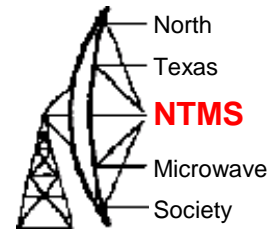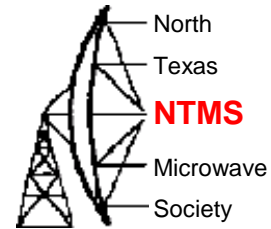North
Texas
NTMS
Microwave
Society

Wavelab 23 GHz ODU module and PA0MHE add on board
Feb. 4, 2022

Wavelab module

Wavelab module

- According to Wavelab ODU brochure, frequency range is 21.2-23.6GHz but original PCB LO can't reach 21.2GHz. TR spacing is 1008 MHz
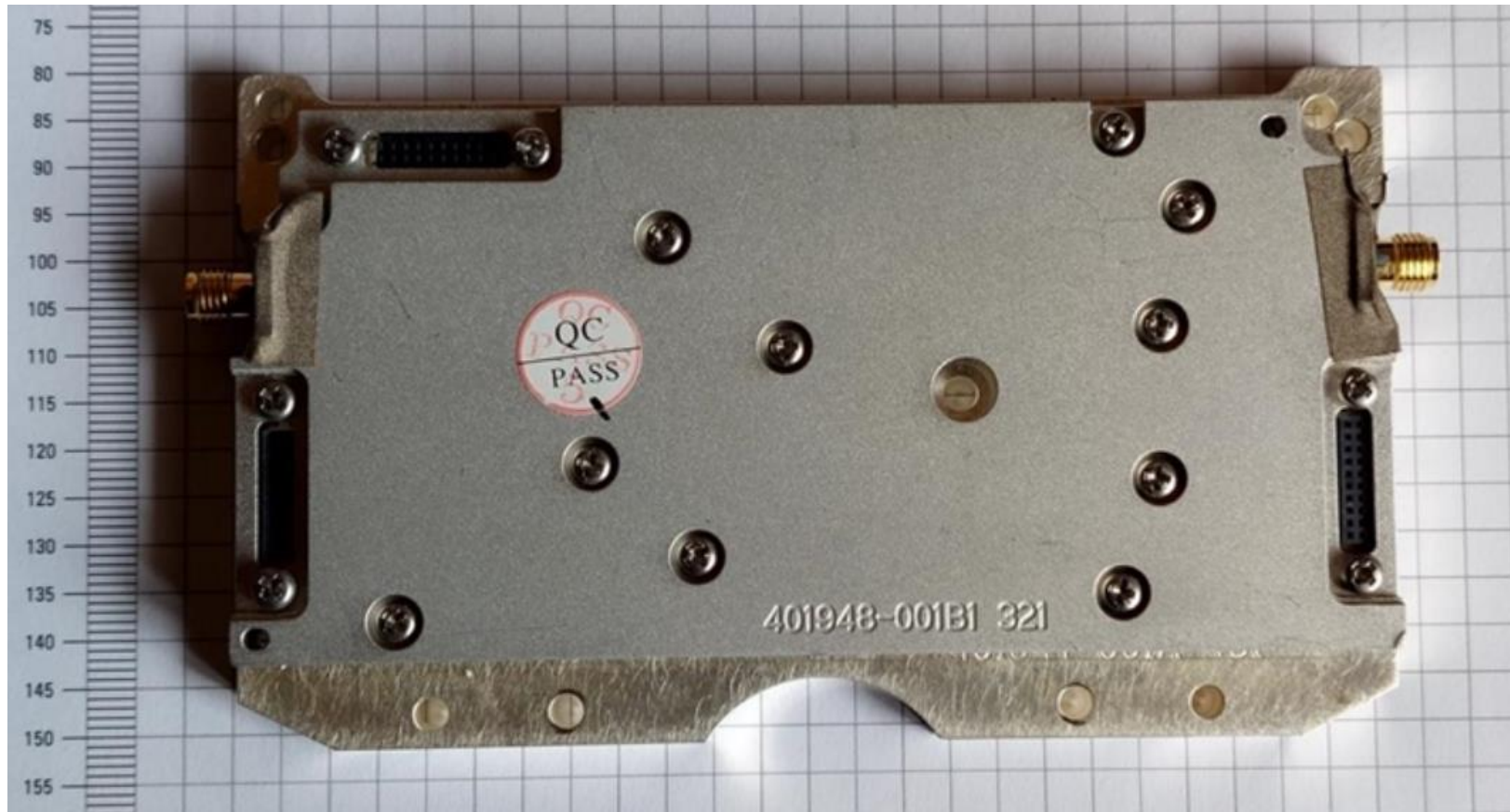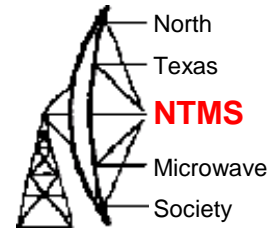
23X1008XP				
TR space 1008MHz (IF Tx 2364MHz-IF Rx 1356MHz); RX=LO+IF Rx; TX=LO+IF Tx; TX= RX+1008MHz				
Motherboard ADF4153 PLL; VCO CRO1728T-LF; LO Range 1670-1770MHz				
Frequency Band*	RX	TX	LO	LO/12 (input)
23.600GHz	22.592GHz	23.600GHz	21.236GHz	1769.66MHz

- The plan to put the module on USA terrestrial 24192 MHz

Synthesizer 1 ADF 1	1819 MHz	x 12 mult	21828 MHz	
Synthesizer 2 ADF 2	2220 MHz		2220 MHz	
			24048 MHz	
			144 MHz	IF
			24192 MHz	Final

W5HN

North
Texas
NTMS
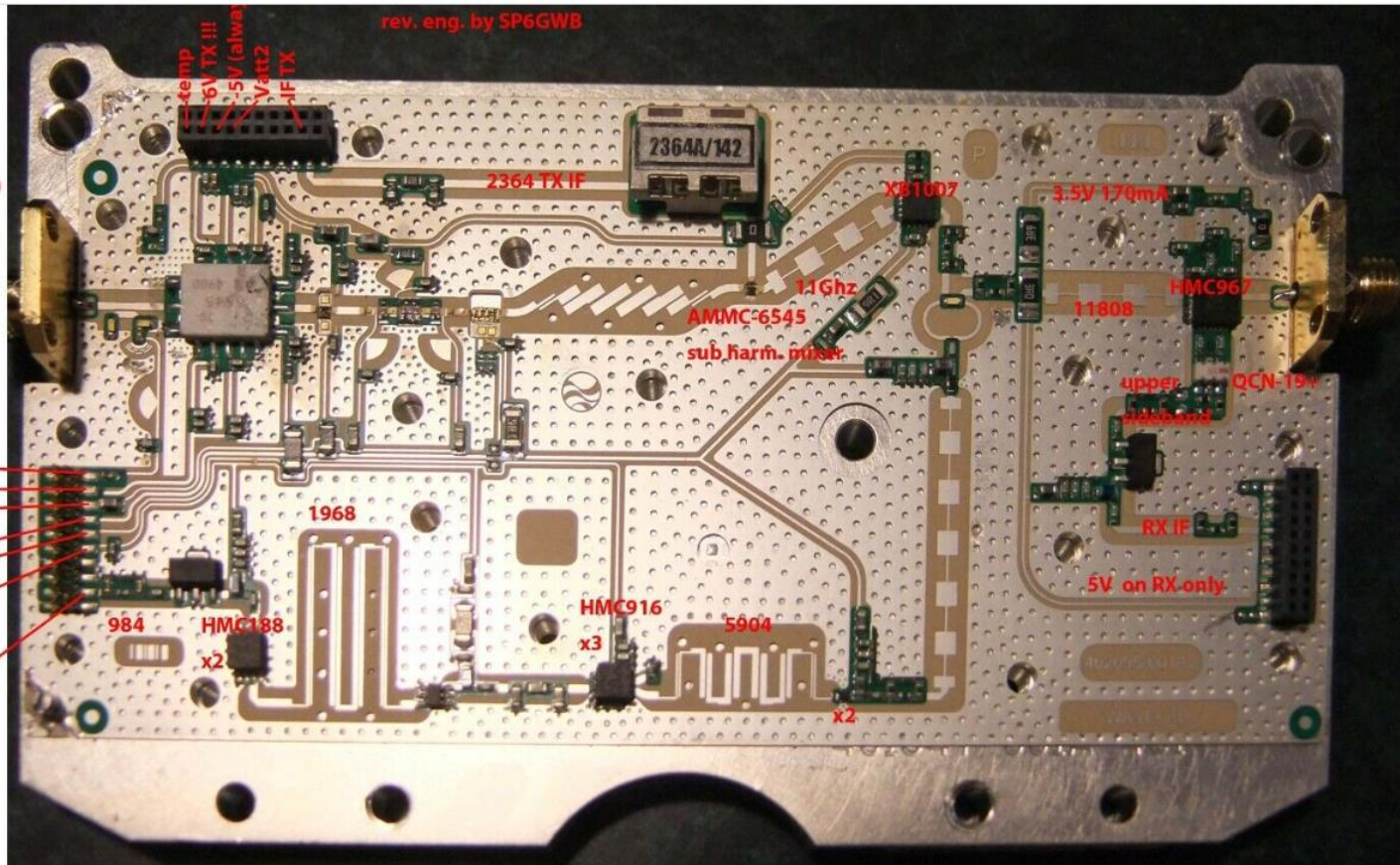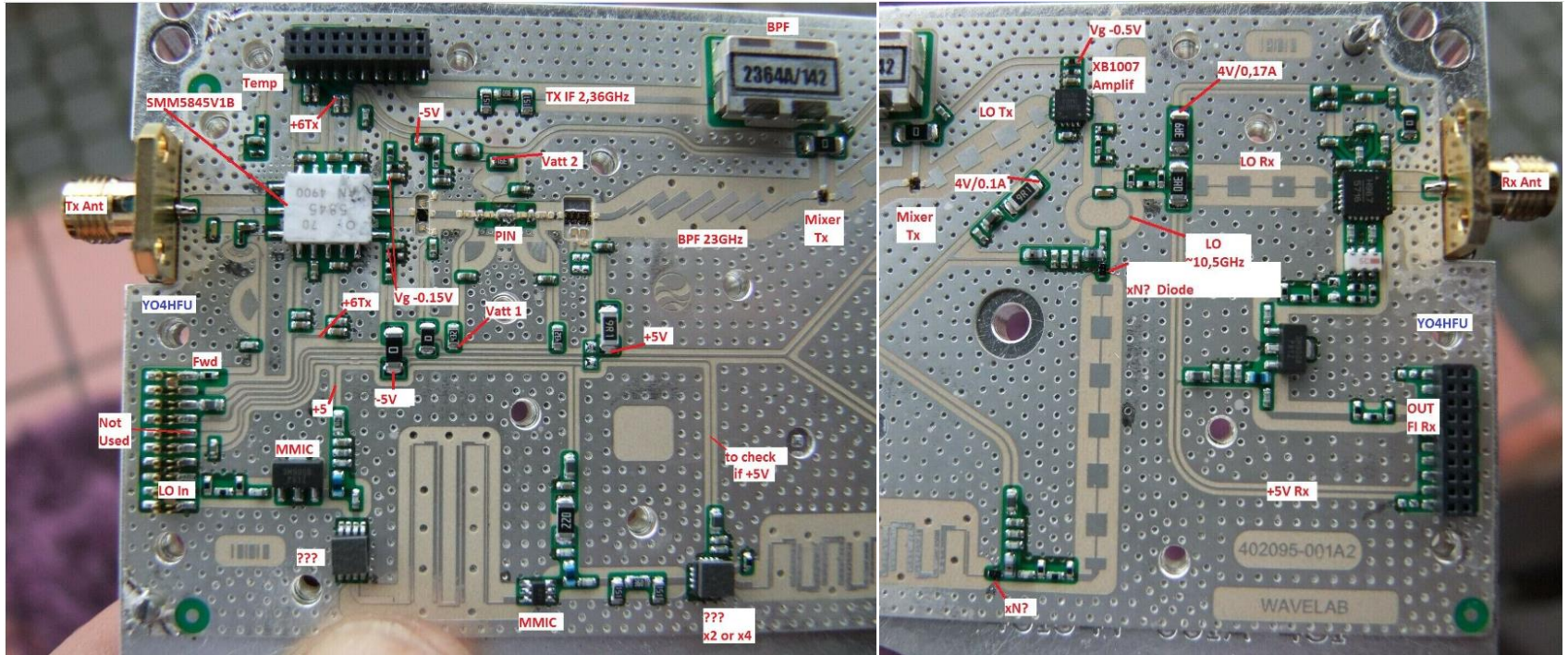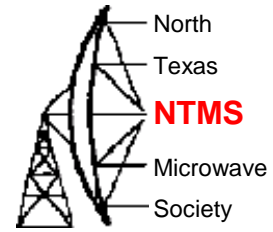Microwave
Society

External view of module

W5HN

North
Texas
NTMS
Microwave
Society

Inside the module
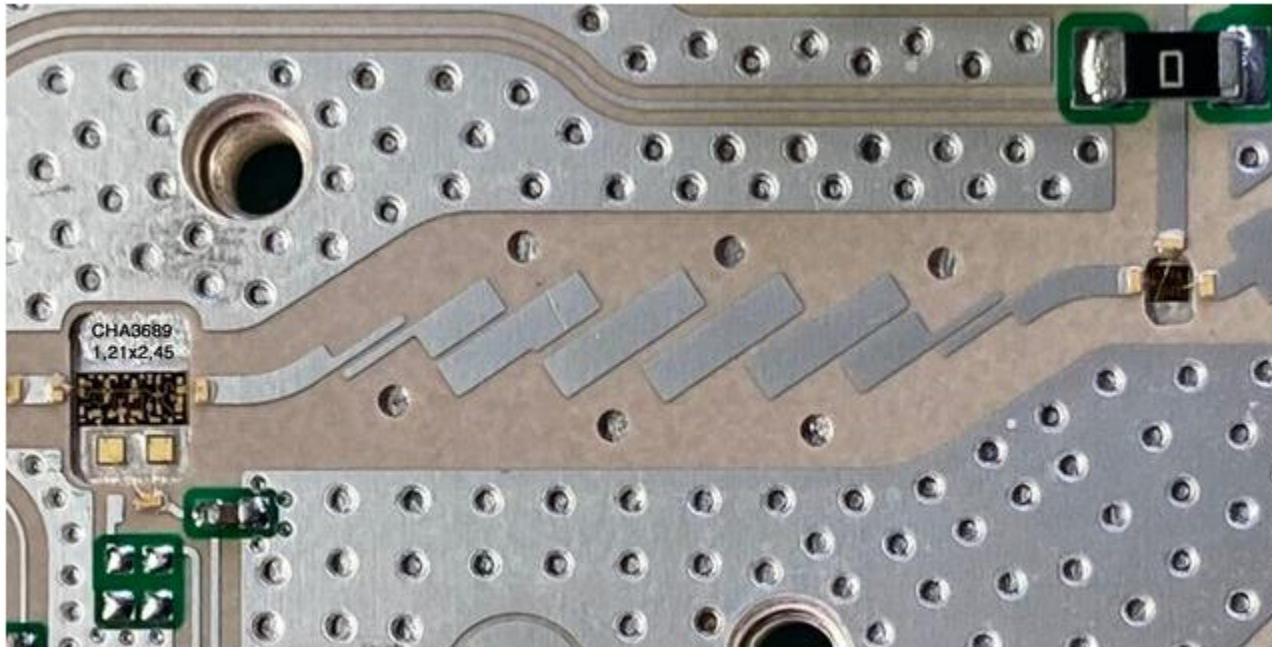
Inside the module

W5HN

North
Texas
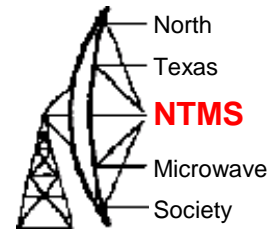**NTMS**
Microwave
Society
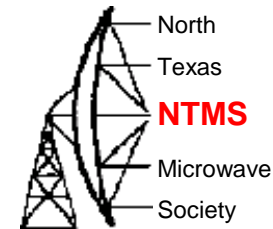
SMM5845
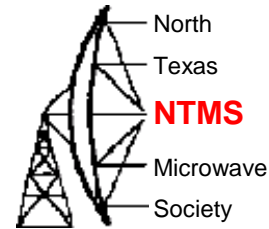

Output Power vs. Frequency
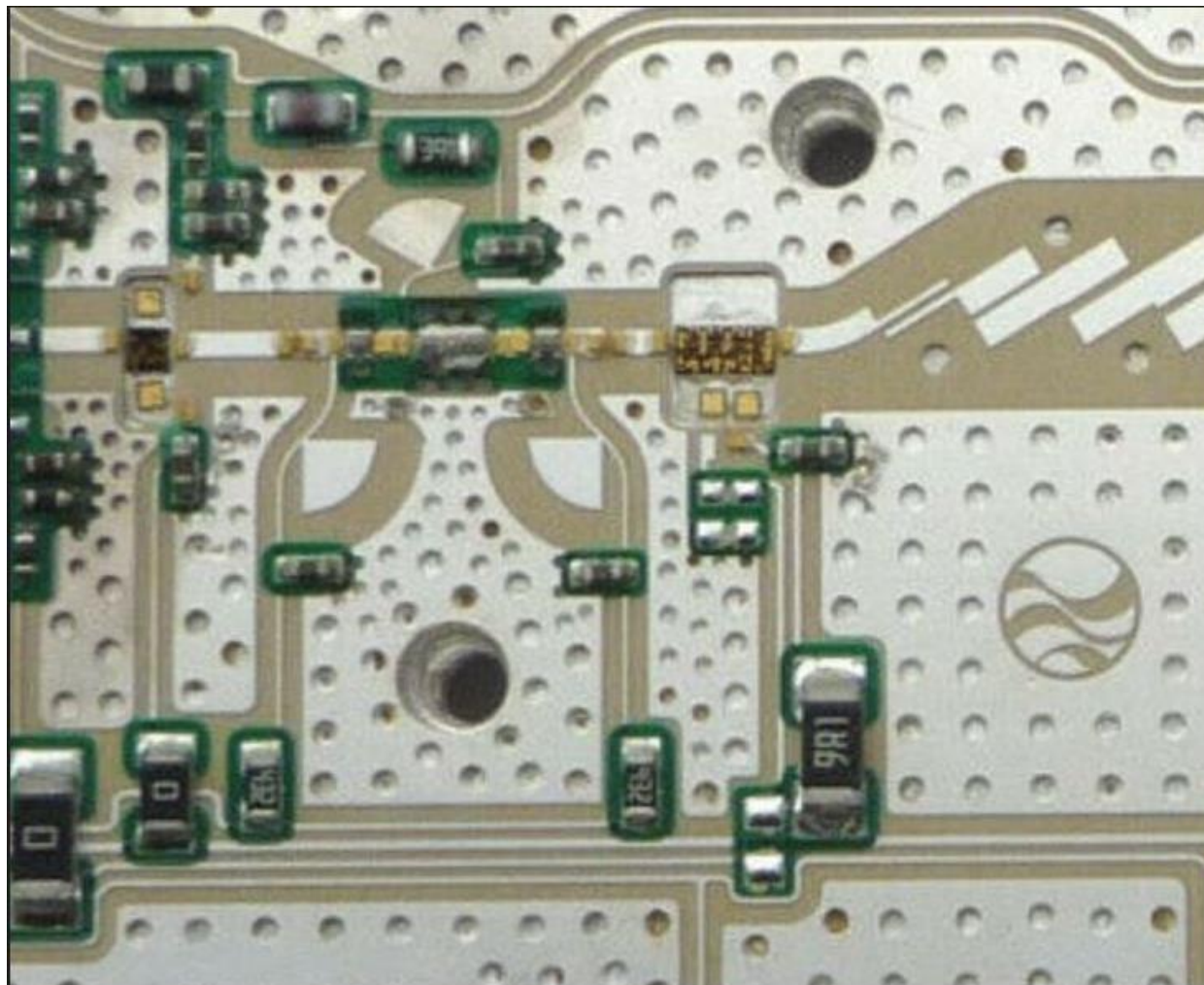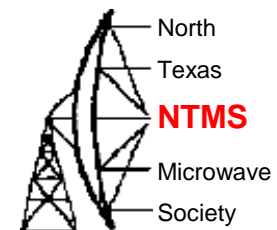**VDD=6V, IDD(DC)=1400mA**

Inside the module

W5HN

North
Texas
NTMS
Microwave
Society
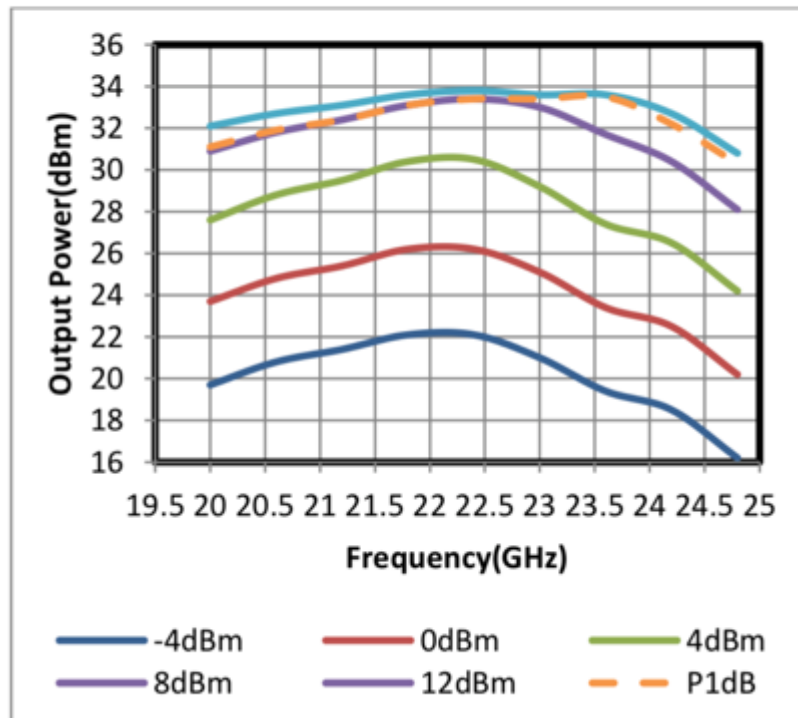
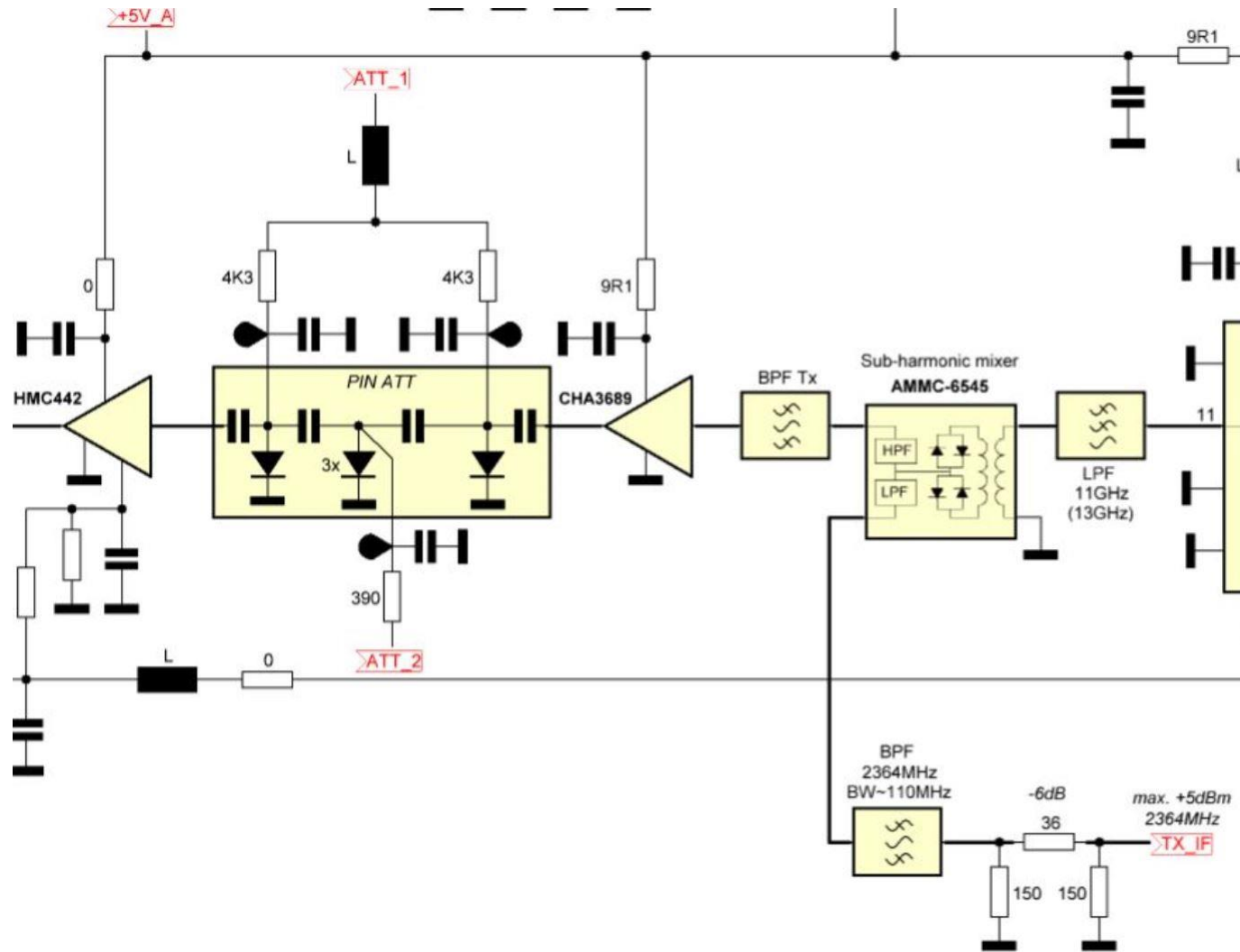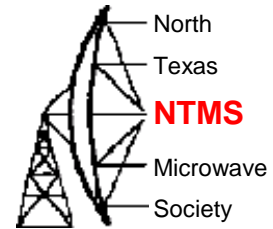|		
12x1700+2364=22764		Ref
12x1633+2364=21960	down 804	-3db
12x1774+2364=23652	up 888	-3db
12x1807+2364=24048	up 1284	-6db

Module schematic
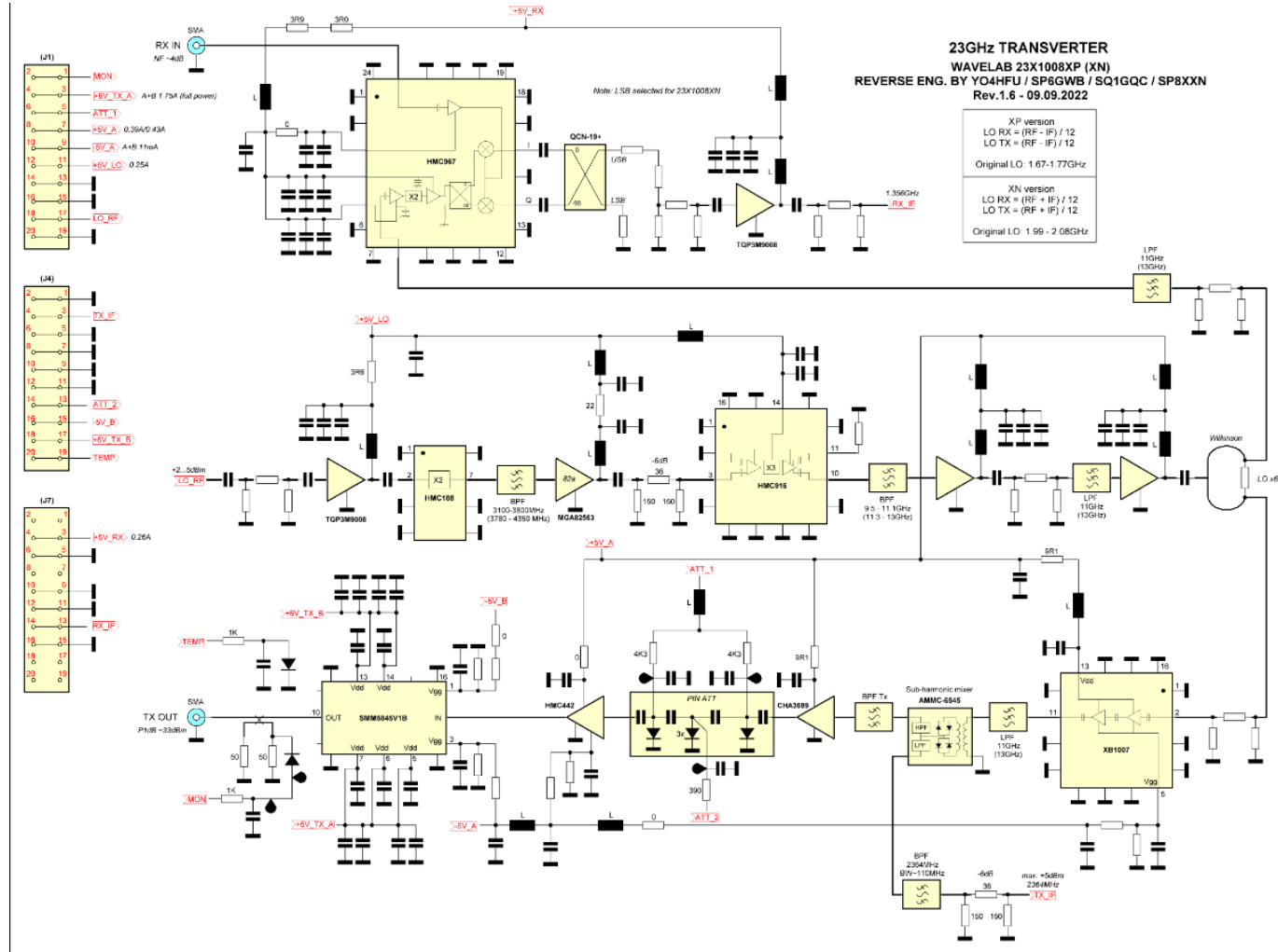
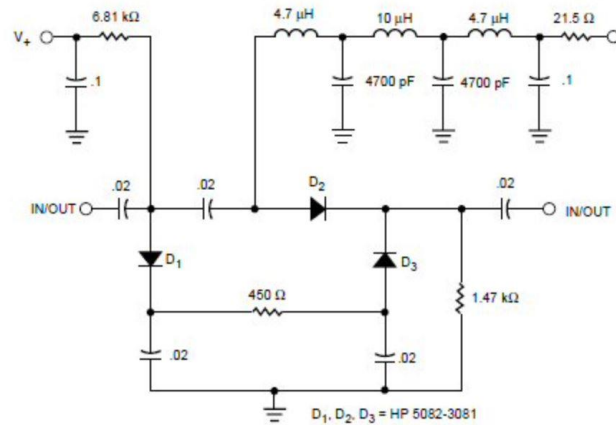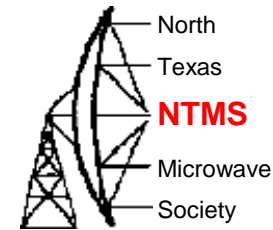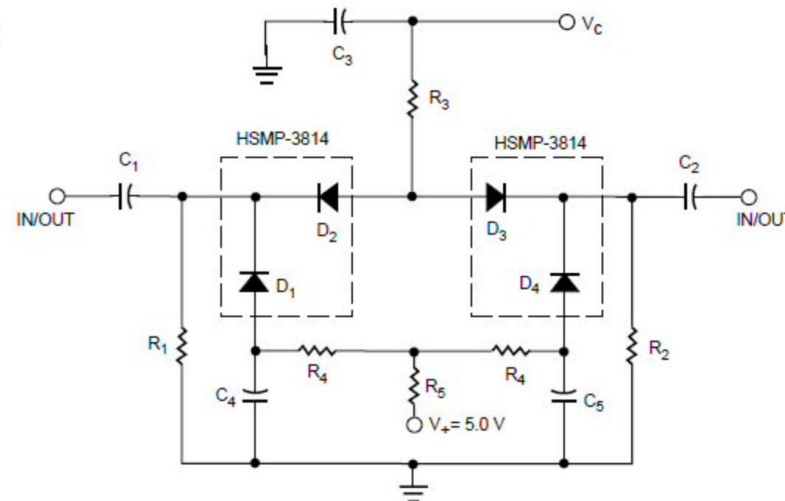# PIN attenuator

Pin closeup

PIN examples

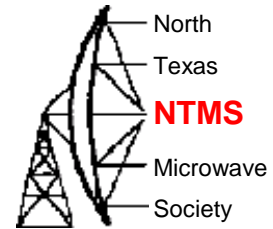*Voltage-variable attenuator using PIN diodes prior to Waugh*
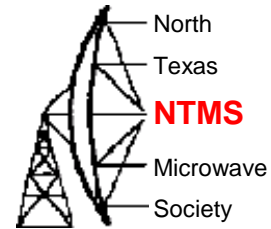

Waugh's attenuator

Ulrich
Rhode

Ray
Waugh

NTMS Group order

Call	Name	Qty
KM5PO	Jim McMasters	2
KI5EMN	Paul Sarver	2
W5LUA	Al Ward	1
AA5AM	Scott Armstrong	1
WA5JAT	Jim Hudson	2
AB5SS	John Maca	1
AA9IL	Mike Kana	2
AF4JF	Herb Ullmann	2
K4CSO	Charles Osborne	2
N7JA	Jim Allyn	1
K6ML	Mike Lavelle	3
		19

Order placed with JLCPCB for 20 boards

W5HN

North
Texas
NTMS
Microwave
Society

JLCPCB order

Most Efficient, Economic, Innovative PCB Solutions

Founded in 2006, JLCPCB has been at the forefront of the PCB industry. With over 15-year continuous innovation and improvement based on customers' need, we have been growing fast, and becoming a leading global PCB manufacturer, who provides the rapid production of high-reliability and cost-effective PCBs and creates the best customer experience in the industry.

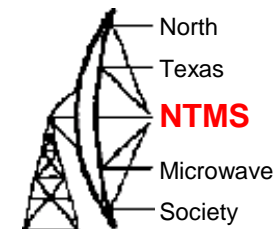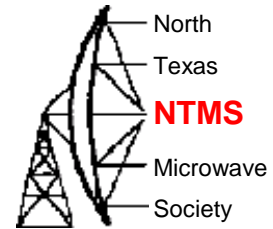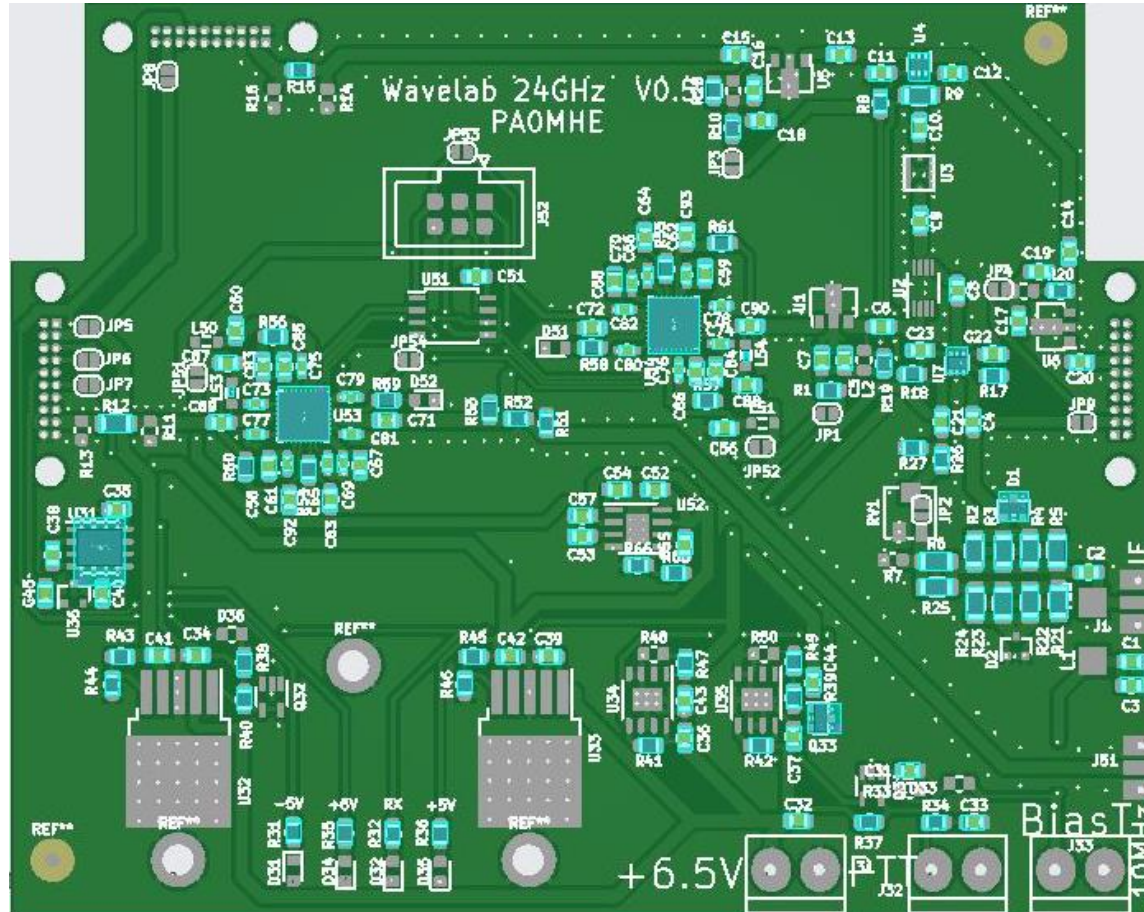| 800,000+	20,000+	450,000㎡	620,000㎡
Customers	Orders Daily	Factory Area	Production Capacity/Month
6 Million+	170+	3000+	15
PCBs Produced/Year	Countries Covered	Employees	Years Founded
>99.97%	<0.23%	1 Day	24/7
On-time delivery	Quality Complaint Rate	PCB Prototype	Online Service

* As of January 2021

JLCPCB order

- Create an account on the website

- Upload the gerber, BOM, positions files
  - Wavelab-24G-Addon-module/Kicad/V05 Kicad6/Wavelab24GHz_v05/production at main · PA0MHE/Wavelab-24G-Addon-module · GitHub

- Review component placement and jlcpcb inventory shortages
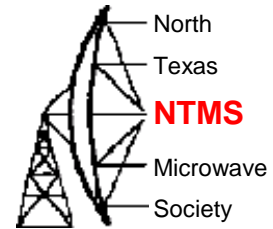 - Using search features you may find replacement parts

- Place the order

JLCPCB order

Confirming parts placement via website image

JLCPCB order

North
Texas
NTMS
Microwave
Society

- Initial cost of PCBs was about a buck each.

JLCPCB order

- Shipment timeline. From payment to shipment < 6 days

Add on board by PA0MHE

North
Texas
NTMS
Microwave
Society

- Board provides:
  - +3.3v, +/- 5v, +6v power to add on board and module
  - LO / IF frequencies (programmable ATTINY for LO freqs)
  - Connections to pin attenuator

- Key components:
  - 2 x ADF4351 RF synthesizers and ATTINY
  - Mixer 1.5-4.5 GHz
  - 800 ma 3.3v regulator
  - 3 x DC-6 GHz 3.9 db NF, 21 db gain MMICs

- Support:
  - NTMS Group PCB order
  - Wavelab groupsio -https://groups.io/g/Wavelab24GHz

W5HN

North
Texas
NTMS
Microwave
Society

V5 changes from V4

R65, R66 added as option for U52 ADM7151 (chip shortage)

R36   update service print to "+5V"

U6   changed footprint to MGA-86576 (still possible to mount PGA103+, but too little gain)

J31, J32, J33, J1, J2, J3 No solder paste

V4   V5

Remaining parts

Soldering technique

W5HN

North
Texas
NTMS
Microwave
Society
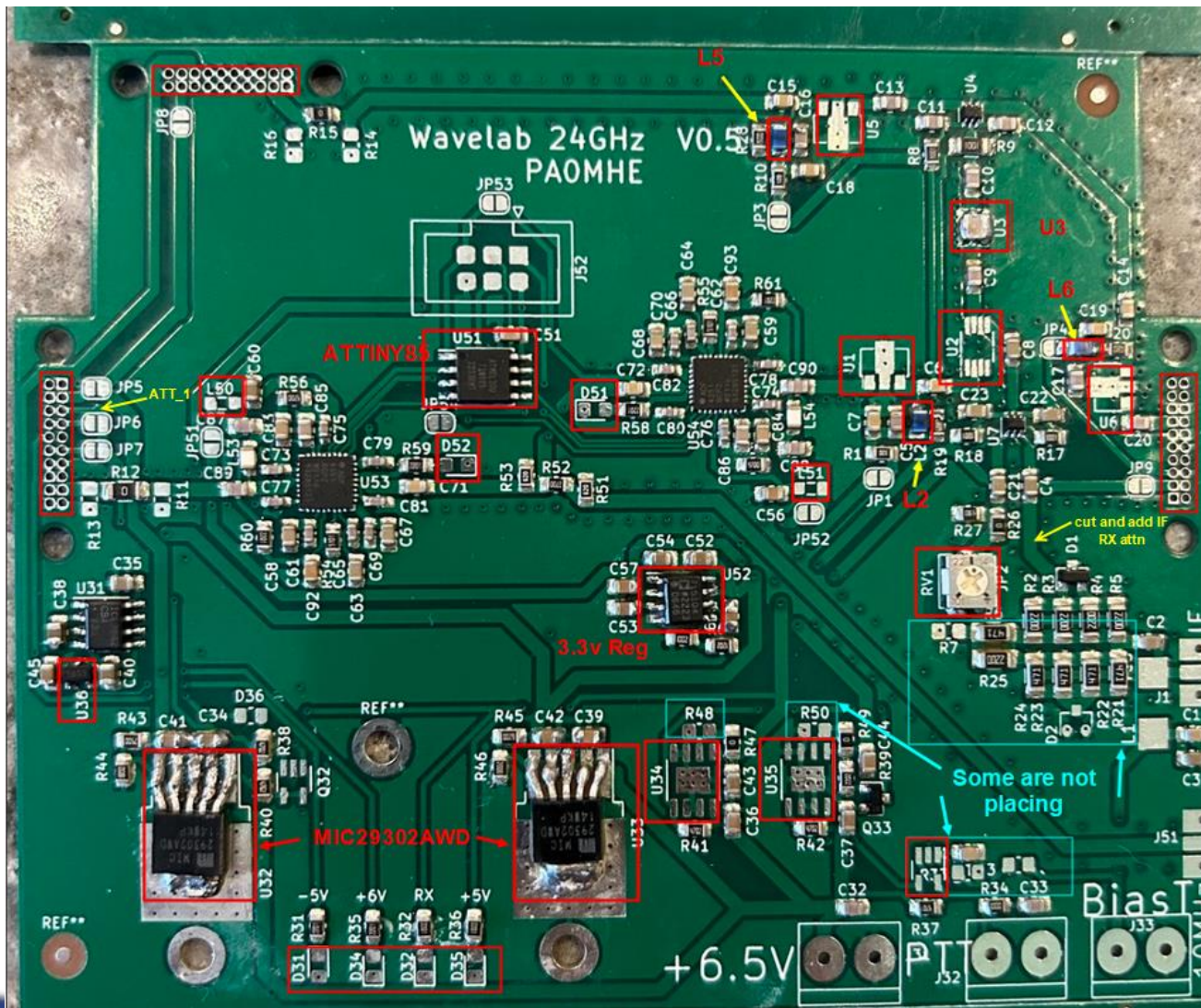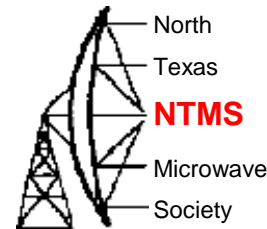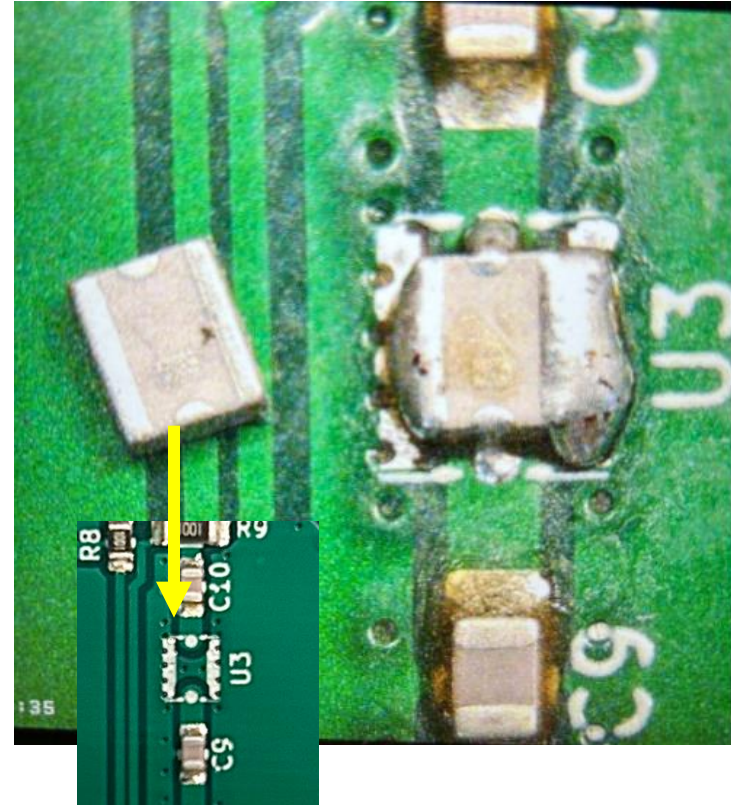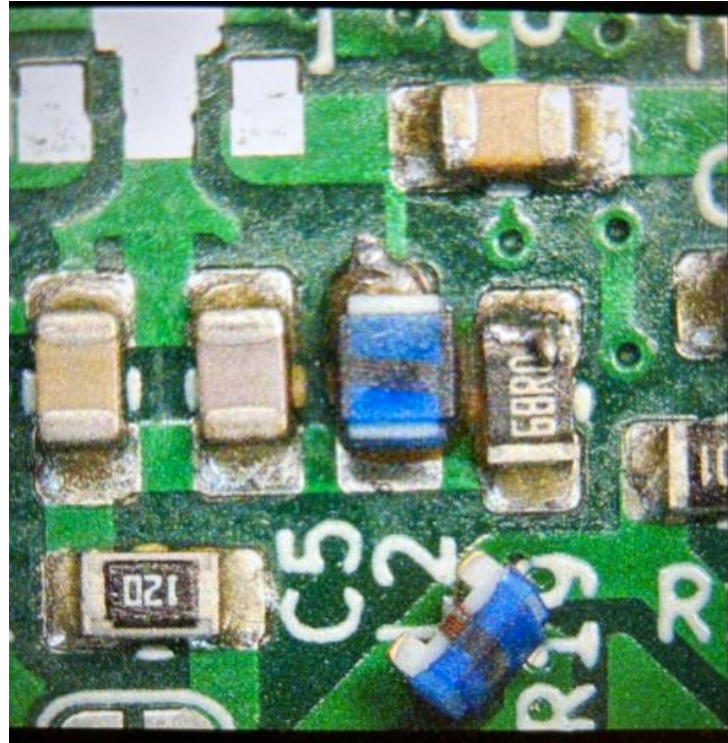
Small I/O footprint before placing

Soldering technique

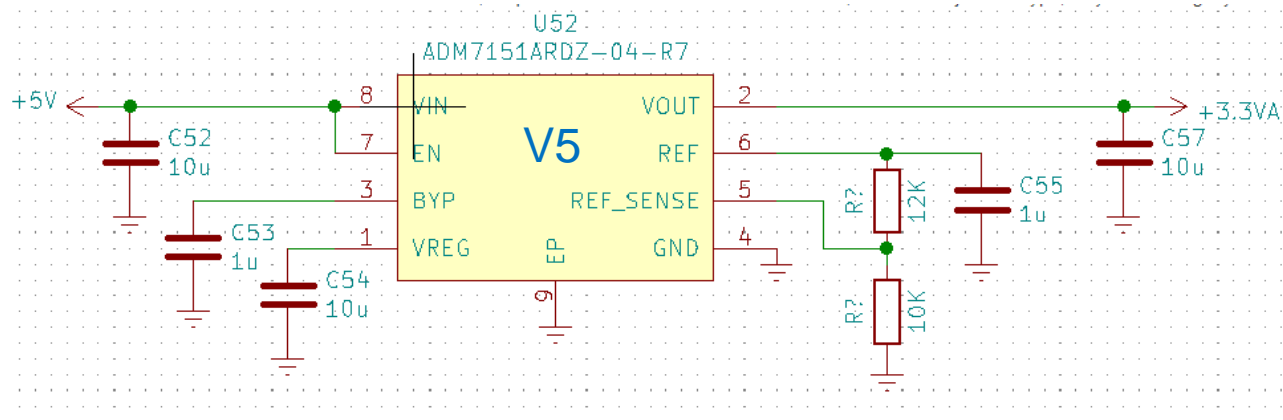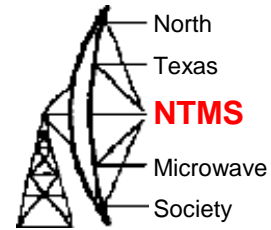- Solder pin strip headers after DC checks are performed and validated
  - Rough up pin hole connections with light sandpaper
  - Tack one pin in place while insuring connector is aligned properly.
  - Start with J3/upper left -TX IF. 5 ground conns ganged together. 1 edge n/c and 1 edge ground.
  - Next is J4/right side - RX IF. 2 ground conns ganged. 2 other ground, 3 edge are n/c.
  - Last is J2/left side – LO. 2 ground conns ganged. 1 edge ground, other edge is MON but "n/c" on schematic.

Soldering technique
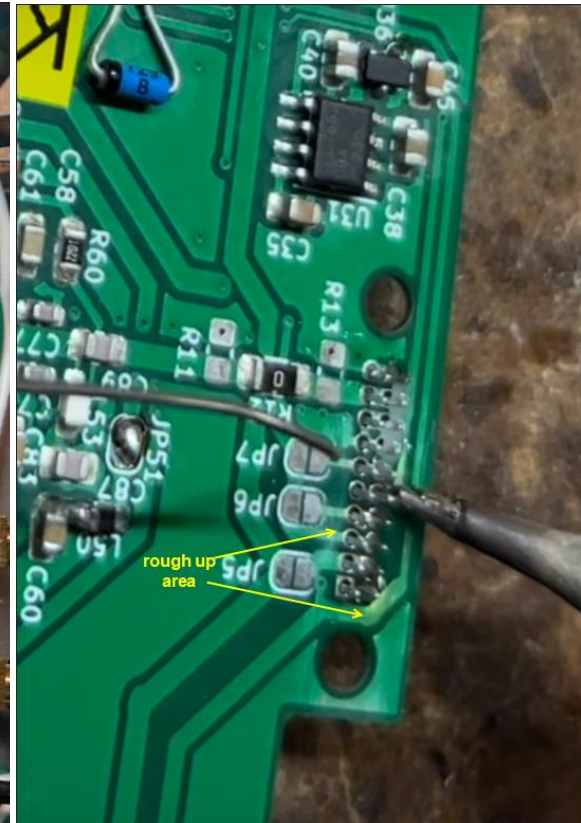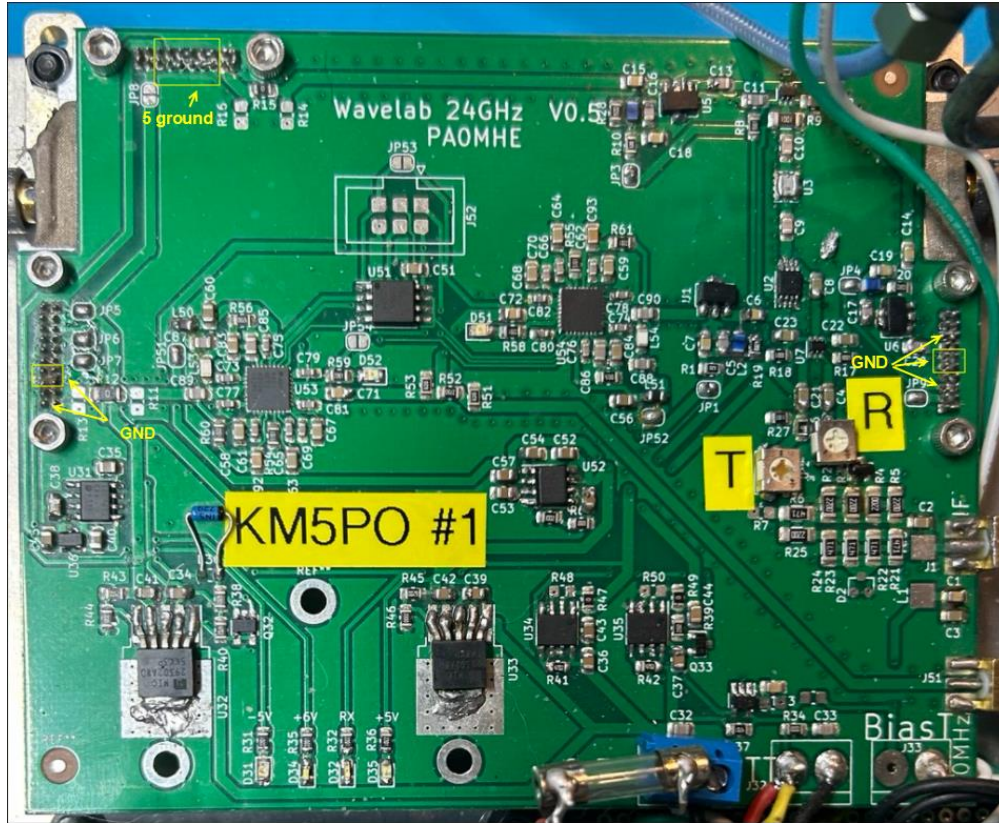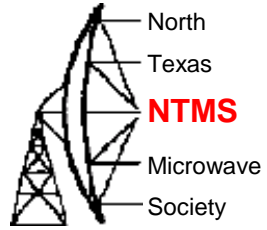
Inspect solder joints

- Ohm out parts from other connecting parts
  - Filter U3 is easy to short to ground.
    - Through filter resistance is slightly lower than filter in/out ports to ground.
  - L2, L5, L6 – do not overheat. Verify through coil resistance is ~ .27 ohm
    - I pre-tin the pads but do not leave a build up of solder on the pad
  - The mixer sanity checks:
    - *IF port ~ 340 ohms to ground*
    - *RF port 10-14 ohms to ground*
    - *LO port 8-9 ohms to ground*

Building tips

- ## Use a checklist of parts placement

  - For the NTMS December 2022 PCB order, a checklist is available here:

  - Parts detail v5.pdf (ntms.org)

Building tips

- ## Use a checklist for initial checkout
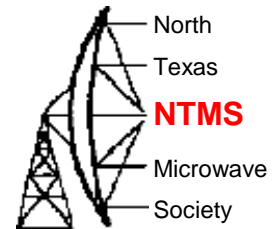
  - ### Test sequence from Maarten/PA0MHE and modified for NTMS PCB with substituted parts is here:

  - ### https://ntms.org/files/Feb2023/Wavelab power up testing.pdf

Building tips

- Use a checklist for initial checkout
    - https://ntms.org/files/Feb2023/Wavelab power up testing.pdf
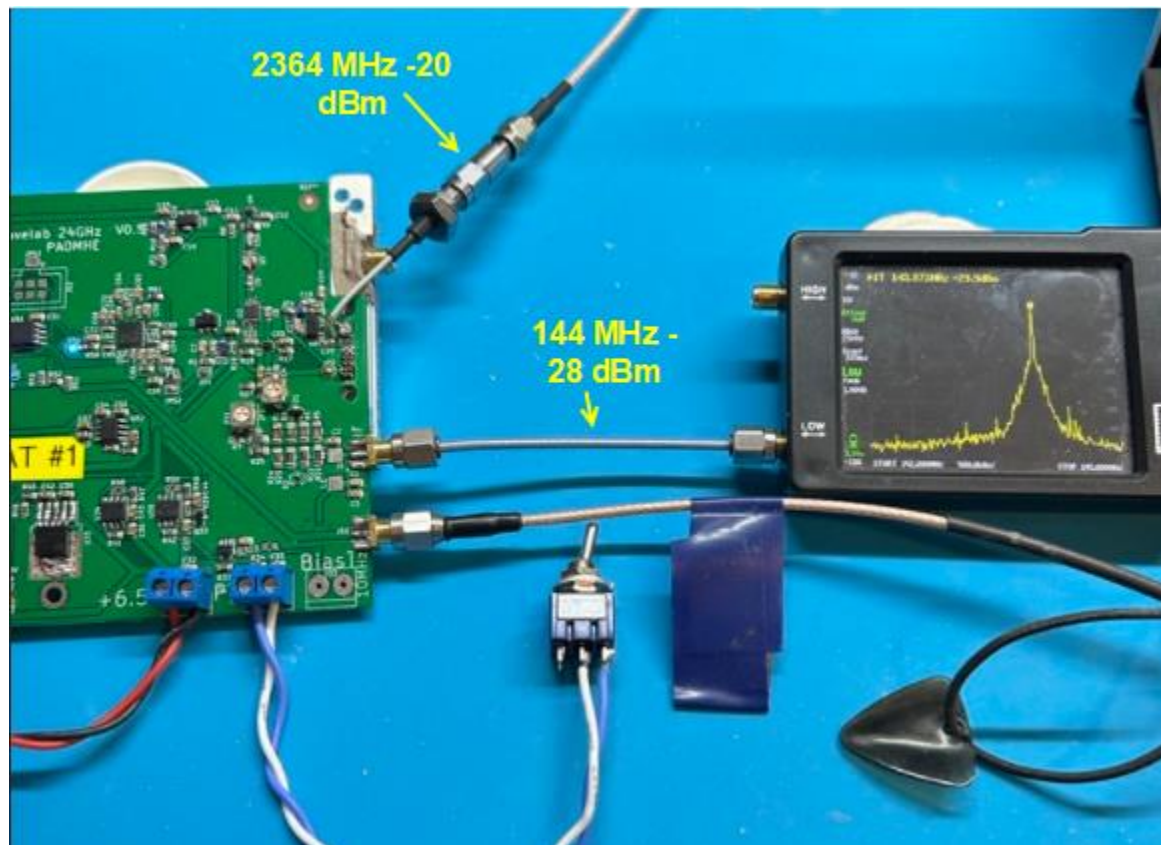
Building tips

- DC power reversal
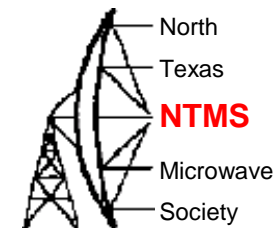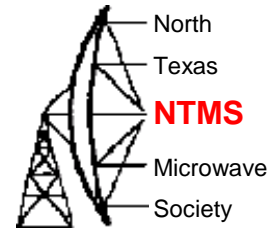   - Hook up the input DC power backwards and expect to replace:
    - U31 – Charge pump voltage inverter
    - U34 – LDO voltage regulator
    - U35 – LDO voltage regulator
    - Many ways to prevent this but at minimum install a 3 A fast blow fuse on +6.5 V line.

- D31 LED (- 5 V sense) place Anode on ground pad!
    - Opposite of the other three voltage sense LEDs…

- Even though LO synth LED "lock" lights up, if you see a big signal ~ 750 Mhz at LO #1 output (*should be 1819 MHz*) then you do not have 10 MHz ref lock.
    - Correct behavior of LO lock LEDs at power on is 1819 MHz lights first (left side of board), then 2220 MHz one second later.
    - I used 15 dBm reference in the shop for initial testing of the PCB boards.
    - Final build used McCoy OCXO with 13 dBm output + 3 dB attenuator ahead of ref input.
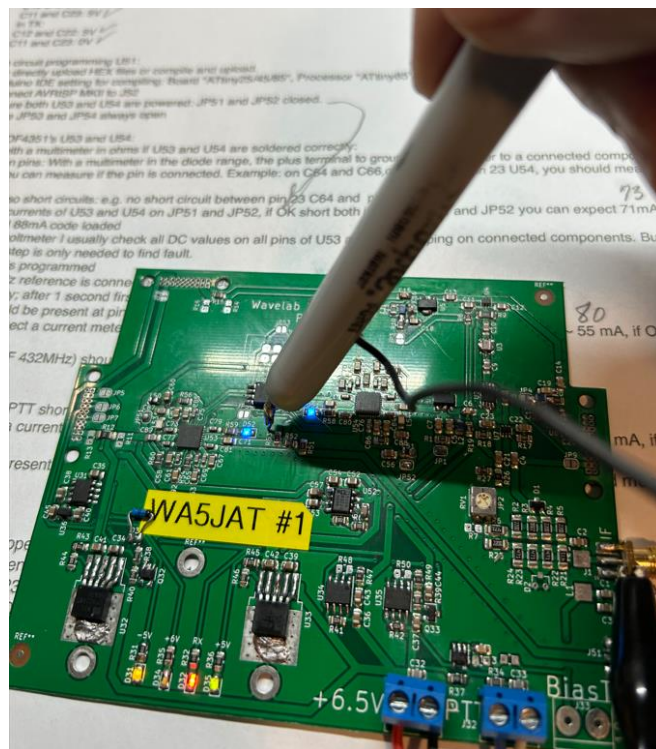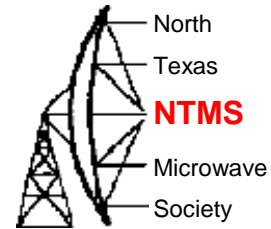
Building tips

- Correct behavior of LO lock LEDs at power on is 1819 MHz lights first (left side of board), then 2220 MHz one second later.
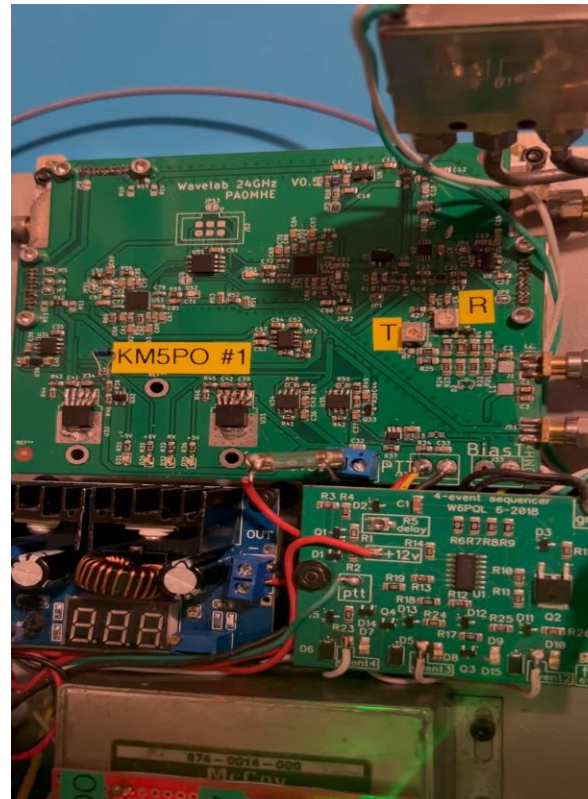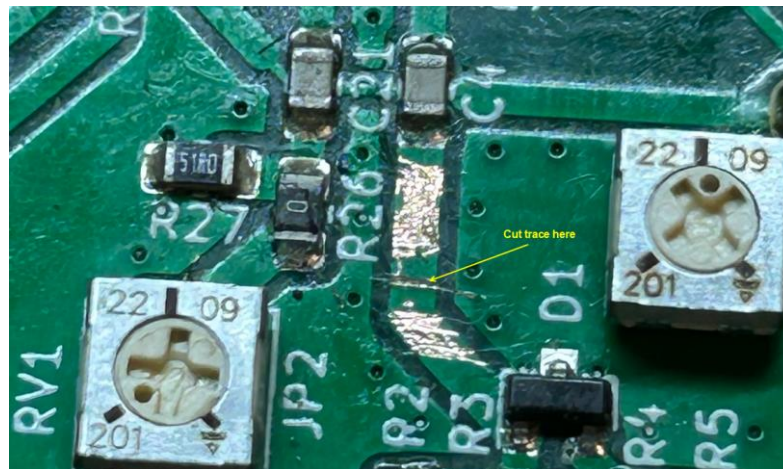
Building tips

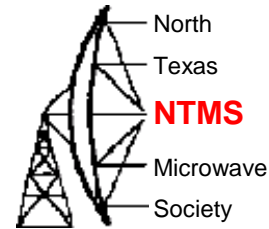- Placing a probe between the LO LEDs will sample both LO frequencies
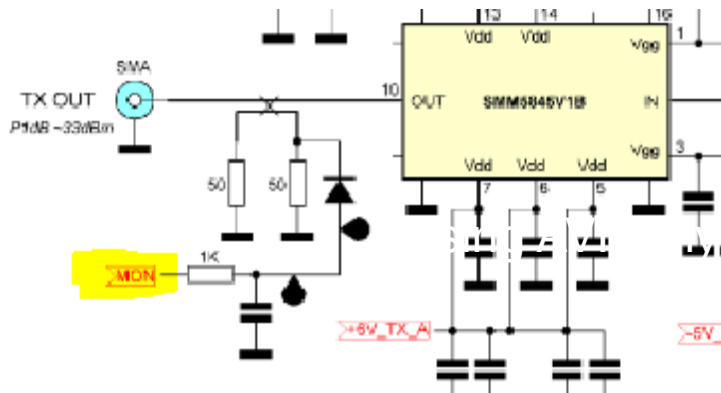
Building tips

If you want to add receive side IF
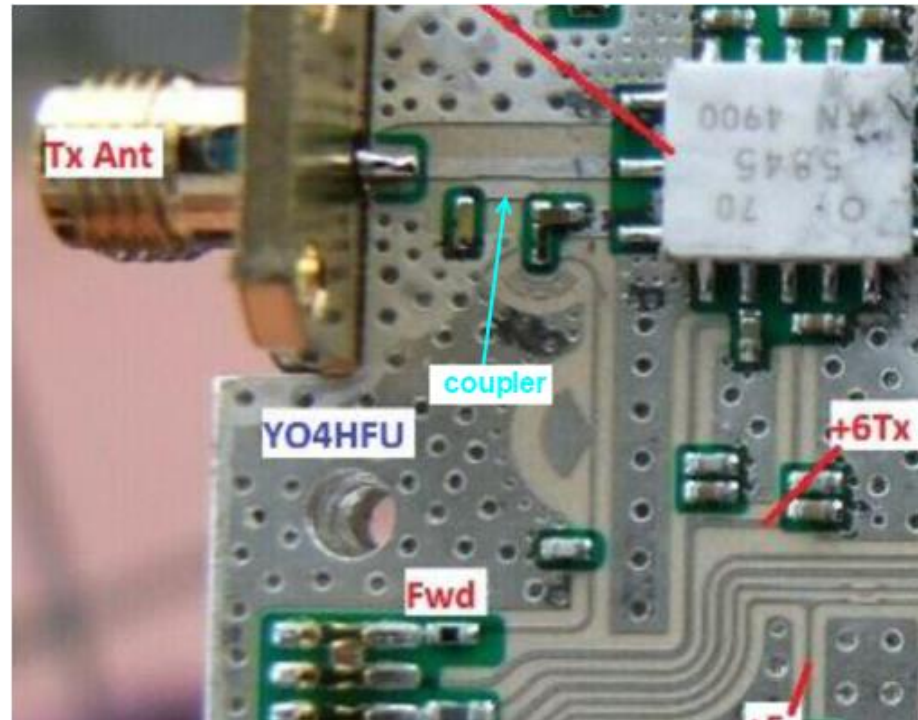attenuation prepare the trace below C4
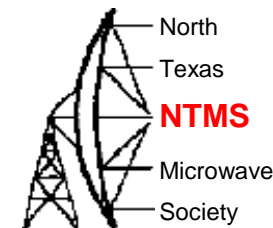
Monitor port

- Mon(itor) port

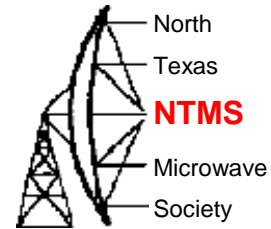Measure varies from -.5 to -3.5v (J2 pin 1)

Program ATTINY

North
Texas
NTMS
Microwave
Society

- Arduino sketch is on GitHub
  - Wavelab-24G-Addon-module/ADF4351_fixed_tiny_24GHz.ino at main · PA0MHE/Wavelab-24G-Addon-module · GitHub
  - Arduino integrated development environment needed (Free)
- Use Arduino IDE to burn bootloader to Uno and then upload Wavelab sketch to ATTINY
  - Uno required, breadboards, patch wiring
  - Program an ATtiny With Arduino : 7 Steps (with Pictures) - Instructables
- Use sparkfun "AVR tiny programmer" and SOIC chip holder, install drivers, upload Wavelab sketch directly to ATTINY
 - This will be explained in the following slides

Programming tools

- Using AVR tiny programmer (windows)

  - Plug the programmer into your USB

  - If drivers are not found then download Zadig USBTiny drivers

  - Ref:https://learn.sparkfun.com/tutorials/tiny-avr-programmer-hookup-guide/all

  - Download the ATTINY addon to your Arduino IDE from GitHub

  - Configure IDE to use ATTINY85 (internal 1 MHz clock)

    - *Tools>Board>ATtiny85 (internal 1 MHz clock)*

  - Configure IDE to use ATTINY85 processor

    - *Tools>Processor>ATTINY85*

  - Configure IDE to use programmer USBtinyISP

    - *Tools>Programmer>USBtinyISP*

  - Plug in the ATTINY

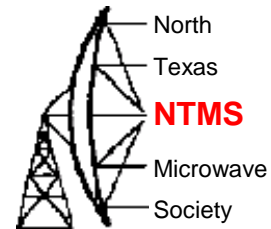 - Upload the code. (Use a blink sample sketch if you want to test 1st time)

Programming tools
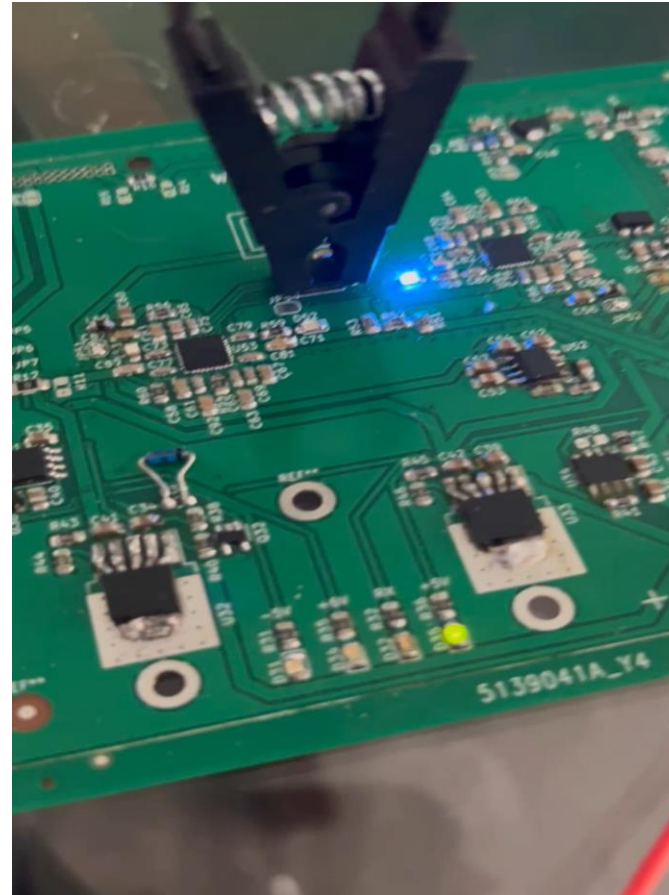
North
Texas
NTMS
Microwave
Society
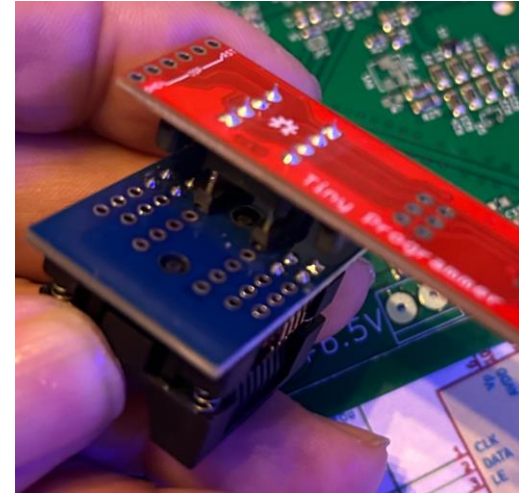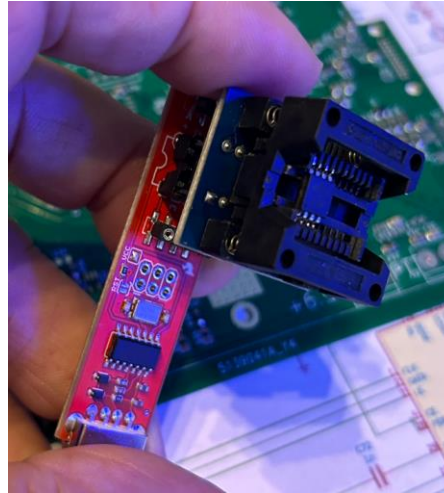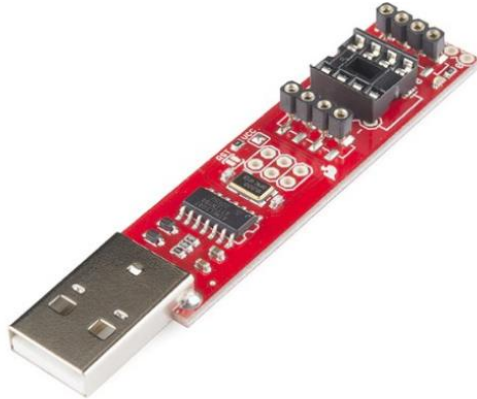
- On Amazon
  - AVR Tiny Programmer
  - SOIC8 SOP8 to DIP8 IC Programmer Socket Converter (verify the device will handle 200+ mil sizing)
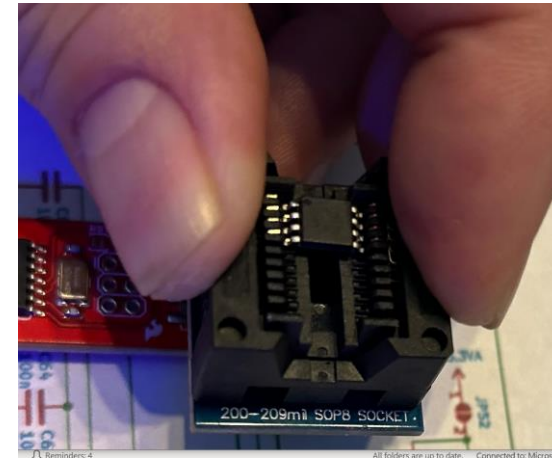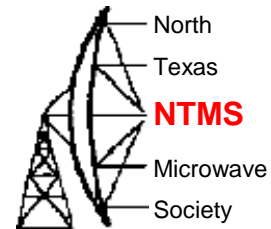
In circuit programmer (clip)

- I use the TinyProgrammer and plug in a cable with clip.
- Red wire in cable orients to pin 1 of the on-board chip to be programmed.

Video: +5v LED lights, #2 LO blinks, #1 LO blinks, then pause and #2 LO steady on.

LO frequencies

- The plan to put the module on USA terrestrial 24192 MHz

Synthesizer 1 ADF 1	1819 MHz	x 12 mult	21828 MHz	
Synthesizer 2 ADF 2	2220 MHz		2220 MHz	
			24048 MHz	
			144 MHz	IF
			24192 MHz	Final

- For 144 MHz IF use the reg1 & reg2 lines below highlighted and comment out all others.

```
23    uint32_t reg1[6] =  {0x5A0038, 0x8008051, 0x1A004E42, 0x4B3, 0x9A003C, 0x580005} ; // 1807MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
24  + //uint32_t reg1[6] =  {0x5A8048, 0x8008051, 0x1A004E42, 0x4B3, 0x9A003C, 0x580005} ; // 1819MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
25    //uint32_t reg2[6] =  {0x378000, 0x8008011, 0x1A004E42, 0x4B3, 0x8A003C, 0x580005} ; // 2m, 2220MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
26  + //uint32_t reg2[6] =  { 0x600018, 0x8008029, 0x1A004E42, 0x4B3, 0x9A003C, 0x580005 } ; //438MHz, 1926MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
27    uint32_t reg2[6] =  {0x608008, 0x8008029, 0x1A004E42, 0x4B3, 0x9A003C, 0x580005} ; // 70cm, 1932MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
```

LO frequencies
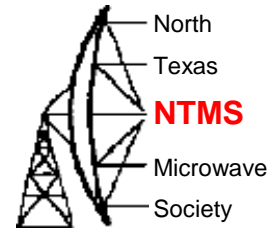
- Pertinent register values are the first two hex strings

```
23    uint32_t reg1[6] = {0x5A0038, 0x8008051, 0x1A004E42, 0x4B3, 0x9A003C, 0x580005} ; // 1807MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
24  + //uint32_t reg1[6] = {0x5A8048, 0x8008051, 0x1A004E42, 0x4B3, 0x9A003C, 0x580005} ; // 1819MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
25    //uint32_t reg2[6] = {0x378000, 0x8008011, 0x1A004E42, 0x4B3, 0x8A003C, 0x580005} ; // 2m, 2220MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
26  + //uint32_t reg2[6] = { 0x600018, 0x8008029, 0x1A004E42, 0x4B3, 0x9A003C, 0x580005 } ; //438MHz, 1926MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
27    uint32_t reg2[6] = {0x608008, 0x8008029, 0x1A004E42, 0x4B3, 0x9A003C, 0x580005} ; // 70cm, 1932MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
```

Reg 1 will control Integer and Fractional values

Enter hex number

5A8048 · 16

= Convert × Reset ⇅ Swap

Binary number

010110101000000001001000 · 2

Reg 2 controls Phase adjust, prescaler (8/9), Modulus value

Enter hex number

8008051 · 16

= Convert × Reset ⇅ Swap

Binary number

1000000000001000000001010001 · 2

WWW.NTMS.ORG

LO frequencies

- There's an app for that!!

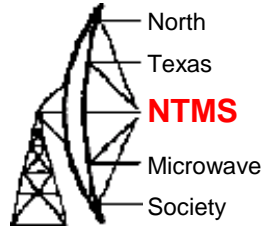# Integration

OCXO

North
Texas
NTMS
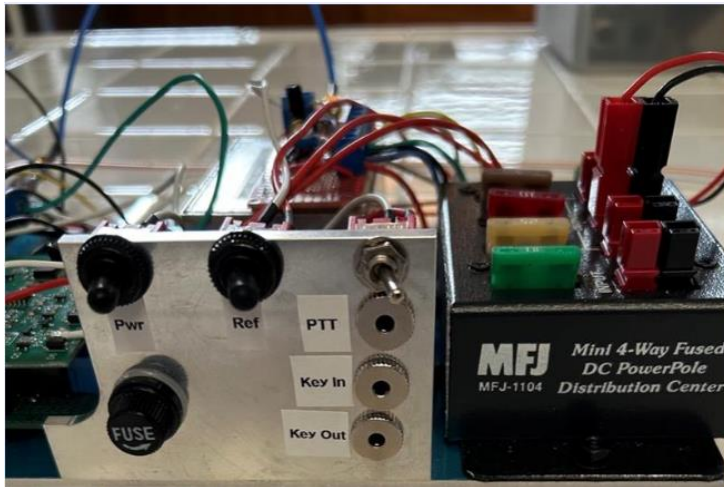Microwave
Society

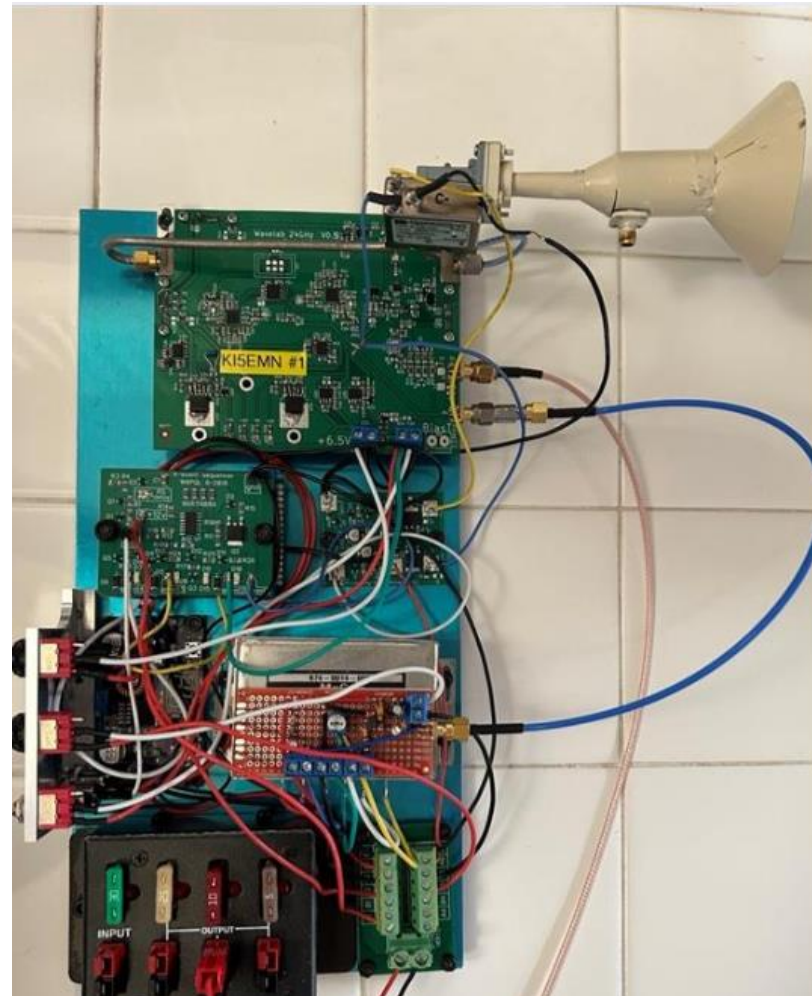# High Hawk proving ground – Feb 3, 2023
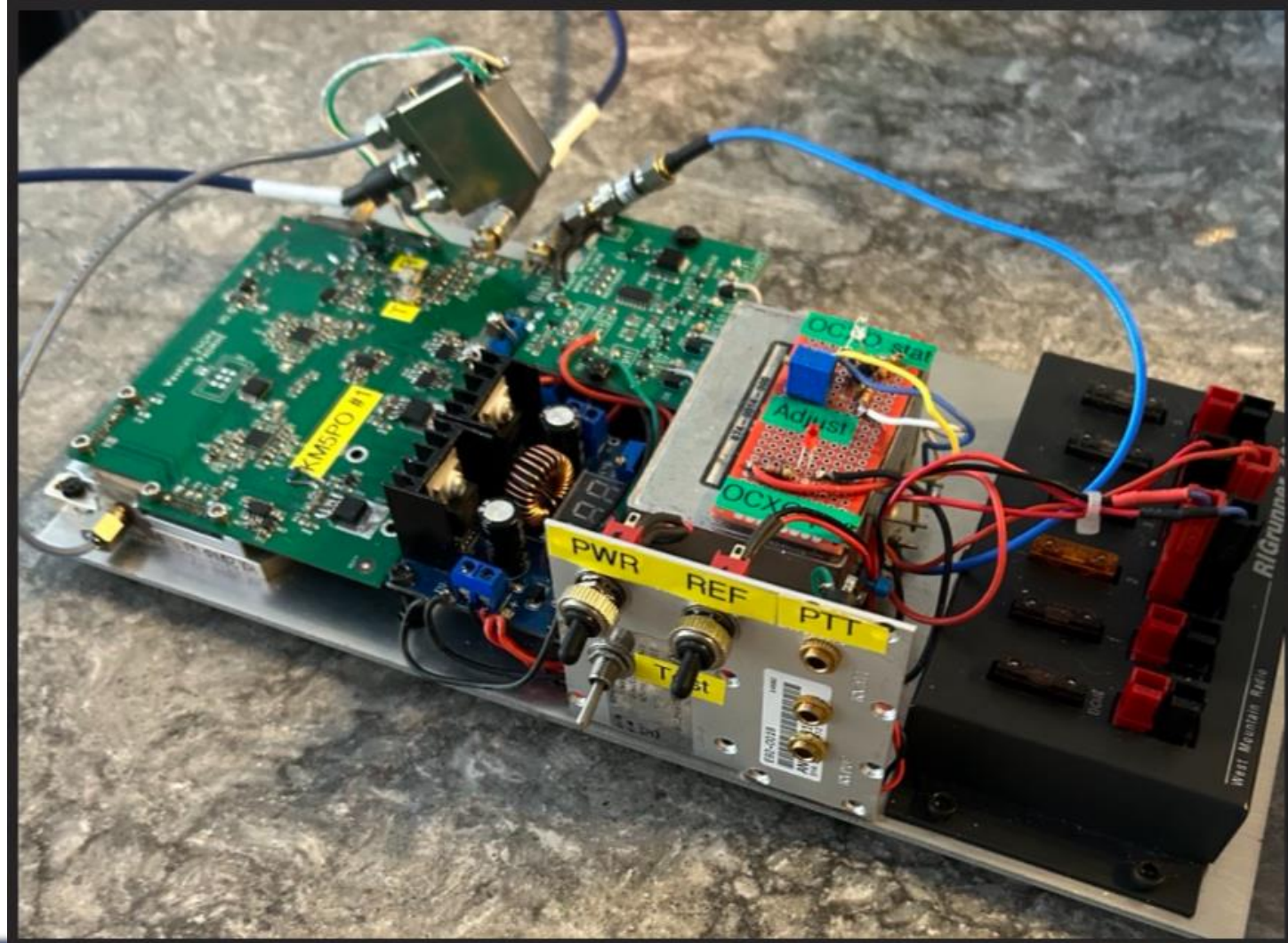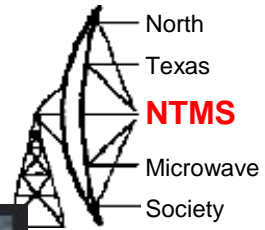
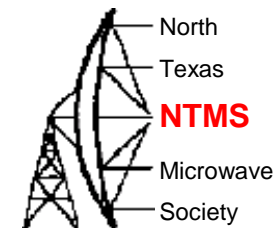# WA5JAT unit

- Passes all tests and measured +32 dBm output

KI5EMN unit

Uses latching relay driver with
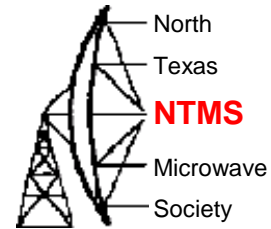SMA latching relay

W5HN

North
Texas
NTMS
Microwave
Society

KM5PO unit

Next steps

- Obtain accurate measurements:
  - Spectral RF output
  - Power output
  - Receive sensitivity, noise figure
- Integrate improvements/optimizations.
- In field tests
  - KI5EMN integration of dish with his 10/24 feed horn
  - Extend DX success
- KM5PO Wavelab rig is available for rover use
  - User will need a horn or dish (I'm willing to help assemble)
- Collect final parts orders from NTMS Dec PCB owners

Resources

North
Texas
NTMS
Microwave
Society

Wavelab24GHz@groups.io | Home

GitHub - PA0MHE/Wavelab-24G-Addon-module

W5HN

North
Texas
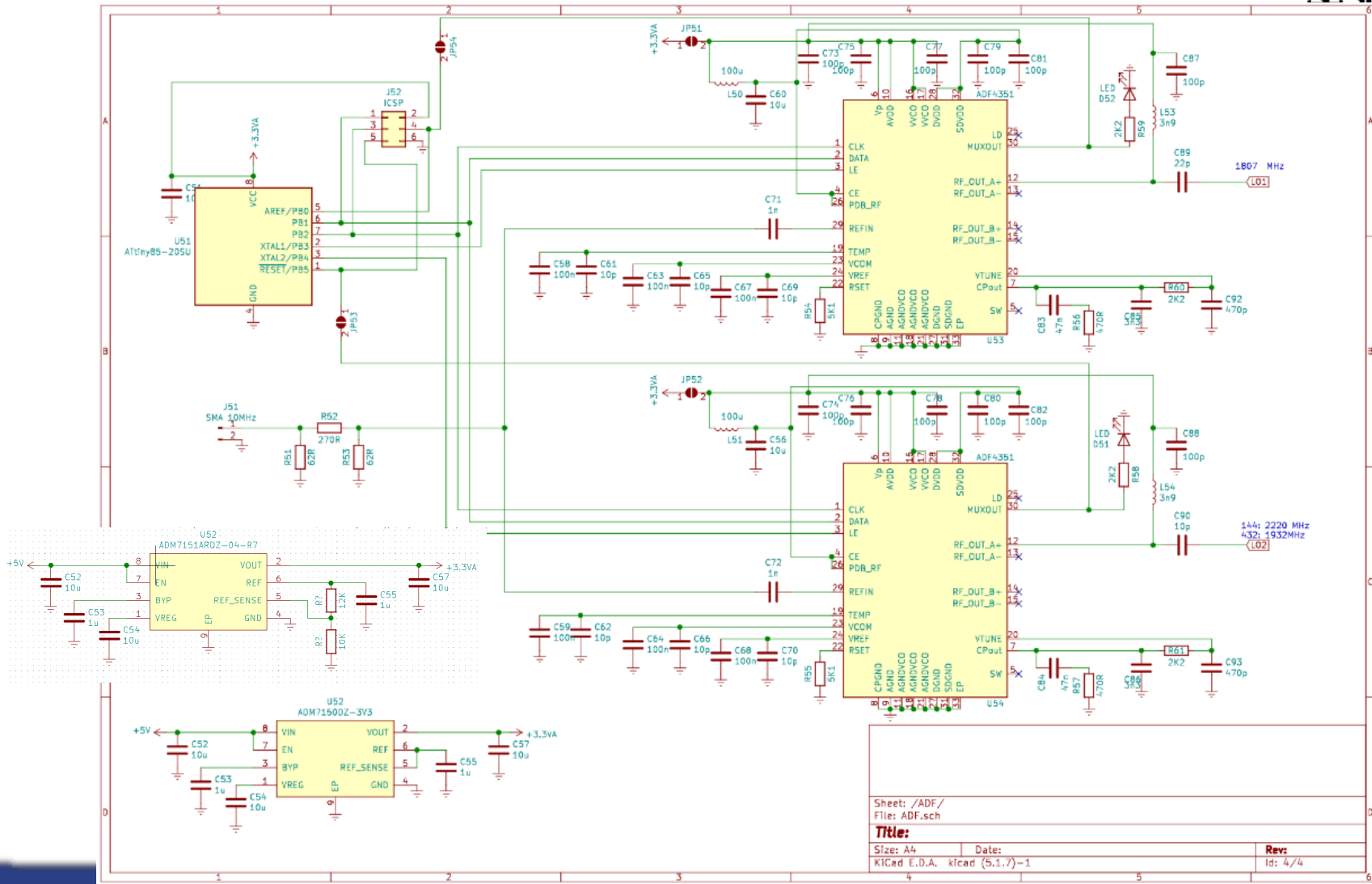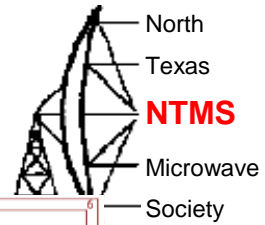**NTMS**
Microwave
Society

Add on board schematic pages

Add on board schematic pages

Add on board schematic pages

Questions?