Packaging a DB6NT 47 GHz XVTR Testing Components at 47 GHz

W5LUA

November 5, 2022

W5LUA 47 GHz Transverter

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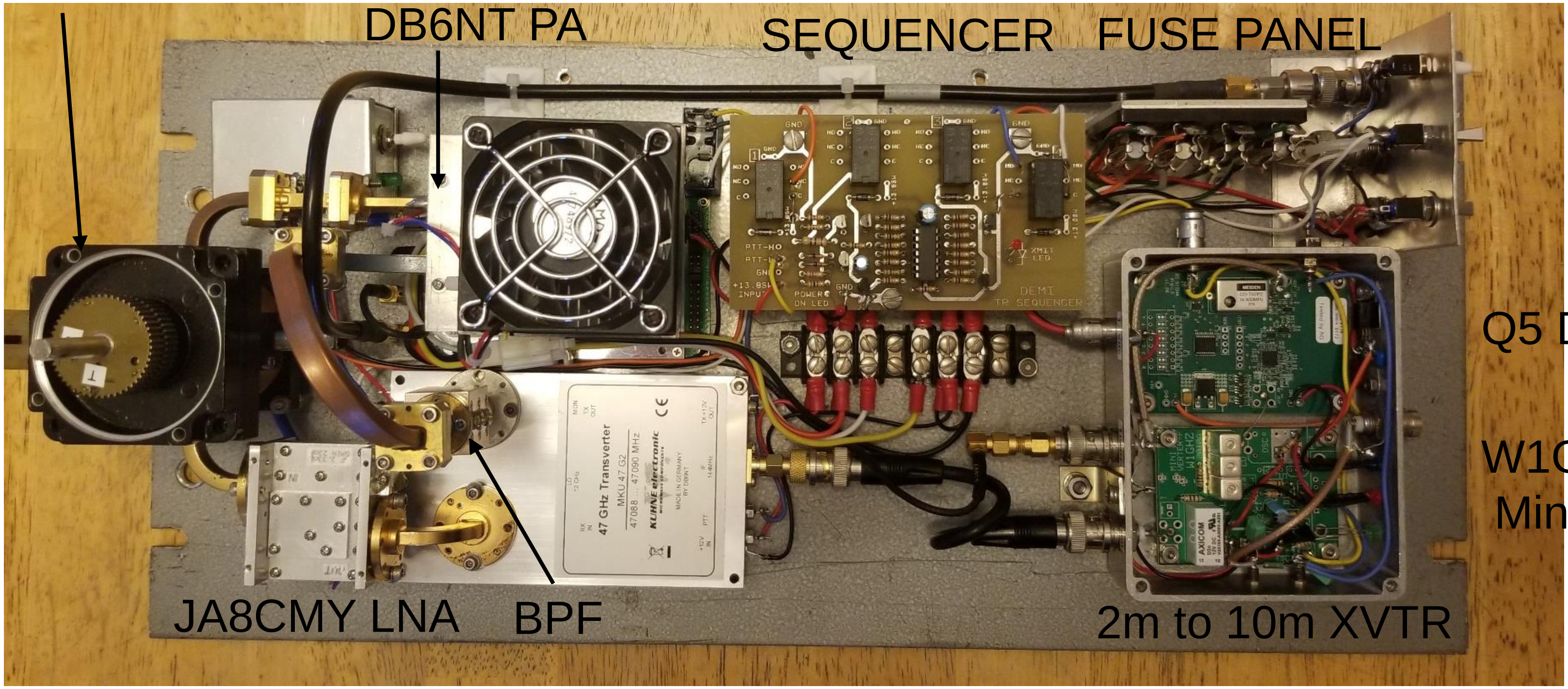

8.75” X 19” Rack Panel. I left a .75” edge around the xvtr layout to allow for the addition of walls. Number 1 priority is to place the LNA as close as possible to the waveguide relay. Priority 2 is to position the PA as close as possible to the waveguide relay.

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Inside view of DB6NT 47 GHz XVTR

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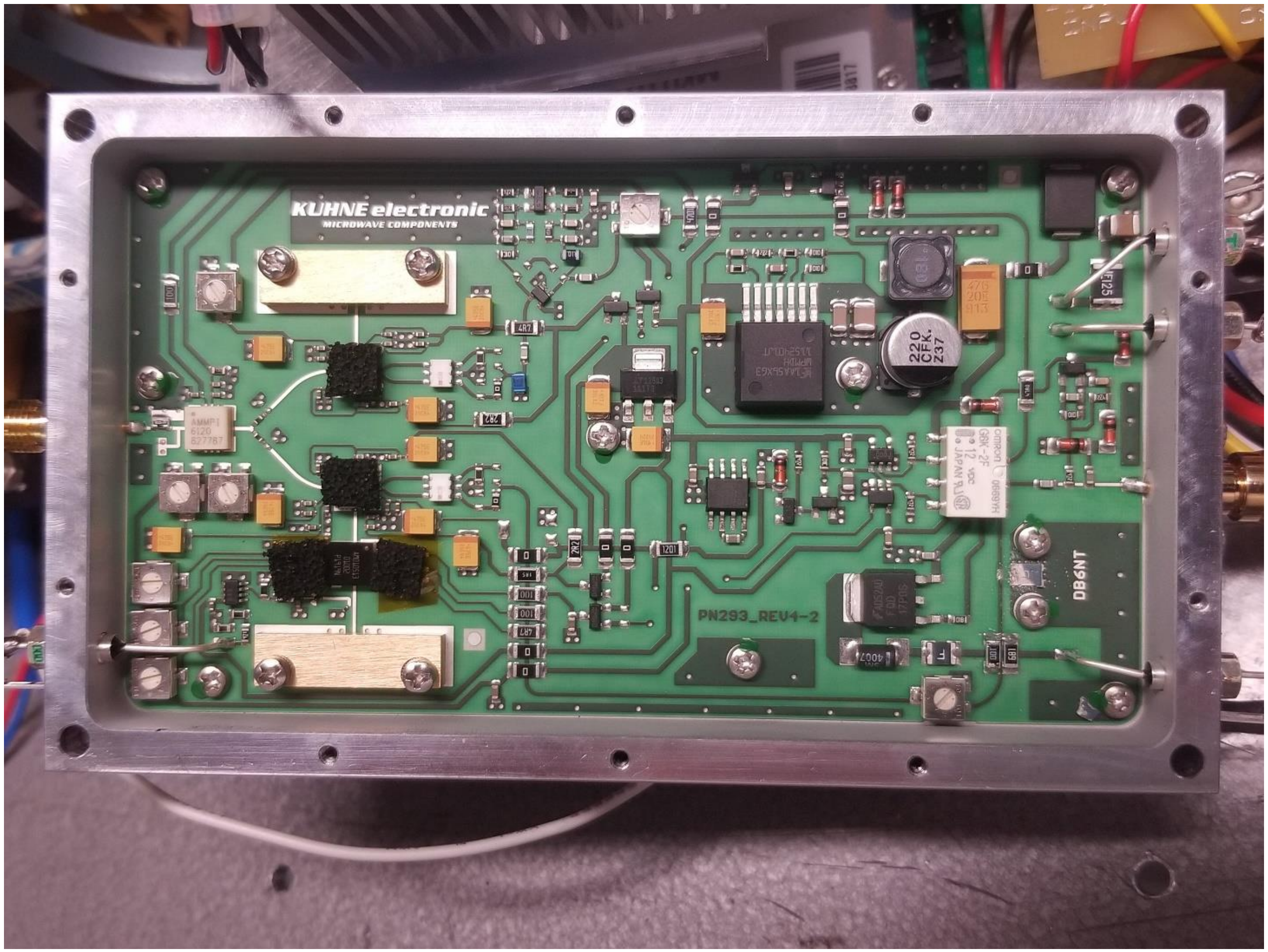

Decreasing the IF drive required for max power output

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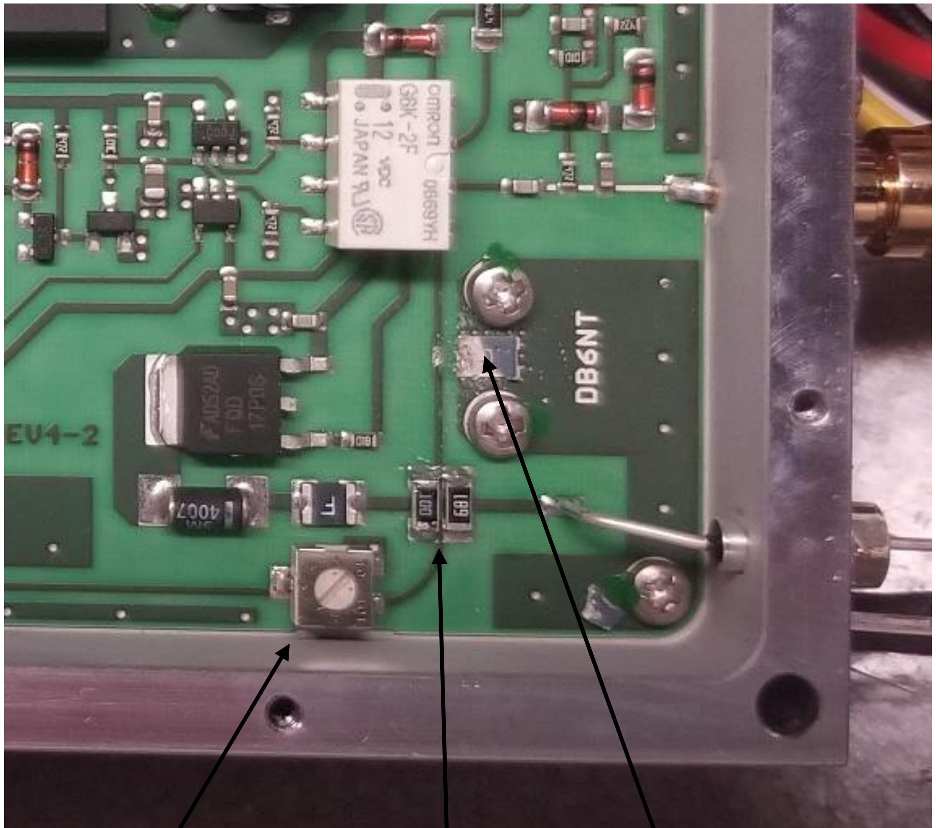

The xvtr as received from DB6NT produces max RF output at input levels as high as 3 to 5 watts @2m

With potentiometer set at maximum, requires .3W @ 2m to drive the xvtr to max Pout on 47 GHz

Paralleling a 10Ω resistor across the pair of 330Ω resistors, decreases drive required at 2m to +7 dBm

Removing the 50Ω termination decreases 2m drive requirement to +3 dBm.

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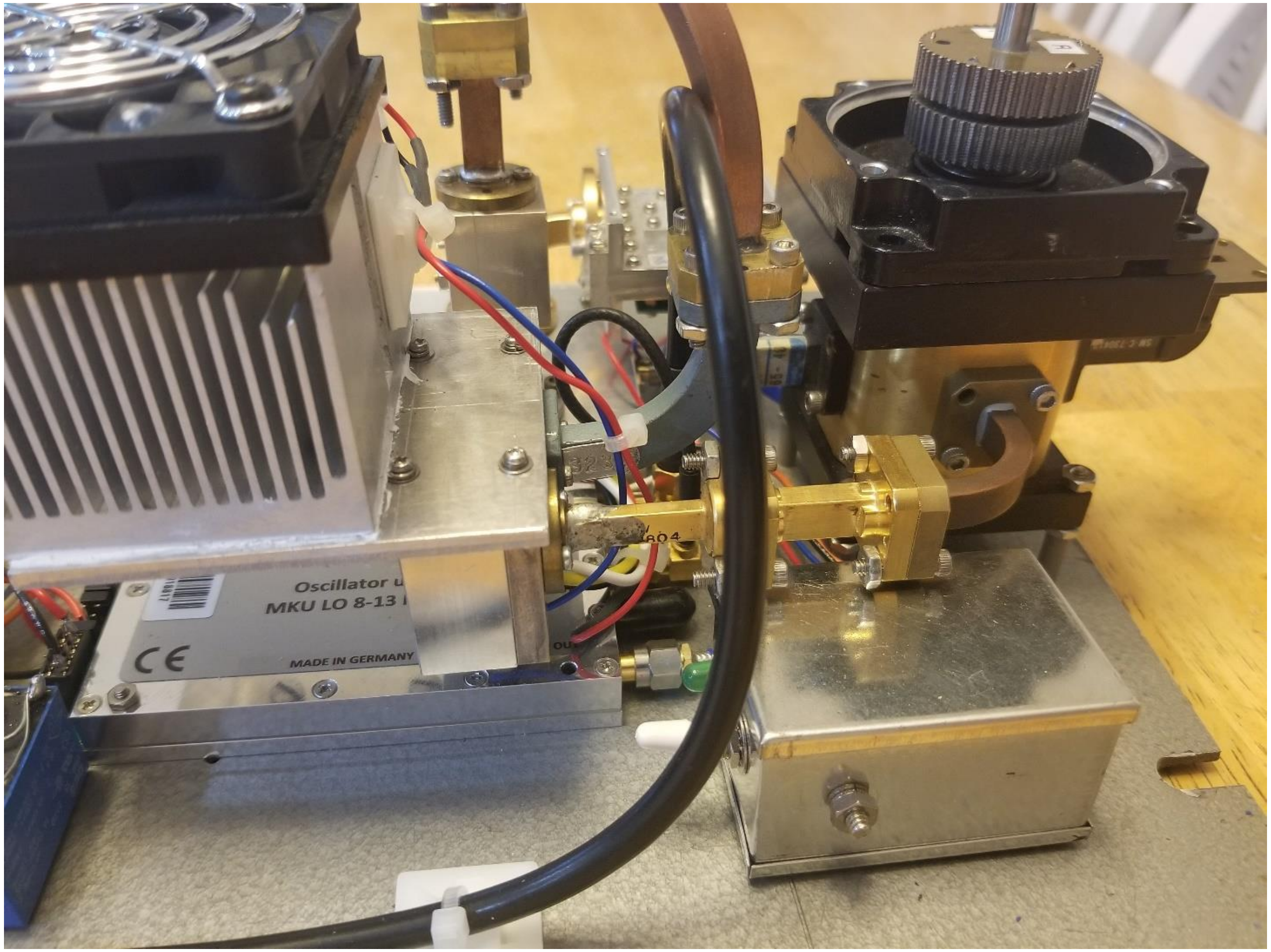
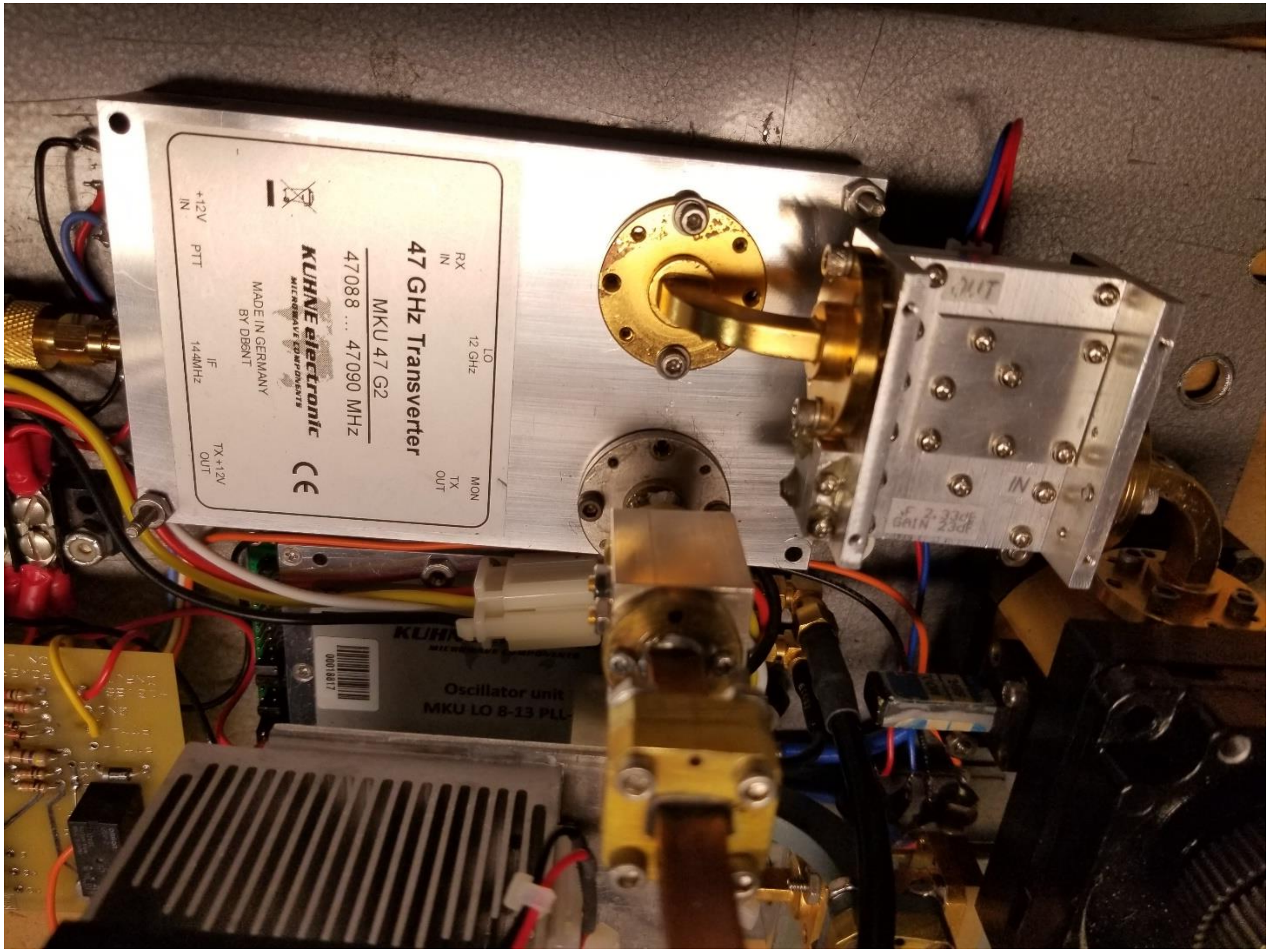
Side View



A combination of WR-19 and WR-22 is used to connect the DB6NT PA to the W/G relay.
The MKU LO 8-13 is visible below the PA
The small box houses the 5V regulator for the JA8CMY LNA

DB6NT/OE9PMJ BPF

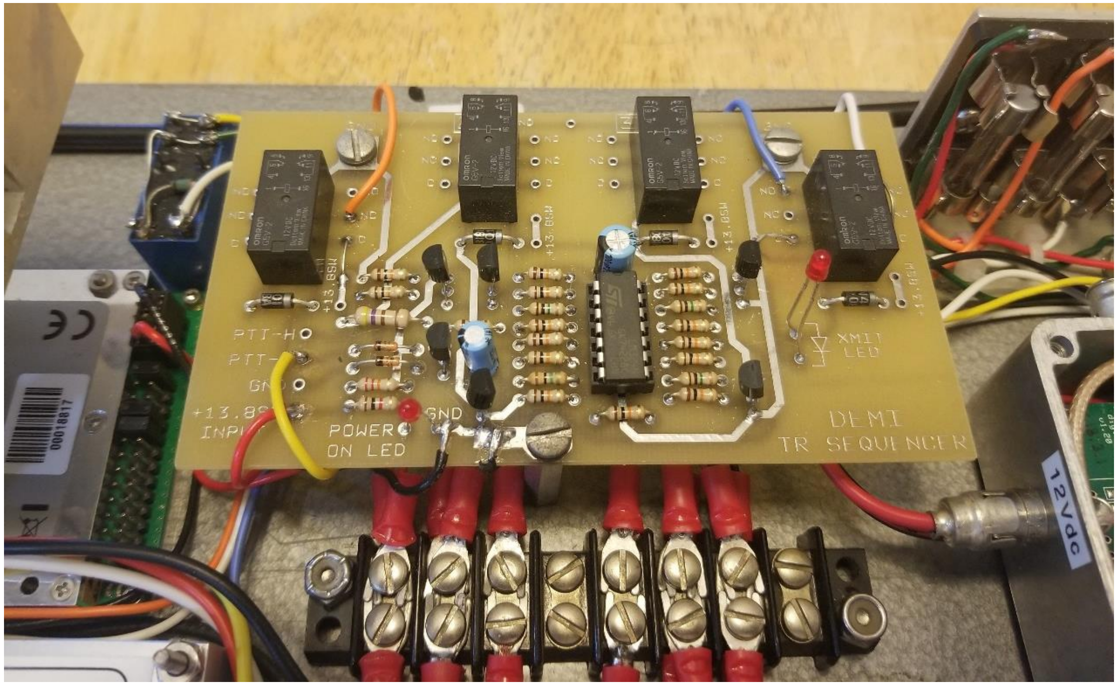


The XVTR has reasonable image rejection but very poor LO rejection.

I was most concerned about LO in the transmit path as it will be further amplified by the PA.

More on this later

DEMI Sequencer



Transmit process starts by 2m to 10m XVTR going to XMIT Same PTT line feeds sequencer

Stage 1 – LNA +12V
Stage 2 – WG RY
Stage 3 – Not used
Stage 4 – PA XMIT & 47GHz XVTR goes to XMIT

An external relay adjacent to the sequencer board handles the higher current of the PA

Note: At the moment the waveguide relay is manual but once it is automated, it will also have a set of contacts that inhibits the PA going to XMIT until the waveguide relay is fully in the transmit position.

My Fancy Front Panel

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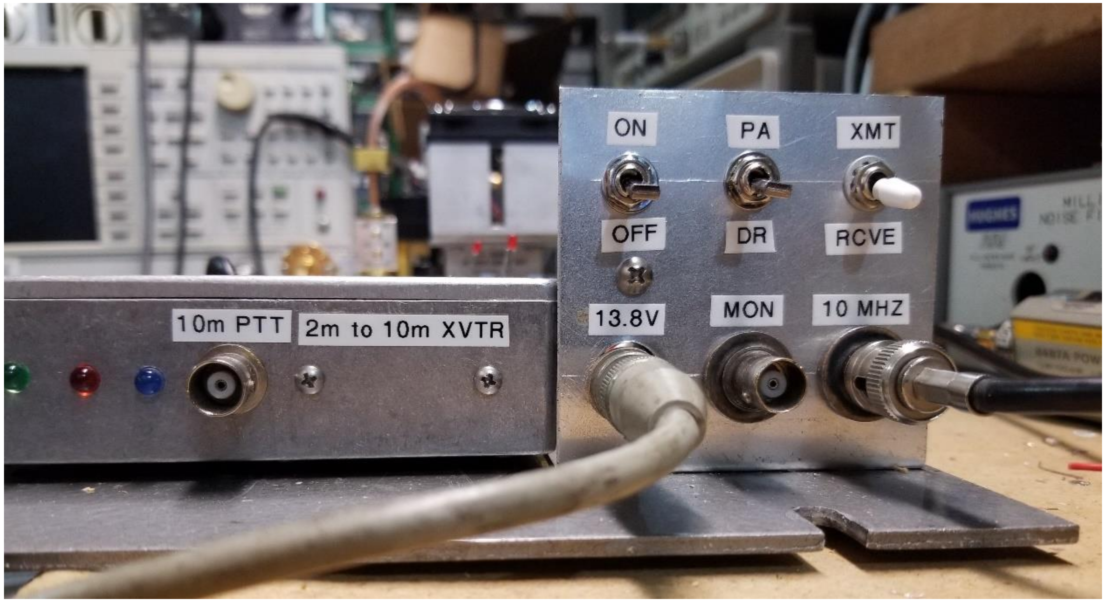
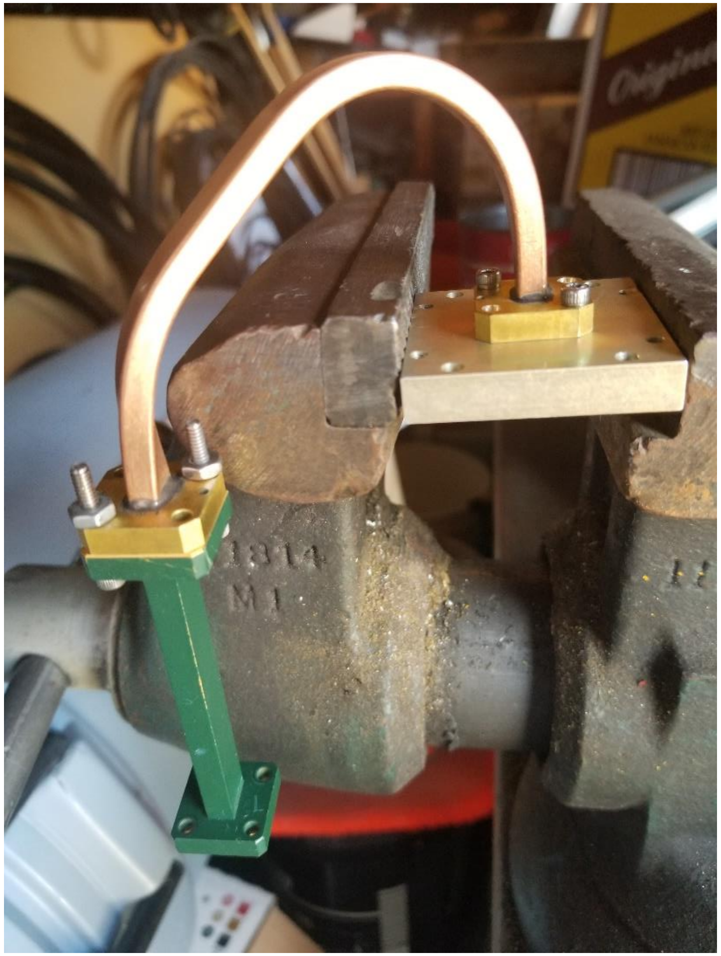
The PTT is coupled into the IF so you never forget to connect the PTT



The middle switch allows both monitor ports on the xvtr and PA to be monitored.

This is a temporary front panel that has the necessities. Once I decide what meter I want to include for monitoring power output, then a new panel will be made. For now, I will use remote monitoring of power.

WR-22 Bending Fixture



I had several sections of WR-22 waveguide that used very soft copper and was relatively easy to bend.

Took me a half dozen tries to get the bend correct.

The green piece of WR-28 waveguide was just used as a handle for bending.

This connects the XVTR transmit port to the PA input.

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WR-19 and WR-22

WR-19 is spec'ed to operate from 40 to 60GHz. DB6NT supplies waveguide and small round flanges as shown on the left. Other flange options are the larger round flange and various small square flanges. The DB6NT 47 GHz xvtr is tapped for both the small and large round flanges. 2.4mm connectors are generally used on transitions

WR-22 is spec'ed from 33 to 50 GHz. Small square flanges and large round flanges are the norm. First 2 flanges are homebrew using cable with 2.4mm connectors. The HP transition in the middle and the square flange transition both with 2.4mm connectors are my preference for testing on 47 GHz.

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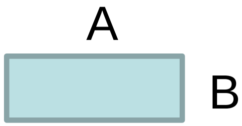
Waveguide at 47 GHz

Waveguide Name	Recommended Frequency Range	Cutoff Frequency Lowest order mode TE10	Cutoff Frequency Next higher mode TE20	Inner Dimension of waveguide A Inches	Inner Dimension of waveguide B Inches
WR19	40 - 60 GHz	31.391 GHz	62.782 GHz	0.188	0.094
WR22	33 - 50 GHz	26.346 GHz	52.692 GHz	0.224	0.112
WR28	26.5 to 40 GHz	21.077 GHz	42.154 GHz	0.28	0.14



- The TE10 cutoff frequency is the frequency at which the A dimension of the waveguide is .5 wavelength in free space. The TE10 mode is considered the dominant mode in rectangular guide.
- The TE20 cutoff frequency is the frequency at which the A dimension of the waveguide is 1 wavelength in free space.
- The table shows the best choice for waveguide at 47 GHz is either WR-19 or WR-22 since we would be using it in the recommended frequency range. Also note that 47 GHz is in between the TE10 and TE20 cutoff frequencies.
- Looking at WR-28, we find that in addition to the TE10 mode other modes such as TE20 and even TE01 and TE11 are capable of propagating at 47 GHz in WR-28. Although the monopole is only capable of exciting the TE10 mode, discontinuities in the waveguide can cause constructive or destructive interference in WR-28. Discontinuities can be cause by E and H plane bends.
- Thanks to Greg McIntire for his comments.

Using WR-28

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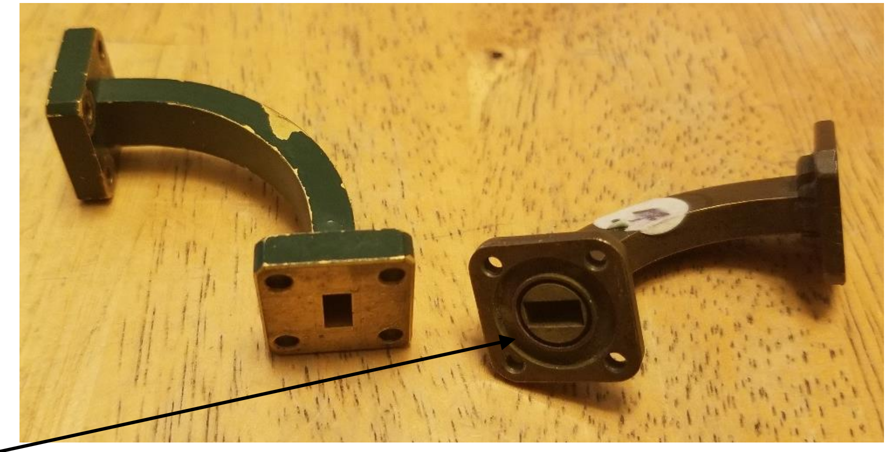


- Despite the challenges of using WR-28, I still use WR-28 in 3 places in my xvtr.
- WR-28 waveguide relay, H plane WR-28 at input to PA, WR-28 termination on the waveguide relay.
- Be sure to avoid chokes on WR-28. They provide unwanted resonances at 47 GHz
- Check out these two articles from MUD 2019.
  "Use of WR-28 waveguide on 47 GHz" by Barry Malowanchuk, VE4MA
  "Relcom WR-28 Waveguide Switch at 47 GHz" by Al Ward W5LUA

Waveguide Calculator

- https://sibersci.com/rectangular-waveguide-temn-calculator/

WR-28 Waveguide to Coax Transitions

2.4mm Connector   3.5 mm Connector

WR-28 is spec’ed to work from 26 to 40 GHz. WR-28 still works fine at 24 GHz but becomes iffy at 47 GHz. Generally I will use the transitions with the 3.5 mm connector only at 24 GHz. When I tested the 2.4mm transitions at 47 GHz, I saw poor return loss, i.e. <5dB. 5dB return loss equates to 1.6 dB of transmission loss.

Coax Connectors

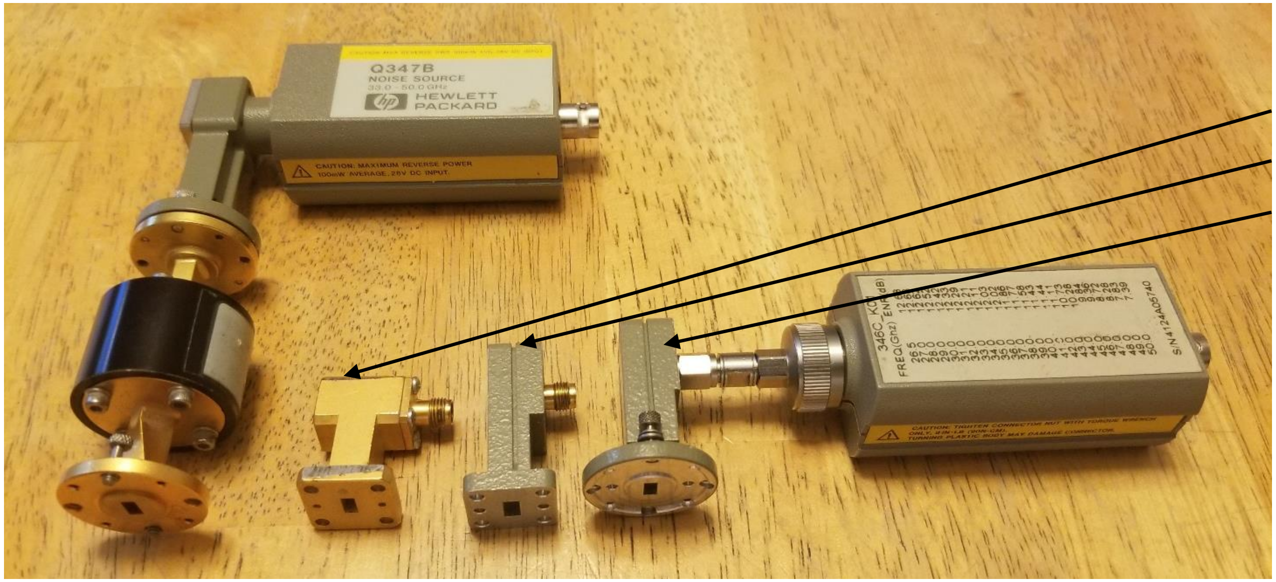
	1mm	1.85mm	2.4mm	2.92mm	3.5mm	SMA
Max Frequency	110 GHz	65 GHz	50 GHz	40 GHz	>32 GHz	18 GHz

Both can mate with each other

All 3 will mate with each other, some 2.92mm work to 46 GHz

Frequency data are average numbers from Pasternak catalog
I have used some SMA connectors w/o dielectric plug (provides pin retention) at 24 GHz

Noise Sources for 47 GHz



WR-22 Transition
WR-28 Agilent R281A
WR-22 Agilent Q281B

The HP 347B and isolator are the most accurate at 47 GHz. Having the isolator or a larger value attenuator minimizes the change in reflection coefficient as the noise source is turned on and off for the noise figure measurement. This can effect the accuracy of the noise figure measurement.

The HP 346C_K01 is a close second as it allows the use of multiple waveguide to coax transitions. The source itself has a 2.4mm connector and is good to 50 GHz.

Noise Figure Measurement

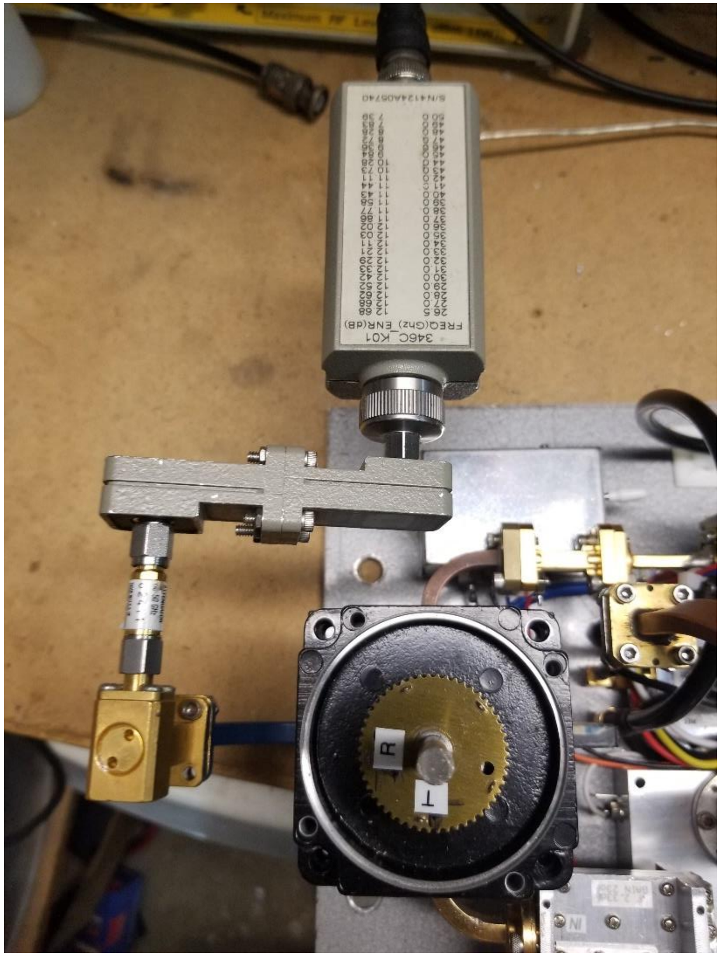
Measuring the noise figure of the LNA was not difficult as I had two ways to measure NF both of which had the larger diameter flange for WR-22 as shown in the previous slide. Results were as expected as the JA8CMY LNA was spec'ed at 2.3 dB. In a similar test, I measured the DB6NT xvtr to be 6 dB as spec'ed.

After I connected the LNA to the waveguide switch, I was now working in WR-28 with a square flange so I had to use my Agilent 346C-K01 and a transition.

I first tried the Agilent WR-28 transition thinking it was the best I had (since it said Agilent) and I measured higher than expected NFs. I knew all a long that WR-28 was only spec'ed from 26 to 40 GHz but I was hopeful. Then I discovered that I had a WR-22 to 2.4mm transition of unknown background (looks commercially made). Keep in mind that both these transitions have the same bolt hole pattern making both convenient. Once I started using the WR-22 transition, the measurements seemed to be more in line with what I had expected.

Noise figure of the system measured around 3.7 dB.

Measuring loss of back to back Agilent R281A/B WR-28 to 2.4mm transitions



Since I now had confidence in my noise figure measurement with the Agilent 346C-K01 and WR-22 transition, I decided to see how much the noise figure increases with a pair of back to back Agilent WR-28 to 2.4mm adapters.

The noise figure increased by 1.5 dB which suggests each transition has a loss of .75 dB at 47088 MHz.

The loss is mainly due to mismatch loss

Let’s now look at return loss or VSWR of the transitions

HP 8340A & HP8757 Scalar Analyzer

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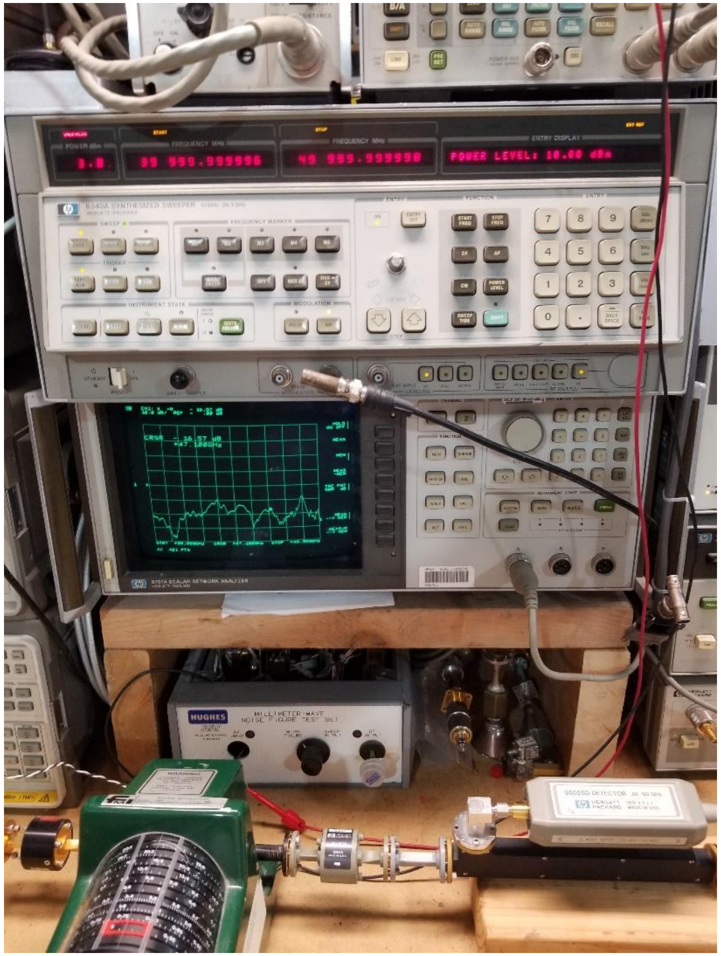

This has been my “go to” setup for years. With appropriate multipliers, I have made measurements to 80 GHz even with a 50 GHz detector The HP8340A is GPS locked to 10 MHz. It is easy to dial in a multiplication factor on the 8340A and have it indicate actual test frequency. The 8340A is about as heavy as my Hallicrafters SX-101A!

33 to 50 GHz Test Setup for Return Loss

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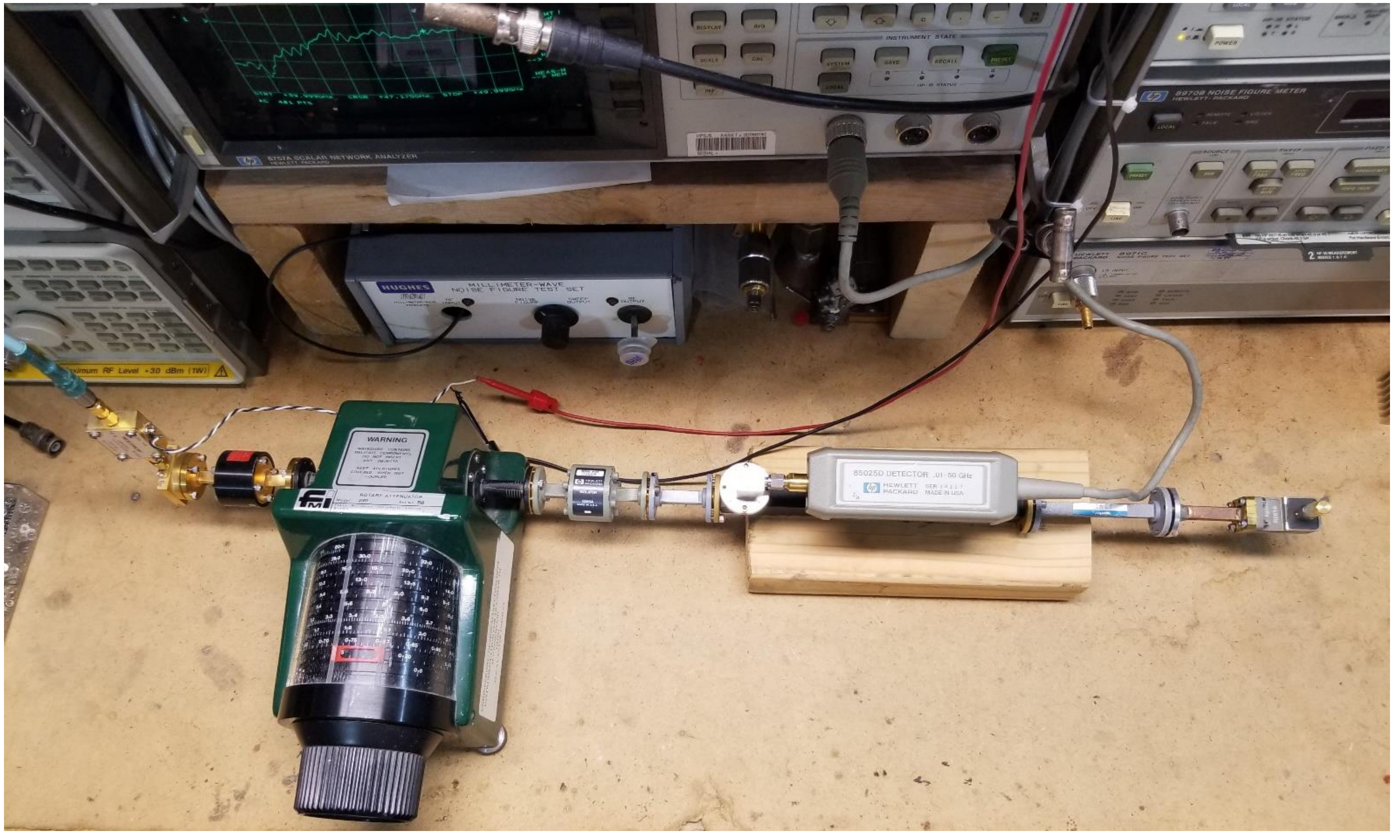

Closer Look

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Input from HP 8340A

Wiltron 13-20 GHz Amplifier 60-C-21372

U-3X Spacek Tripler

Hughes 45113-1000 WR-22 Isolator

HP Q365A WR-22 Isolator

Flann Microwave Rotary Attenuator Model 2311

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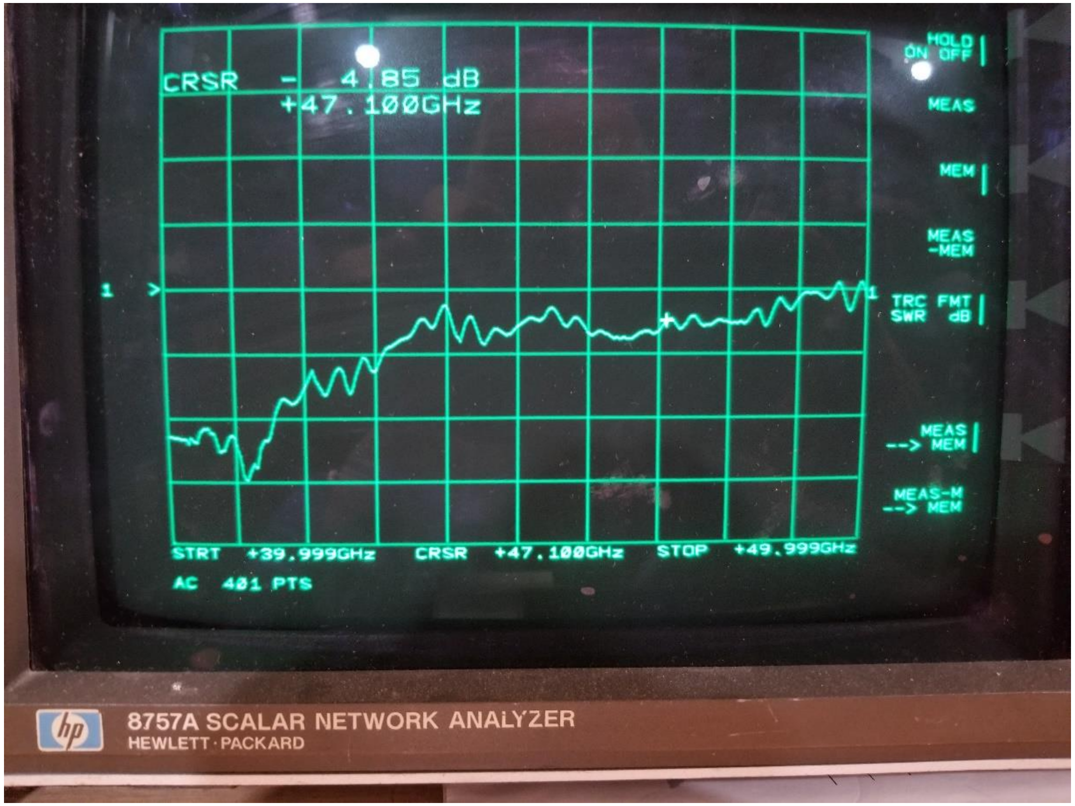
Coupler & Detector

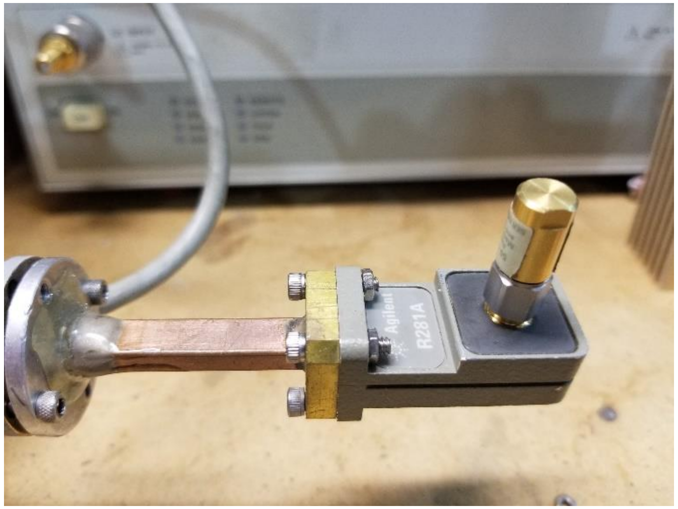
Wiltron 40-60 GHz 35WR19VF

HP 85025D .01 to 50 GHz Detector

Flann Microwave 23132-10 Directional Coupler

Agilent R281A WR-28 to 2.4mm Transition





Return loss < 5 dB at 47 GHz

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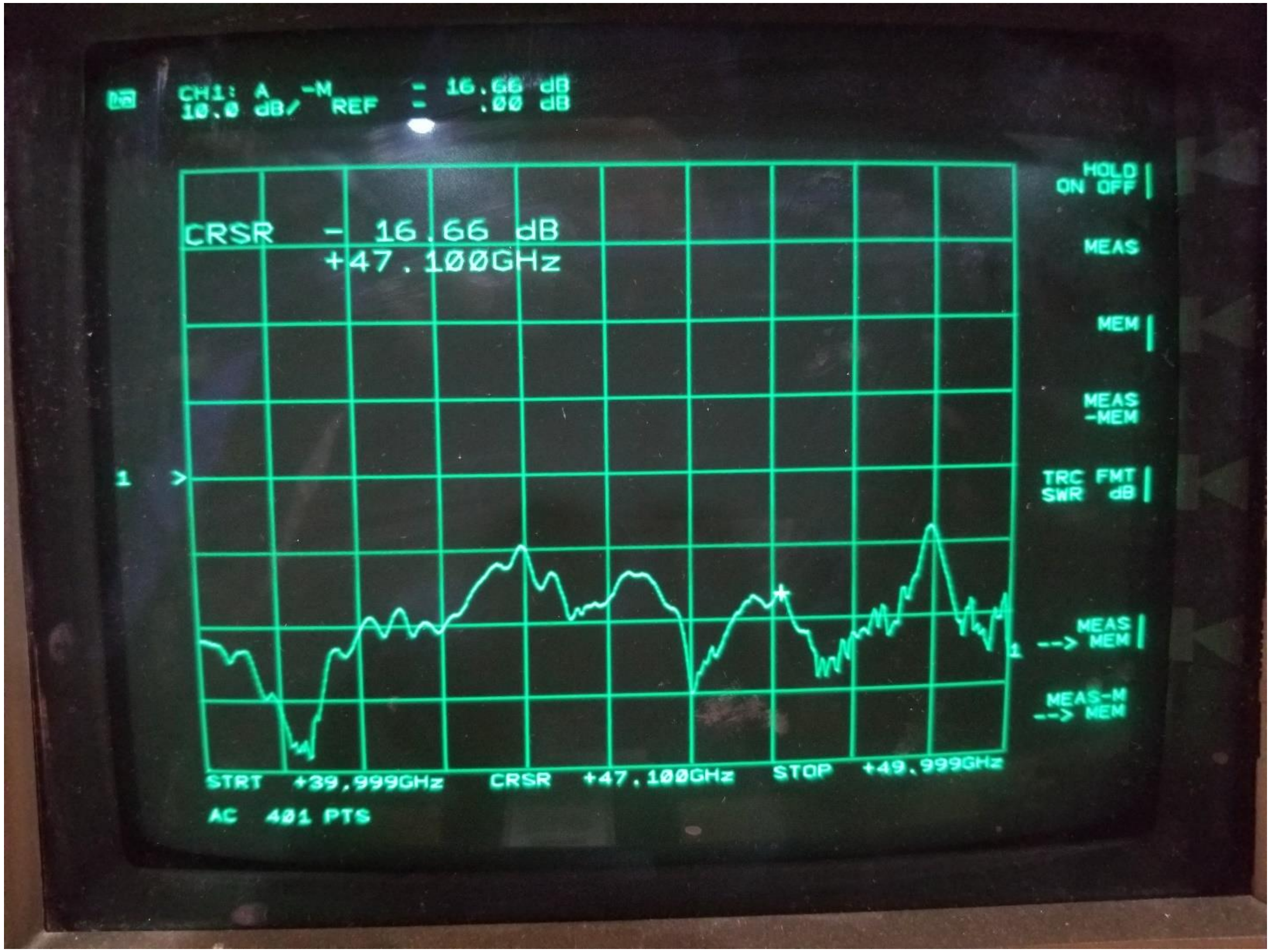
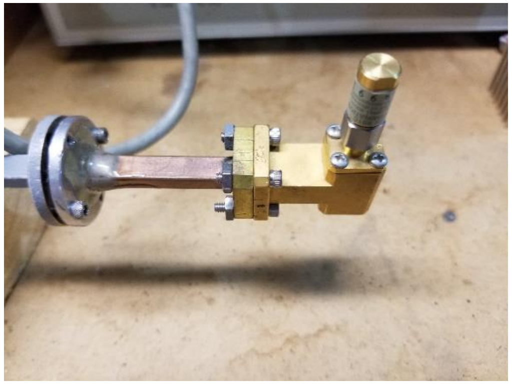
WR-22 to 2.4mm Transition





Return loss 16.7 dB
At 47 GHz!

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Retuned WR-28 to 3.5mm Transition

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Tried retuning one of the transitions that had tuning screws but best I could do was 8 dB return loss. Still some work to be done to improve the return loss

Modifying a WR-28 to 2.4mm Transition for 47 GHz

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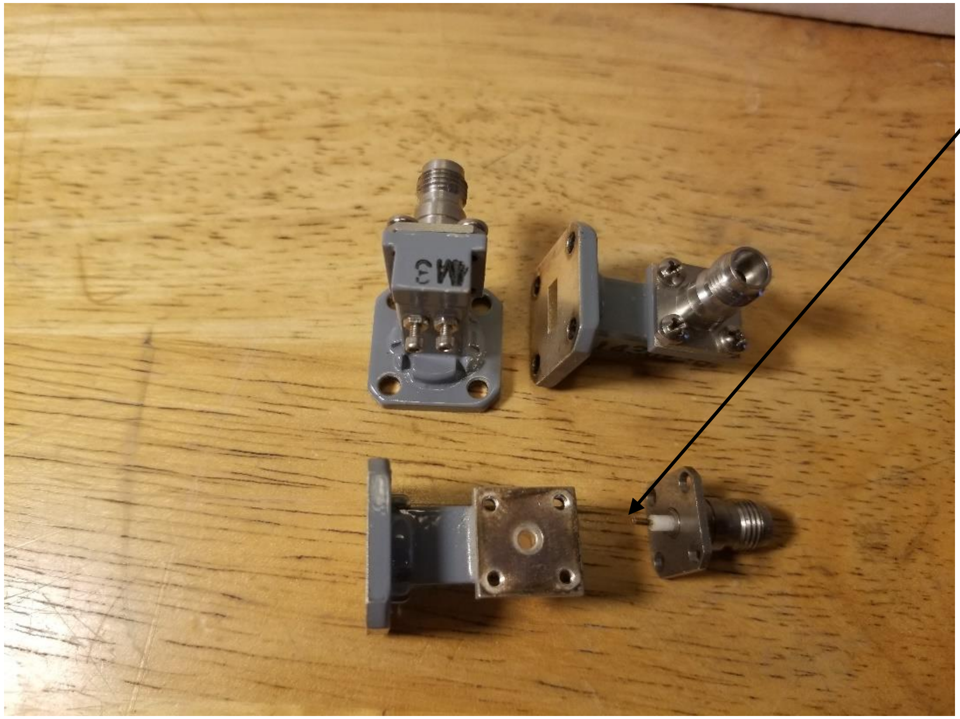
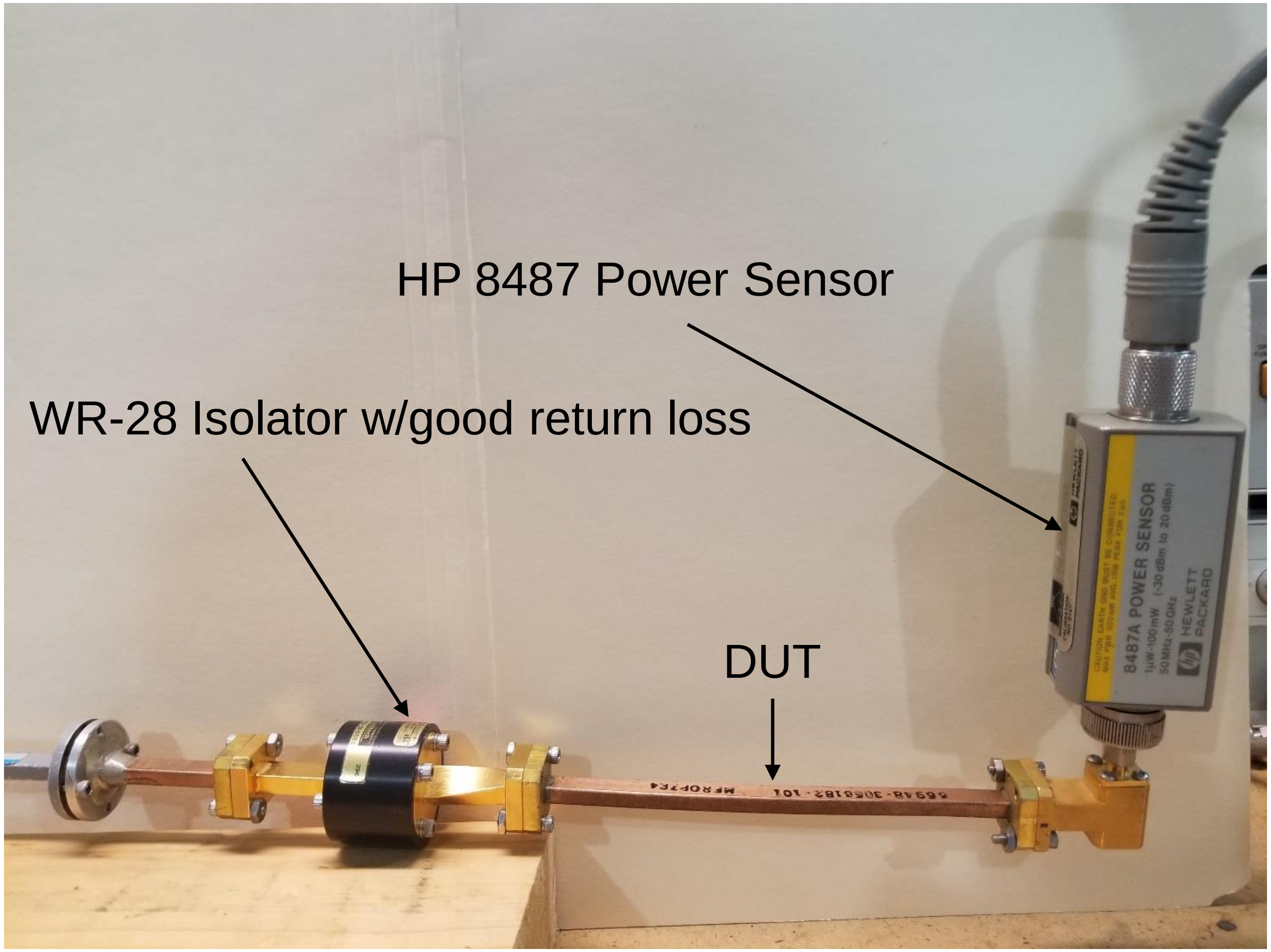


The probe is very small and fragile

Chatted with Jim Hudson WA5JAT about building a holding fixture that will allow me to carefully file away at the probe to move the optimum frequency to 47 GHz

Next project!

Loss Measurement Setup



Loss Measurements@ 47 GHz

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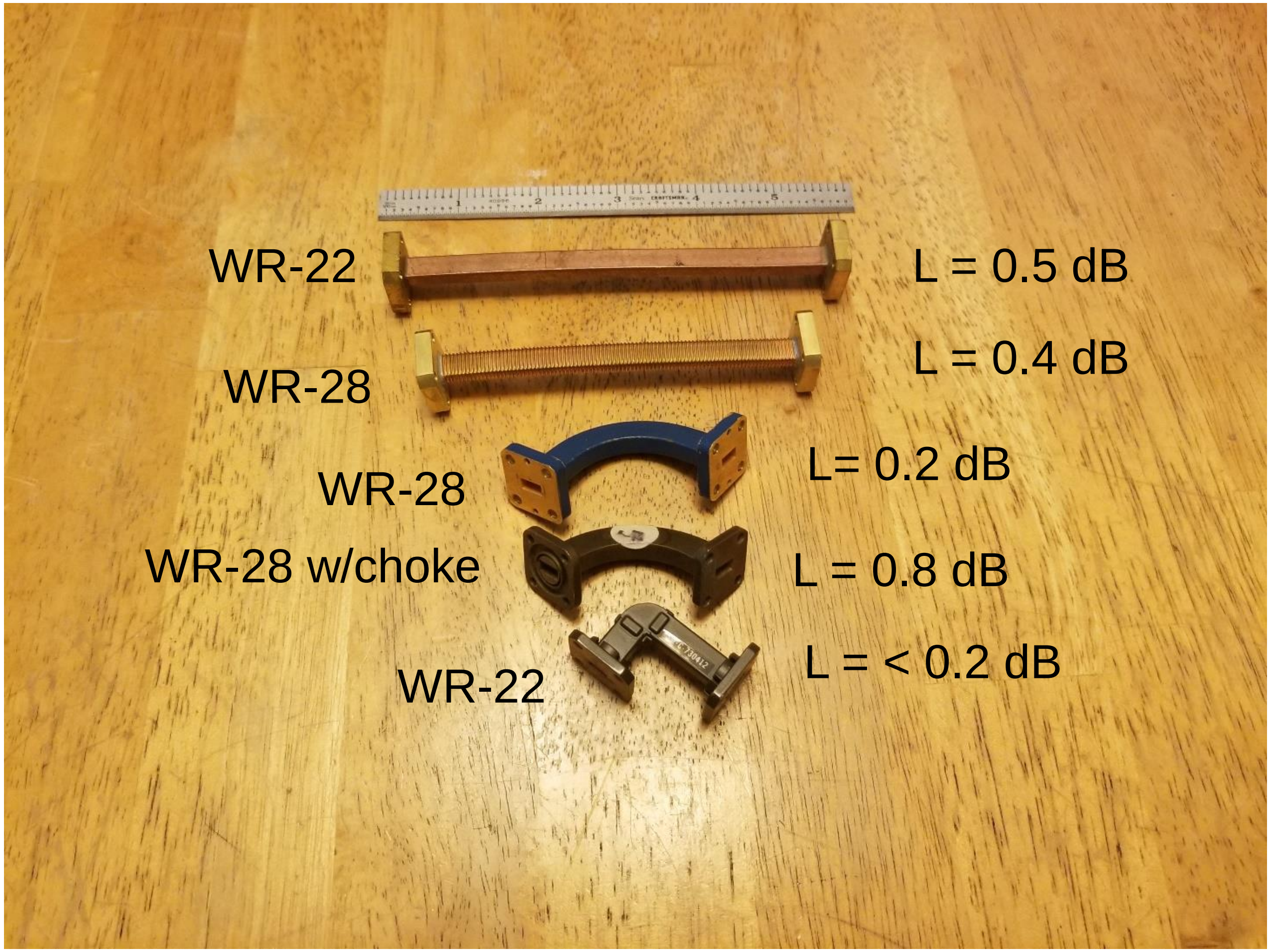

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WR-28 Flexible Waveguide at 47 GHz

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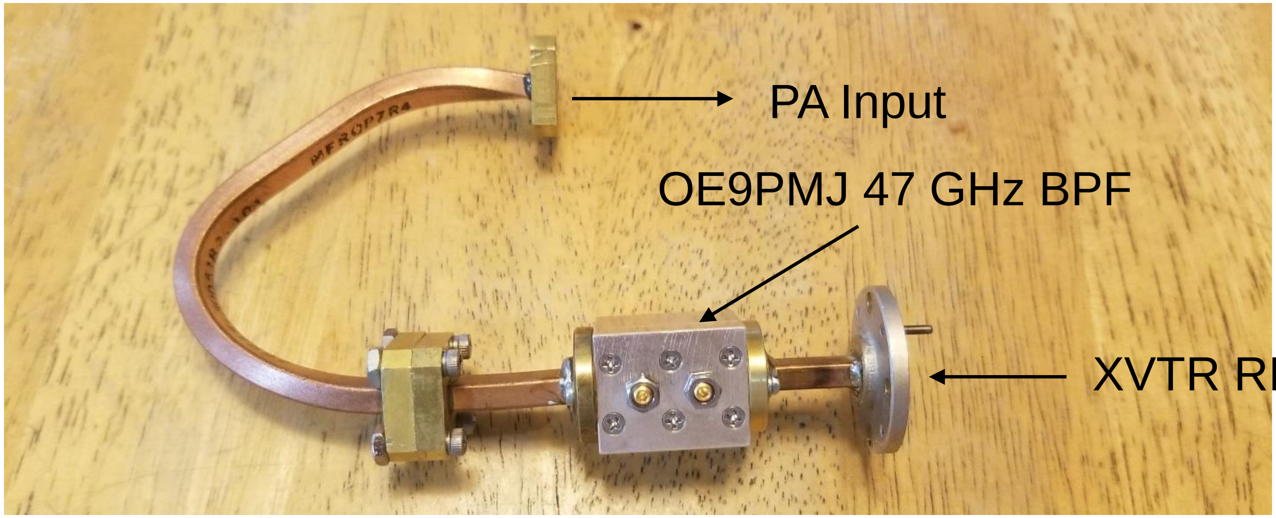
DB6NT 47 GHz XVTR Power Tests

- My XVTR was tested at +19 dBm at 47 GHz by Kuhne.
- At optimum IF drive I was able to achieve +19.5 dBm RF output using an HP 8487A power meter head and an HP 438 power meter. Voltage at the monitor port was 2.04V.
- I did notice that the RF output with no IF drive was still +15.8 dBm and the monitor port still showed a significant dc voltage (1.245V)
- The specs talk about having image rejection but they say nothing about LO leakage at the RF port.
- Apparently the LO power output at the RF port is +15.8 dBm. Both of my DB6NT 47 GHz XVTRs show significant LO power leakage.
- LO + RF = +19.5 dBm = 89 mW and
- LO = +15.8 dBm = 38 mW
- Subtracting suggests that the actual RF output is 51 mW = +17 dBm

DB6NT with filter



- Filter added < 3 dB loss
- I am able to supply +15 dBm of RF to the PA
- Btw..not all the dBs always add up but we take what we have and move forward….

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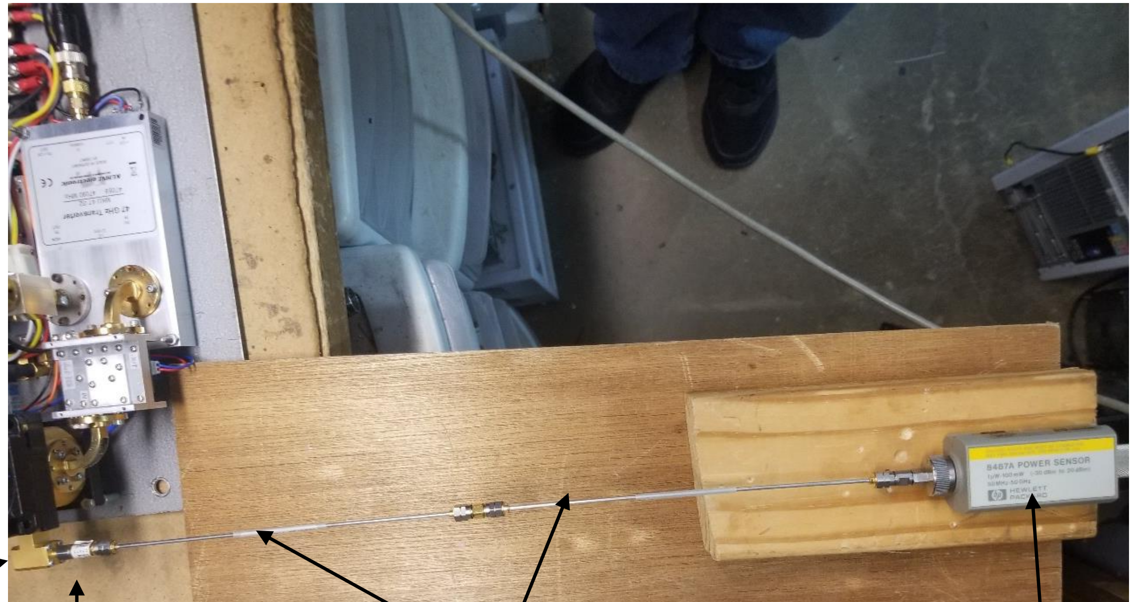
High Power Measurement



WR-22 to 2.4mm

3dB Attenuator

Anritsu V120MM-20cm
With 1.85mm conns

HP8487A Power Sensor

Measured loss of attenuator/cables/adapters to be 8.5 dB
Now allows me to measure up to +20 dBm + 8.5 dB = +28.5 dBm
Measured RF out of xvtr to be +19.5 + 8.5 dB = +28 dBm or 630 mW

Summary

- Time to call it done and put it on the air!
- Noise figure 3.7 dB and 630 mW power output.
- Now to mount it on my flyswatter and make some QSOs with AA5C, AA5AM and KM5PO.
- However I did learn a lot about test techniques on 47 GHz…
- I will let you know if I am successful in retuning a WR-28 transition to 47 GHz
- Questions or comments?