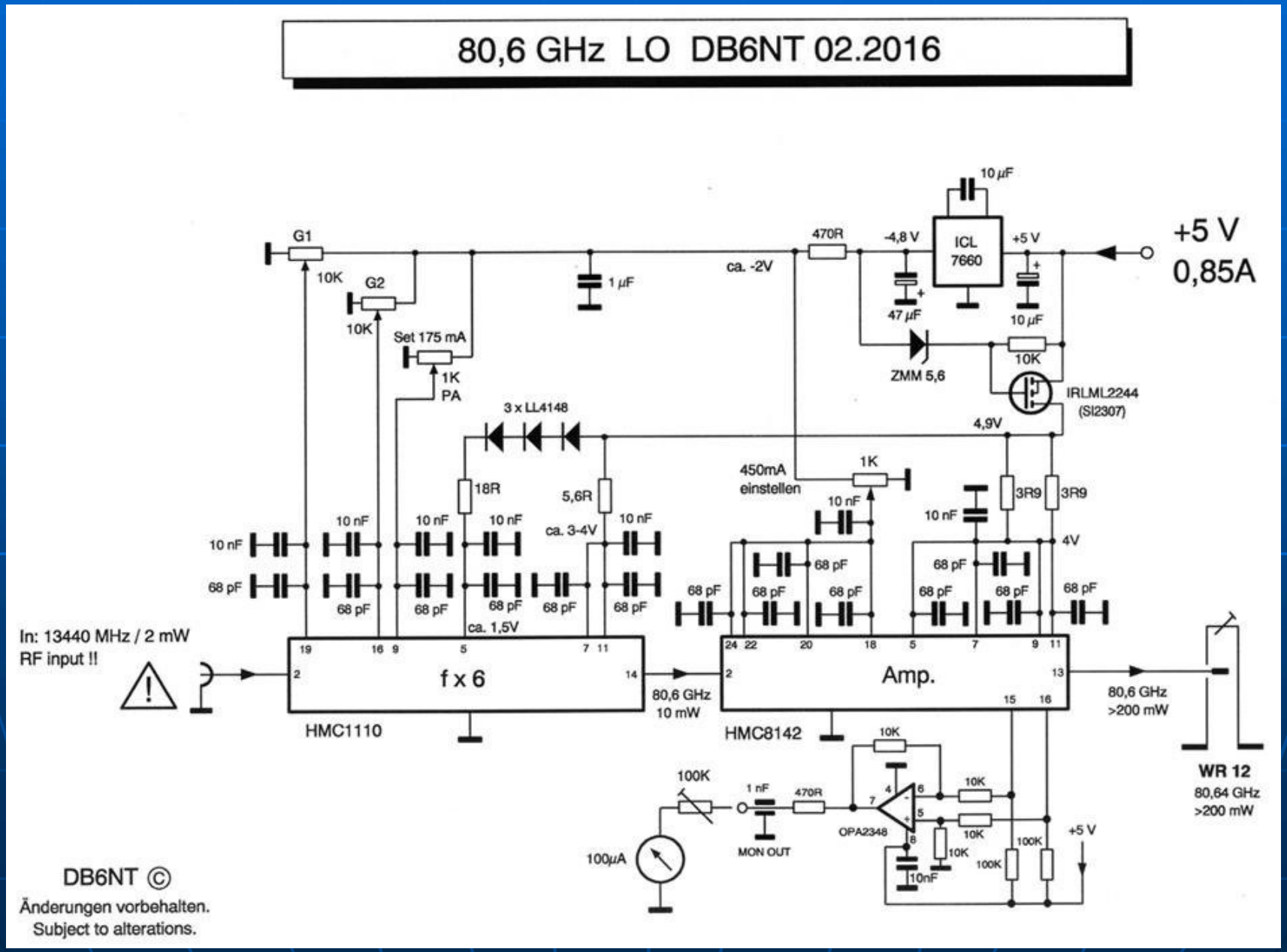
Not being content with 411GHz Michael then went onto develop a system at the incredible frequency of 725GHz
The 3RD harmonic of 241 was in the 711-730 GHz band

DB6NT 725 GHz system

DB6NT “After the completion of my second 241 GHz station, I wondered if the harmonics of the transmission signal could still be heard. Then I looked at the amateur radio frequency allocation for the bands above 300 GHz”

DB6NT 725 GHz system

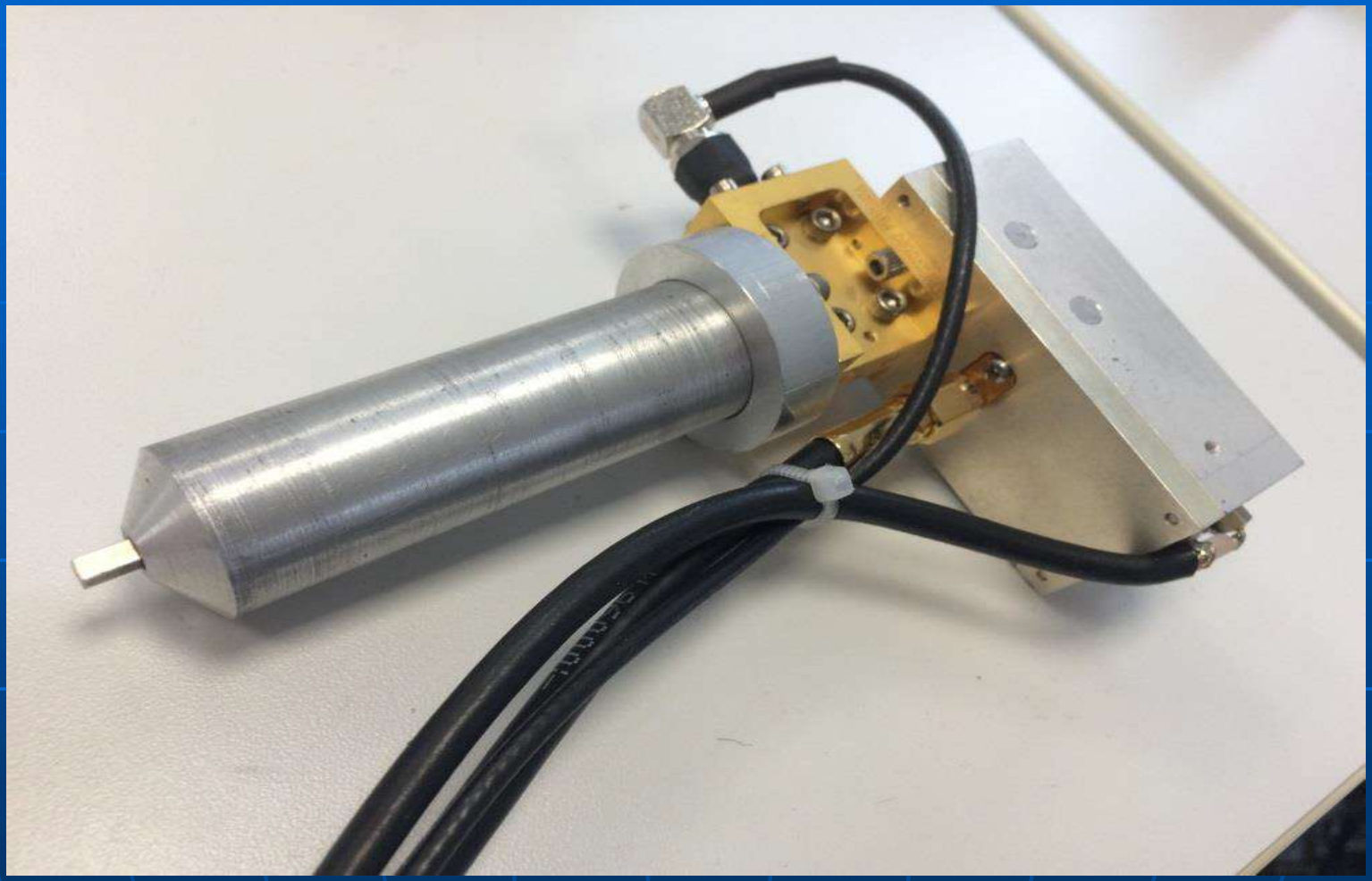
DB6NT 725 GHz system



DB6NT 725 GHz system

- Michael was already using a tripler driven at 80GHz to produce >20 mW!! at 241 GHZ.
- This gave 3rd harmonic output at 725 GHz.
- To receive 241 GHz he was using a sub-harmonic mixer with LO at 120 GHz.
- The 725 GHz harmonic (x6) mixer used the 120 GHz LO.
- HPF essential. 0.4 mm ID tube used. (450 GHz cut-off)

DB6NT 725 GHz system



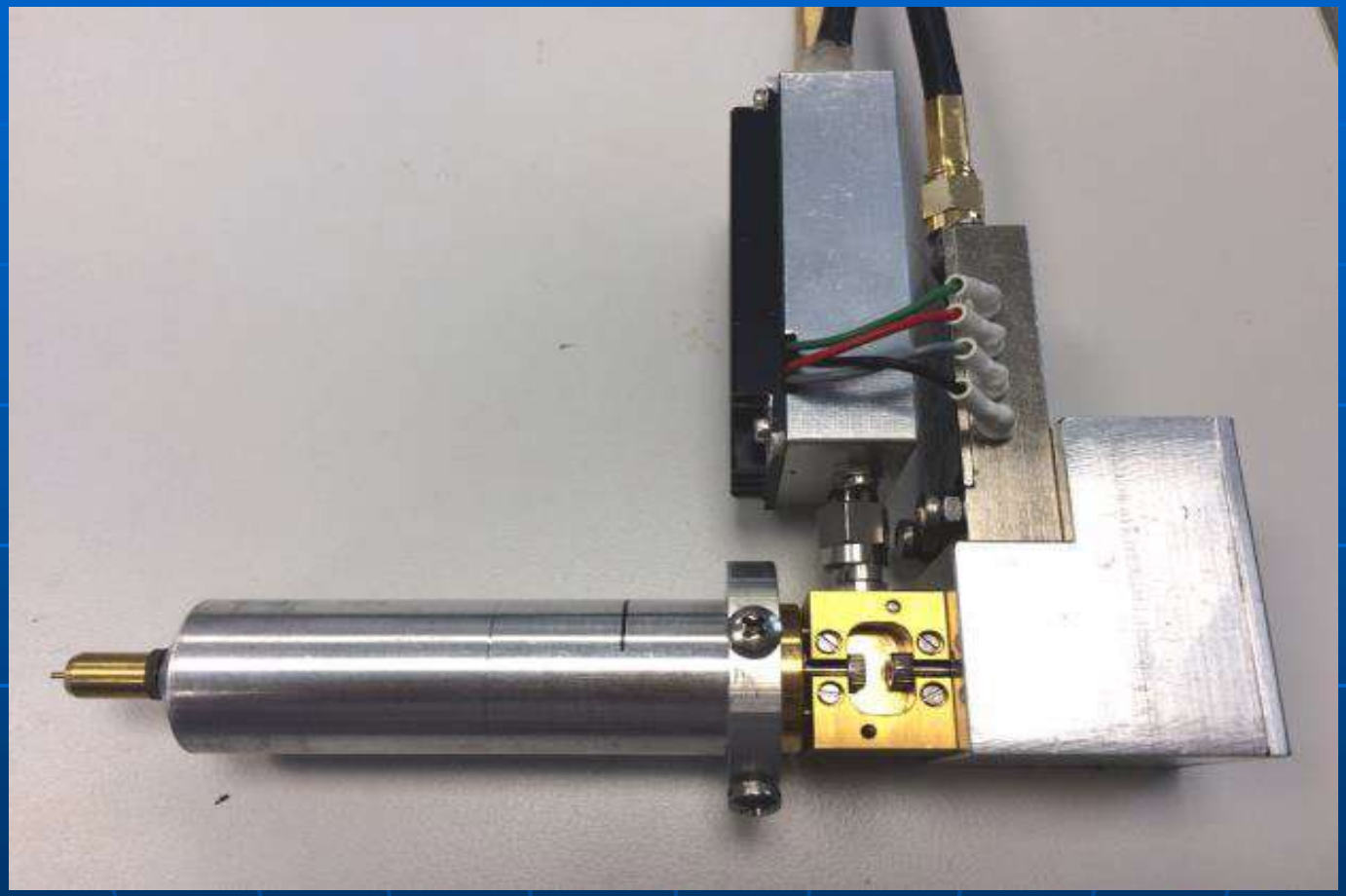
The antenna used was a 350 mm metal paraboloid having a gain of 67dB

(equiv. to 29 m! dish @ 10 GHz)

DB6NT 725 GHz system

Note the tiny hole for the circular waveguide is 0.25mm and cuts off at below 704 GHz

DB6NT 725 GHz system



The mixer assembly mounted at the focus of the dish

DB6NT 725 GHz system

Note that in both cases (411 & 725 GHz) the antennas could be either metal or silvered glass paraboloids. As we are quasi-optical we could also use lenses to provide gain

DB6NT 725 GHz system

DB6NT 725 GHz system

Michael DB6NT and Andreas DB2NP made on 20th July 2020 first-ever QSO on 725GHz over 20m


DB 6 NT EHF TRIBAND TRANSVERTER 122 / 134 / 241 GHz
CE
OUTPUT POWER
PLL - LOC
HF
U-BATT
CW TX ON
10 MHz IN
Intern
Extern
12...15 V
134 GHz
122 GHz
241 GHz
ZF
Key
BAND
144 MHz IF
max. 3 Watt


241 GHz
RX

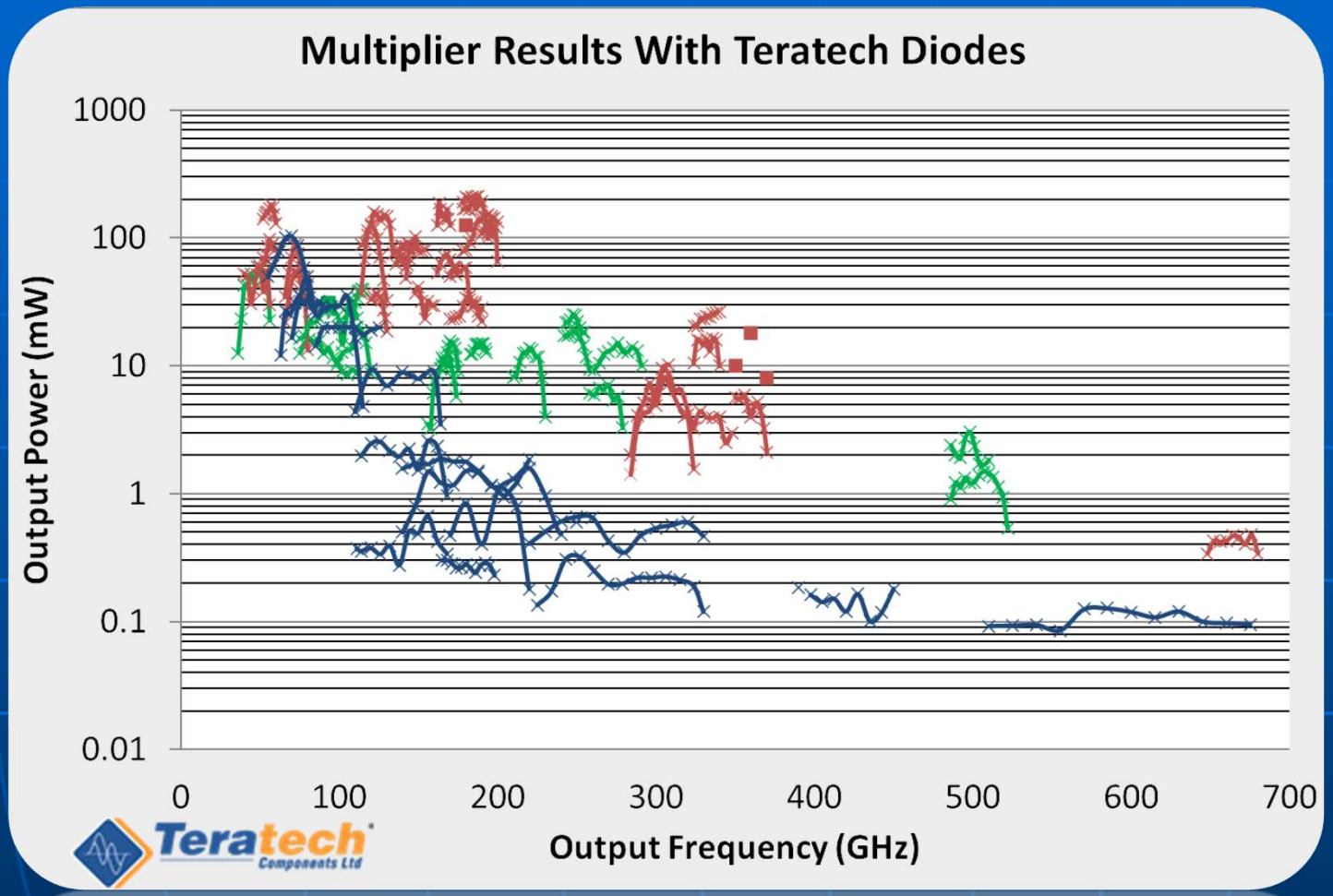
Australia

Australia

- On the 21st August 2011 VK3FH & VK3XPD worked on 324 GHz over a distance of 25 metres (0.025 kms)

Operating on the highest frequencies

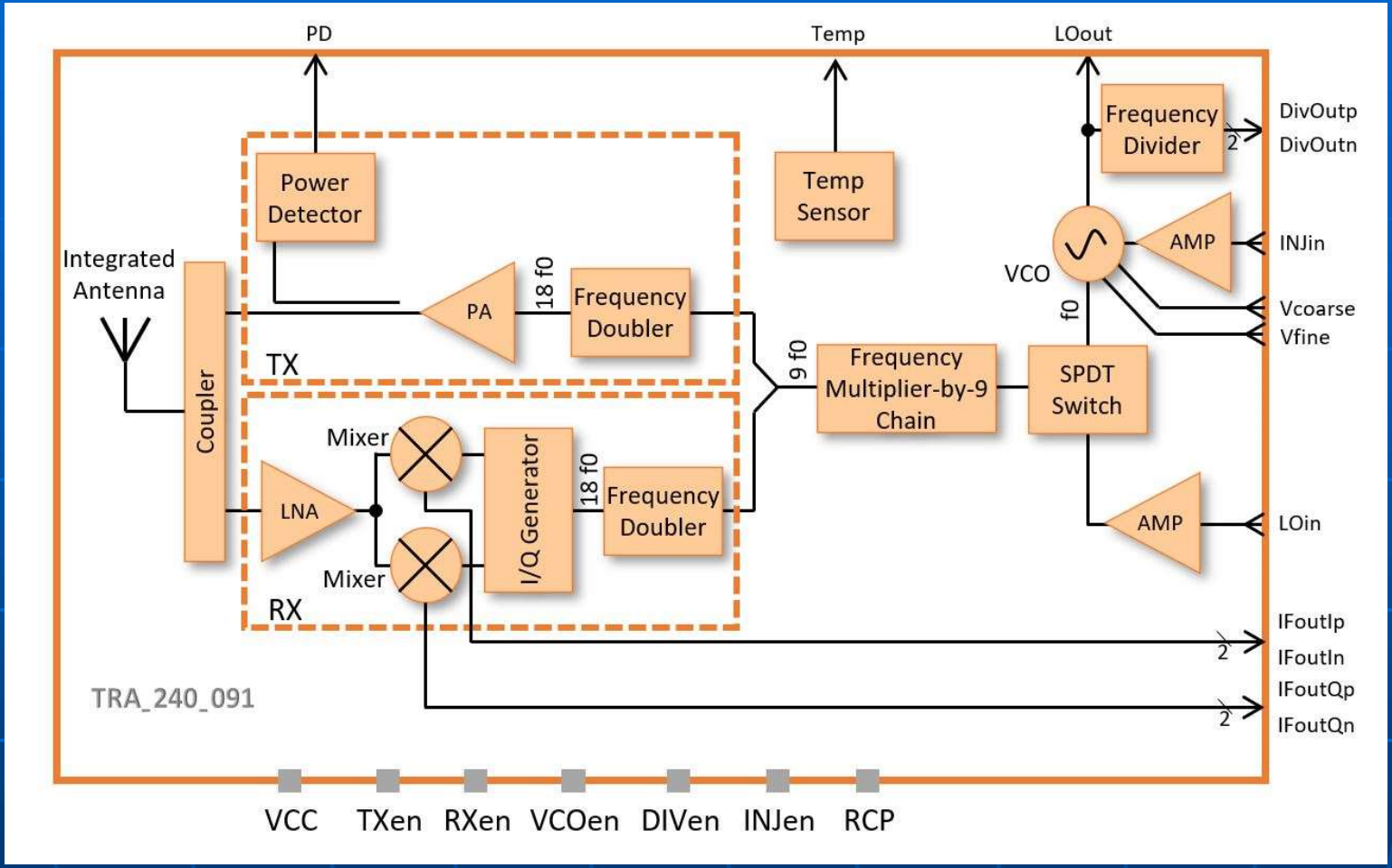
- Reliable equipment and power supply essential
- Radio talkback is highly desirable for real time usage
- Some pre-site map work with path drawn on OS map is very useful - landmarks on/near path
- Alternatively use http://k7fry.com/grid/?qth=JO65HQ which will work with 10 digit locators which are preferable at this frequency
- Rifle site needs careful alignment with antenna system
- Use of a high power 5W red LED behind a Fresnel lens (A4 page magnifier) using nanowave technology for alignment - can be seen in daylight over many kilometres !!
- Temperature/humidity data will help to determine the best time to operate



RED Doubler

GREEN Tripler

BLUE Wideband



New Indie 222.5 – 267.5GHz Transceiver TRA_240_091
Not quite >275GHz yet!

The End