Ham Radio Crowd Development of the **sBitx**

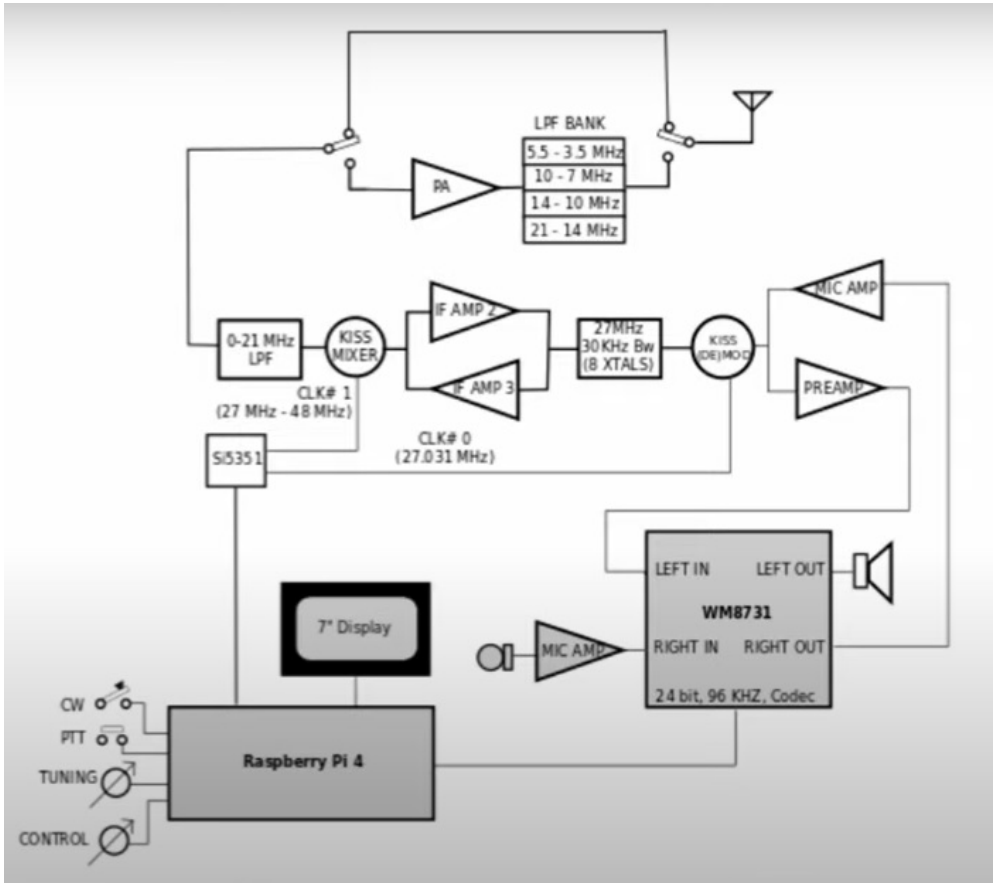
Gordon Gibby KX4Z NCS521 NND4FL

Sbitx Introduction

- SDR architecture
- Modulation / demodulation performed in math
- Rpi4 processor
- Touch Screen
- Any mode you can mathematically describe possible
- FT8 built in
- PSK31 built in
- 10-20-30-40 watts
- Digital filtering

Overview

- 2021 talk
- $4 WM8731 CD player codec
- 27MHz IF expected then
- Ended up being 40 MHz



Comparison to ICOM 7300

ICOM 7300

- Proprietary software / hardware
- 100 Watts / extremely clean
- Solid system $1100
- **Direct RF freq mod/demod**
- $$$$ A/D D/A
- Extremely well engineered, ready for prime time product

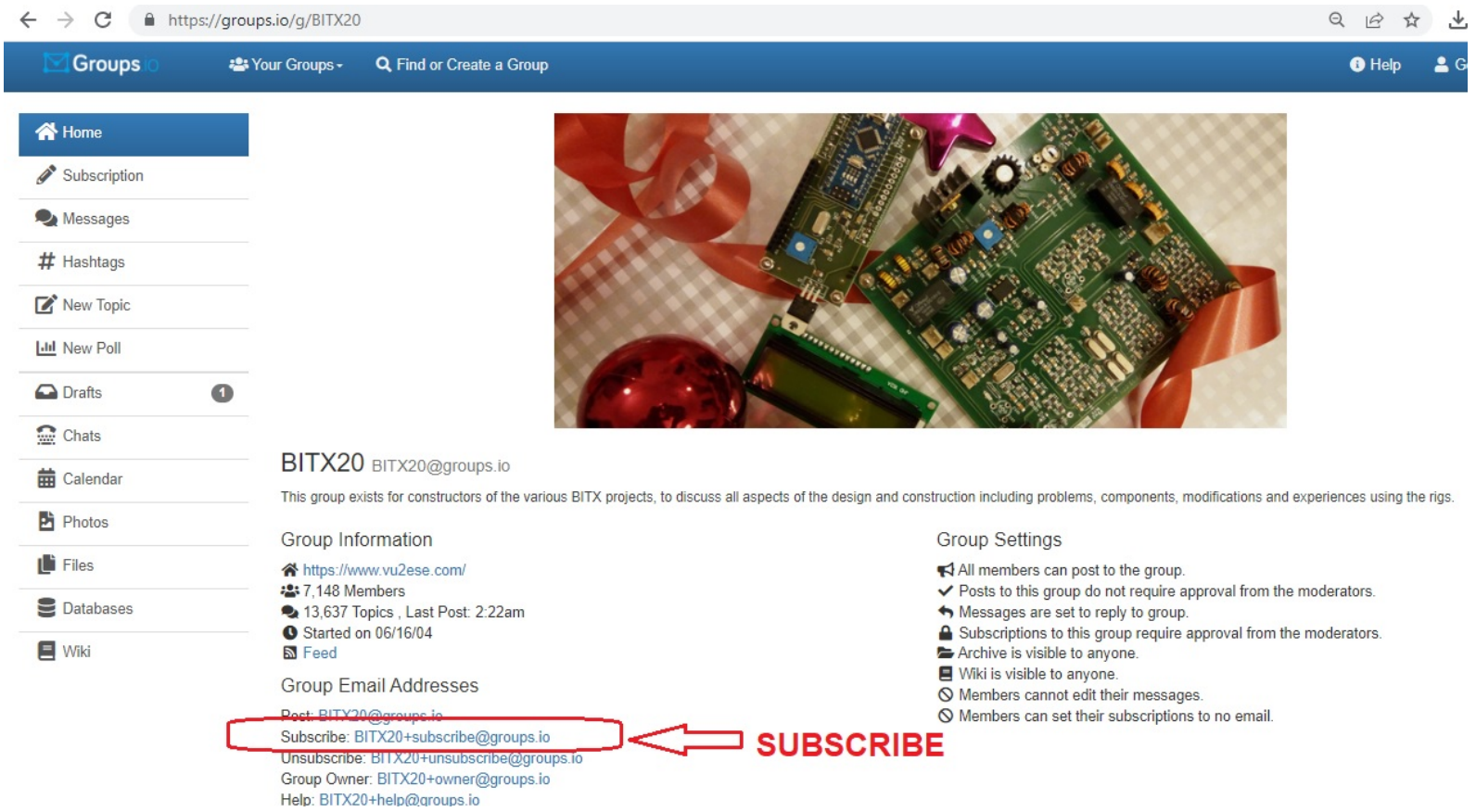
Sbitx – Developers' Edition

- Open source software / schematics (Boards copyrighted but you could build your own – welcomed!)
- 40 watts at best, declines to 10@ 10M
- Iffy system, unknown
- $500 / delayed delivery – we knew what we were getting into…
- **Mod/Demod at 25kHz** (50 kHz swath), then heterodyned (mixed) to desired band as needed (much cheaper)
- Cheap hifi audio A/D D/A WM8371 CODEC

Groups.io BITX20

- Internet forum
- Anyone welcome
- Multiple reading options
- Email / digests / none

- Started with a kit/homebrew 20meter radio many years ago.

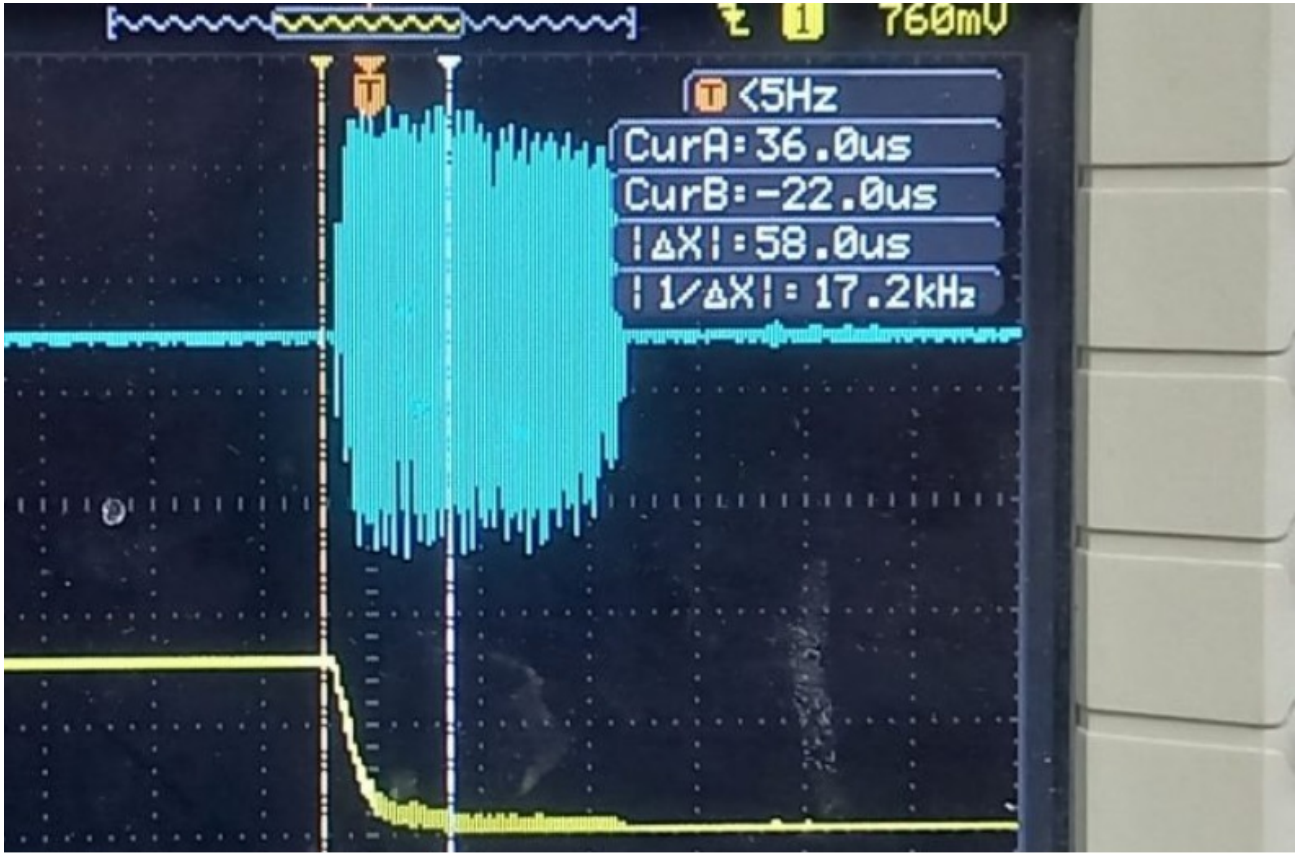


Early BIG Problem

- FINAL MOSFETS ARE BLOWING LIKE POPCORN BEFORE THE MOVIE!
- Purchasers scared to turn on their radio
- (I used a 2A wall wart and didn’t transmit!)

Early Problem Cause: Oscillation.

- Units were blowing Finals right and left
- 220V RF OUPUT SPIKE (100 W oscillation)
- >20 v RF on gates of final MOSFETS → GONE!

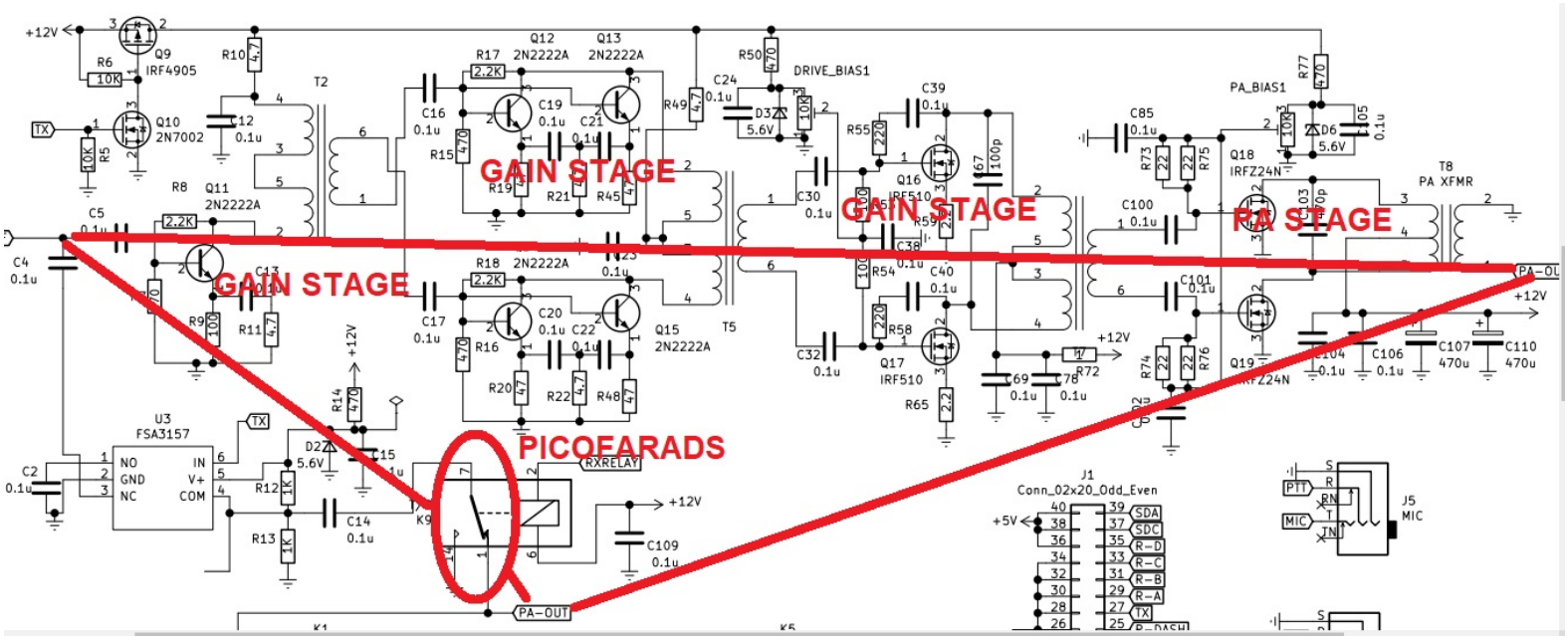


First Upgrade: Sequencing Bandaid/ New +5VDC Supply

- A trace cut, changes to timing
- Moving to a carefully chosen switching supply to allow parallel bar to hold the PA MOSFETS squarely
  - Previous LM309 was thicker than the PA Mosfets and made it difficult to keep all properly pressed against generous heatsink. (Said too hot for normal insulators – Ashhar pushes components, huh?)
  - Switcher chosen supposed to have low RFI
- Uh-Ohh: Some Units Still Blew up FINALS!!

Real Cause of Oscillation Discovered

- Inadequate separation between RF output and low-level stages in reed relay TR switch.

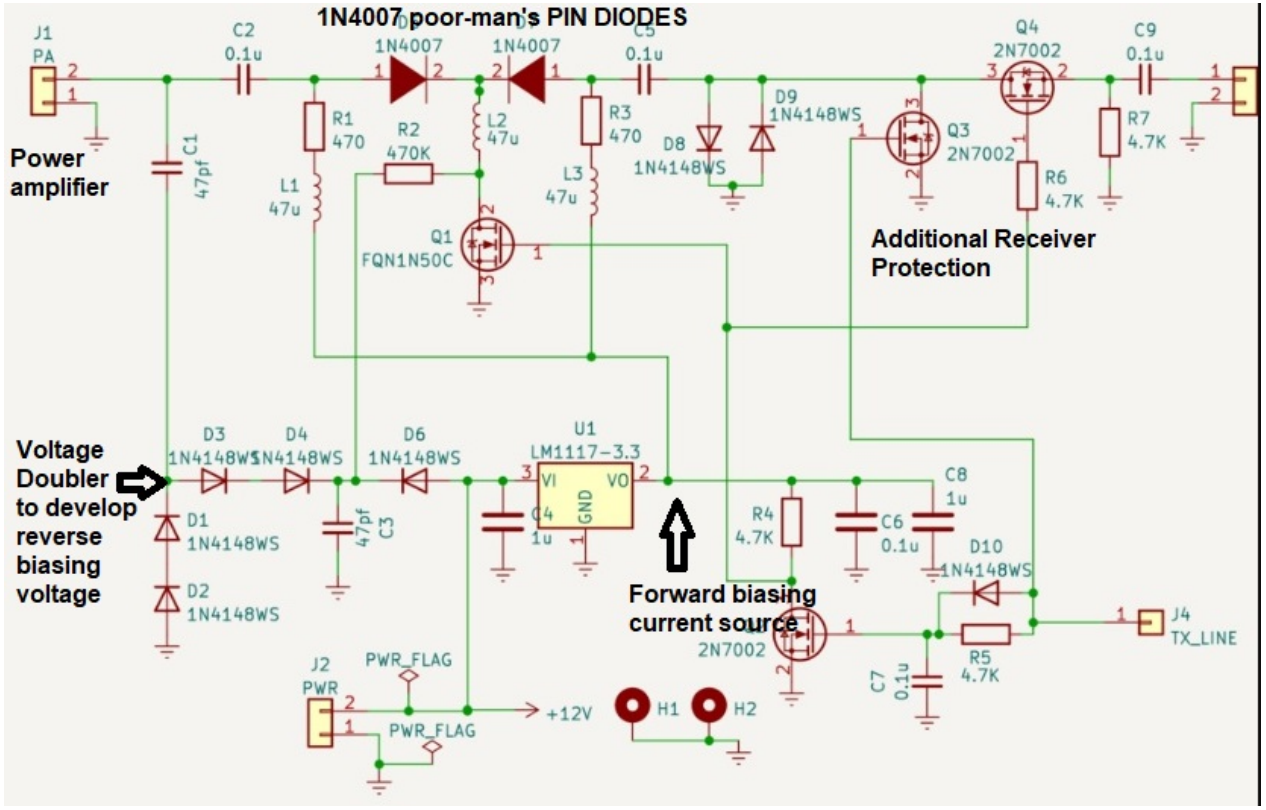


Failure traced to feedback through TR Relay

- Long discussions of how to fix.
- Consideration of using Solid State TR Switching
  - I was VERY MUCH in favor of that: Chance for sBitx to develop near full break-in CW and move to the top of the class for CW
  - Depends on the intrinsic layer in 1N4007 high voltage rectifiers
  - Carriers “hang around“ long enough to conduct BOTH SIDES of an RF sine wave when conducting!!! RF SWITCHING!
- Help from Hans Sommers with design

Auto-Bias Developing TR Switch

- Brilliance: voltage doubler from the RF itself!
- Mosfets used to control DC biasing
- 2N7002
- Bias current only has to suppor RECEIVE
- Transmitter always connected to antenna
- Transmitter stages depowered when not transmitting
- Receiver only connected when receiving



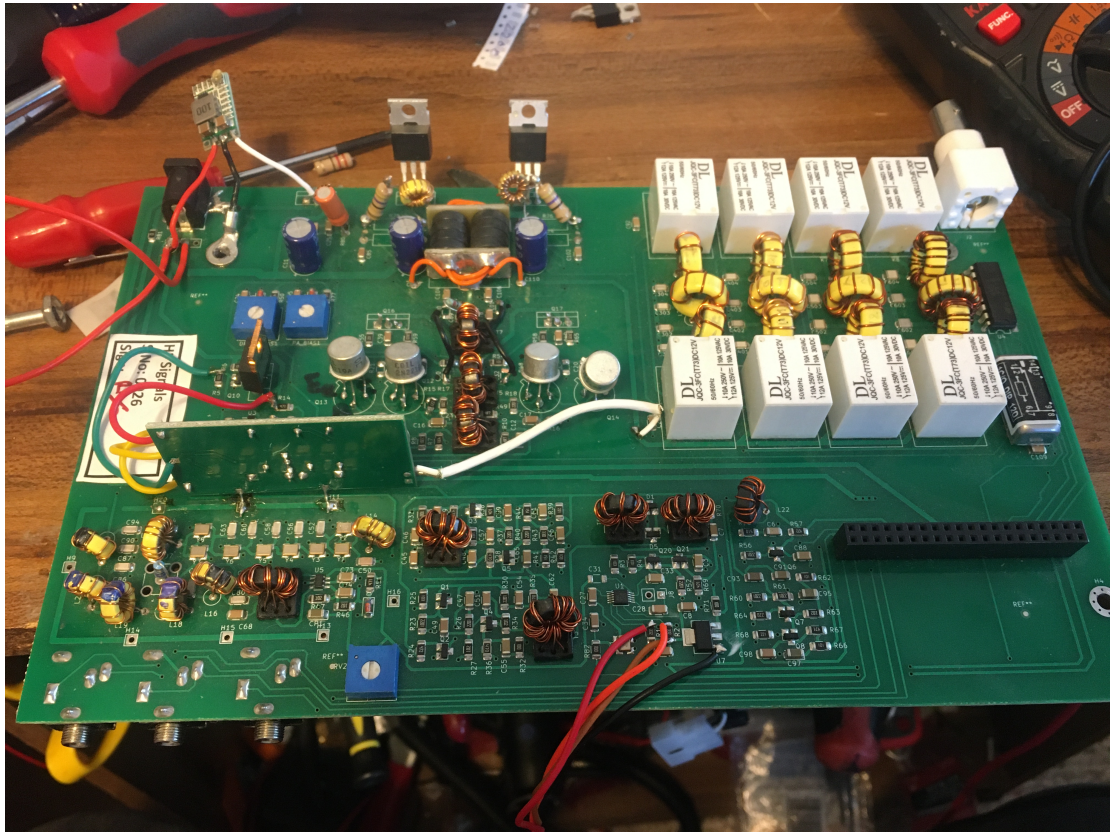
Second Upgrade Package

- Remove entire previous IRF501 “Driver“ stage!
- Upgrade quad 2N2222 stage to quad 2N2219 (to push harder)
- Reverse some of the trace cuts
- **NEW TR SWITCH – solid state TR**
  - **This got me REALLY excited about this transceiver**
- Massive Google Docs instructions…..SMD repairs...

Upgrade #2 – delayed by supply / mailing chain

Driver / Raspberry Pi Power Update

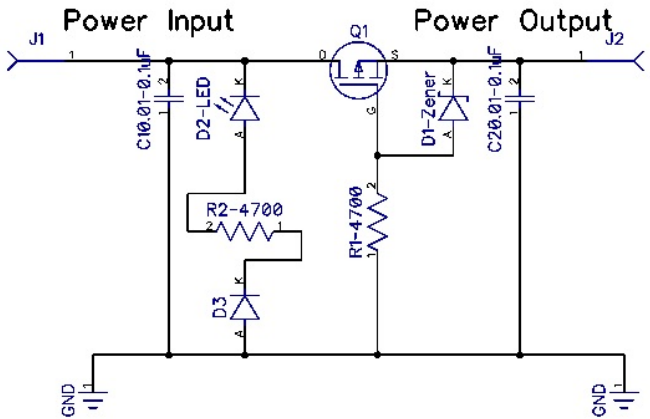
- Drivers changed to higher power 2N2219 (larger version of 2N2222)
- Emitter biasing replaced with single resistor
- 5VDC Linear power replaced with switching adapter

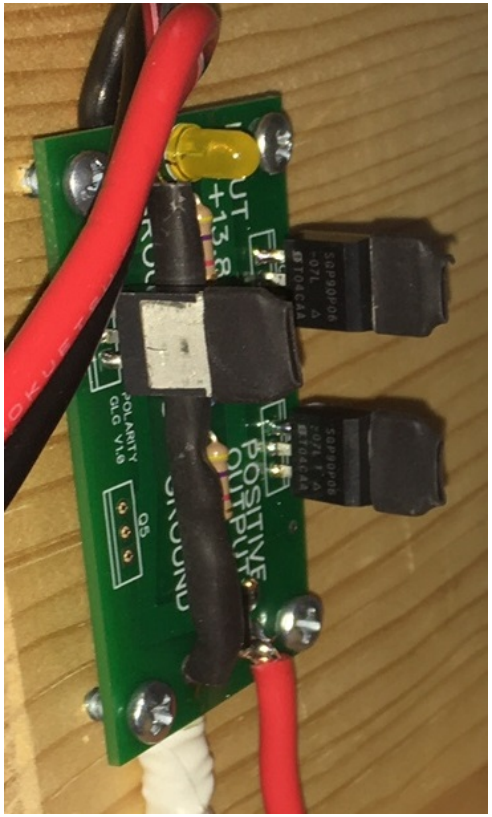


$500 investment….protect it.

Sbitx protected by quad-p-channell MOSFET inside, attached to left side panel.

This unavoidably added more wiring to +12V line inside cabinet.





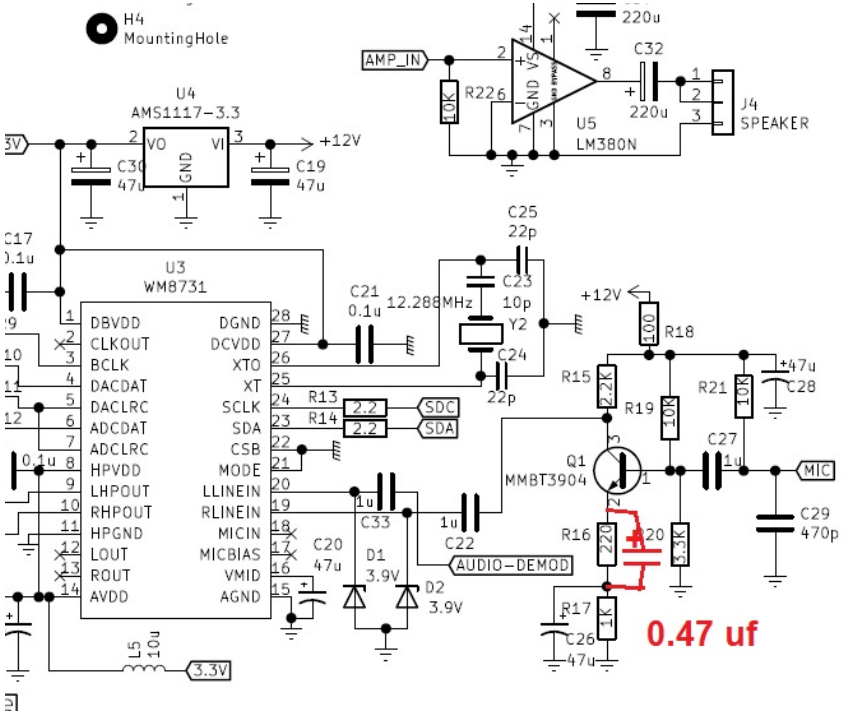
Example view of polarity protector in a wooden go-box

Problems still…..

- Burn-Your-Fingers-Hot Driver 2N2219‘s
- Ashhar unconcerned
- My calculations suggested junctions up near 150C….
- Tried to change biasing to reduce temperature
- Ashhar cautioned that high current needed to reduce IMD
  - Huh? (He’s right – the spurs decrease with heating of the devices)

Me: Adding hardware treble to mic

- **This was a mistake**
- 2N3904‘s blew!



Measurements

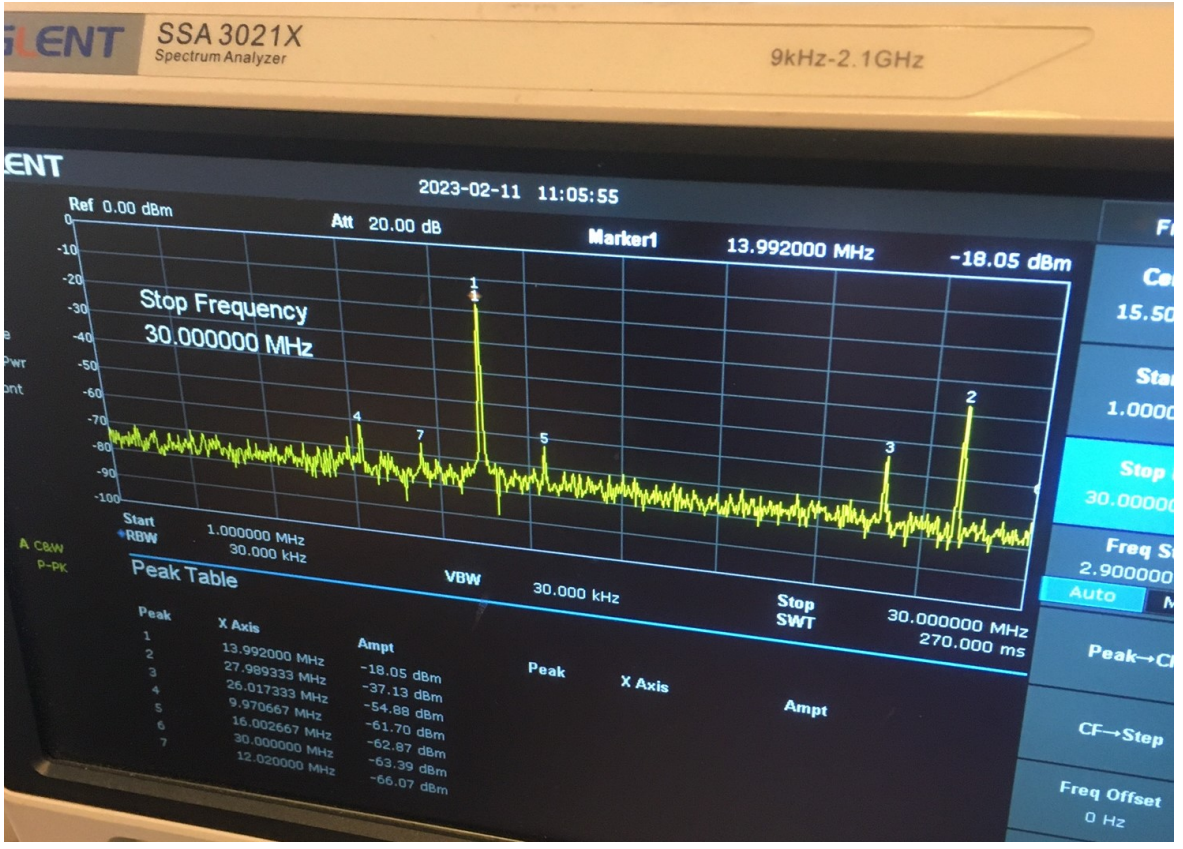
My horrified measurements of spurs that spawned a threat with over 260 posts….

Frequency	Signal	-43dBc Limit	Over/under limit
14.000	-9.95	*(carrier)*	
18.0	-47	-53 dBm	+6dB
10	-50	-53 dBm	+3dB
12	-51	-53 dBm	+2dB
16	-53	-53 dBm	right at the limit

WHERE ARE THEY BEING GENERATED????

Predriver Collector

- There are no low-pass filters here
- Note no 2MHz spur

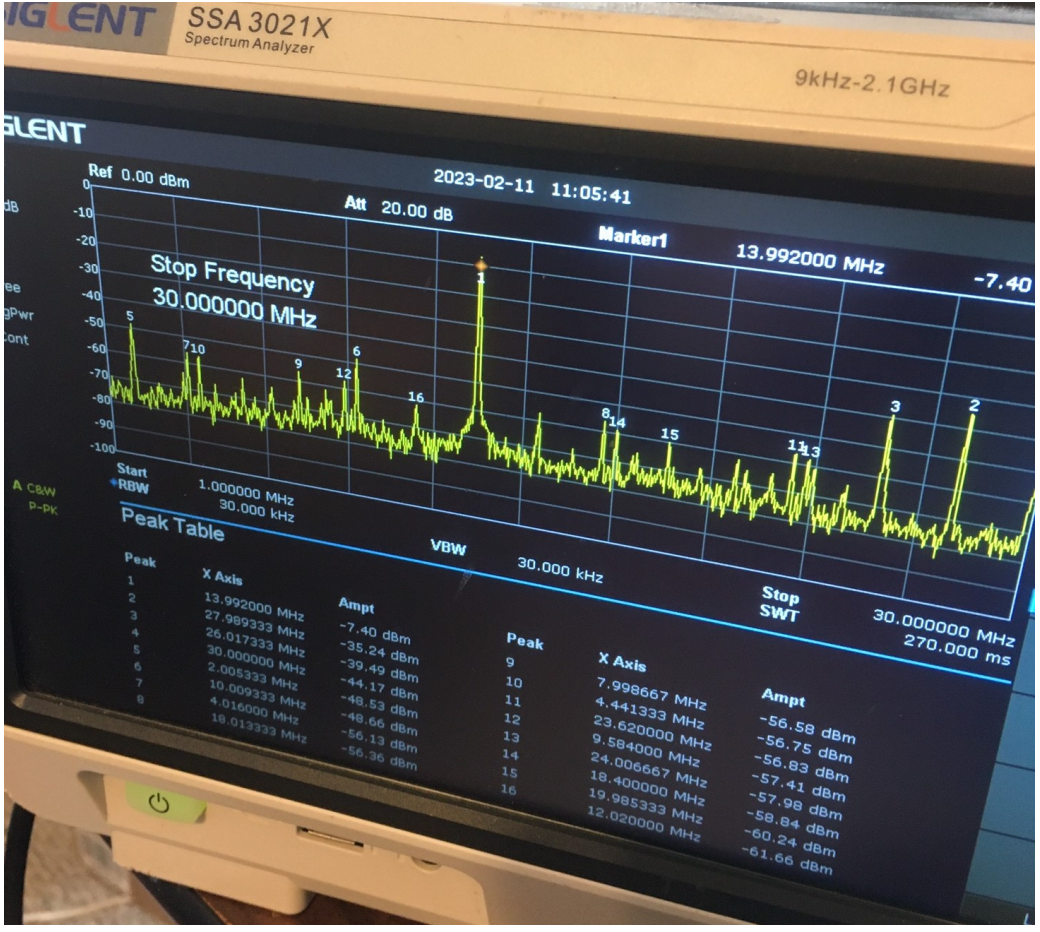


Drivers – MUCH WORSE

- (note no low pass filters until you get to the final PA stage)

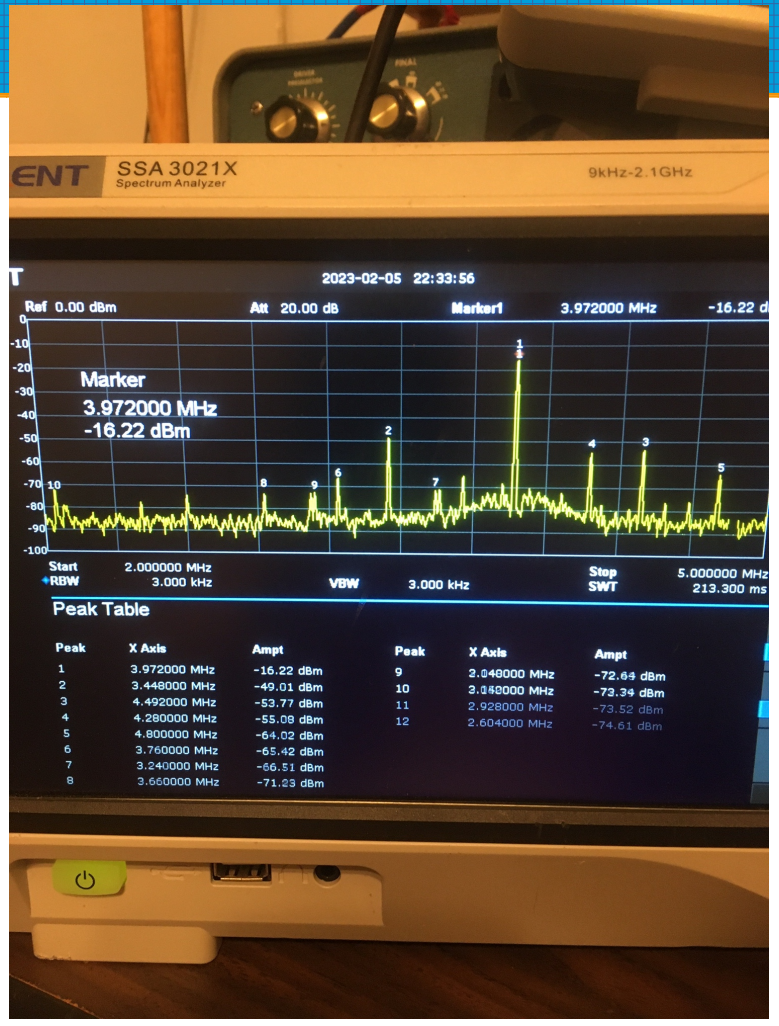
Spurs at 2N2219 Driver Collector

- Driver collector



75 meter spurs

- Illegal spurs in the -30‘s dBc 520 kHz up and down from desired 75 meter frequency



Amplify with SB-200 Vacuum Tubes

MUCH BETTER!
Far fewer spurs.
Legal.

Mixer?

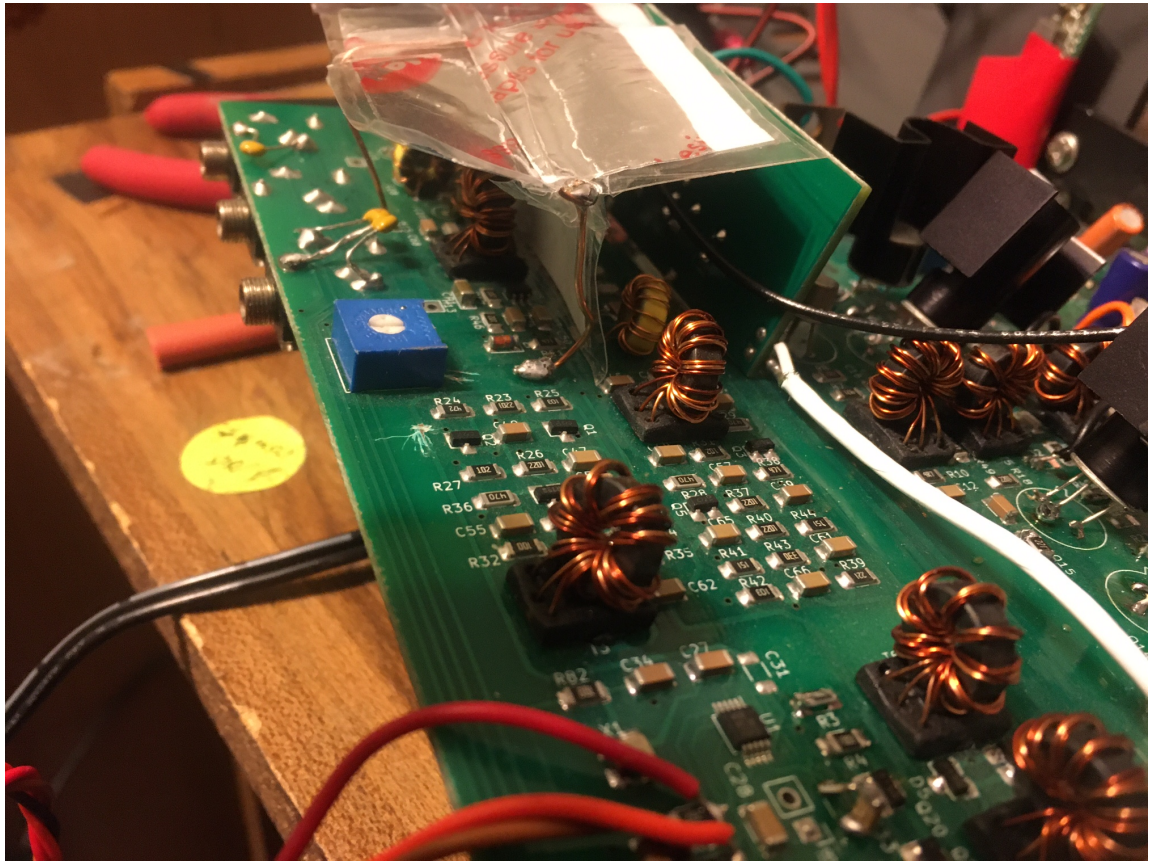
- The “zero crossing point“ of the solid state commutating mixer can be changed by RV2, much like biasing an op amp.
- Turn out to have critical influence on reducing some spurs by 6 dB or so…
- I got really good at adjusting that.

Amplifiers?

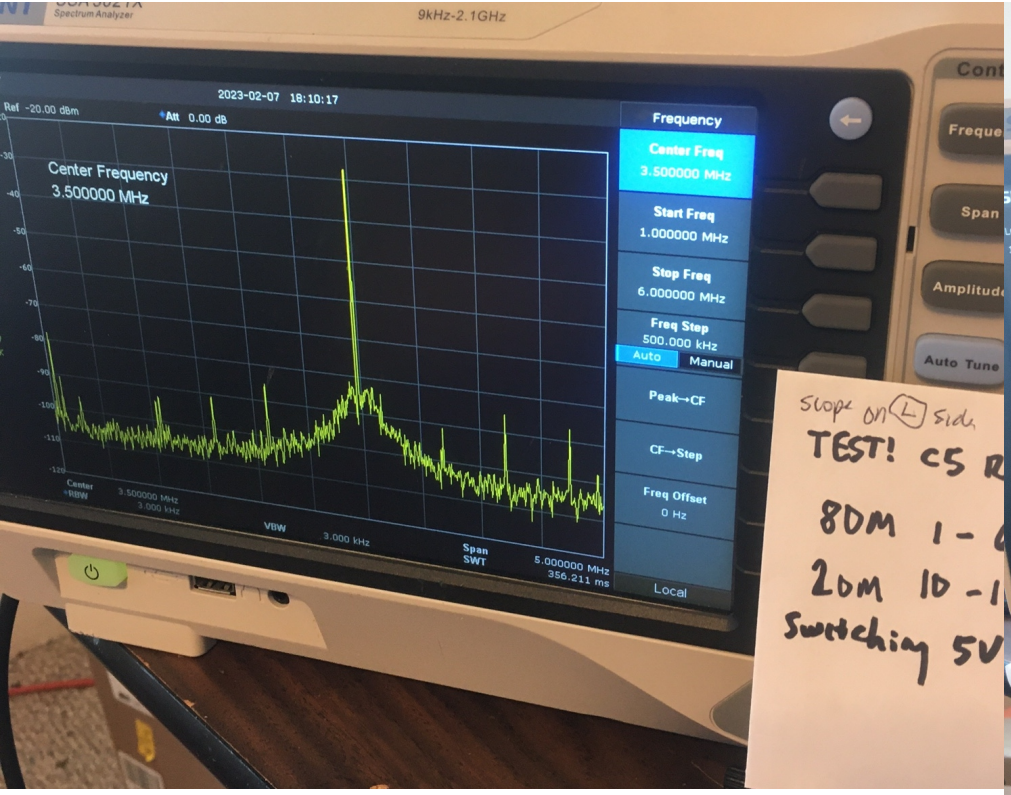
- Using transistors with Ft of about 300 Mhz, Ashhar is asking for a LOT of gain from each stage, and reducing negative feedback to get it.
- The dramatically increased spurs stage by stage suggested this might be the issue.
- I never got to the point of changing the stage gain.

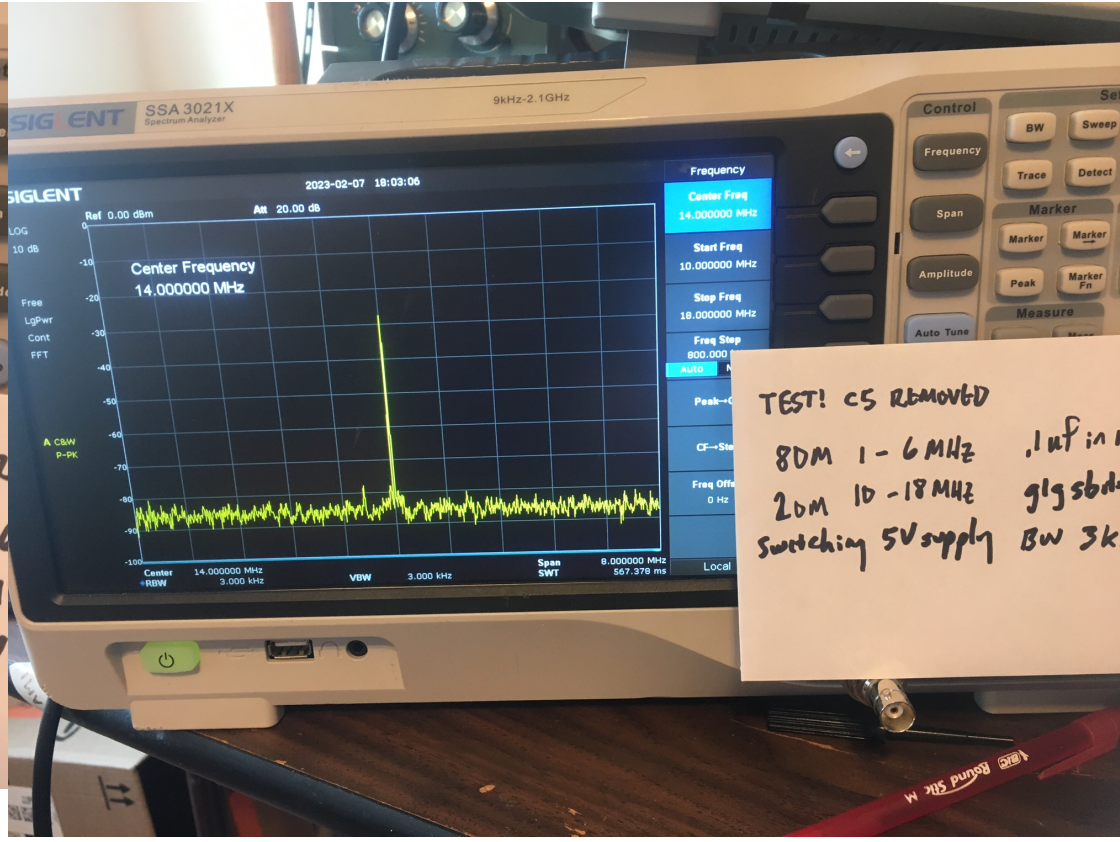
Shielding Test

- Didn’t Help.



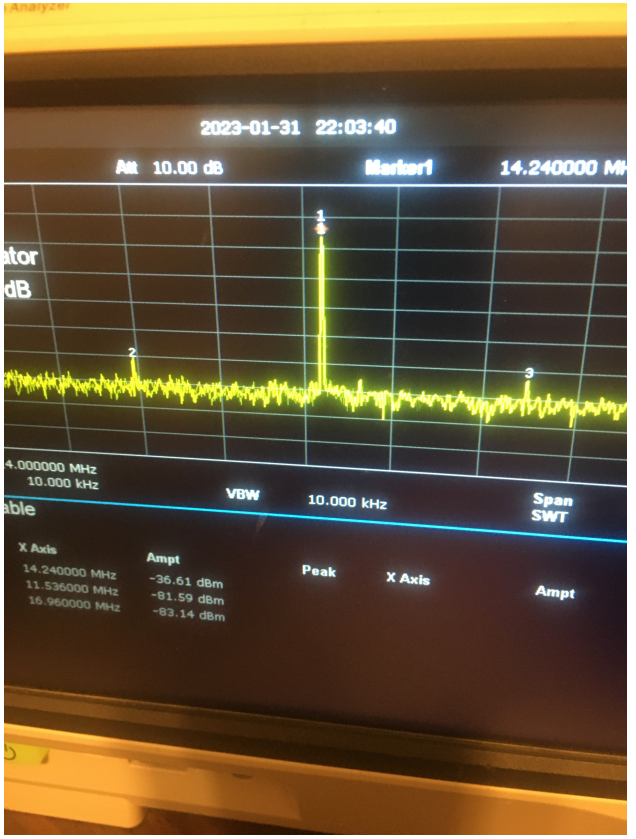
Ashhar asked to measure Mixer w/o amp





Predriver without amplifier

- Basically very clean signal at 2N2222 (pre-driver, class A but still not enough feedback to be completely linear)
-
- Add more stages and it is dramatically worse...

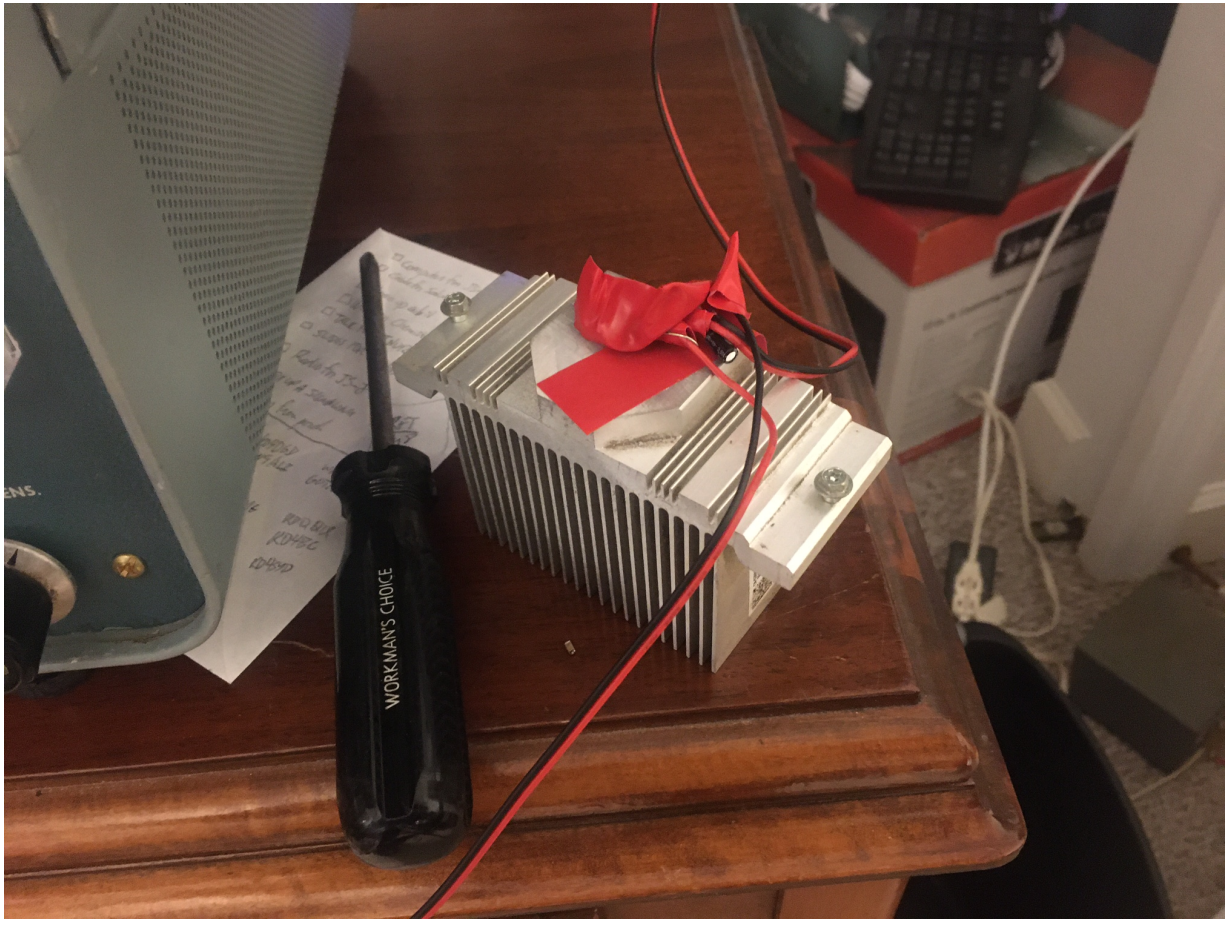


I tried and tried to reduce those spurs…

- Raspberry / Codec generate a 24kHz modulated signal
- First mixer (diode ring) takes it to 40 Mhz using one of 3 Si5351 square waves
- 50 kHz 40 Mhz IF filter throws away unnecessary junk (we hope)
- Second mixer (a „“solid state relay“) commutating mixer subtracts from another Si5351 square wave to get to desired band (e.g. 20 meters)
- Predriver, Driver and PA amplifiers

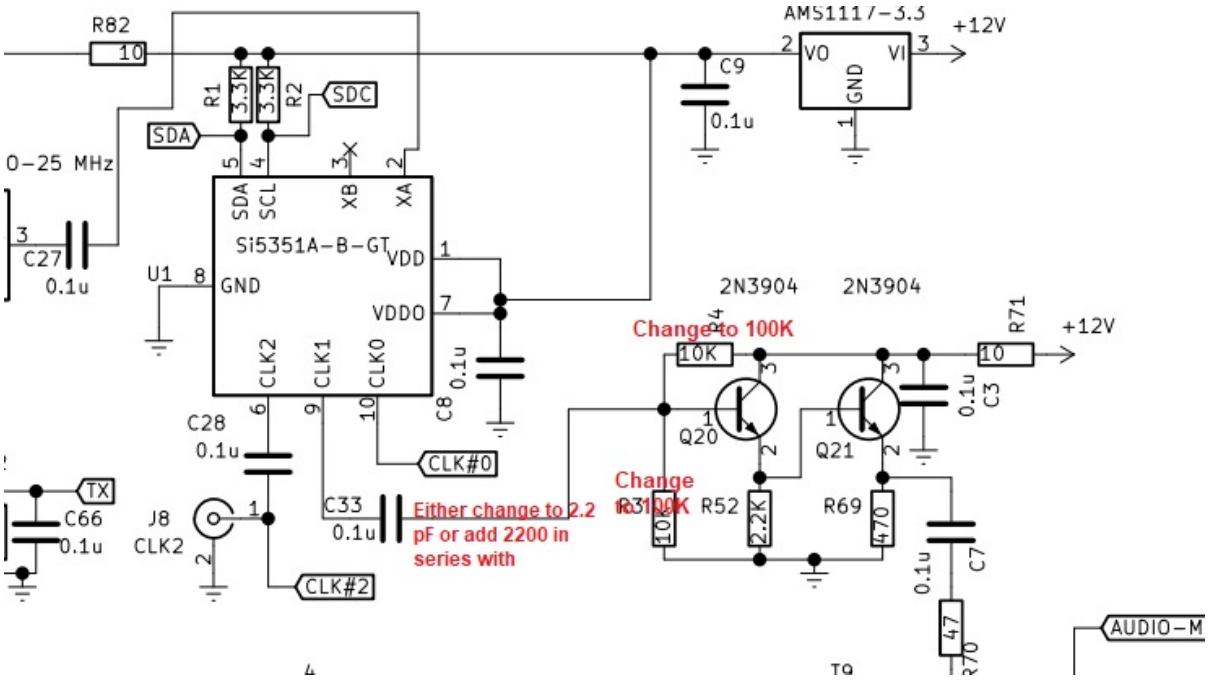
520 kHz 75meter Spur Explanation

- Found to be coming from the SWITCHING +5VDC power supply
- Feeding in through inadequate filtering
- Went to an external +5VDC linear supply.



Ashhar demonstrated si5351 Crosstalk

Reduce Si5351 crosstalk (?spur genesis?)



Reduce loading on the si5351

Changed the coupling capacitor from si5351 from 0.1 uf to 10 nf and reduced internal drive to 2mA and changed resistors on emitter follower….
Better, but that 2MHz spur is still not legal.

Went to using an external Raduino

- External Raduino to provide the 1st mixer with 40 Mhz
  - Took some work to find one of my earlier projects and get it reprogrammed….
- Internal Raduino to provide the 2nd mixer with 54 Mhz
- Began to get some legal outputs.

The the output power began to be flaky

Lost 20dB of output power.
Making less than a watt.
Intermittent….took FOREVER to track down….
This took me out for days.
Cold or damaged solder joint on the drain lead of one of the push-pull output MOSFETS. Fixed!

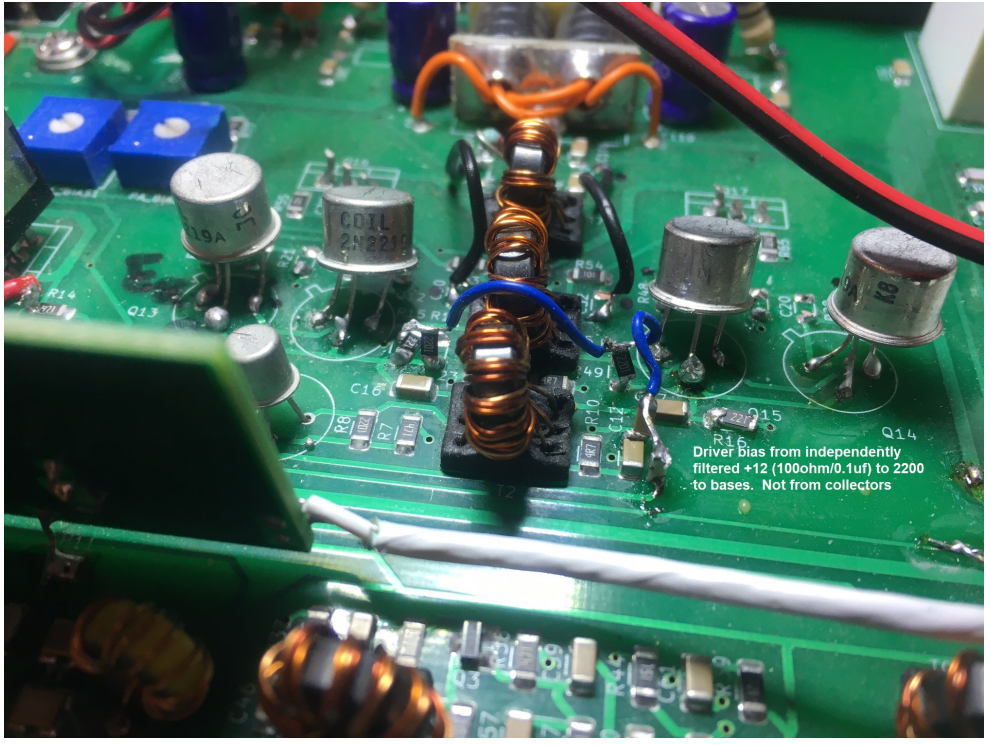
Attempt Matching 2N2219s by Infrared

- Infrared measurements indicated one transistor reaching 34 C while another hitting 28 C (both steadily increasing)
- No significant difference in emitter bias resistors (all measure 4.8 ohms)
- Swapped a couple of transistors with small improvement in spurs

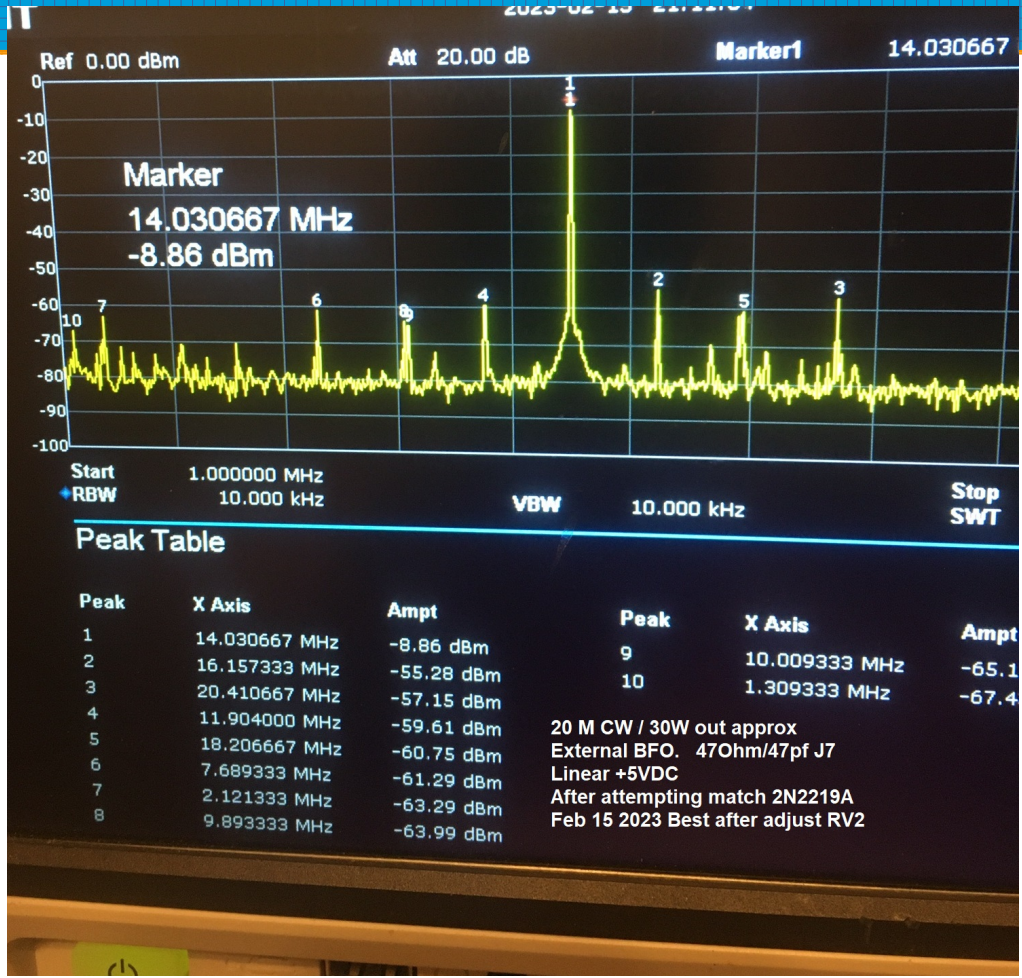
Bias Change Experiment

Remove collector – base bias to attempt to reduce spur addition.

Added additional filtering to bias

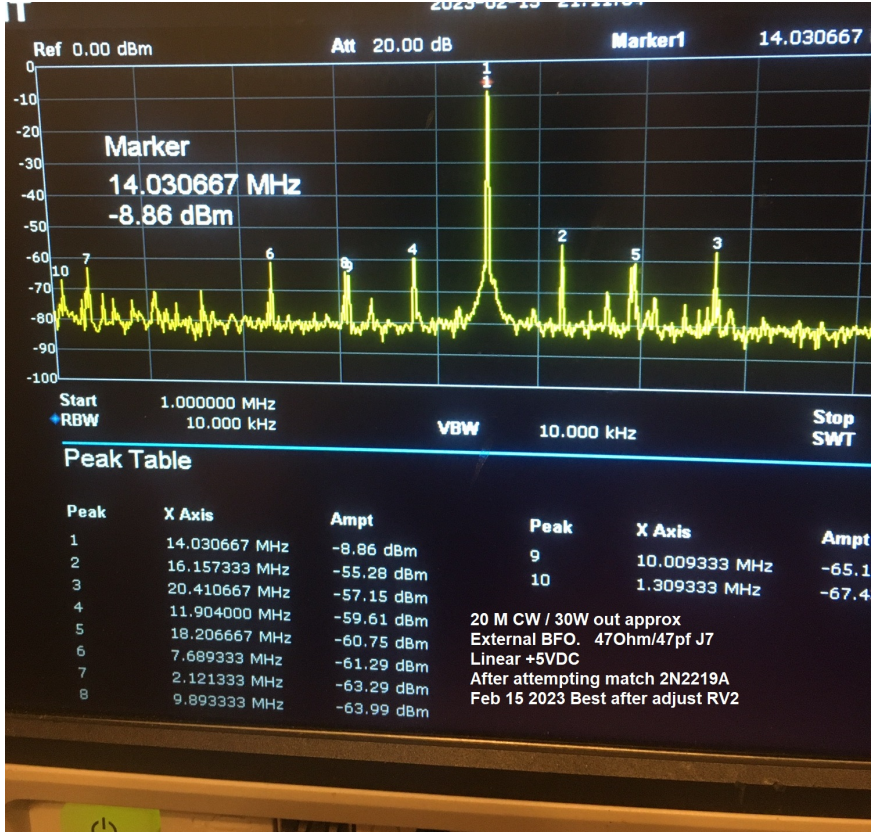


LEGAL!!!


Ref 0.00 dBm
Att 20.00 dB
Marker1 14.030667
Marker
14.030667 MHz
-8.86 dBm
Start 1.000000 MHz
RBW 10.000 kHz
VBW 10.000 kHz
Stop
SWT
Peak Table
Peak X Axis Ampt
1 14.030667 MHz -8.86 dBm
2 16.157333 MHz -55.28 dBm
3 20.410667 MHz -57.15 dBm
4 11.904000 MHz -59.61 dBm
5 18.206667 MHz -60.75 dBm
6 7.689333 MHz -61.29 dBm
7 2.121333 MHz -63.29 dBm
8 9.893333 MHz -63.99 dBm
Peak X Axis Ampt
9 10.009333 MHz -65.1
10 1.309333 MHz -67.4
20 M CW / 30W out approx
External BFO. 47Ohm/47pf J7
Linear +5VDC
After attempting match 2N2219A
Feb 15 2023 Best after adjust RV2

Best Ever Achieved (2/15/2023)

- Actually legal
- Didn’t last long



Eventually moved the linear +5VDC to inside

Fateful night

- Moved +5VDC into enclosure
- Worked fine for a while….
- Then complete loss of display
- Raspberry 4 appears to be dead
- Carefully replaced, low power
- Only remaining raspberry also destroyed.
- **End of my current efforts**.

Dead Radio.

Hardware Tradeoffs

- More stages allow more linearizing negative feedback on each stage and still total gain required
- More stages increase complexity and might increase oscillation risk
- Ashhar tends toward highest gain per stage and runs problems with IMD products….

Allison's Amplifier (QRP Labs)

10W output from 2 to 30MHz, using 12V Supply

- Suitable for 10W PEP, CW or Digital modes
- Generously-sized heatsink, will not overheat even on continuous 100% duty-cycle modes
- 2-stage amplifier provides 26dB of gain
- Push-pull driver and push-pull finals, for high linearity and low harmonic content
- +/- 1dB gain flatness from 1.8 to 30MHz
- 4dB down at 6m (50MHz) and 8dB down on 4m (70MHz)
- Standard 50-ohm output
- Through-hole plated PCB, all through-hole components (no Surface Mount Devices)
- PCB size 69.69mm x 33.97mm (2.744 x 1.338 inches)
- Standard inexpensive components throughout
- Tested for 1 hour at full-power 10W, 100% continuous duty-cycle with no forced air cooling
- Tested for 15 minutes at 20W, 100% continuous duty-cycle with no forced air cooling
- Tested at 20V supply
- Tested into open load, shorted load and various mismatches without instability (oscillation)

10W Clean RF @ 12V

20W Clean RF @ 20V

Problems with Development

- Delivered boards don’t match published schematic
  - Unexpected MOSFET on TR switching line
  - Unexpected 47 ohm termination to IF filter
- No component or trace layout available (hard to find traces and signals)
- Changes don’t result in new schematics so schematics become increasingly out of date
-

Development Weaknesses

- Lack of clear explanation of how to find/install libraries and compile the code
  - You sorta need to be a linux guru to stay up with these folks!
- Failure to keep schematics up to date
- Lack of trace layout information to find signals and connections
- Lack of benchmark spectrum analyzer plots on all bands
- Testing the extremes of component survivability
- Testing the edges of component gain/linearity
- Will it work with cheaper raspberry??

Development strengths

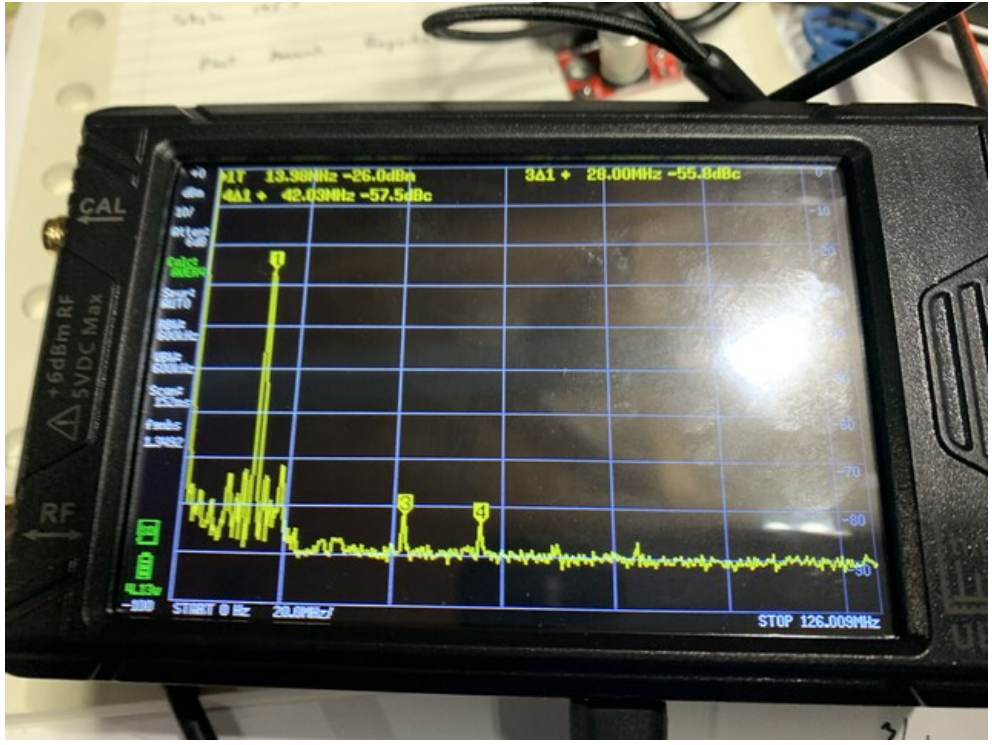
- Amazing delivery of upgrade products with clear instructions, tips and photos
- Steady supply of final MOSFETs
- Complete openness of code (github)

MegaFiltering +12VDC may solve 500 kHz

- Evan Hand AC9TU reported Feb 19 that a 3300 uF capacitor on the +12VDC line (input to the switcher) –
  - Raspberry started correctly
  - Display started correctly
  - 500kHz spurs gone
  - Spurs may be related to inadeuate 12VDC filtering??

Evan Hand’s excellent findings

Evan pioneered the +12V filtering and has demonstrated legal outputs, +/- the 3rd harmonic of the 20 meter emissions.



My Suspicion

- The +12VDC line may be inadequately filtered
- The +5VDC line definitely appears to be inadequately filtered
- The extra physical wiring of my “polarity protection“ may have allowed RF onto the +12VDC line----and thus into non-linear circuitry
- Unfortunately my Rpi’s failed before I could study that possibility.