

A Synthesized F-Band Signal Source for 122 and 134 GHz

James Morris W7TXT

<https://w7txt.net/>

Microwave Update 2025, Tucson, AZ

Overview

- What: an accurate, high-quality signal source for F-band* amateur allocations 122 GHz and 134 GHz.
- Why: testing transverters, receivers, components etc., as an LO, or transmitter (beacon, CW).
- How: reference-locked PLL synth, low phase noise, multiply.

* F-Band: 90-140 GHz, WR-8

Amateur Microwave & Millimeter Wave Bands

US Primary Allocations (MHz)

Start	Stop	Total
2390	2417	27
24000	24050	50
47000	47200	200
134000	136000	2000
248000	250000	2000
		4277

Total: 23.105 GHz

US Secondary Allocations (MHz)

Start	Stop	Total
1240	1300	60
2300	2310	10
2417	2450	33
5650	5925	275
10000	10500	500
24050	24250	200
76000	77000	1000
77000	81000	4000
122250	123000	750
136000	141000	5000
241000	248000	7000
		18828

Project Background

- Inspiration: Microwave Update 2018 (Dayton, OH)
 - Tom WA1MBA update on 47 GHz quadrupler – importance of utilizing our bands.
 - Many great talks, including:
 - Skip VE6BGT (100W 6cm SSPA)
 - Paul W1GHZ (waveguides are just metal)
 - You can just do things!

Project Background

- Acquired a WA1MBA quadrupler & wondered whether it would work outside the 40-50 GHz design spec?

- Yes! “We observed and validated output signals from 26.9 GHz through to 95 GHz” - DUBUS 02/2024
- Ok, what next?

Investigating the Extended Frequency Range of the WA1MBA Millimeter Wave Quadrupler

James Morris, W7TXX, January 2023

Introduction

This brief paper discusses a qualitative investigation into the usable frequency range of the active millimeter wave quadrupler [1] produced by Tom Williams, WA1MBA. These quadruplers, the design and production of which were discussed at Microwave Update 2018 [2], and 2023 [3], are specified to operate with an input frequency range of 10 GHz to 12.5 GHz, and an output range of 40 GHz to 50 GHz. They may be used to construct beacons or CW transmitters in the 47 GHz amateur band. Other potential uses include local oscillators (LOs), test equipment, science experiments, and further multiplication to higher bands.

Having purchased a quadrupler, I ran some basic tests with a Kuhne MKU LO 8-13 PLL-2 synthesizer, a coaxial attenuator, a Hughes Q band power detector (45772H-11), and an HP 432A power meter. I was seemingly able to detect strong signals significantly outside the specified range of the device, although these measurements were also pushing beyond the specifications of the power detector, and were limited by the range of the signal source (which has a gap between 6.85 GHz and 8.4 GHz, and an upper limit of 13.6 GHz). Of course, none of this equipment was calibrated.

I was also unsure of what was being measured by the power head when running equipment out of specification: was it the expected output signal, or perhaps only mixing products or other spurious signals? Intrigued, I decided to try and characterize the full useful range of the quadrupler, drawing upon the resources of the local microwave community [4], and Ebay.

Quadrupler Overview

The WA1MBA quadrupler specifications are as follows:

Parameter	Minimum	Maximum	Notes
Input Frequency	10 GHz	12.5 GHz	
Output Frequency	40 GHz	50 GHz	
Input Level	3 dBm	8 dBm	5 dBm nominal.
Output Level	5 dBm	12.5 dBm	Peak in 47 GHz band.
Power Supply	6 VDC	13 VDC	Nominal 160 mA. Use 8 VDC if beacon.
Operating Temperature	-	40 C	25 C nominal.

There is typically some conversion gain; nearly 6 dB in the amateur 47 GHz band.

The device's RF path consists of two active frequency doublers, as follows:

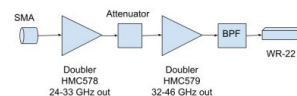


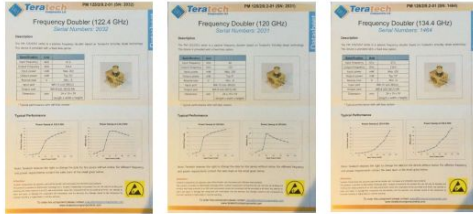
Fig. 1: RF block diagram.

Per the quadrupler design specification, source signals in the range 10-12.5 GHz are input via an SMA connector. These signals are then doubled to the 20-25 GHz range. An attenuator ensures the signal level is correct for the next stage, which doubles again to the 40-50 GHz range. For full implementation details, see the MUD 2018 presentation video [2]. Note that a BPF following the first doubler was disabled in the production version, which helped increase final output levels, according to an email discussion with Tom, WA1MBA. It is not included in the diagram above.

Project Background

- Roger G8CUB in Scatterpoint (UKuG newsletter): generating 122 GHz signals with a Teratech doubler.
 - Feed 61-67 GHz output of quadrupler to this & cover 122/134?
 - Acquired a doubler, **optimized for 134 GHz**.

122GHz Frequency Doubler update



With the doublers just having arrived from Teratech Components, I made a quick measurement on my existing 122GHz TX. They had been supplied with a self-bias resistor as requested. Drive was +19.4dBm. Output 35mW as shown on the power meter. This is using a 75-110GHz head. However this has been shown to be within 0.5dB of a calibrated power meter. The results from Teratech above, show that the doubler will work at 134.4GHz with enough drive. Using the 50-66GHz amp, I only had +16dBm drive. This gave around 3.5mW out. But the potential to use 122 & 134 is great. To get the most output at 134, bias will be required. The interest at 120GHz is to drive a sub-harmonic mixer for 241GHz, requiring +9dBm. Note that the data sheets are for three different doublers, though results are likely to be fairly consistent.

Roger G8CUB

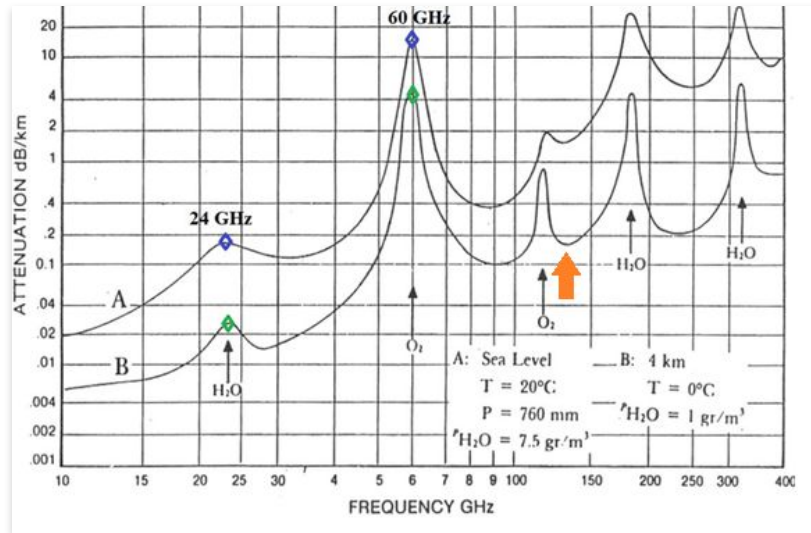
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microwaves.org

Scatterpoint December 2024

Why 134 GHz?

- Primary allocation
- Less well-traveled
 - Commercial transverters up to 76 GHz and 122 GHz project
 - SHM projects often use CMA triplets, which will cover 122 but not 134 GHz.
 - 122/134 GHz project stalled – but design is available.
- D-band window?
 - Local minima of O₂ attenuation is ~130 GHz, previous peak was ~119 GHz.
 - See talk on mmwave propagation by Mike K6ML



Existing Approaches

- DL2AM
 - Sub-harmonic Mixer (SHM), c. 2012
 - 0.2 mW, 30 dB NF

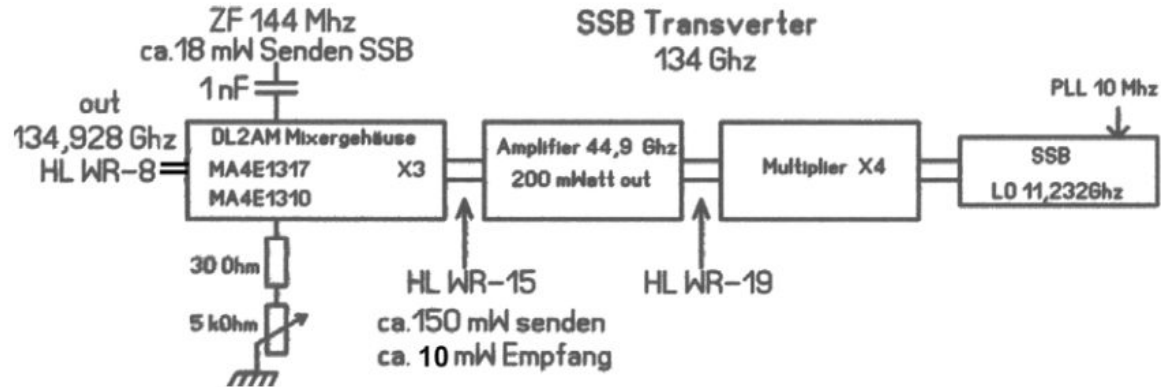
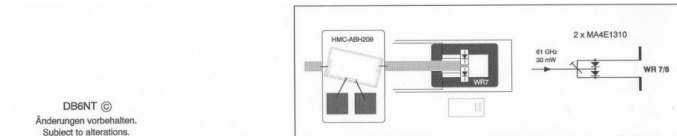


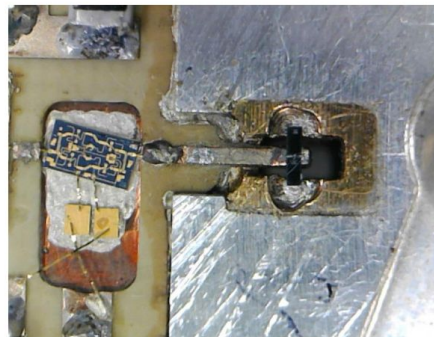
Fig. 2: Concept for the 134 GHz transverter

Existing Approaches

- DB6NT 2016
 - [Diode doubler](#) at final stage
 - Russian diodes: 1-2 mW at 122 GHz
 - MACOM diodes: 5 mW at 122 GHz
 - Did not see a figure for 134 GHz, assume similar possible

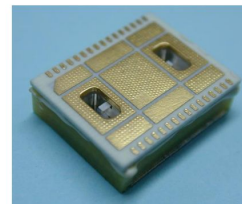
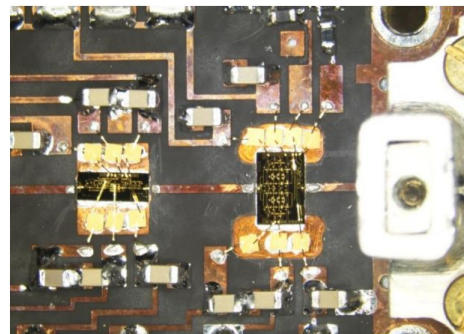
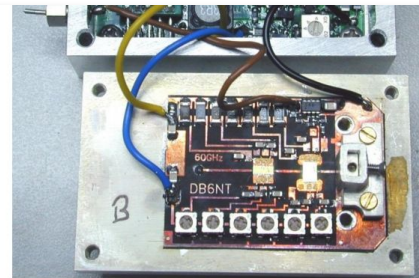


An experiment with two MA4E1310 Schottky diodes in double-path switching yielded approximately 5 mW at 122 GHz. This circuit was very critical in construction. Even the adjustment was very difficult and is not reproducible.



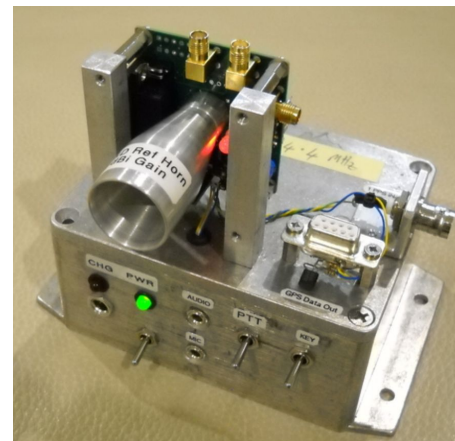
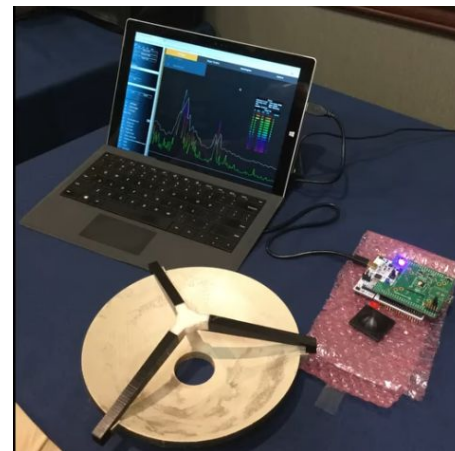
Existing Approaches

- DB6NT 2021
 - [CW Power TX for 122 and 134 GHz](#)
 - 200+ mW possible with very specialized chips, or a VDI doubler (requires 600mW at 67 GHz).
 - Developed an active 6x multiplier and 500mW 60 GHz PA using Gotmic chips, to drive VDI doubler.
 - 134 GHz [world record](#) in 2022 (157km), with DK5NJ.



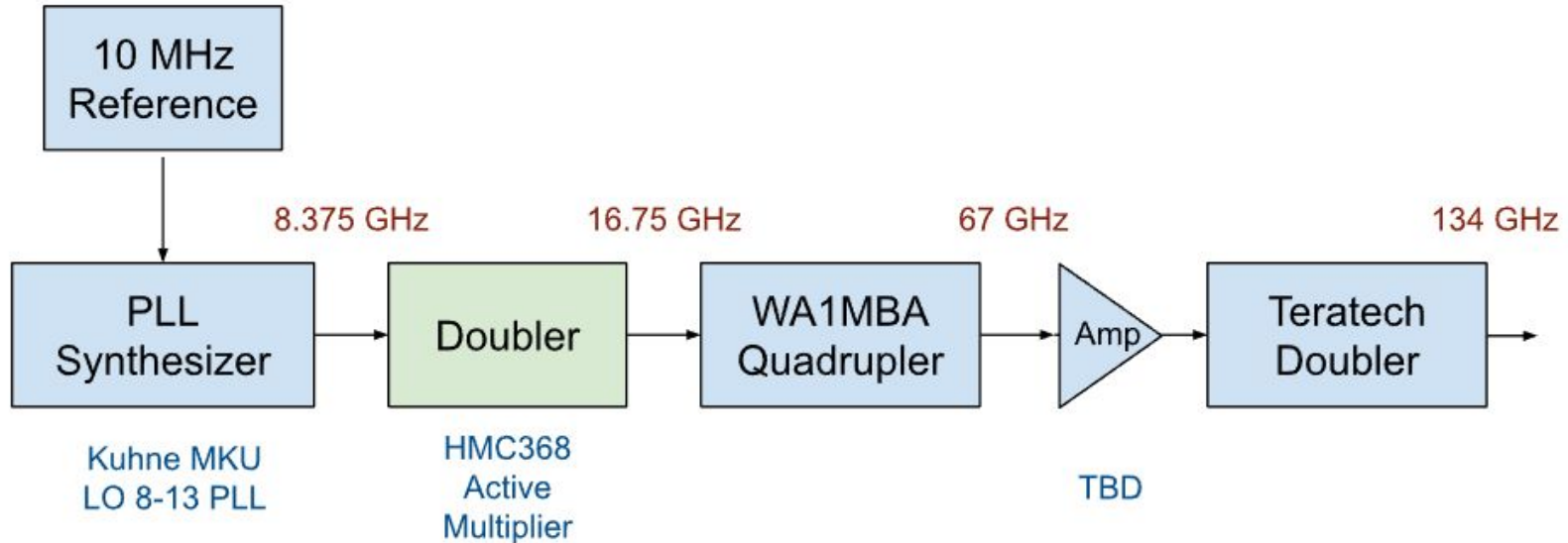
Existing Approaches

- Silicon Radar chip investigations (Michelle W5NYV, Mike K6ML, Henning DF9IC, Andrew VK3CV, et al), from 2017.
- [122 GHz Project](#)
 - 0.5 mW, NF 9 dB
 - Specs say up to 3 dBm (5mw)
 - FSK or FM transmit, can demodulate anything on receive
 - Some JT modes
 - Out of production
- 122/134 GHz 2022 Version
 - **Project delayed** indefinitely due to reasons
 - Design is open source, some folk building their own
 - 045 chip is best for 134 GHz
- K6ML Approach (2025)



This Project: Current Build

Simplified Block Diagram:



Not shown: filters, isolators, attenuators, etc.

Analysis: LO Synthesizer

MKU Synthesizer:

- 8400-13600 MHz, 13 dBm
- Needs a doubler for 134 GHz
- Still does not cover 122 GHz
- Not suitable for JT modes or sweeping (!)
- Ok for initial testing

RF Out (MHz)	RF/2	RF/8	RF/16
122250	61125	15281.25	7640.625
123000	61500	15375	7687.5
134000	67000	16750	8375
136000	68000	17000	8500
141000	70500	17625	8812.5

Other Options, for future development:

- Synth chip covering 7.60-8.9 GHz with open source control s/w.
 - Many possibilities.
- Synth chip covering up to 17 GHz without need for external doubler?
 - Yes, also more difficult & expensive (e.g. LMX2820).

Analysis: Ku Band Doubler

HMC368 Active Doubler:

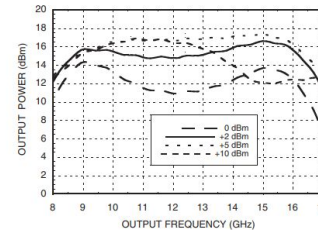
Electrical Specifications, $T_A = +25^\circ \text{C}$, $V_{d1} = V_{d2} = +5.0 \text{ Vdc}$, +2 dBm Drive Level

Parameter	Min.	Typ.	Max.	Units
Frequency Range, Input	4.5 - 8.0			GHz
Frequency Range, Output	9.0 - 16.0			GHz
Output Power	12	15		dBm
Fo Isolation (with respect to output level)		18		dB
3Fo Isolation (with respect to output level)		18		dB
Input Return Loss		10		dB
Output Return Loss		10		dB
SSB Phase Noise ($F_{out} = 13 \text{ GHz}$, 100 kHz Offset) $P_{in} = +2 \text{ dBm}$		-140		dBc/Hz
Supply Current (I_{dd})*		75		mA

*Adjust V_{g1} , V_{g2} between -2V to 0V to achieve $I_{dd} = 75 \text{ mA}$ typical

- Can it stretch to 16.75-17 GHz?

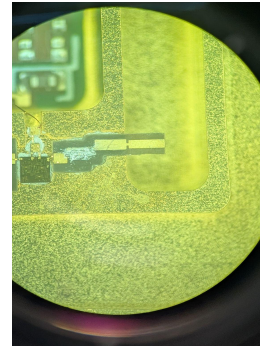
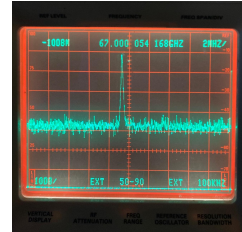
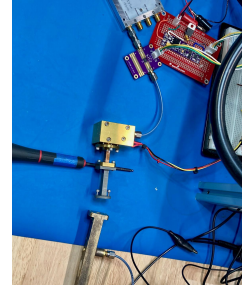
Output Power vs. Drive Level



Analysis: ~~Q-Band~~ V-Band Quadrupler

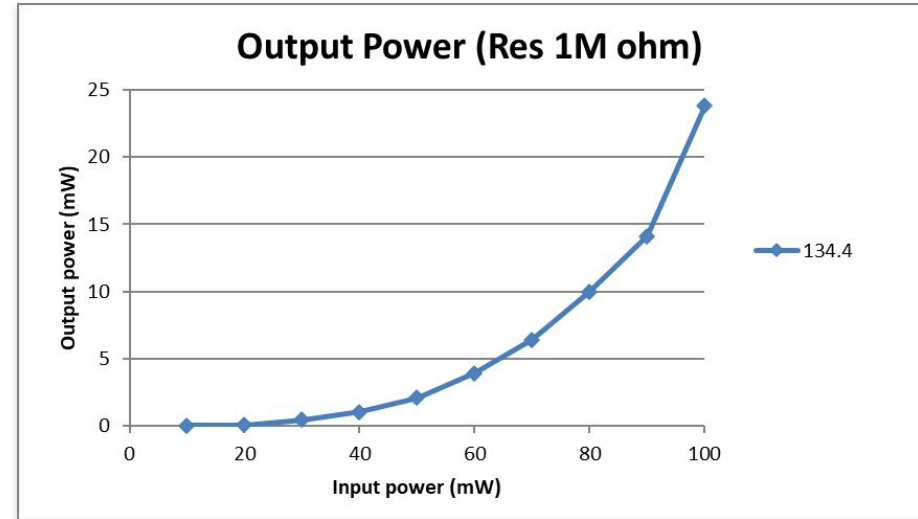
WA1MBA Quadrupler:

- Requires 3-5 dBm input (easy, from HMC368)
- Estimated to provide around **-36 dBm** output at 67 GHz (interpolating some spot checks performed by Tom).
 - I measured **-21 dBm** via open waveguide.
- Can try and improve via:
 - Add tuning stub to output
 - Shorting final filter experiment by Tom WA1MBA:
 - **+5.4 dBm** output measured at 60 GHz!
 - Disaster strikes :-(
- Will still need some amplification.
 - Salvage PA from 60 GHz wireless backhaul?



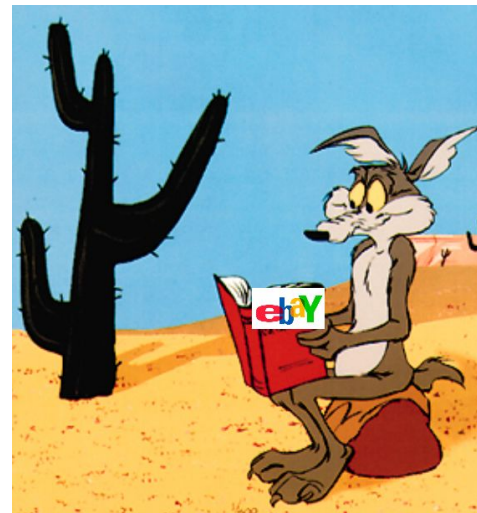
Analysis: F-Band Doubler

- Teratech doubler needs 80 mW (19 dBm) input to make “usable power”.
- Can handle up to 120 mW.
- Bias can be further optimized
 - Roger G8CUB active bias.
- Can it make *amateur* signals with much less (like, say, -36 dBm)?



Improve State of the Art?

- Build this and investigate potential improvements:
 - Power output (25mW at 134 GHz, vs. 0.5 mW)
 - Extended frequency range (122-141 GHz for US bands, and beyond?)
 - Expand test & measurement capability
 - Flexible F-band LO
 - Transmit modulation types (IQ mixing, or regular SSB)
 - Receiver NF (e.g. vs SHM mixing)
 - Cooled fundamental mixers?



Project Build, the Story so Far

Simple: just connect all of this together and test it. Right?

Just a few issues to sort out...



WR-22 to WR-15 Transition

Need to connect the output of the quadrupler to the input of the doubler.

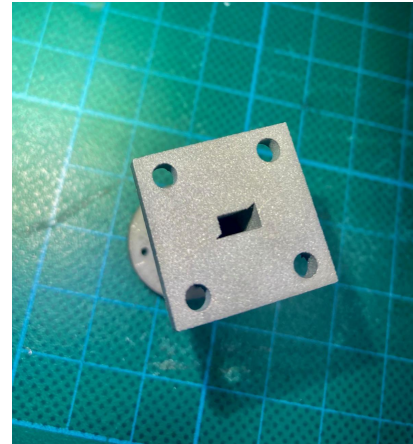
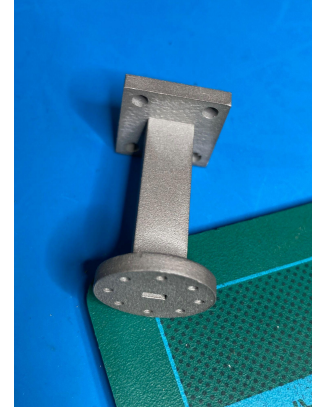
These are kind of expensive, I'll make my own!

- Step 1: Learn CAD (Fusion)
- Step 2: Design a split-block waveguide transition, 3D print prototype
- Step 3: Learn 3D printing
- Step 4: Submit design for CNC machining estimate
- Step 5: Discover metal 3D printing*, unsplit the design, simplify
- Step 6: Send to fabricator in CN to prototype, \$8 per unit

* Shout out to [桑様 @kuwahara82](#)

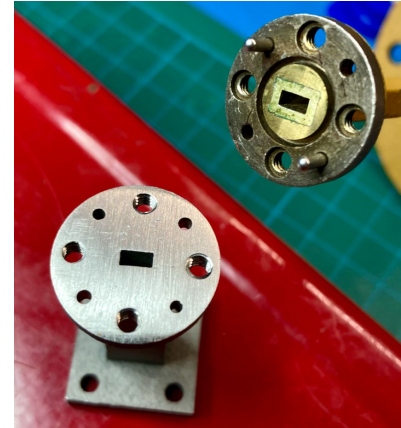
WR-22 to WR-15 Transition

- Stainless steel workpiece received, but noticed one end was weird.
- After some back and forth, determined this was probably the supports.
- They reprinted and sent a new version (very good service).



WR-22 to WR-15 Transition

- New version looked good.
- Measured 0.1mm small in every dimension with my Mitutoyo calipers. Within their spec but problematic.
- Tapped 4-40 holes.
- Belt-sanded rough end. Better to use mill.
- Works, but at what cost?



First Test - PNW Microwave Build Day

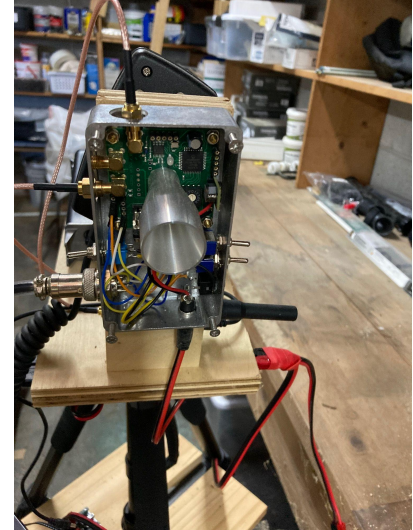
Tested Quadrupler to Doubler chain at Frank AG6QV's QTH.

- No way to measure 134 GHz, so used Frank's 122 GHz transverter as detector.
- Wrong bias resistor for 122 GHz but let's try anyway.
- Used CW output of his HP lab synth:
 - 15.28125 GHz at 5 dBm
 - Directly into V-Band quadrupler



Success!

- Loud, easily detectable signal across the room.
- Output via open waveguide, best signal seemed to be off-bore, possibly reflected by nearby metal object.

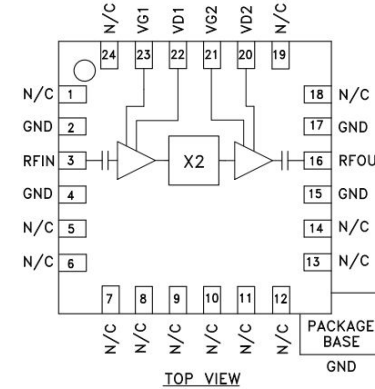


Now for the Ku-Band Doubler

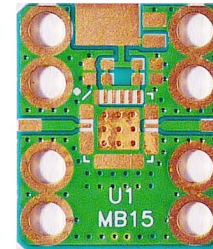
HMC368:

- Depletion mode amps, needs $\sim -2\text{V}$ V_g and $+5\text{V}$ V_d .
- Modified the K5TRA bias design.
- Tried modifying a Twin Industries RO-4030 prototyping board, damaged it.

Functional Diagram

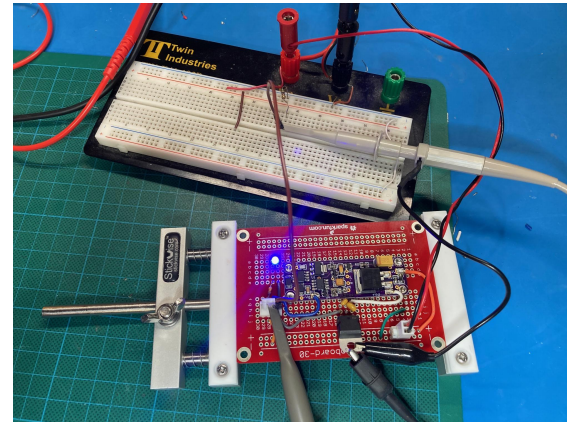
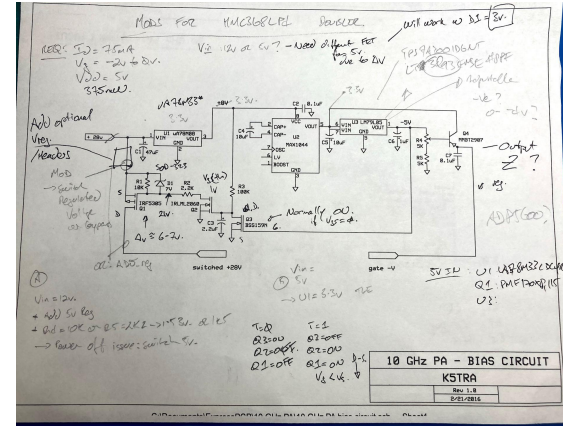


MB-15



K5TRA Bias Modification

- Original design is for higher power 28v devices, with V_g around -4v.
- Relatively simple to modify, only had one HMC368 chip so had to be extremely careful.
- Verified operation with simulated device & CRO.
- I will publish the updated circuit soon.



PCB for HMC368 Doubler

After the MB-15 disaster, I had to bite the bullet and make my own PCB.

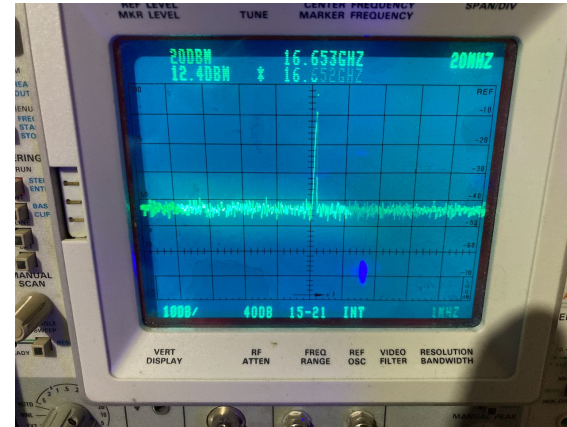
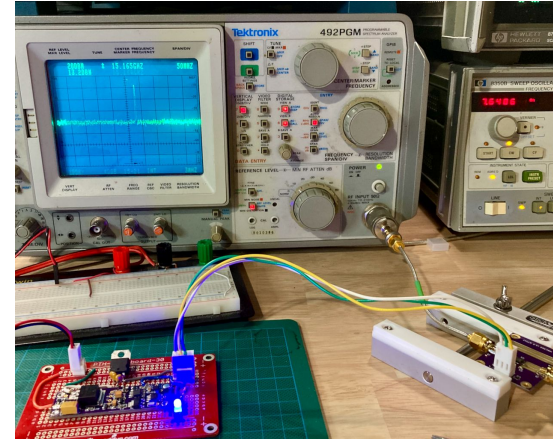
- Step 1: Learn KiCAD
- Step 2: Design my first full board from scratch
- Step 3: This is for RF at 16 GHz
- Step 4: Send design for 0.8mm FR4 to OSH Park
- Step 5: Test thru-line & then fit device, and test with sweeper input.

Loss was several dB at 16 GHz, as expected, but acceptable for this project. 4-layer is next step.



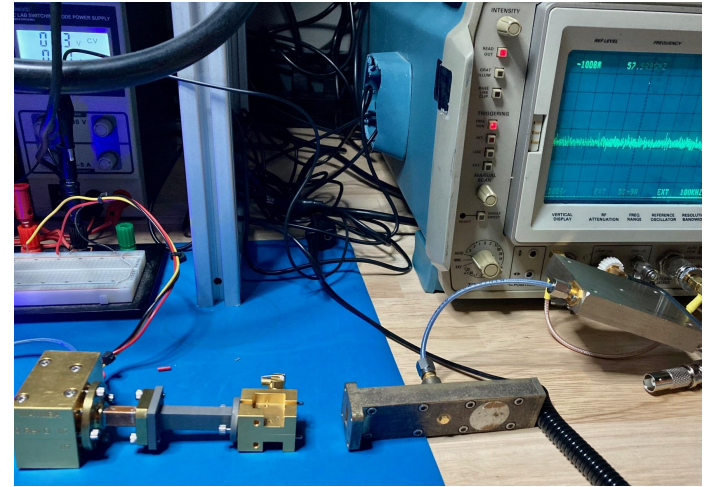
It Worked!

- Very nervously applied power, adjusted $-V_g$ for correct I_{dq} .
- Applied RF, I_d increased, no magic smoke.
- More than enough power for the V-Band Quadrupler.



Testing With MKU Synth

- Used a Tektronix 494 with an 18-26.5 GHz external mixer, open waveguide.
- Did not detect anything at 134 GHz.
- MKU synth does actually work from 7.5 GHz, very low signal ~ -8 dB.
- MKU also refused to lock to 10 MHz GPS ref and calibrated HP signal generator, at 8 dBm. Rude.
- Several things to fix & try here.
- Recall this was just to see what might work without a 67 GHz amp.



Next Steps

- Synthesizer update
- 134 GHz transverter as receiver
- 67 GHz amplifier
- Better waveguide mixer for SA
- Actually connect all the waveguides
- Need a WR-8 transition
- Thermocouple mount + power meter
 - I have some components but they don't currently work, and/or are in unknown state
- Suggestions?



Anritsu ML81A power meter for mm-wave sensors.
Makes a strange noise.

Bonus Slide

Repurposed W1GHZ MMIC PCB as low pass filter, using Mini-Circuits device, for output of RFZero beacon transmitter.

Simple, cheap, works perfectly!

