PWNVHFS Microwave Special Interest Group Activities

Ray Cannon W7GLF

(Many slides courtesy of K6ML)

What is “microwave”?

The term “microwave” is not a scientifically defined unit. Different sources define different ranges as microwaves. The ARRL defines it as the range of frequencies from 900 MHz to 300 GHz. If you search on Google you will find a definition of between 1 meter and 1 millimeter wavelength which would be from 300 MHz to 300 GHz. Another common definition in radio frequency engineering is the range between 1 and 100 GHz (wavelengths between 0.3 m and 3 mm).

Most hams consider anything from 900 MHz up to infrared (300 GHz) as “microwave”.

Higher Frequencies:

All modes and licensees (except Novices) are authorized on the following bands [FCC Rules, Part 97.301(a)]:

> 2300-2310 MHz
> 2390-2450 MHz
> 3300-3450 MHz (Access to the 3.45 - 3.5 GHz Amateur Radio allocation ceased 4/14/22)
> 5650-5925 MHz
> 10.0-10.5 GHz
> 24.0-24.25 GHz
> 47.0-47.2 GHz
> 76.0-81.0 GHz*
> 122.25 -123.00 GHz
> 134-141 GHz
> 241-250 GHz
> All above 300 GHz

* Amateur operation at 76-77 GHz has been suspended till the FCC can determine that interference will not be caused to vehicle radar systems

Why Operate Microwaves?

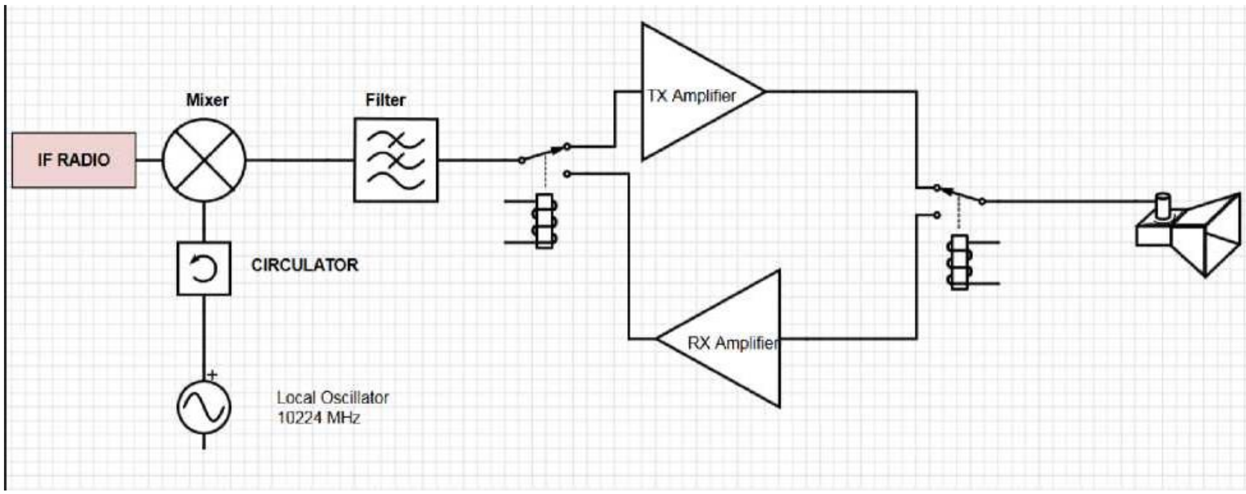
- “Because they are there”
- Smaller antennas for the same gain
- Challenge of building your own radio
- Challenge of working DX
- “Use it or lose it”
- Portable operation
- Extra points in contests
- Short haul high capacity data links
- Experimentation

Challenges of Microwaving

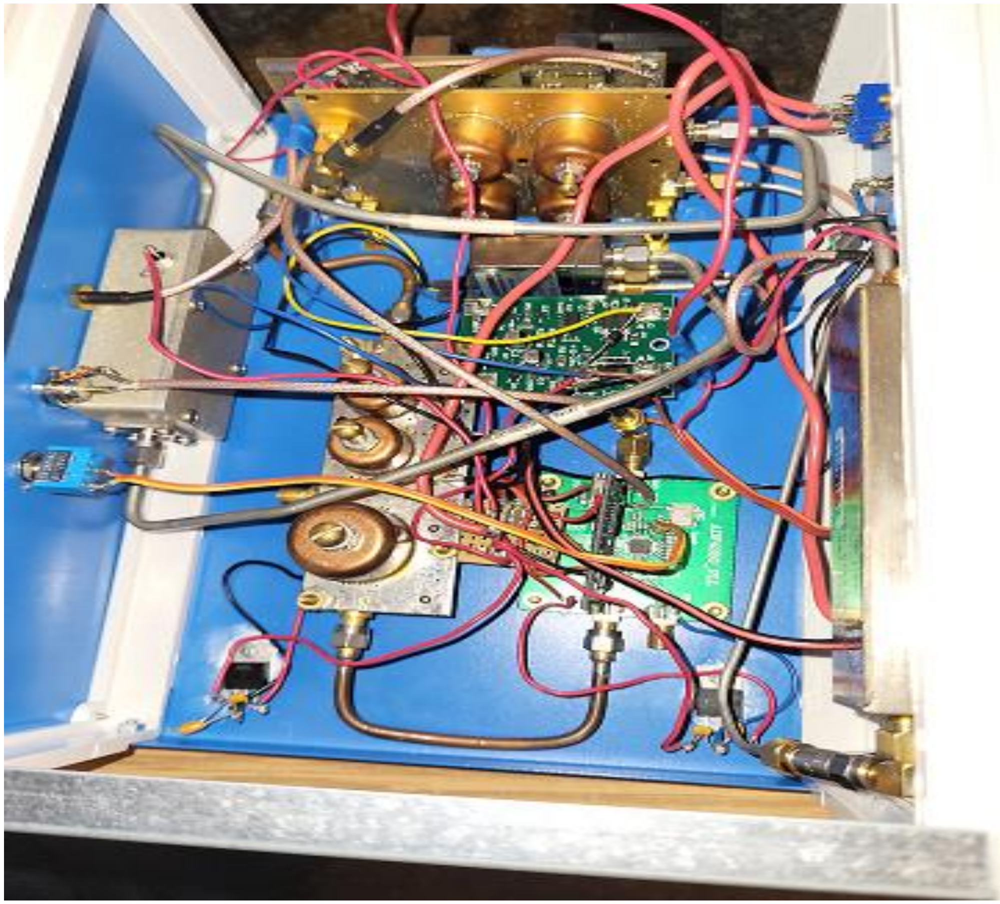
- ***Above 100 MHz…***
  - the ionosphere rarely reflects signals, we are limited to line of sight propagation, with some occasional tropo enhancements
- ***Above a few GHz…***
  - wires aren't wires, normal PCB traces and materials don't work
- ***Above 20 GHz…***
  - the atmosphere starts fighting us (water vapor, oxygen losses)
- ***Above 100 GHz…***
  - most transistors stop working
- ***Other than that…***
  - no worries.

Microwave Group Projects

Review: A transverter is conceptually a very simple device



Our first project was building 10 GHz transverters based on W1GHZ boards
http://www.w1ghz.org/MBT/Simple_and_Cheap_Transverter_for_10_GHz.pdf
Here is a picture of mine (I recently added a DEMI preamp and a 200 mW amplifier). It can lock an internal or an external Local Oscillator.



Another project was building W6PQL 1296 amplifiers from scratch.   Which included etching Duroid PC Boards with a homebrew light box using UV LEDs (by AG6QV Frank)…

A Current Project

A number of our group purchased 122 GHz Transverter boards.
Why 122 GHz? See the W1MBA Microwave Group to the message below…

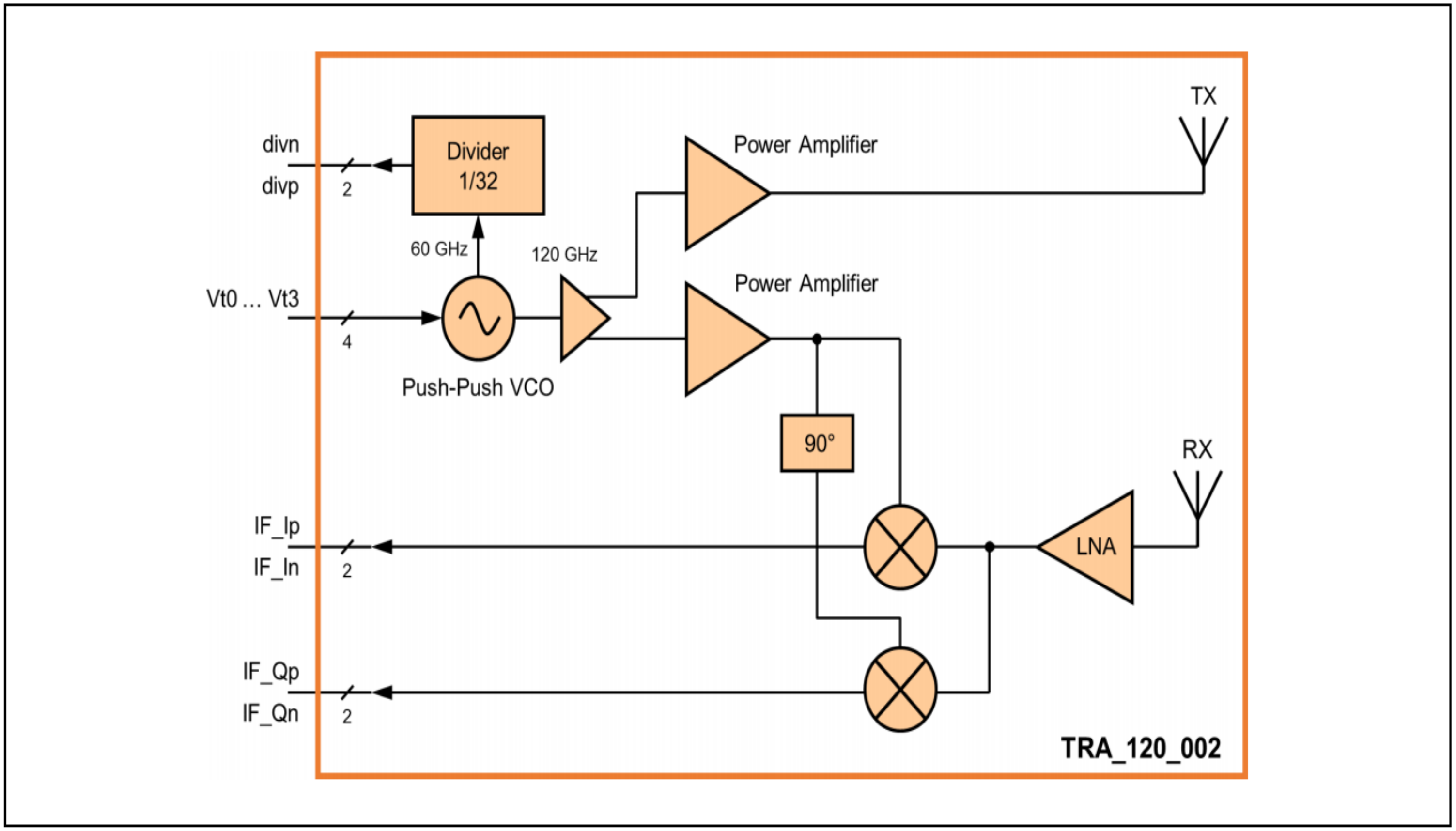
From: MIKE LAVELLE (K6ML) <miclevel@comcast.net> on W1MBA Microwave Reflector 9/17/2019

FYI, Andrew (VK3CV) has just published (in DUBUS magazine) a second 122 GHz radio design based on a Silicon Radar chip (https://siliconradar.com/products/#120ghz-radar-chips). Tim (VK2XAX) is organizing a group buy of assembled PCBs and machined horns based on Andrew's design.

The RF specs are **half a milliwatt power out, 11 dB NF and separate in-package Tx and Rx antennas.** 122 GHz propagation is not easy; it's very highly dependent on water vapor and oxygen absorption loss (about 1 to 2 S-units extra loss for each 10km of path length at typical humidity and sea level, see WA1ZMS's mmwave loss charts at www.wa1mba.org). The way to get DX on this band is to operate at an extremely low dew point and high elevations, to reduce H2O and O2 losses, and on a LOS (Line Of Sight) path.

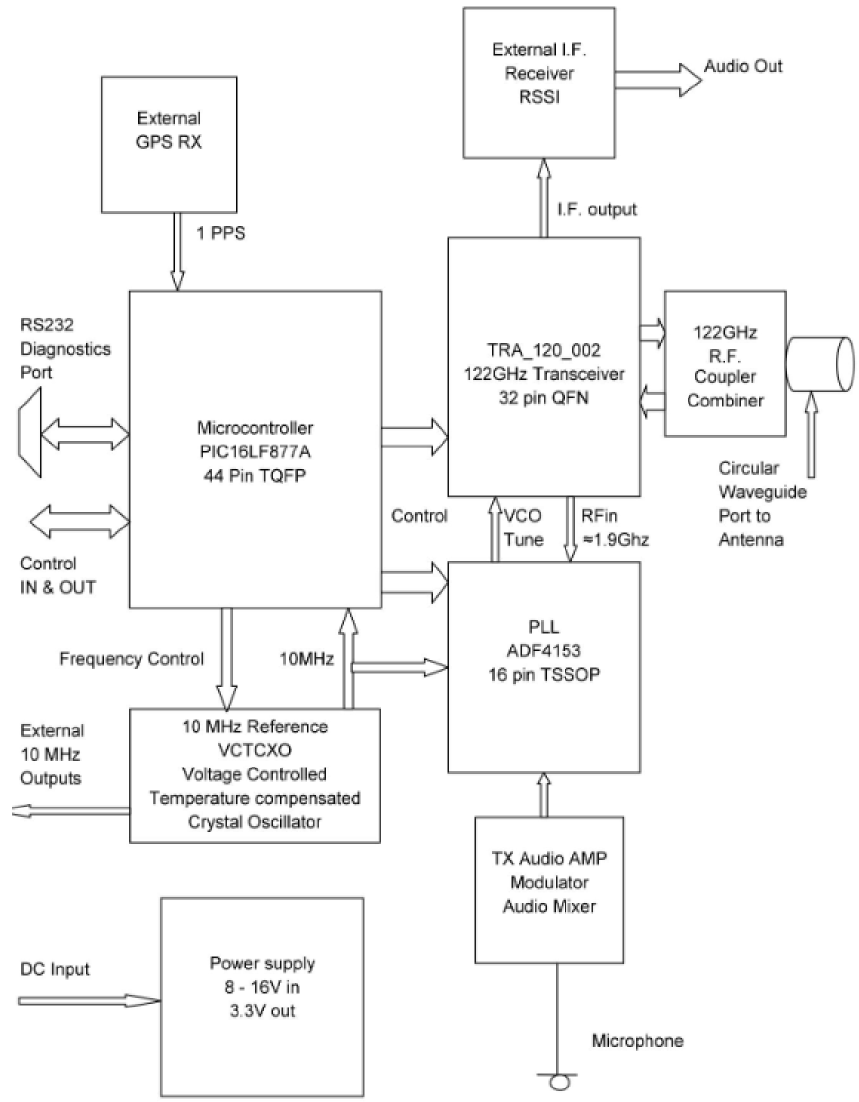
TRA_120_002

120-GHz Highly Integrated IQ Transceiver with Antennas on Chip
in Silicon Germanium Technology



Note: all of the high frequency RF is on the chip. The interface to the outside world is at 122500 MHz divided by 64 or at 1914.06875 MHz which is supplied by an ADF4153 synthesizer chip.

Simplified Block Diagram of the 122GHz Transverter



Items From VK2XAX

Chaparral style feed horn & coupler

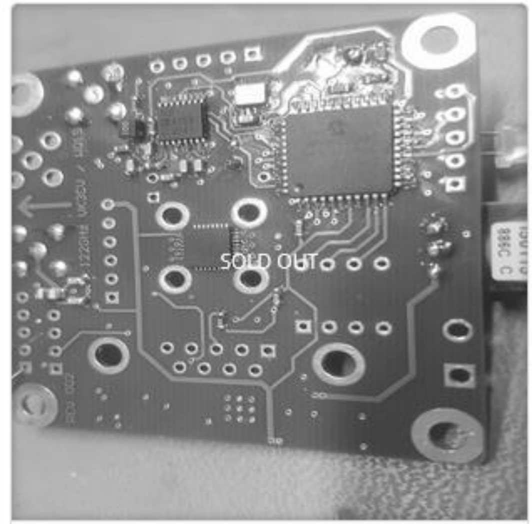
$31 USD

Feed horn & coupler used with an offset feed dish in the published article

Conical Horn

$42 USD

21DBi Conical horn with integrated coupler as used in the portable beacon

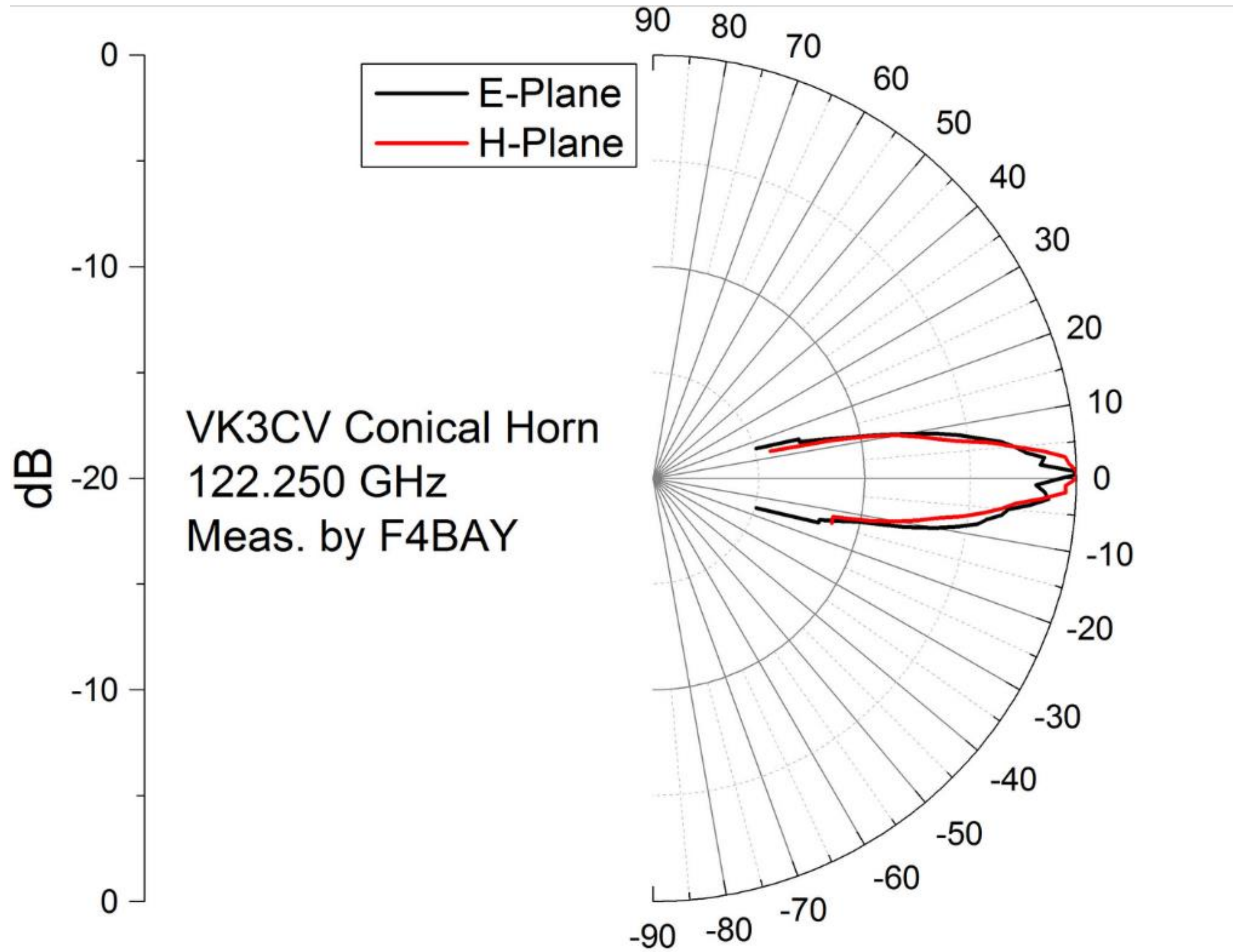


Assembled & tested PCB

$128 USD

122GHz assembled and tested PCB, SMA sockets not included.

Read more



The Real World

FREE SPACE, BENIGN PROPAGATION CONDITIONS

The frequency and distance dependence of the loss between two isotropic antennas is expressed in absolute numbers by the following equation:

$$L_{FSL} = (4\pi R/\lambda)^2 \quad \text{Free Space Loss}$$

where R: distance between transmit and receive antennas; λ: operating wavelength.

After converting to units of frequency and putting in dB form, the equation becomes:

$$L_{FSL\ dB} = 92.4 + 20 \log f + 20 \log R$$

where f: frequency in GHz; R: Line-of-Sight range between antennas in km.

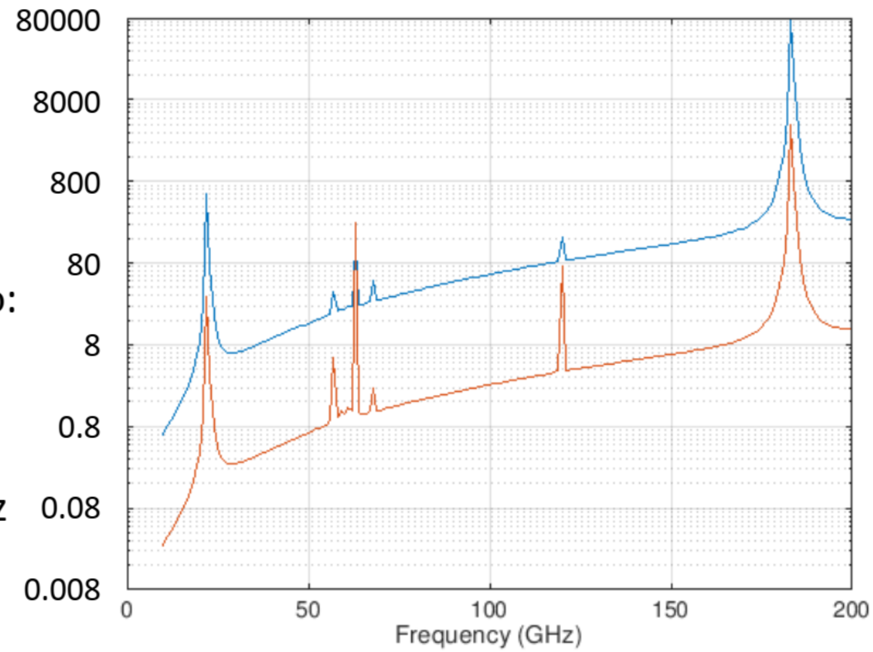
The Rest of the Story

Additional Atmospheric Loss

(dB / 100 km)

Above 20 GHz, additional losses due to:

- Water Vapor loss (humidity)
  - Steady upward trend
  - Peaks at 22 & 183 GHz
- Oxygen resonances at 60 & 119 GHz
  - Worst at sea level



➢ Blue curve for 68F, 50% RH, sea level

dB	144 M	1.2 G	10 G	122 G
TOTAL FSPL (100 km)	-115.5	-134.5	-152.5	-172.5
ATML (50%RH, at SL)	-0	-0	-0	-80
TOTAL PATH LOSS	-115.5	-134.5	-152.5	-252.5

For comparison, the typical 2M moon bounce (EME) path loss is -252 dB

➢ Red curve for 60F, 10% RH, 4700' ASL. It tells us "for best DX, go to the mountains in extremely dry weather"

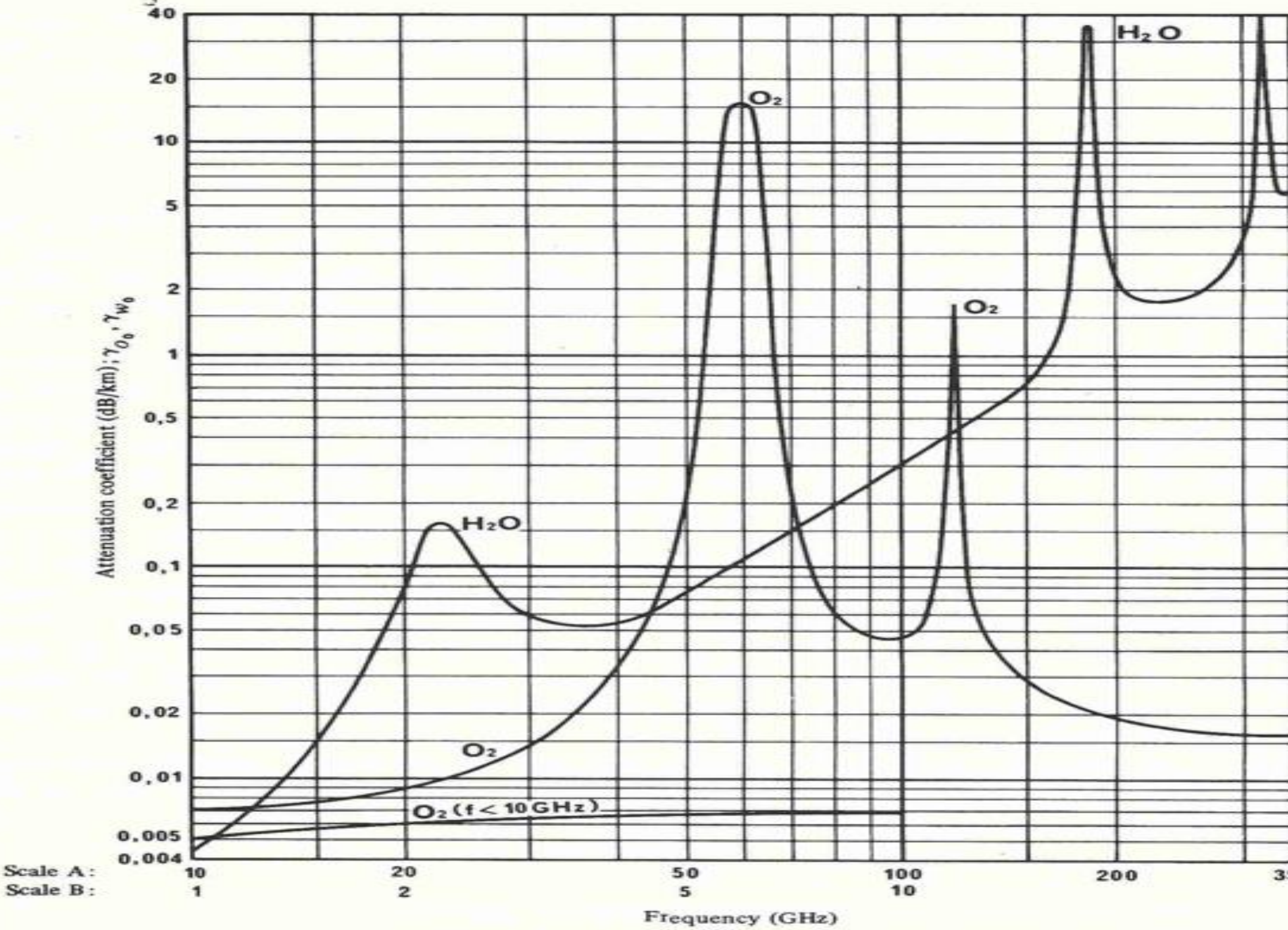
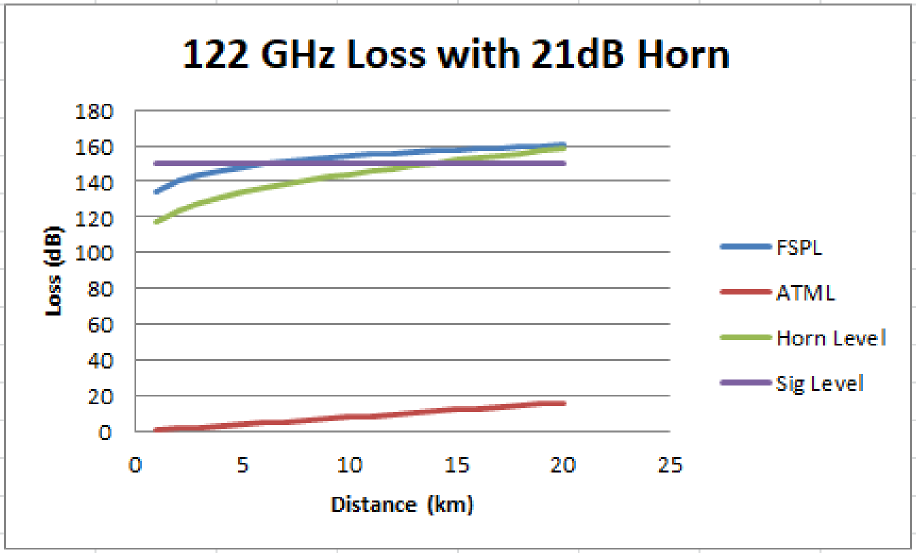
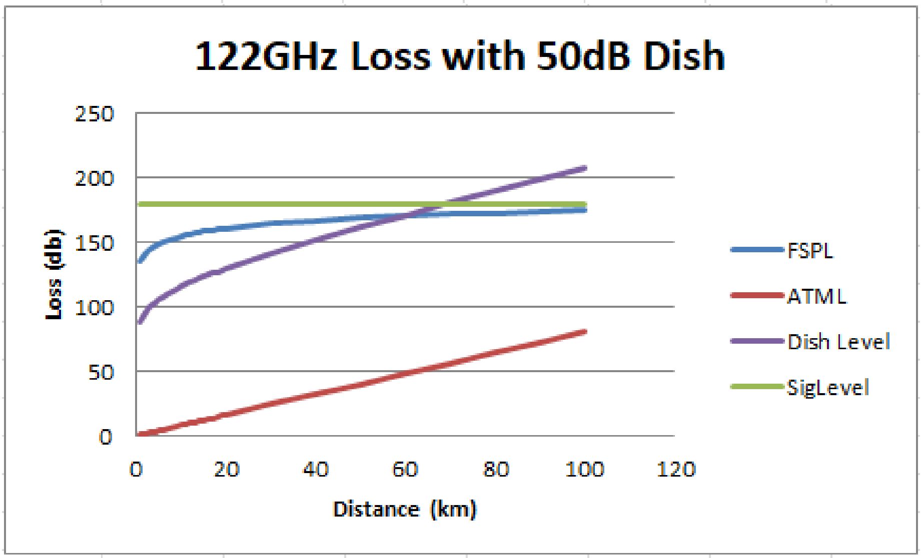


FIGURE 6.1 Atmospheric attenuation by oxygen and water vapor. Use Scale B for oxygen absorption below 10 GHz. Pressure, 1 atm (1013.6 mb); temperature, 20°C; water vapor density, 7.5 g/m^3. From CCIR Rep. 719 (Ref. 2). Courtesy of ITU-CCIR, Geneva.





Derived from page 7-55 and 7-56 of ARRL UHF/Microwave Experimenter's Manual. Horn/Dish Level equals SigLevel is predicted path distance at 50%RH Sea Level.

Gain - One solution (13 dB gain over 21 dB gain conical horn). Beamwidth 2.3 degrees.

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Inspired

LAT150 - Plano-Convex PTFE Lens, Ø3", f =150 mm @ 500 GHz

Part Number:	LAT150 -Ask a technical question
Package Weight:	0.66 lbs / Each
Available:	Today
RoHS:	N/A
Price:	$65.51
Add To Cart:	Qty : 1 Add To Cart
Release Date:	Mar 11, 2016

Drawings and Docum

- Auto CAD PDF
- Auto CAD DXF
- Solidworks
- eDrawing
- Step

Another choice - A Parabolic Dish

Roughly Equivalent Antennas

← 150 foot Stanford Big Dish, operating at around 1 GHz

18" TV satellite dish, → operating at 122 GHz

Both have over 50 dB gain (and both have less than ½ degree beam)
Because both are about 200 wavelengths in diameter

What about dish surface error?

I posted this question to the 122GHz reflector and received this response:

On 9/14/2022 11:52 PM, Mike Lavelle K6ML wrote:
Using a satellite dish at 122 GHz definitely works.

I've been using 24" Winegard satellite dishes designed got 11 GHz DBS service, with QSOs up to the current DX record (139 km).

Andrew, VK3CV, designer of the boards that you all have, also used 24" dishes for his QSOs on 122 and 134. IIRC he made ~60 km or more with them.

We did SNR measurments with SDRs on 7/15/25/40/80/139 km paths and calculated expected path loss & system budget.
I also did antenna pattern/beamwidth measurements on a 15 km path.

Here are links to some of my earlier posts to this group about estimating the dish gain:
https://groups.io/g/The122GProject/message/477 system gain budget/dish gain estimate and why it's hard to say exact gain
https://groups.io/g/The122GProject/message/452 data sheet for the dish I use
https://groups.io/g/The122GProject/message/488

I am seeing 0.3-0.4 degree beamwidth, which implies ~50 dBi gain. The SNR vs path loss measurements support an estimate of about 45 dBi gain. An 18" dish would be a couple of dB lower.

Reducing path loss

in descending order of importance (1 > 2 > 3 > 4)

1. Find two mountains with LOS … the higher the better …
   - More distant horizon
   - Lower water content
   - Lower (oxygen) pressure

2. Look for a ***<u>very low dew point</u>*** day (T_{dew} < **-20 °C**)
   - *Dew point* is the air temp at which water saturation (dew, fog, mist, rain) occurs
   - Dew point is a *direct* (*absolute*) measure of how much water vapor is in the air
   - Looking for a **dry air duct** between the two mountains
   - Beware: path "sags" in middle (usually wetter)

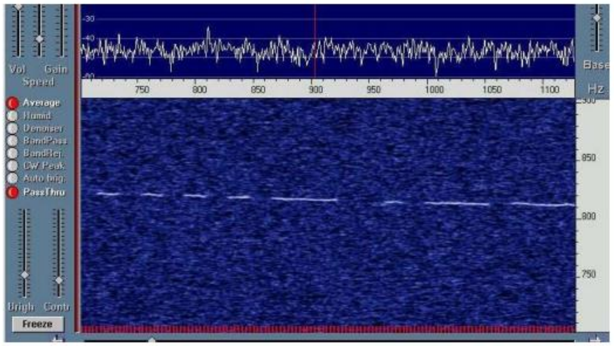
3. Look for high dew spread ($T_{air} - T_{dew}$) or low *relative* humidity (RH)
   - RH (or dew spread) measures how close we are to saturation at current air temp (*not* how much water)

$T_{air} - T_{dew}$	RH	Weather
0 °C	100%	Dew/frost/rain…
10 °C	~45%	Everyday
20 °C	~22%	Pretty Dry
30 °C	~11%	Verrrrrry Dry
40 °C	~6%	Bone Dry

4. Use the top end of the band to get away from the 119 GHz O_2 absorption line.

122 GHz DX

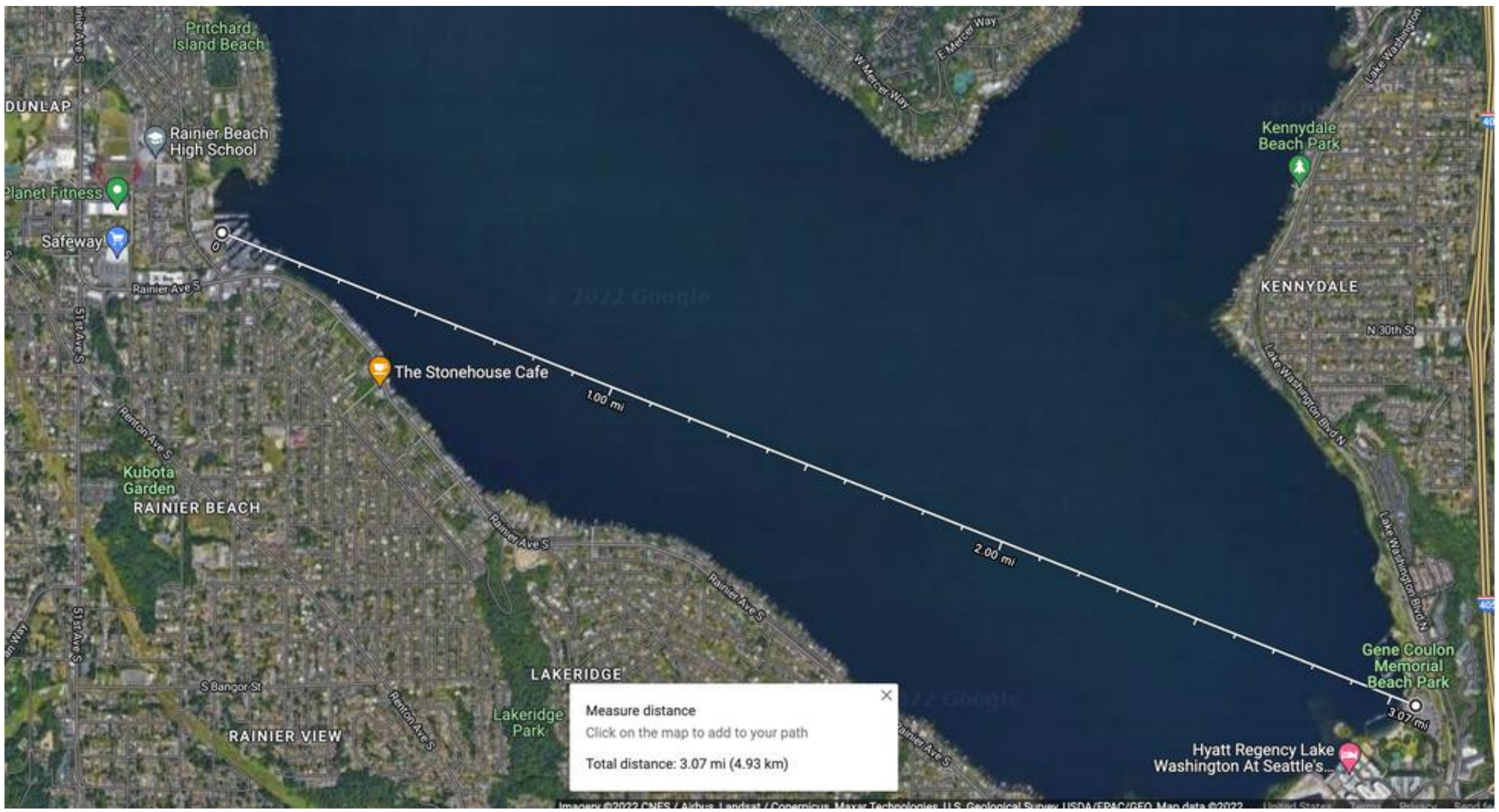
Year	Km	Mode	Callsigns, Dew/Air ^{0}C		Rigs
2004	**25**	**CW?FM?**	**W0EOM**	**KF6KVG**	**30cm?, µW, diode mixer**
2019	60	CW	VK3CV -8/?	VK3NH -9/?	60 cm, 0.5 mW, TRA120
2019	70	SSB	VK4CSD -4/+26	VK4FB -4/+26	Diode mixer
2019	80	CW	K6ML -4/+3	KB6BA -3/+4	60cm, 0.5 mW, TRX120, ~15 NF
2019	92	FT8	VK4CSD -5/+19	VK4FB -5/+19	Diode mixer
2005	**114**	**QRSS* CW**	**WA1ZMS -23/-12**	**W4WWQ -21/-18**	**30 cm, 5 mW, diode mix**
2013	**132**	**CW**	**OE5VRL ? -2/+12 ?** *"250 km visibility"*	**OE3WOG ? -13/+2 ?**	**120cm, 0.5 mw, ~25 NF** **47cm, 1.2 mw, ~25 NF**



*QRSS: super slow CW, 6 sec per dit, 0.2 WPM in this case, and a super stable frequency reference allow 0.5 Hz bandwidth. Using SPECTRAN SW, you can "see" the signal even when you can't hear it.

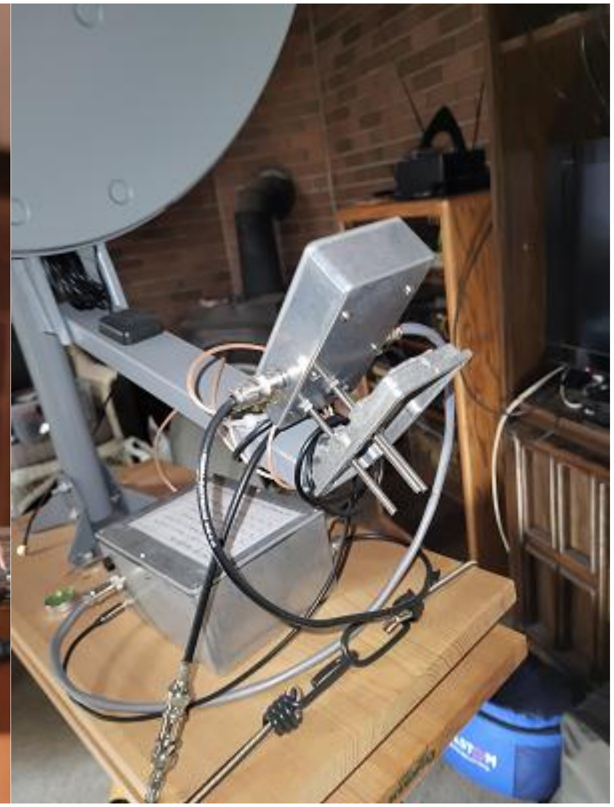
Testing

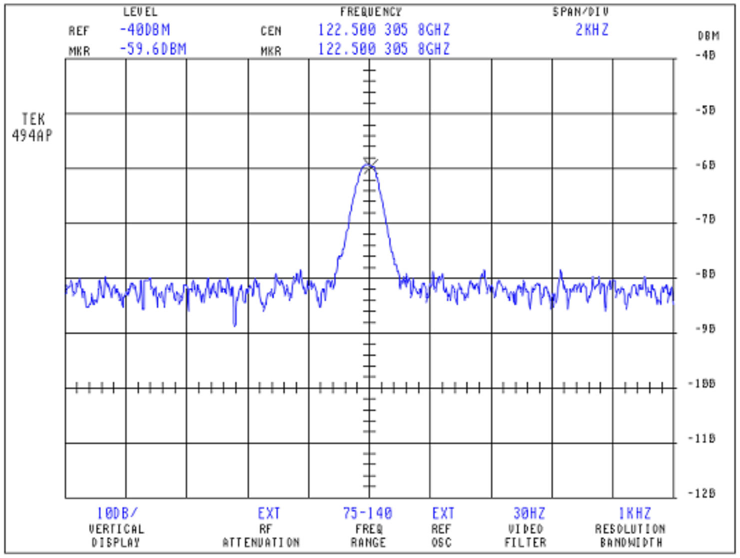
We have found several places where we could try several miles as a beginning. Here is one at the South end of Lake Washington.

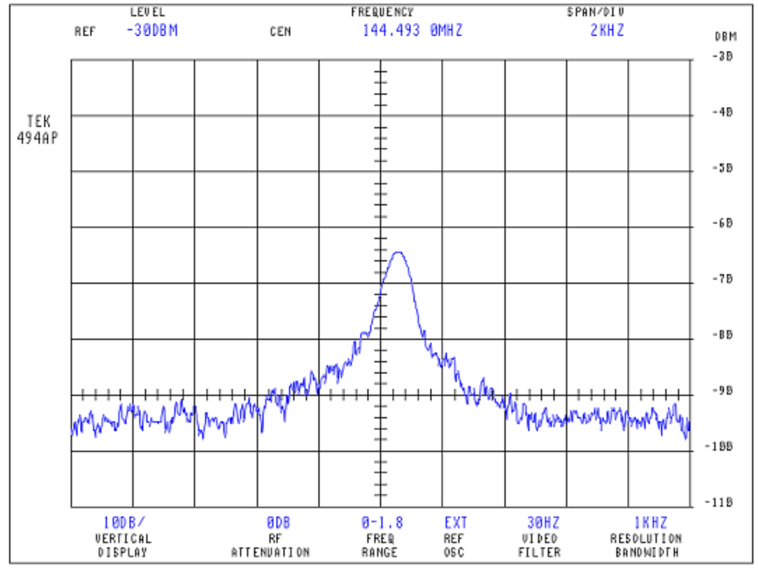


Some Pictures of Our Gear

Frank AG6QV inspecting his dish versus my dish


LEVEL
FREQUENCY
SPAN/DIV
REF -40DBM
CEN 122.500 305 8GHZ
2KHZ
MKR -59.6DBM
MKR 122.500 305 8GHZ
DBM
TEK 494AP
10DB/ VERTICAL DISPLAY
EXT RF ATTENUATION
75-140 FREQ RANGE
EXT REF OSC
30HZ VIDEO FILTER
1KHZ RESOLUTION BANDWIDTH


LEVEL
FREQUENCY
SPAN/DIV
REF -30DBM
CEN 144.493 0MHZ
2KHZ
DBM
TEK 494AP
10DB/ VERTICAL DISPLAY
0DB RF ATTENUATION
0-1.8 FREQ RANGE
EXT REF OSC
30HZ VIDEO FILTER
1KHZ RESOLUTION BANDWIDTH

Future Plans

- We need to find a good place to align the feeds for the dishes. Dish Far Field is about 171 meters (561 feet).

- I suspect we will have to modify the gear to improve our pointing ability – half a degree is really tight. Note the size of the moon is about half a degree from Earth.

- We plan on working on other projects as well. 10 GHz power amps. Experimenting with HackOne RF SDR. Microwave Moonbounce? On 1296? On 10 GHz?

- Interest in trying longer paths on 10 GHz. Spokane to Central Oregon? PNW to California?

References

https://groups.io/g/The122GProject

https://groups.google.com/g/pnw-microwave

http://www.pnwvhfs.org/conference/2018/microwave-group.html

The ARRL UHF/Microwave Experimenter's Manual (Antennas, Components and Design)