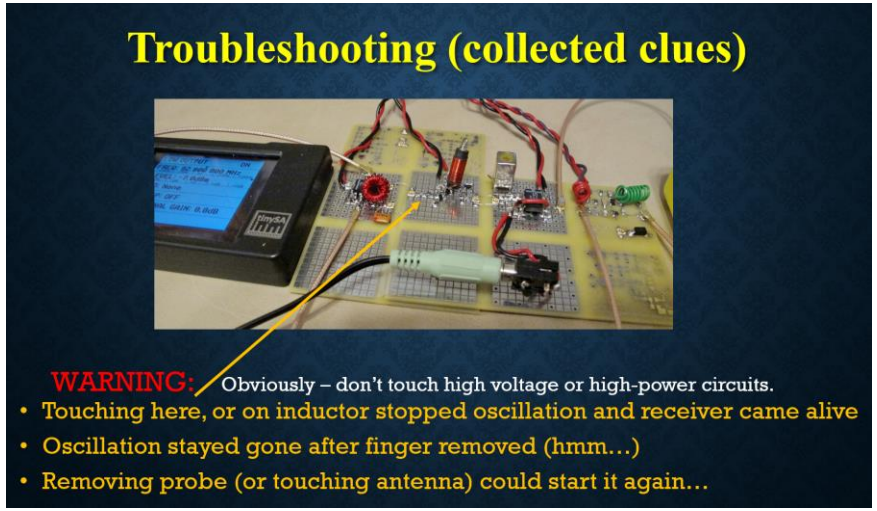
# Radio Design 101 Epilogue 2 – Debugging and Troubleshooting

Slides downloaded from: https://ecefiles.org/rf-design/
Companion video at: https://www.youtube.com/watch?v=31MhI3RSQEI



This second follow-up (epilogue) to the Radio Design 101 series offers tips on how to troubleshoot electronic circuits. The problems found in Epilogue 1 are addressed and the radio performance is improved - but the main focus is on general troubleshooting techniques. A preview look at emerging Q-enhanced filter technology is also provided, as is an example of applying the troubleshooting techniques to car repair to illustrate that the techniques are useful in general problem-solving.




# Radio Design 101

## Epilogue 2

# Debugging / Troubleshooting

# *"Radio Design 101" and "NanoVNA" Series*

20+ videos based on and supporting a university senior-design class in RF/wireless circuits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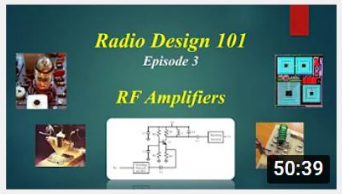


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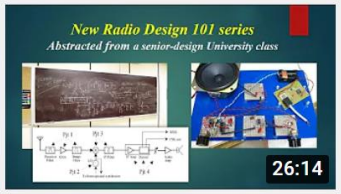


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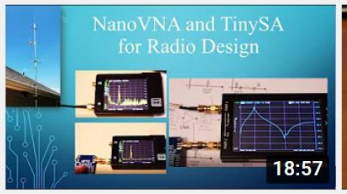


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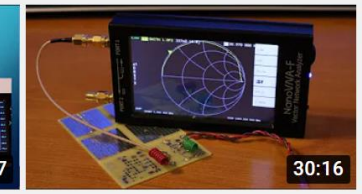


NanoVNA - Measuring RLC Components

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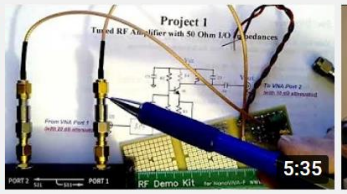


NanoVNA - Measuring S21 and S11 of a small-signal...

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NanoVNA - Measuring Impedances

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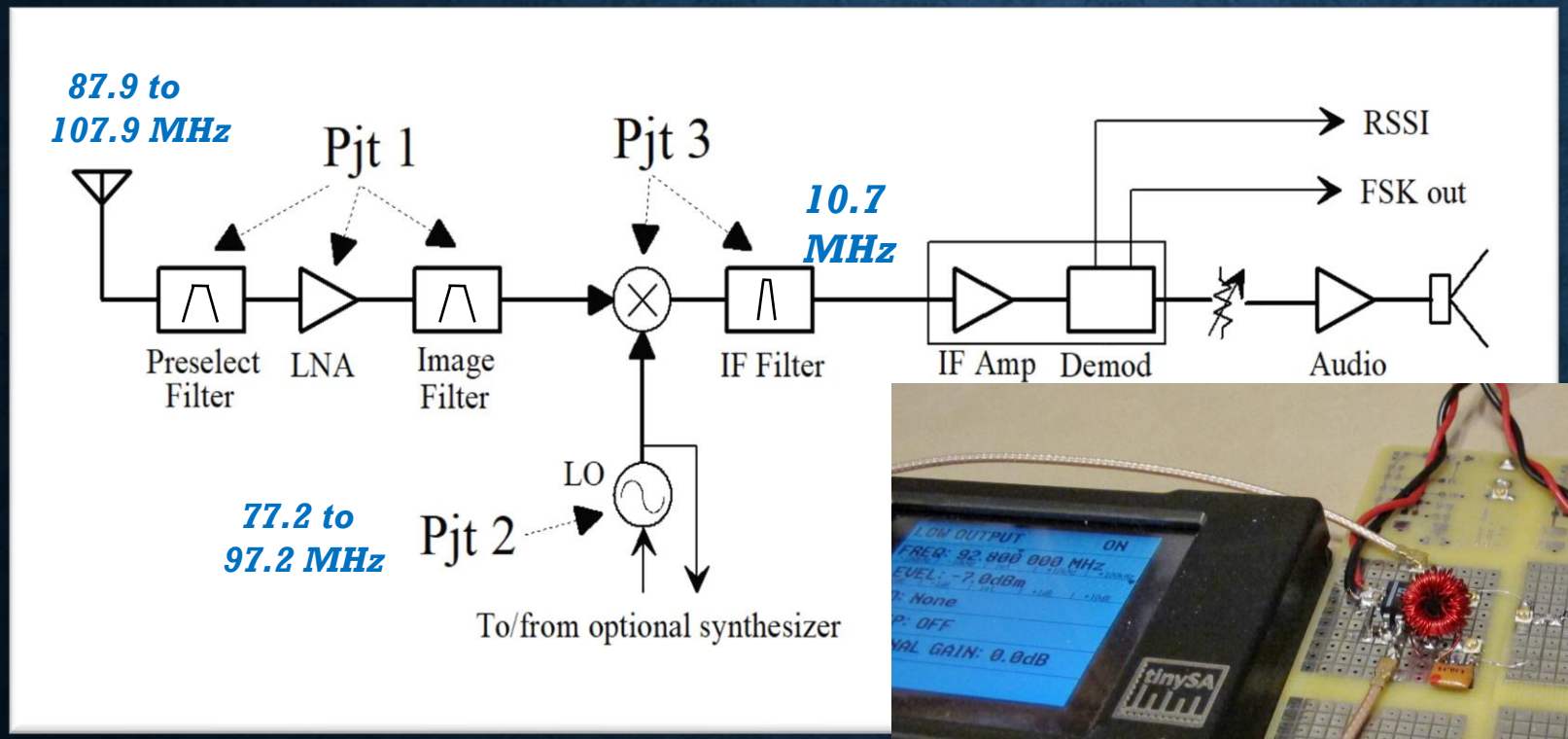
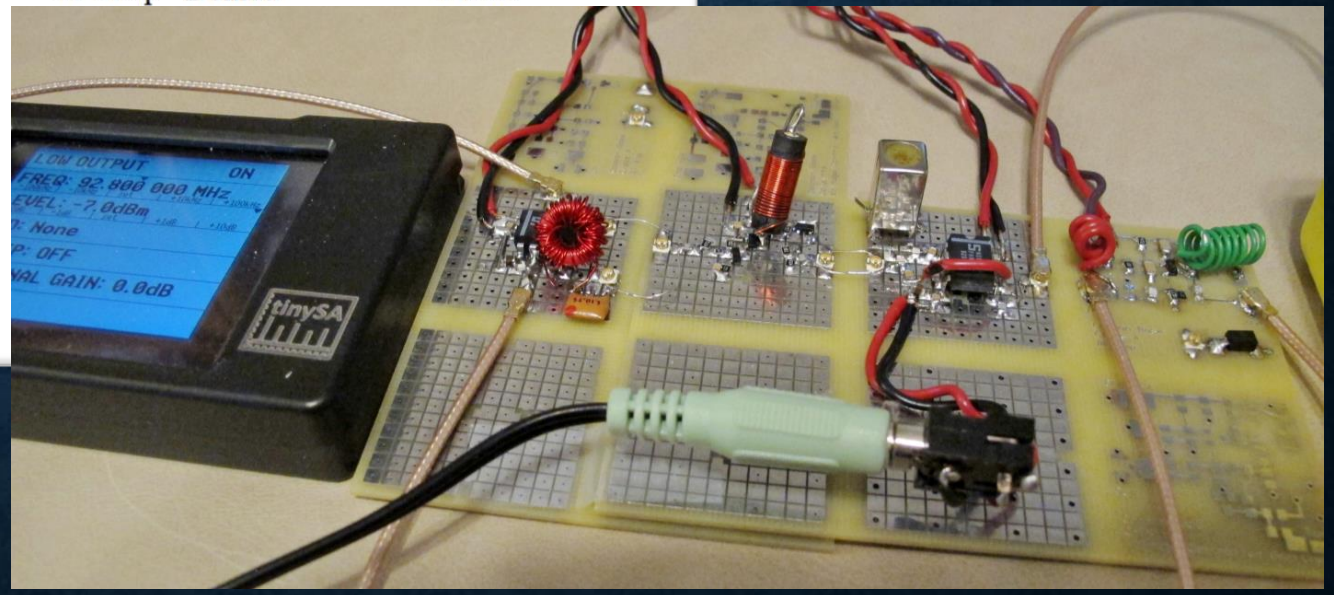
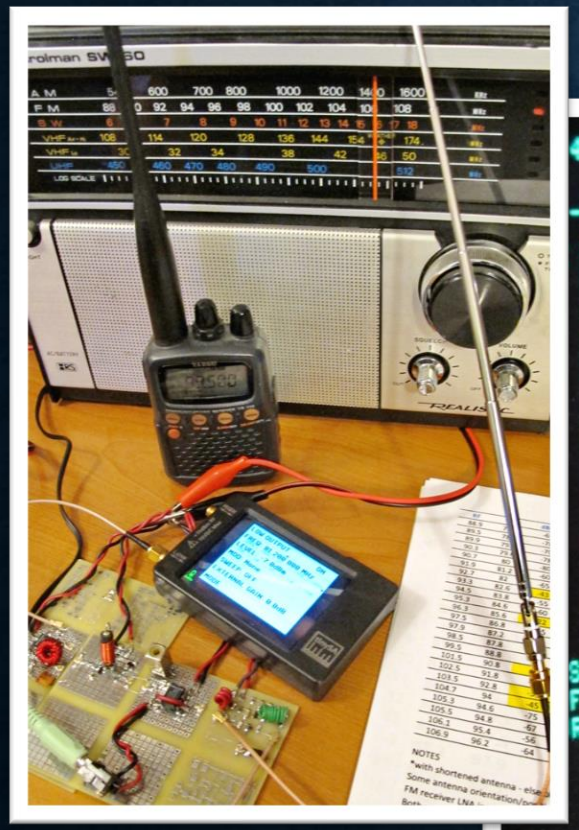
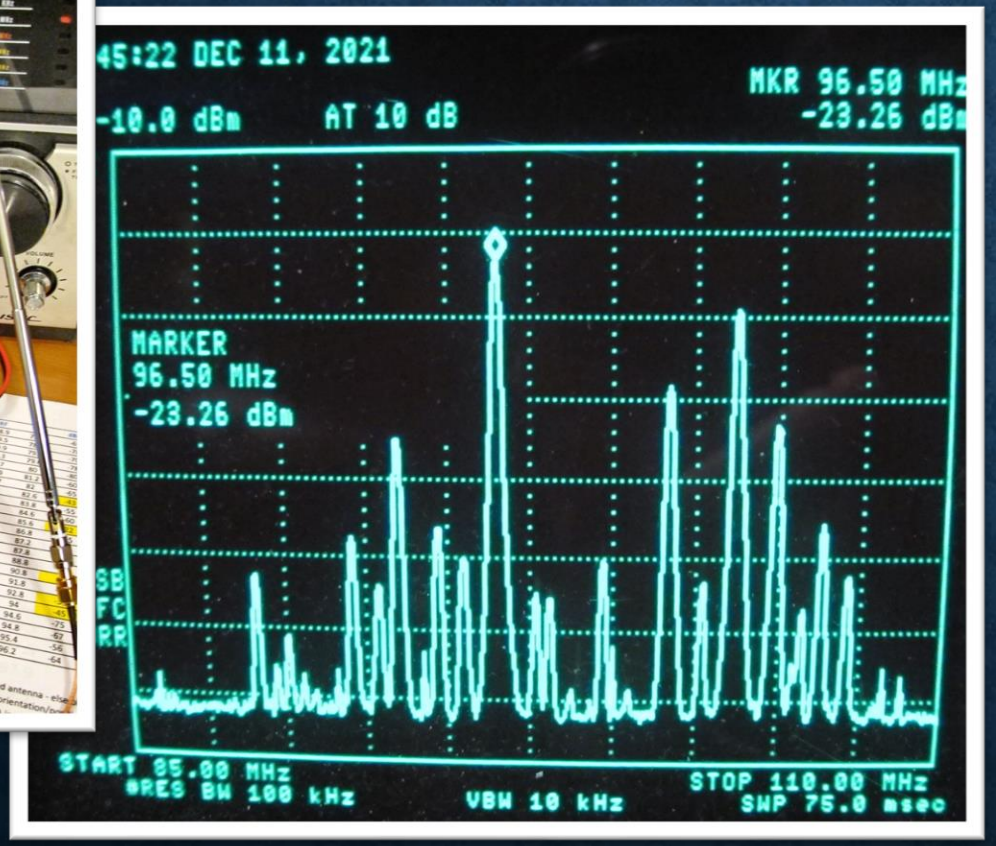
# FM Receiver built in Radio Design 101



# Test Results from Epilogue 1



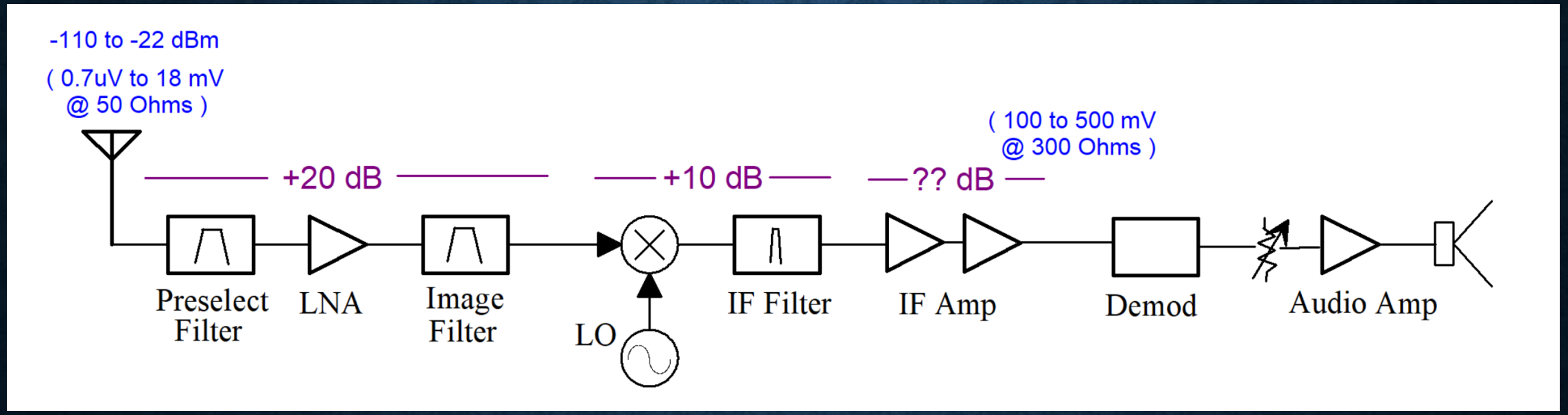



| RF | LO | dBm | FMrx | VR120 | VR120atten | Old Radio |
|---|---|---|---|---|---|---|
| 88.9 | 78.2 | -65 | | | yes | yes |
| 89.5 | 78.8 | -78 | | yes | | yes |
| 89.9 | 79.2 | -70 | quiet | yes | yes | yes |
| 90.3 | 79.6 | -78 | | | yes | yes |
| 90.7 | 80 | -80 | | | | yes |
| 91.9 | 81.2 | -60 | quiet | yes | yes | yes |
| 92.7 | 82 | -65 | | | yes | yes |
| 93.3 | 82.6 | -43 | excellent | yes | yes | yes |
| 94.5 | 83.8 | -55 | quiet | yes | yes | yes |
| 95.3 | 84.6 | -60 | quiet | yes | yes | yes |
| 96.3 | 85.6 | -22 | excellent | yes | yes | yes |
| 97.5 | 86.8 | -65 | | | yes | yes |
| 97.9 | 87.2 | -67 | quiet | yes | yes | yes |
| 98.5 | 87.8 | -80 | | | | ? |
| 99.5 | 88.8 | -61 | ? | | yes | yes |
| 101.5 | 90.8 | -40 | excellent | yes | yes | yes |
| 102.5 | 91.8 | -62 | | | | yes |
| 103.5 | 92.8 | -30 | excellent | yes | yes | yes |
| 104.7 | 94 | -45 | good | yes | yes | yes |
| 105.3 | 94.6 | -75 | | | | yes |
| 105.5 | 94.8 | -67 | | yes | yes | yes |
| 106.1 | 95.4 | -56 | | yes | yes | yes |
| 106.9 | 96.2 | -64 | | yes | yes | yes |

# Outline of Today's Episode

- *Review of problems found in Epilogue 1*
- *Troubleshooting and fixing it*
- *General troubleshooting techniques*
- *Future topics*

# Recall Epilogue 1 Conclusions



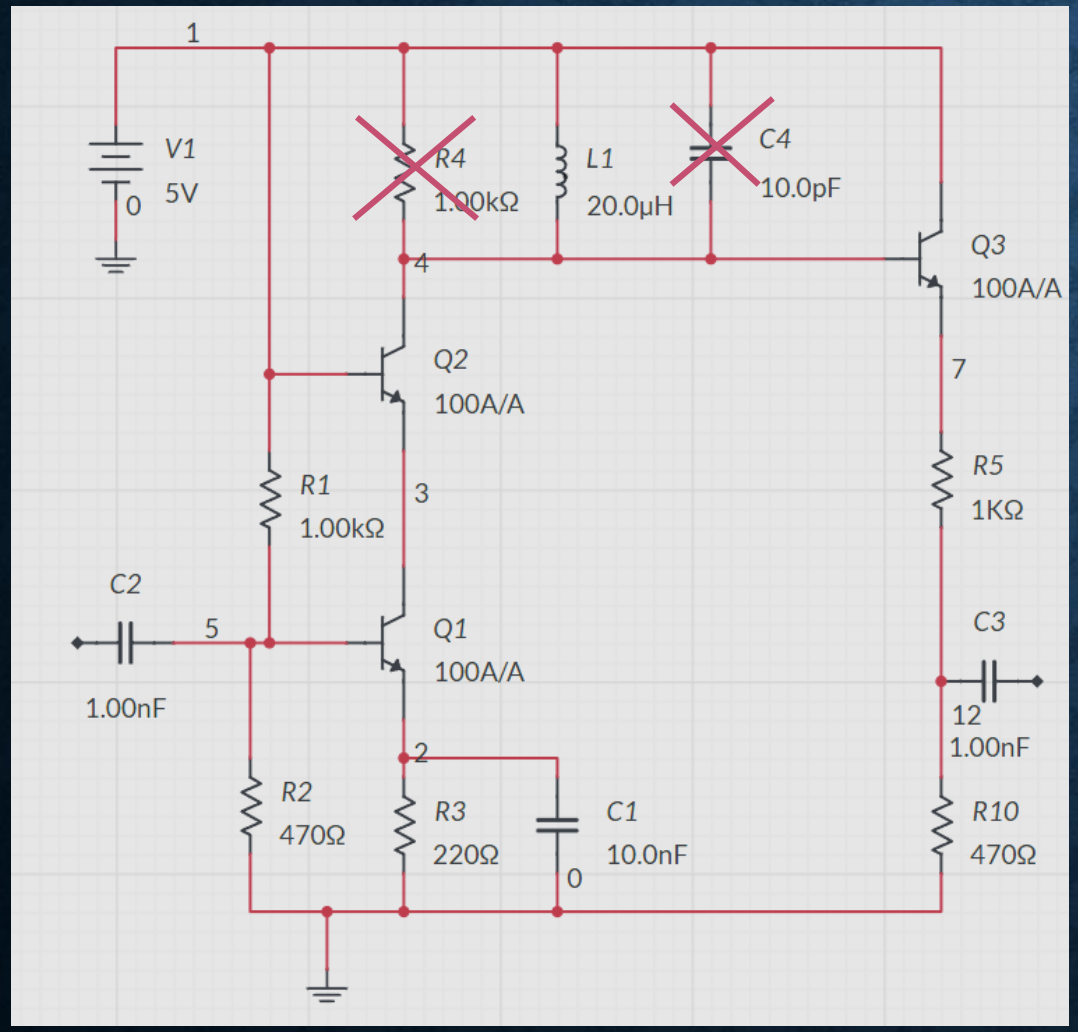

Front-end bandwidth is too narrow, desensitizing top and bottom of FM band

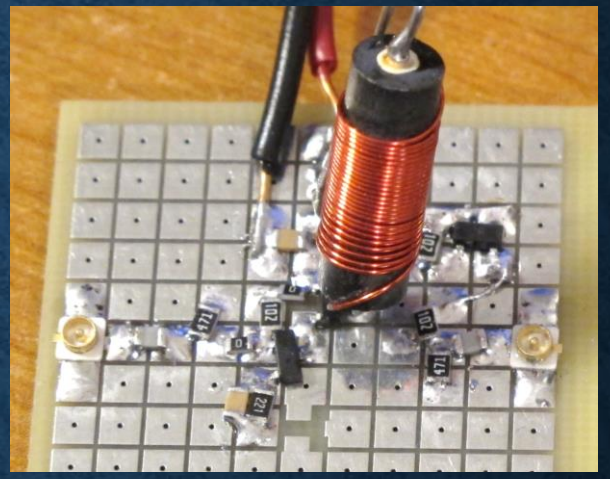
Mixer is overdriven in local area due to 96.3 MHz station, reducing overall gain

IF filter has limited off-channel rejection causing some "signal blocking"

IF amp gain is low and not centered at 10.7 MHz **(We need more gain *at IF* ! )**

# Simple IF Amp Modifications



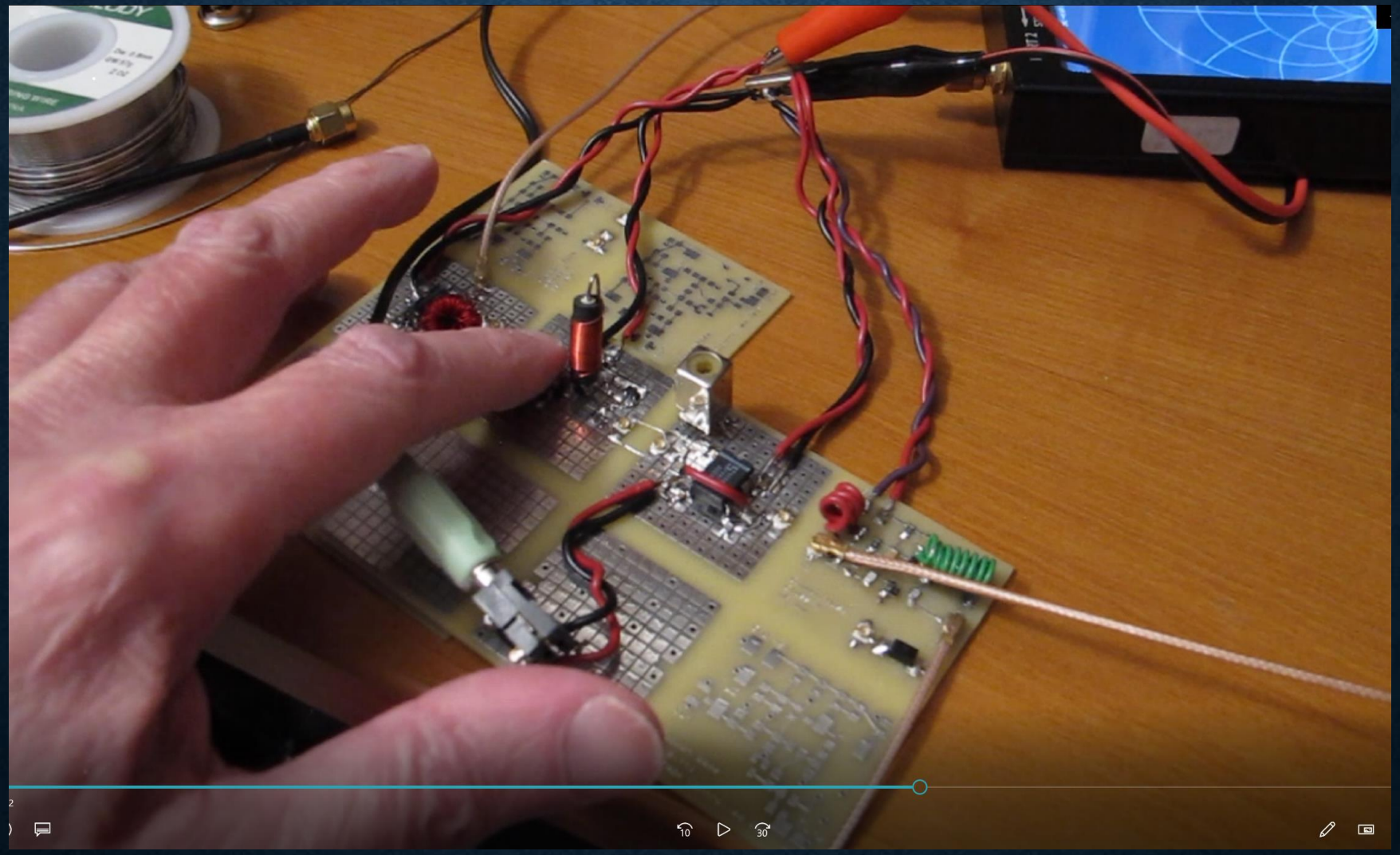



- Removed R4 and C4 to increase gain and raise resonant frequency.

$$A_v = -g_m R \qquad f_o = \frac{1}{2\pi\sqrt{LC}}$$

- Receiver lost virtually all sensitivity ! ☹

# The Problem



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- ***Troubleshooting and fixing it***
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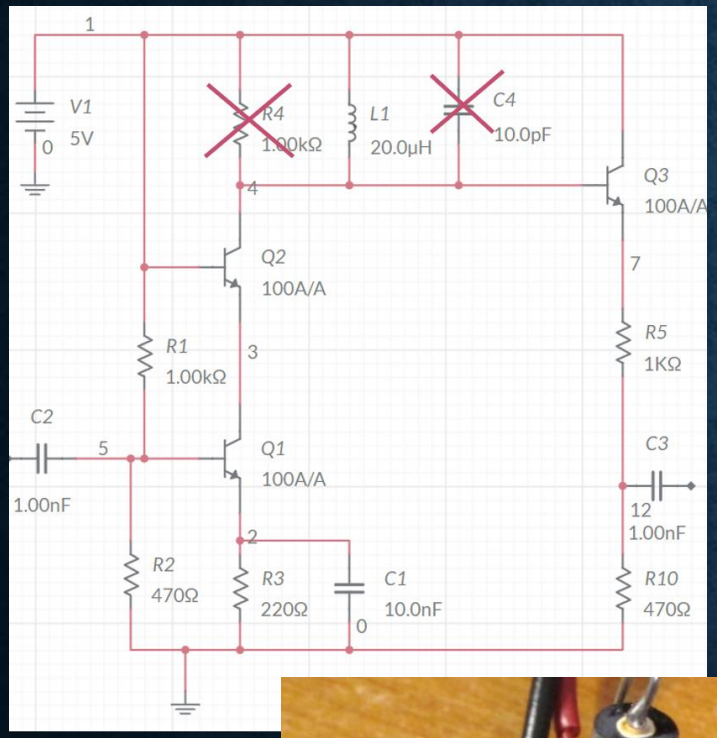
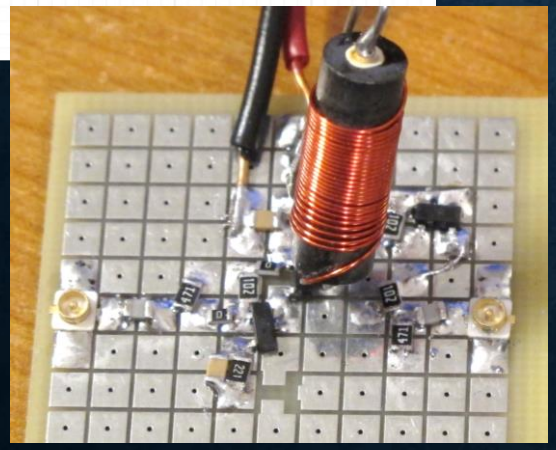
# Troubleshooting (basic checks)

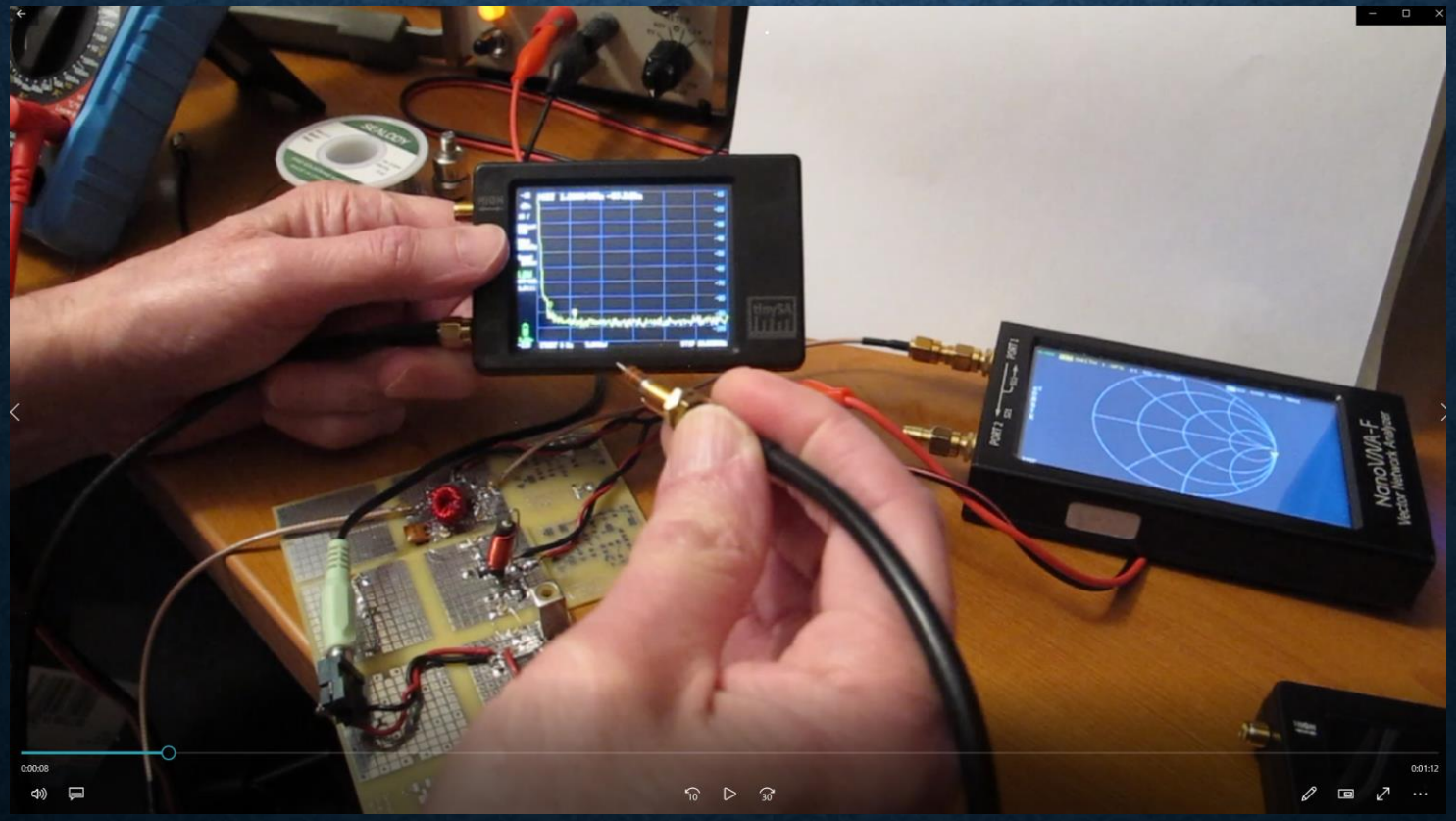


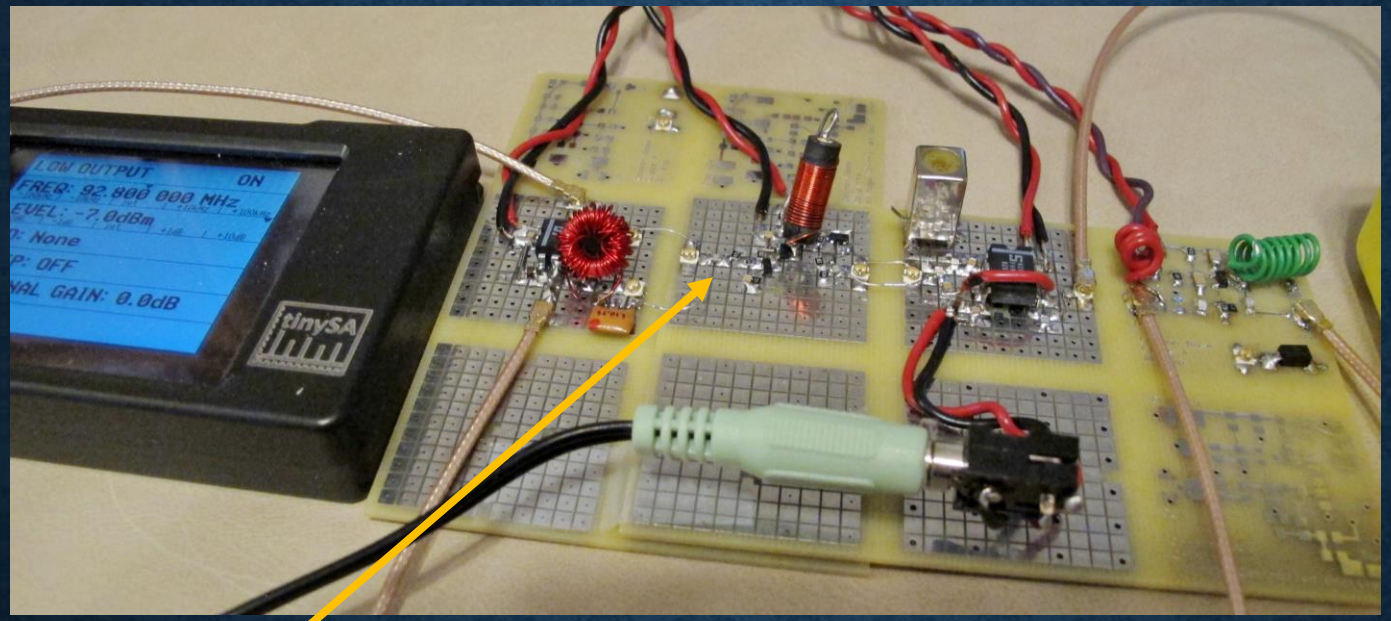
- What changes were made since last time it worked? (de-soldering in IF amp output stage)
- Verified visually and with Ohm meter that connections were OK
- Verified DC bias voltages at Vcc, and at Q2 and Q3 base and emitter
- Probed signal at IF amp output with receiver tuned to a strong station
- Noticed it's oscillating around 6 MHz !

# Troubleshooting (RF probing)

WARNING: Only for low voltage, low-power circuits and with a DC block (and suitable attenuation)!



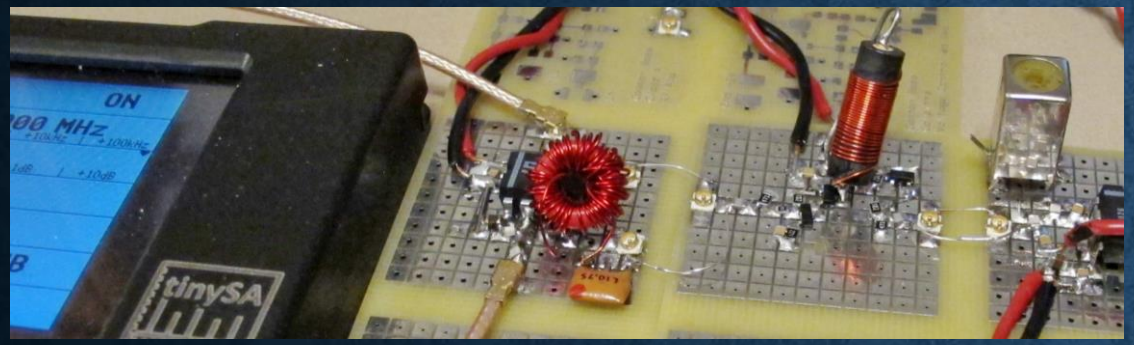
# Troubleshooting (collected clues)

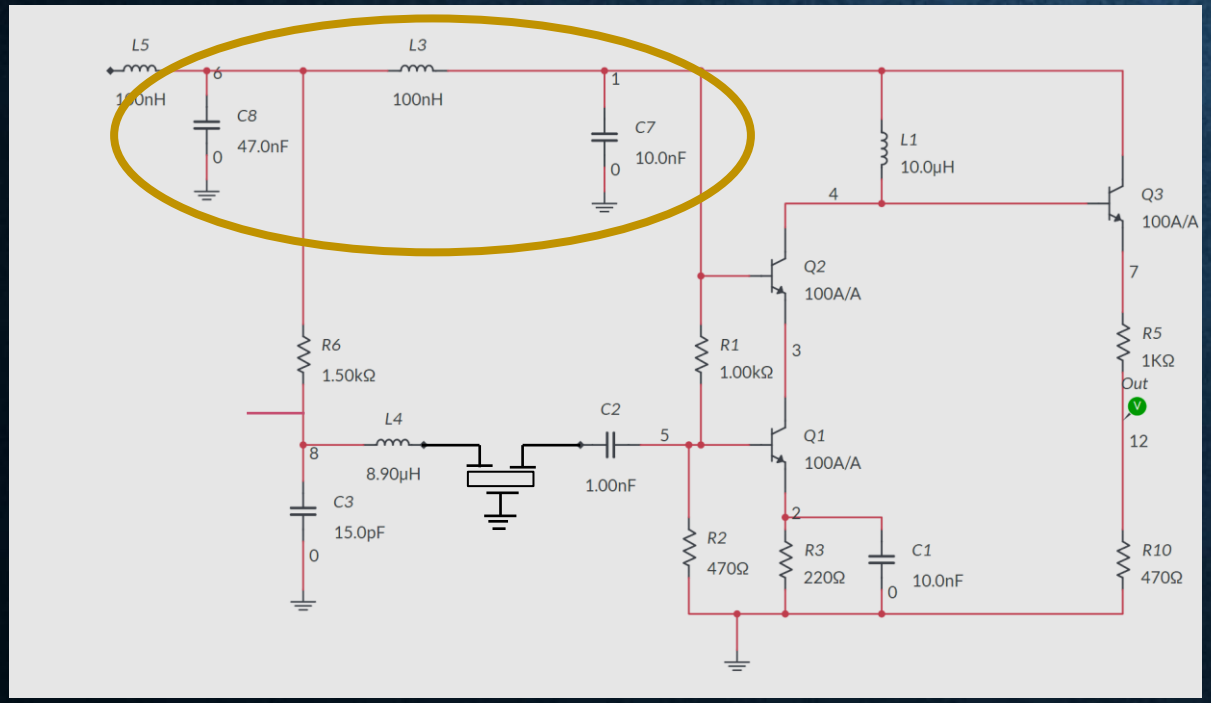



WARNING: Obviously – don't touch high voltage or high-power circuits.

- Touching here, or on inductor stopped oscillation and receiver came alive
- Oscillation stayed gone after finger removed (hmm…)
- Removing probe (or touching antenna) could start it again…

# Developing Theories

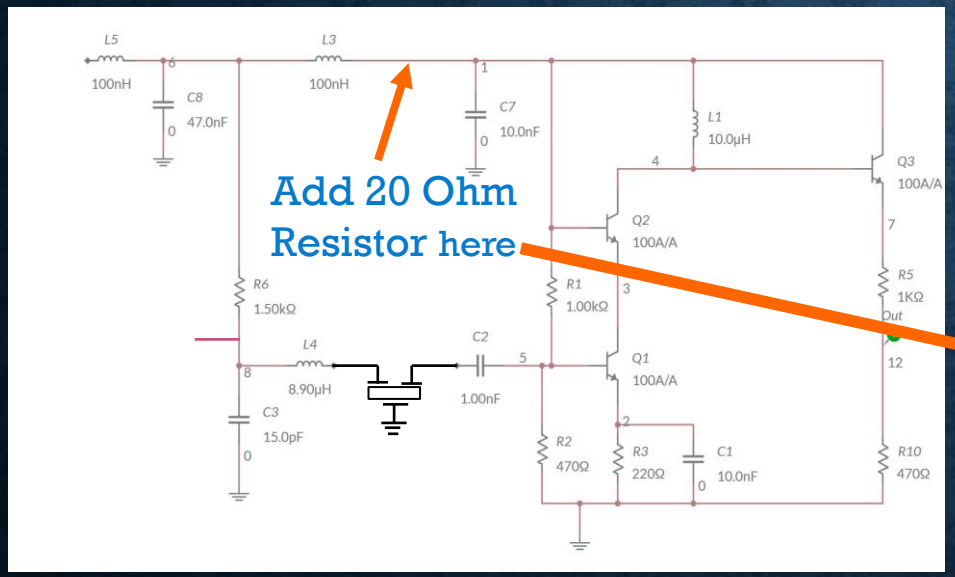


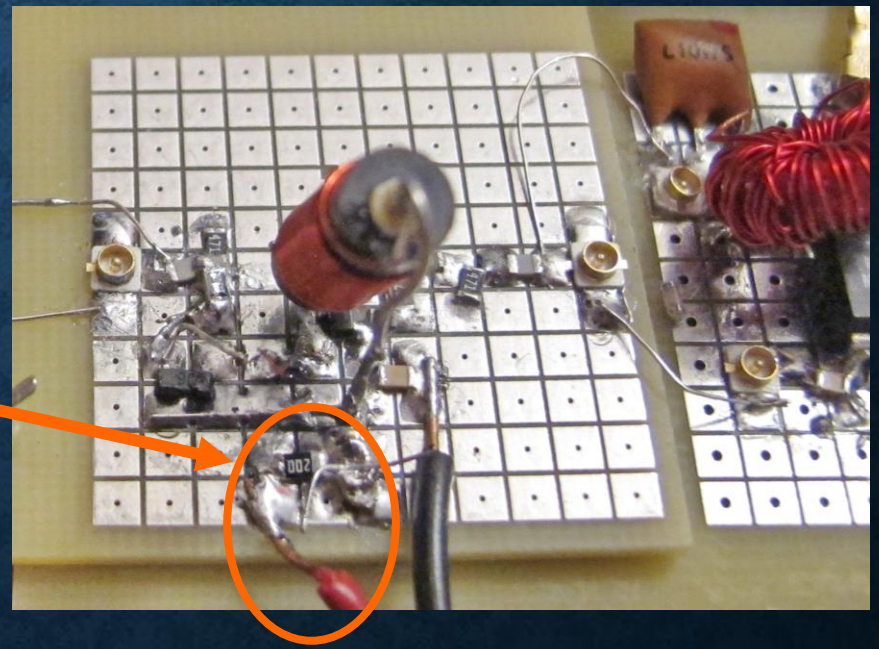




- Clues include frequency (6 MHz), and ‘stickiness’ of oscillation
- Ruled out common cause of RF oscillation: (CC amplifier with capacitive load at emitter and inductive base impedance)
- Remaining theories included parasitic 100 nH L in Vcc lead resonating with 10 nF C7 bypass, or possible loop back through mixer stage (unlikely due to filter in-line)
- Also, high C from forward biasing of Q3 base - collector junction during limiting could shift resonance from 11 MHz to 6 MHz, making it sticky. Hmm…

# Testing Theories

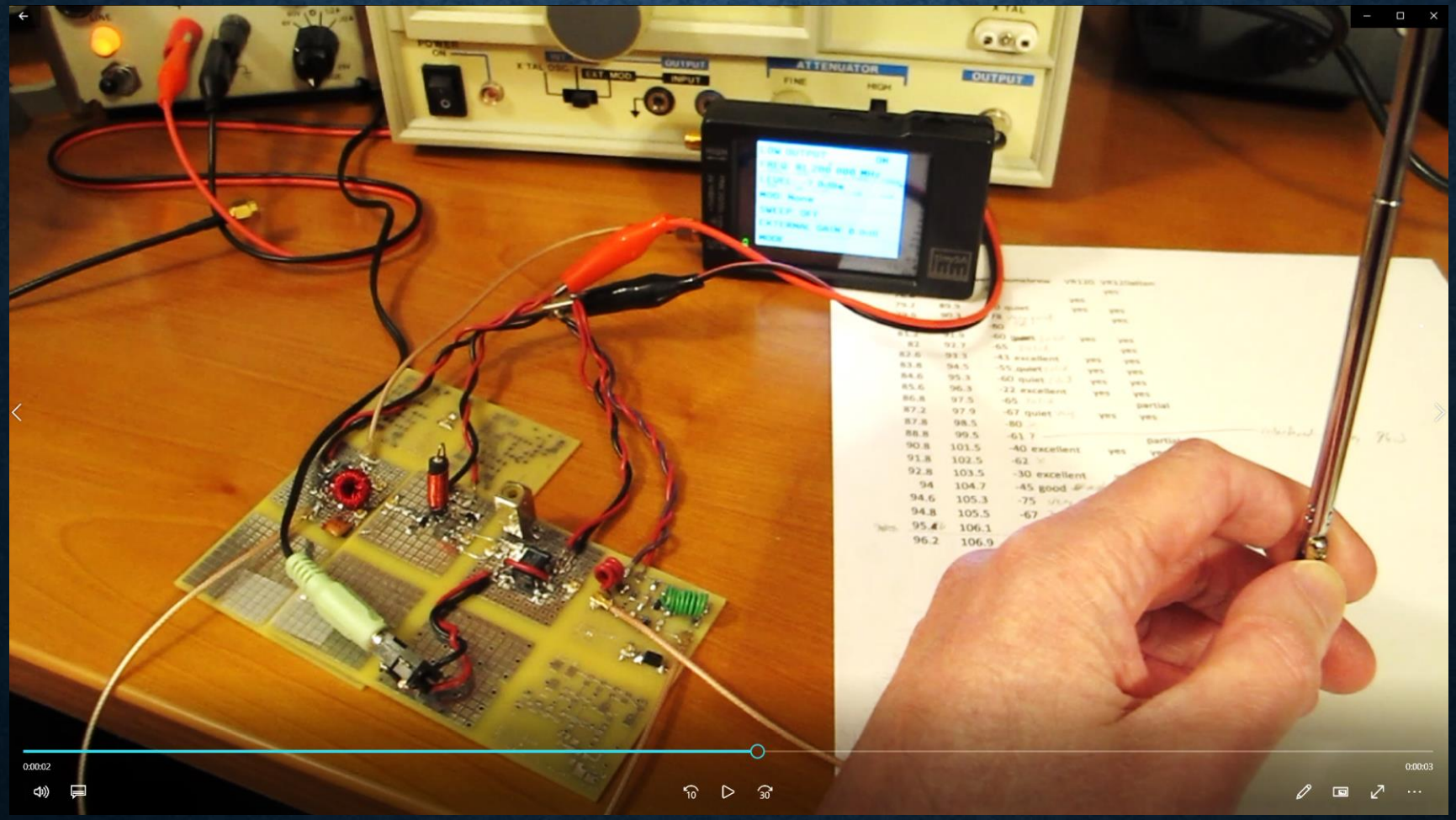
- Proposed solutions included adding series R in supply lead to “de-Q” resonance between C7, L3.
- Added 20 Ohm series R with supply feed and got excellent, stable reception ☺



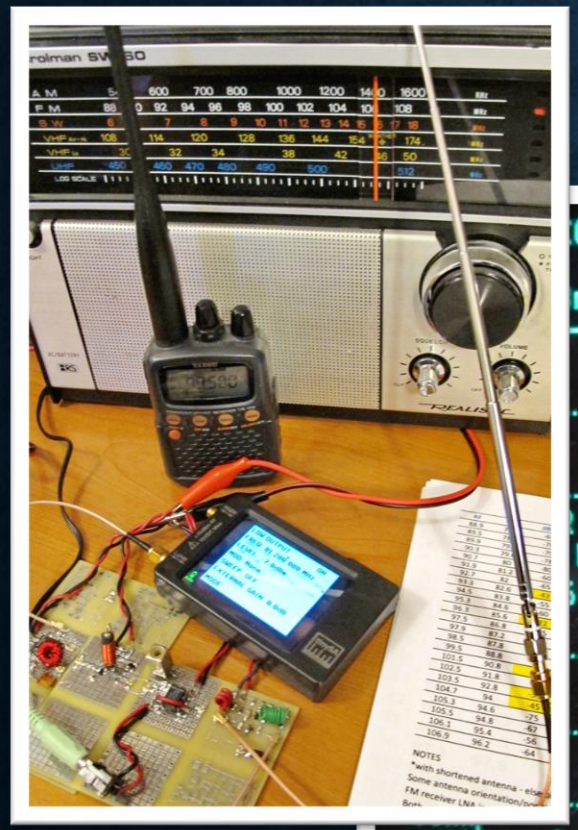



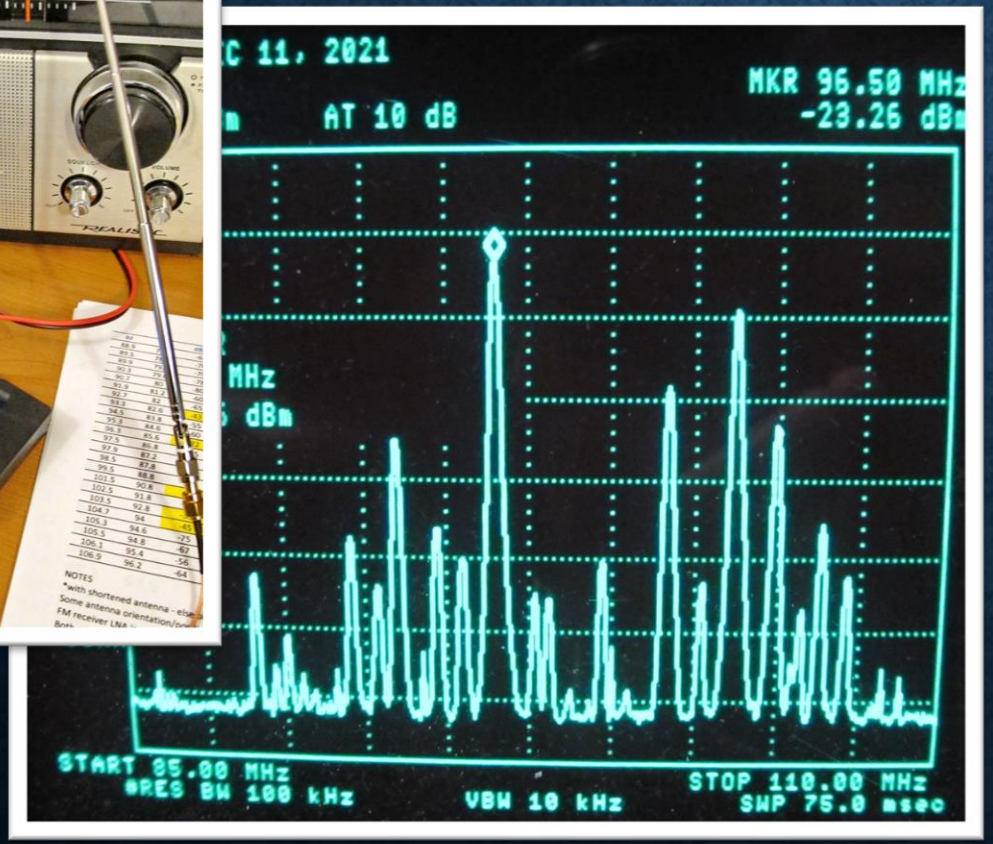
***NOTE:*** This was standard practice in older designs. Modern books / papers / PCB layout guidelines surrounding bypass cap issues fall under the term “Power Integrity”

# Fixed ☺



# Performance Now



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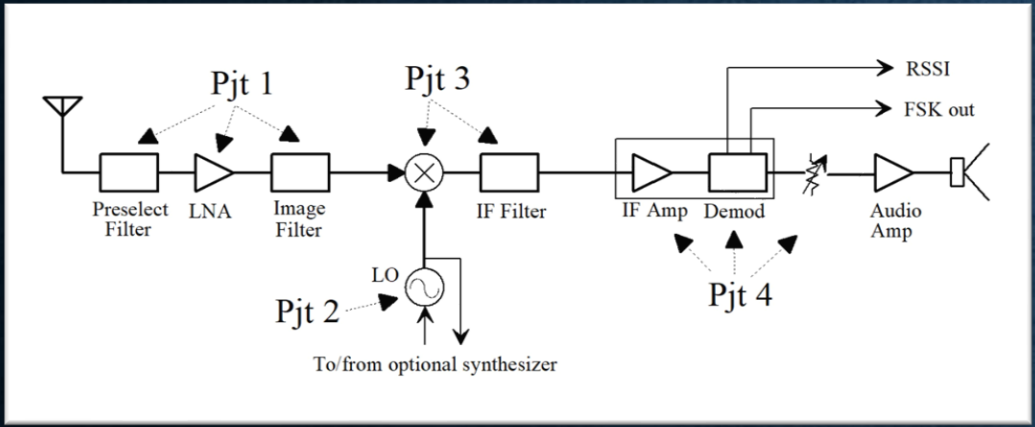
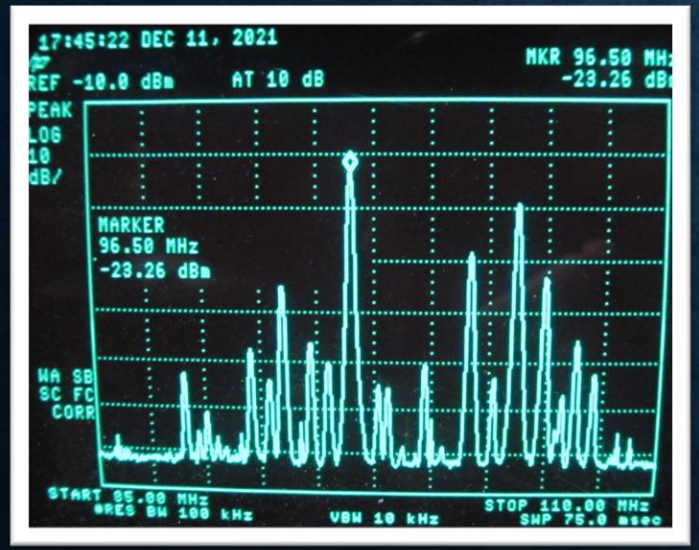
# Performance Now
## (and future improvements)




- Approaching performance of commercial VR120 receiver
- Both require moving antenna to get clear reception sometimes
- Low and high frequency sensitivity issues remain due to narrow LNA bandwidth and low IF gain
- Maybe add additional IF amp stage and second IF filter, and reduce Q in LNA to lower its gain and increase its bandwidth.
- Could also change mixer to diode-ring type (higher compression point) at cost of higher power
- OR… Use techniques like tracking preselection or a "Q-enhanced" LNA ! (modern use of regen :-)

# Outline of Today's Episode

- *Review of problems found in Epilogue 1*
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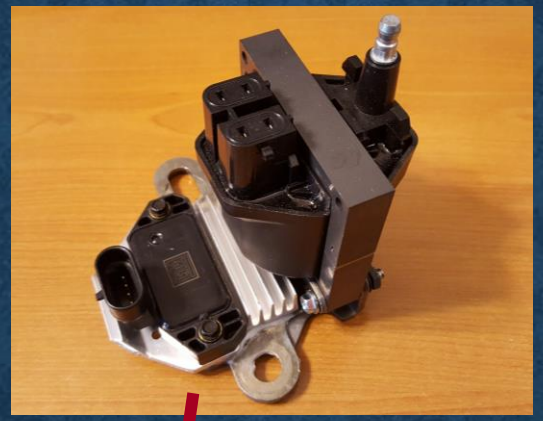
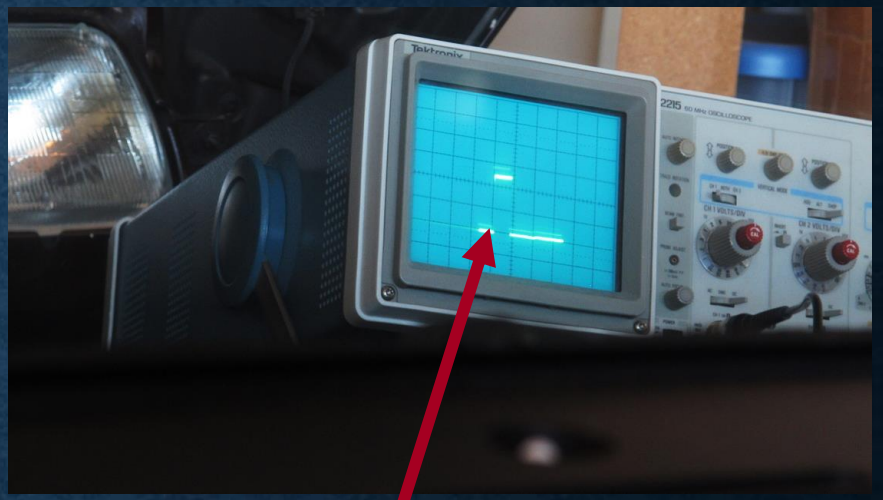
# Generalizing …

- Review / understand the system being debugged  (and safety issues)
- Ask what changed since last time it worked
- Assess the known symptoms and try to localize the problem
- Do the simple / quick things first  (visual checks, DC bias checks, etc.)
- Consider, but don't overemphasize common causes

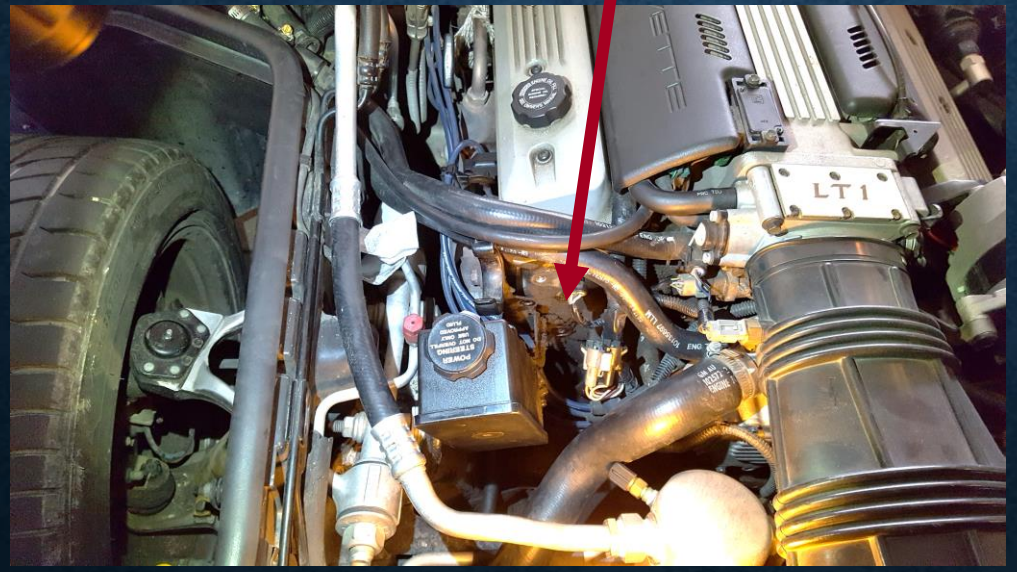
- Collect additional clues  (e.g., inject known signals and do signal tracing)
- Test theories  (but consider KISS principle and time and monetary costs)
- Recognize that faults will change circuit, so it may be different than we think
- Sleep on it if needed and restart fresh ☺

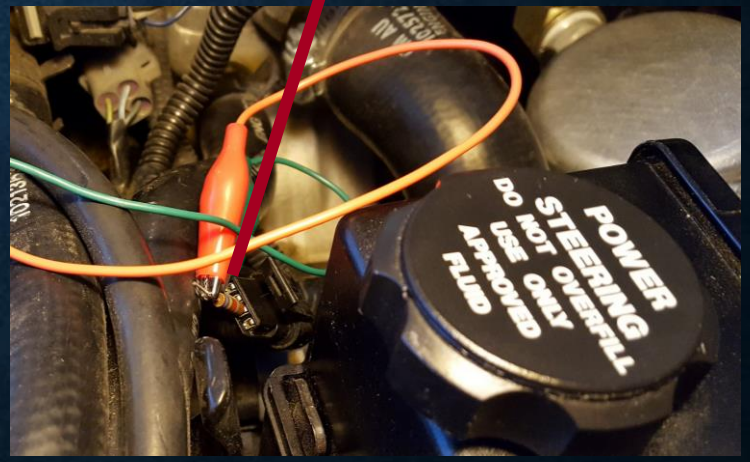
# Application to a ‘92 Corvette ☺









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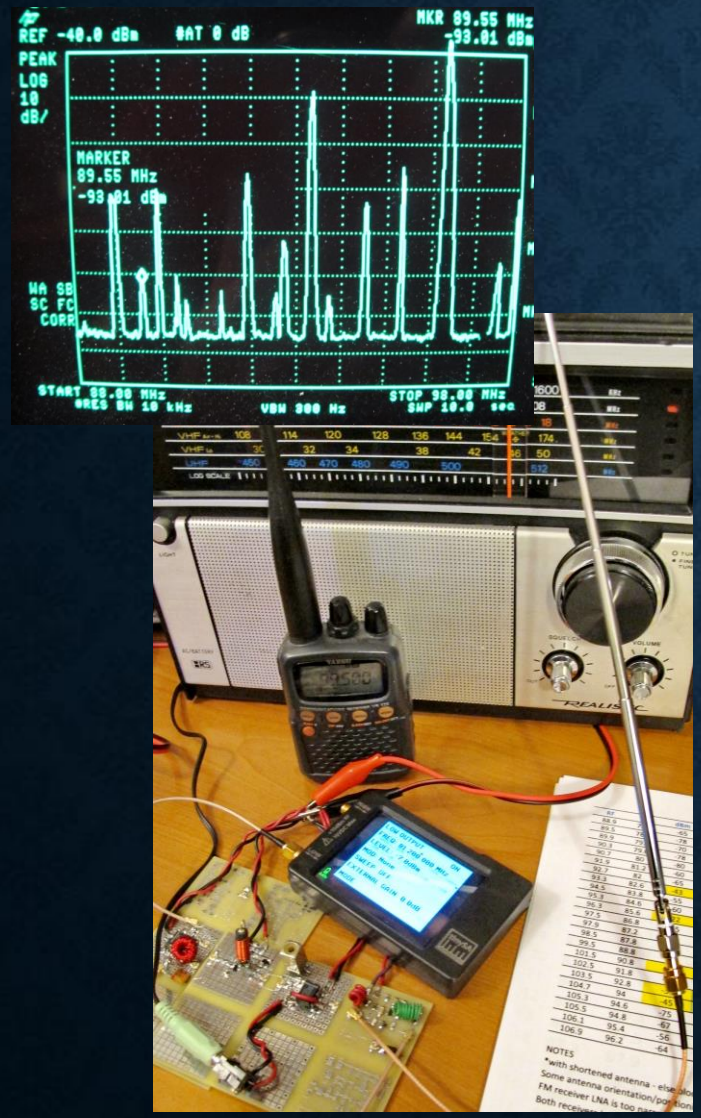
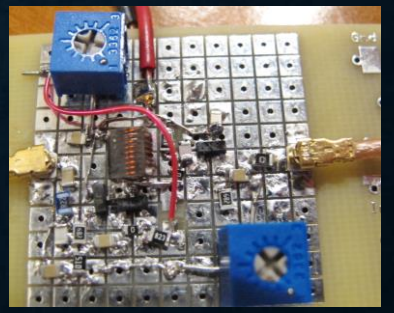
# Future Topics




- Study commercial radio designs and schematics
- Performance considerations (compression points, intermodulation, power consumption)
- Spurious products from mixers
- Receiver ideal sensitivity (MDS, Noise Figure, etc.)
- Elevated Noise Floors  (RFI caused by modern switch-mode power supplies and lighting)
- Project ☺
  - Q-enhanced Low Noise Amplifier

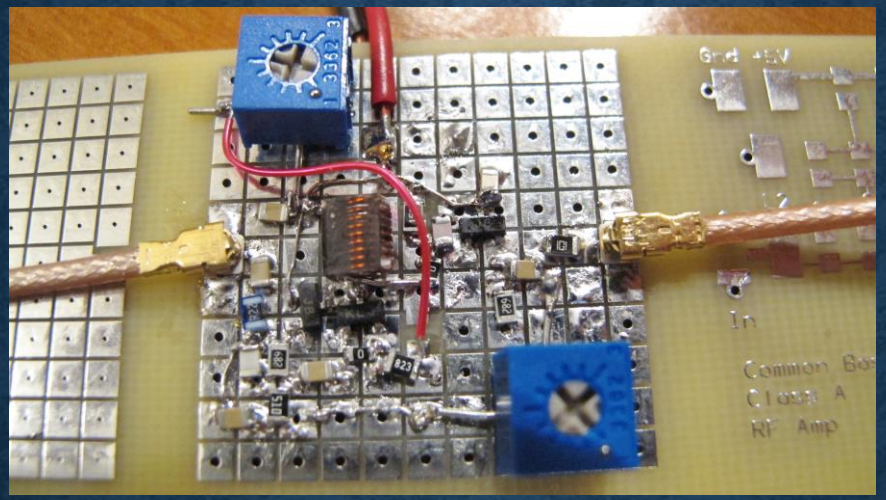


# Preview of Q-enhanced LNA

## Signals from Antenna

Bottom end of Band
(88 to 98 MHz)

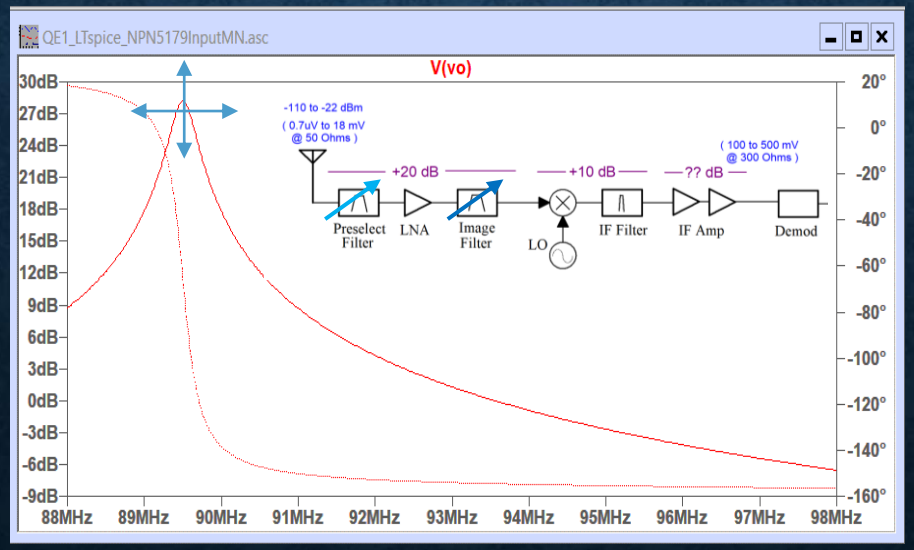
Spectrum analyzer noise
floor of -104 dBm (30 dB NF)

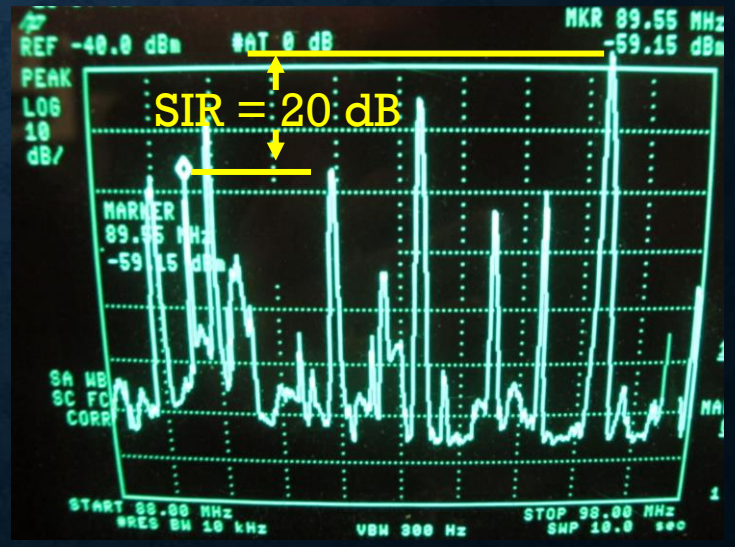


## Output from Q-enhanced LNA

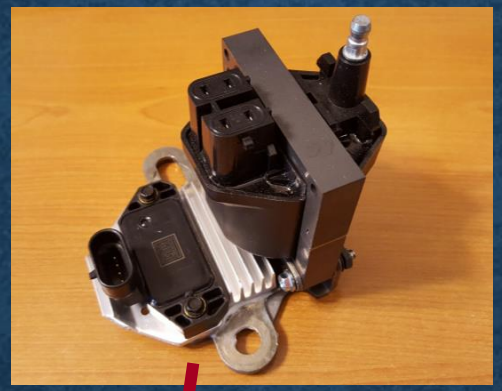
RF filtering tuned to 89.5 MHz

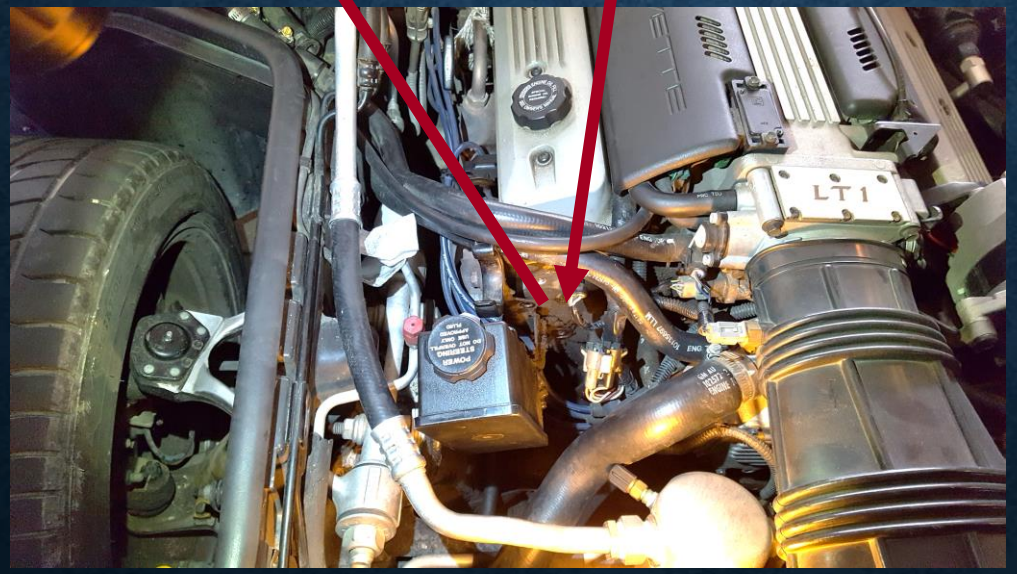
Q enhanced to 500 => 200 kHz
bandwidth (at RF, before mixer !)

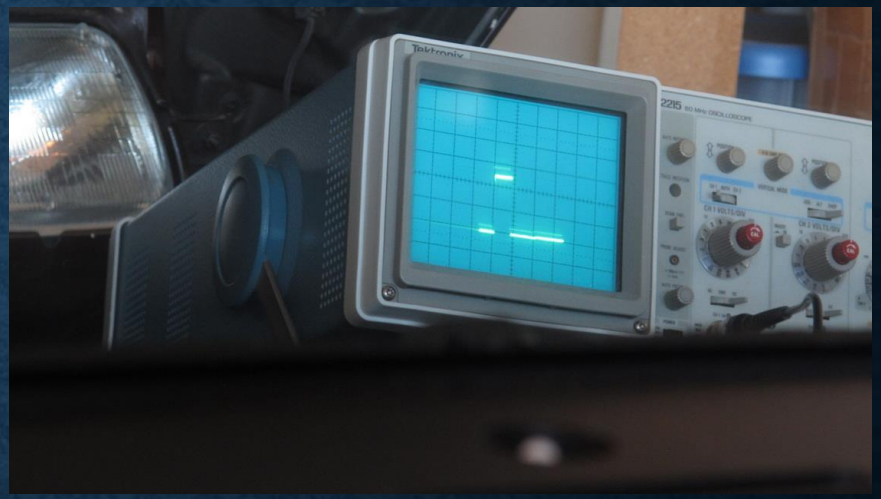



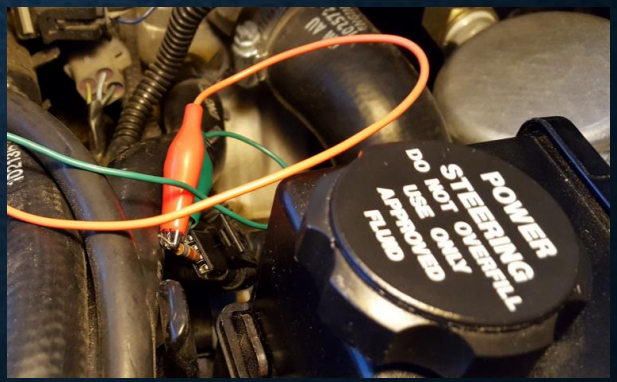



# Troubleshooting a ‘92 Corvette ☺



# Troubleshooting Techniques

- Review / understand the system being debugged  (and safety issues)
- Ask what changed since last time it worked
- Consider, but don't overemphasize common causes
- Assess the known symptoms and try to localize the problem
- Do the simple / quick things first  (visual checks, etc.)

- Collect additional clues  (e.g., do signal tracing)
- Test theories  (but consider KISS principle and time and monetary costs)
- Recognize that faults will change system, so it may be different than we think
- Sleep on it if needed and restart fresh ☺

***Thanks For Watching !***