The TinyFilter – a 2m bandpass filter for your handheld radio

Ara Kourchians
N6ARA



Mike Seiffert
K6STR

Ara N6ARA …

- Ham since 2007
- APRS radio trackers in High Altitude Balloon payloads

  (caught the ‘make things tiny’ bug)
- Tinker and homebrew a lot of gear… it’s almost unhealthy
- Used to not enjoy hiking, really into SOTA now
- Accidentally started a business: N6ARA Electronics



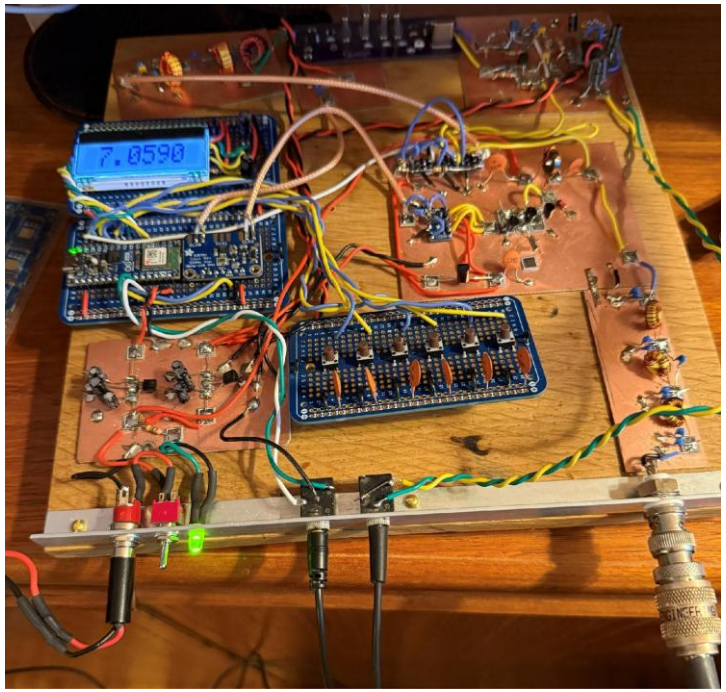
Mike K6STR …

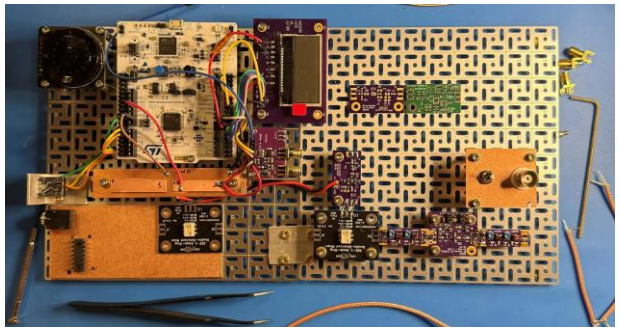
Loves portable operating! Loves Summits-on-the-Air!

Loves hanging out in nature, particularly mountains!

Loves building stuff!

Amateur Extra – first licensed in 2002

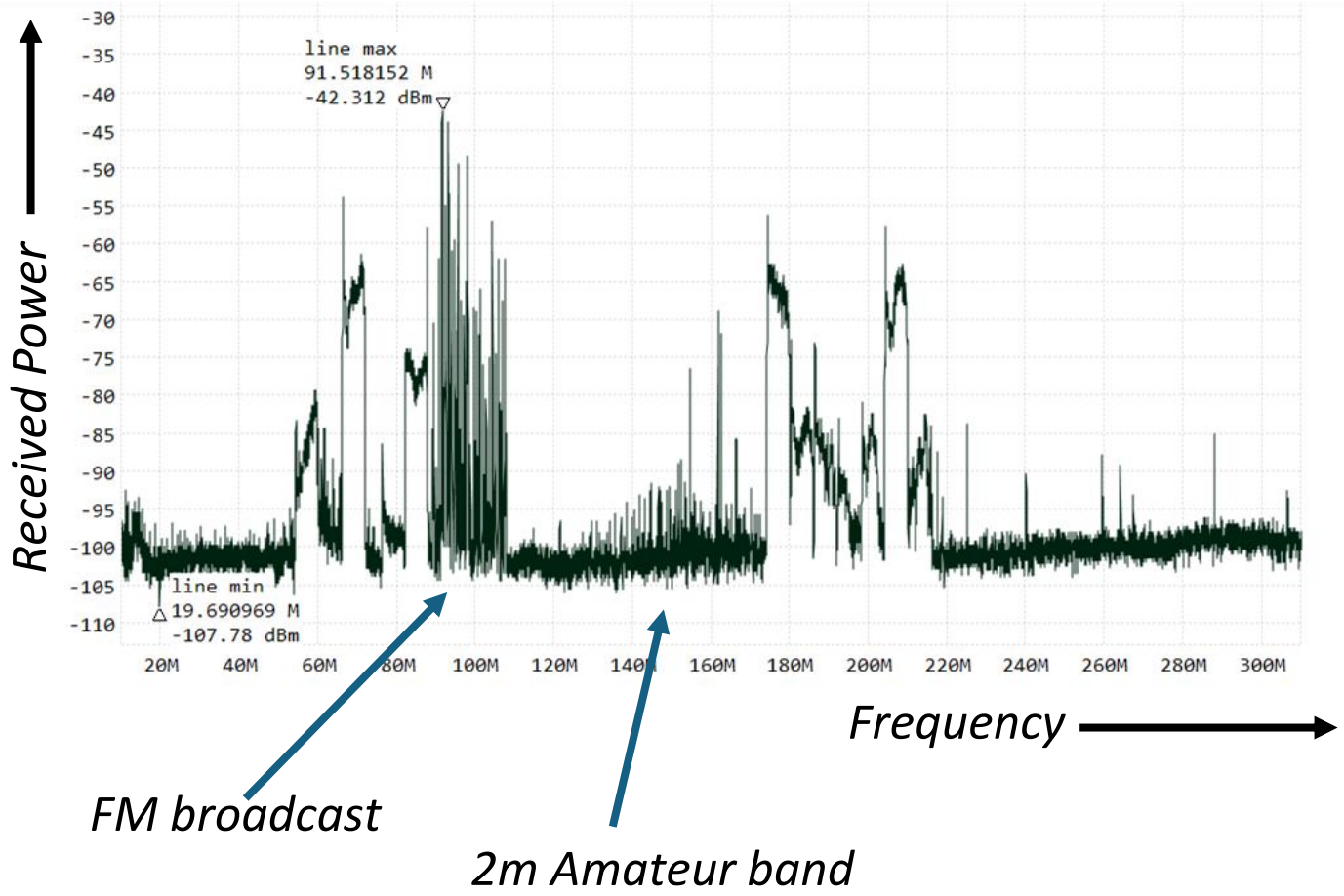


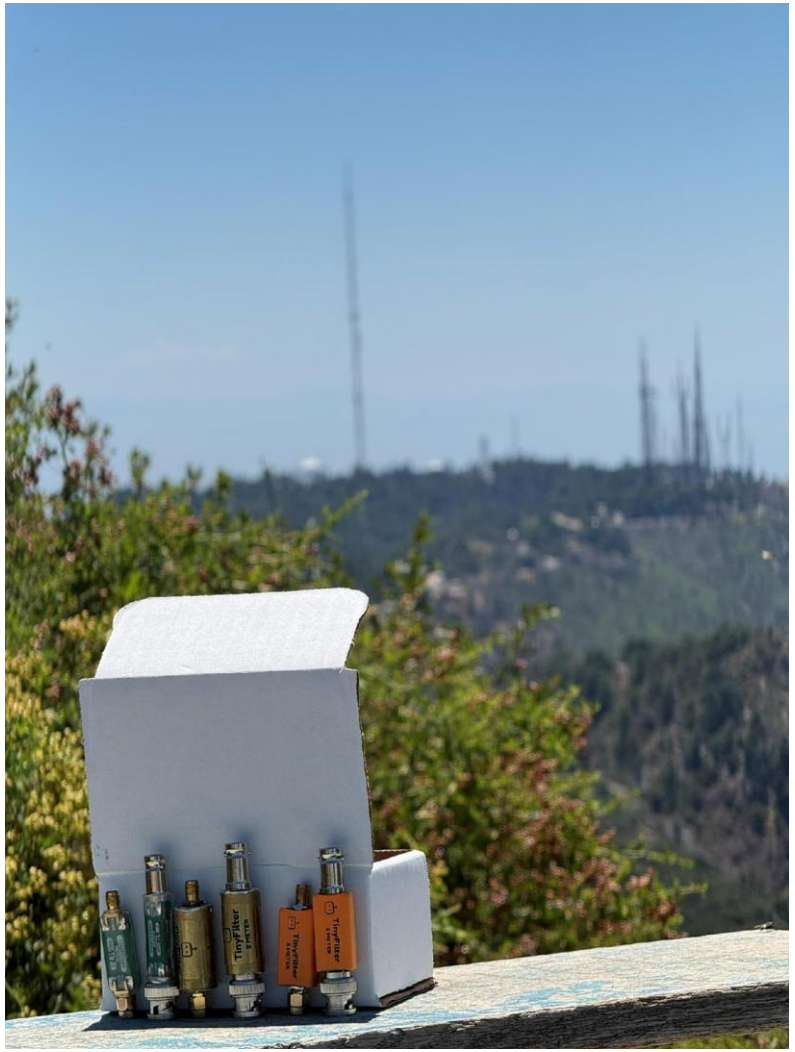




What is a bandpass filter and why would you want to use one?

VHF spectrum from my home – lots of other signals





Filters with Mt Wilson in the distance

Doesn’t my radio already have a bandpass filter? Why do I need something extra?

Your 2m radio generally already has a bandpass filter, but …

- Filter effectiveness can vary widely
- High-quality base stations may have excellent filtering
- Inexpensive HTs may have poor filtering

Poor filtering allows other frequencies to bleed through and interfere with a station that you may be listening to.

In mild cases, this is merely annoying.

When severe, out-of-band interfering signals make your radio completely deaf to receiving a desired signal!

Summits-on-the-Air (SOTA) operators are familiar with the issue, as they attempt to make simplex contacts from comm sites with other strong signals.

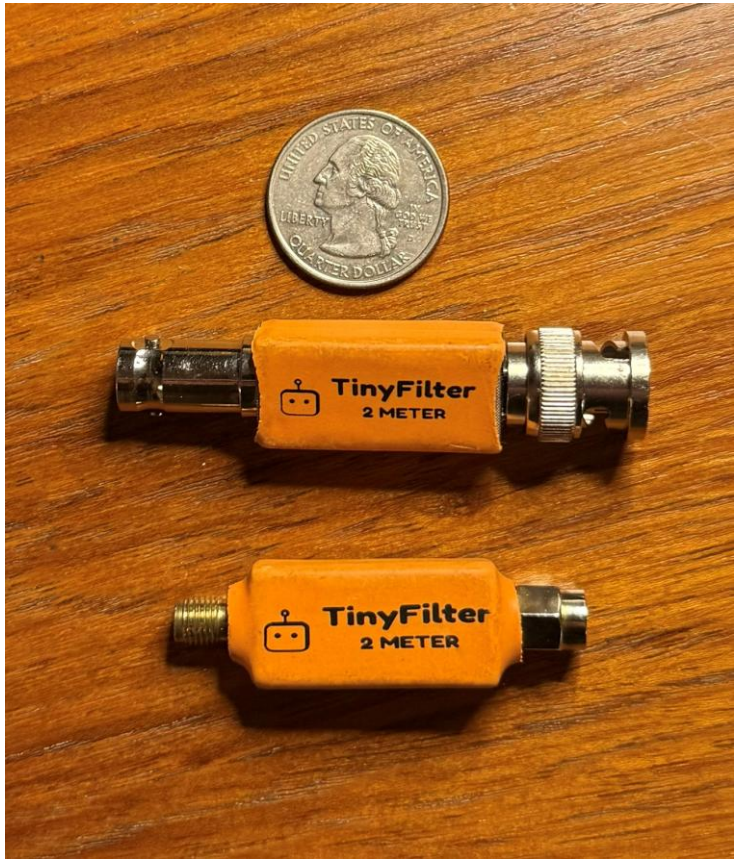
Using a better antenna makes the problem worse, not better!



… introducing the TinyFilter!

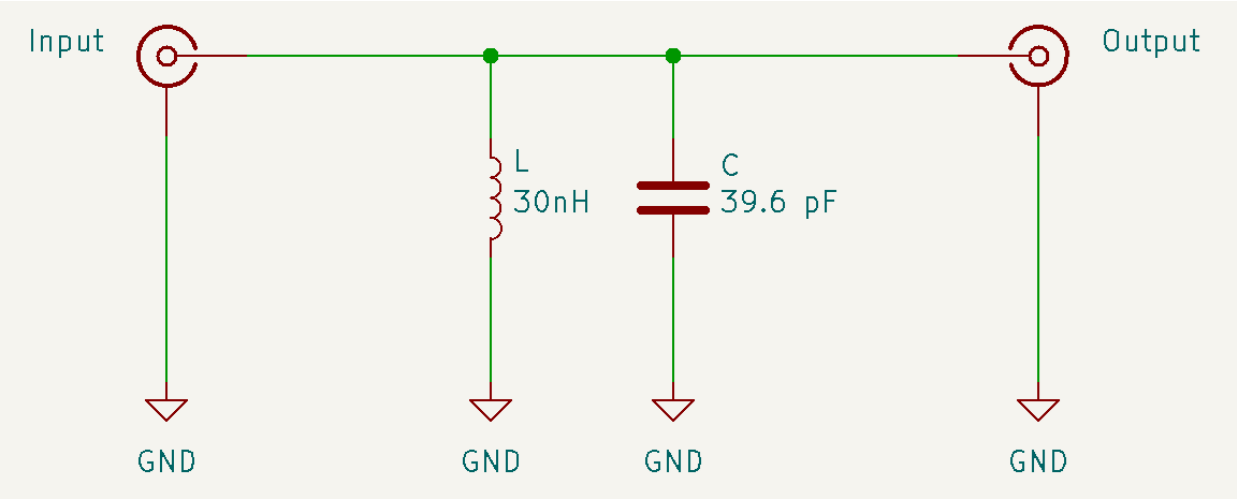
Mounts directly to an HT
Rejects strong out-of-band signals
Available with both SMA and BNC connectors
Small, lightweight
Can handle the full power from a typical HT

Simply adding the TinyFilter between an inexpensive HT and its antenna can make the difference between hearing nothing and being able to carry out a distant simplex contact!



How does it work?

First, let's look at a single stage filter:

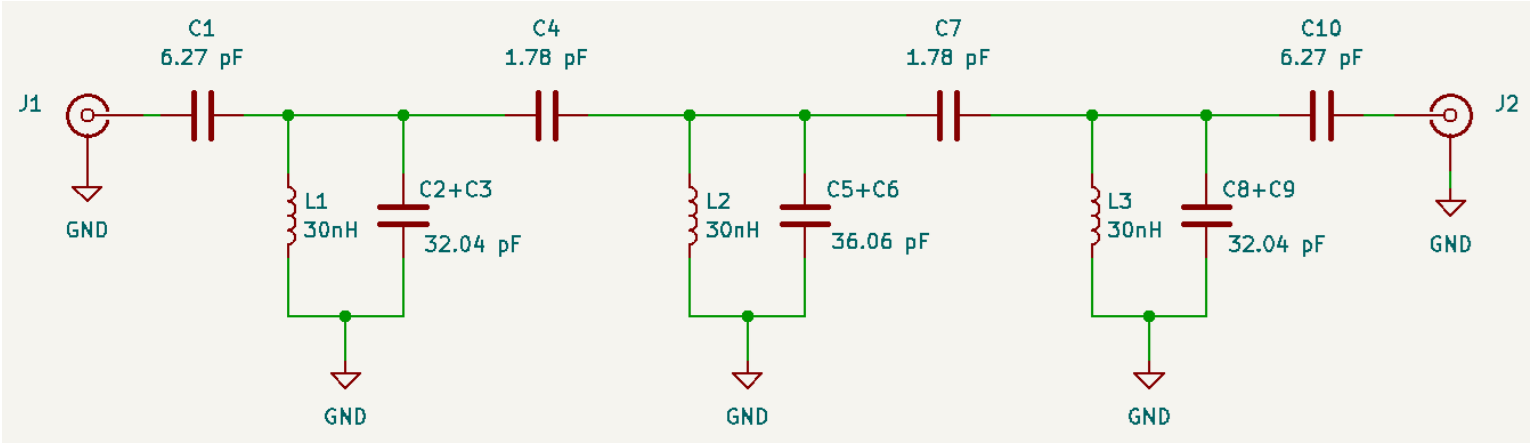


$$f_{\text{resonant}} = \frac{1}{2\pi\sqrt{LC}}$$

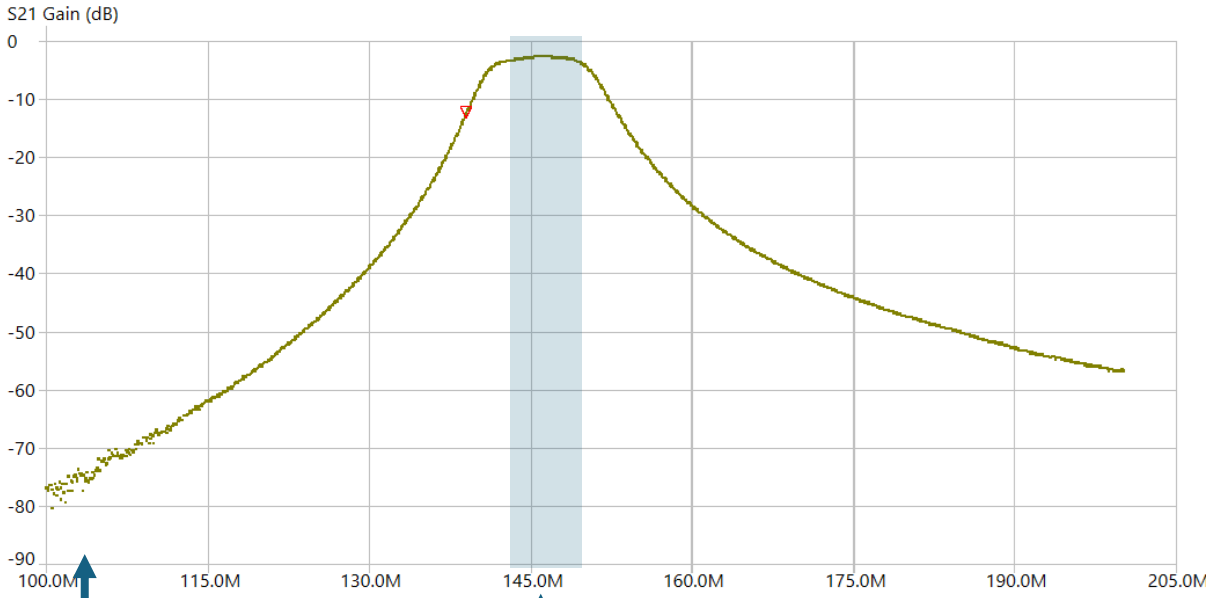
$$f_{\text{resonant}} = 146 \text{ MHz}$$

How does it work?

3 stage filter



3rd order Chebyshev design



Measured performance

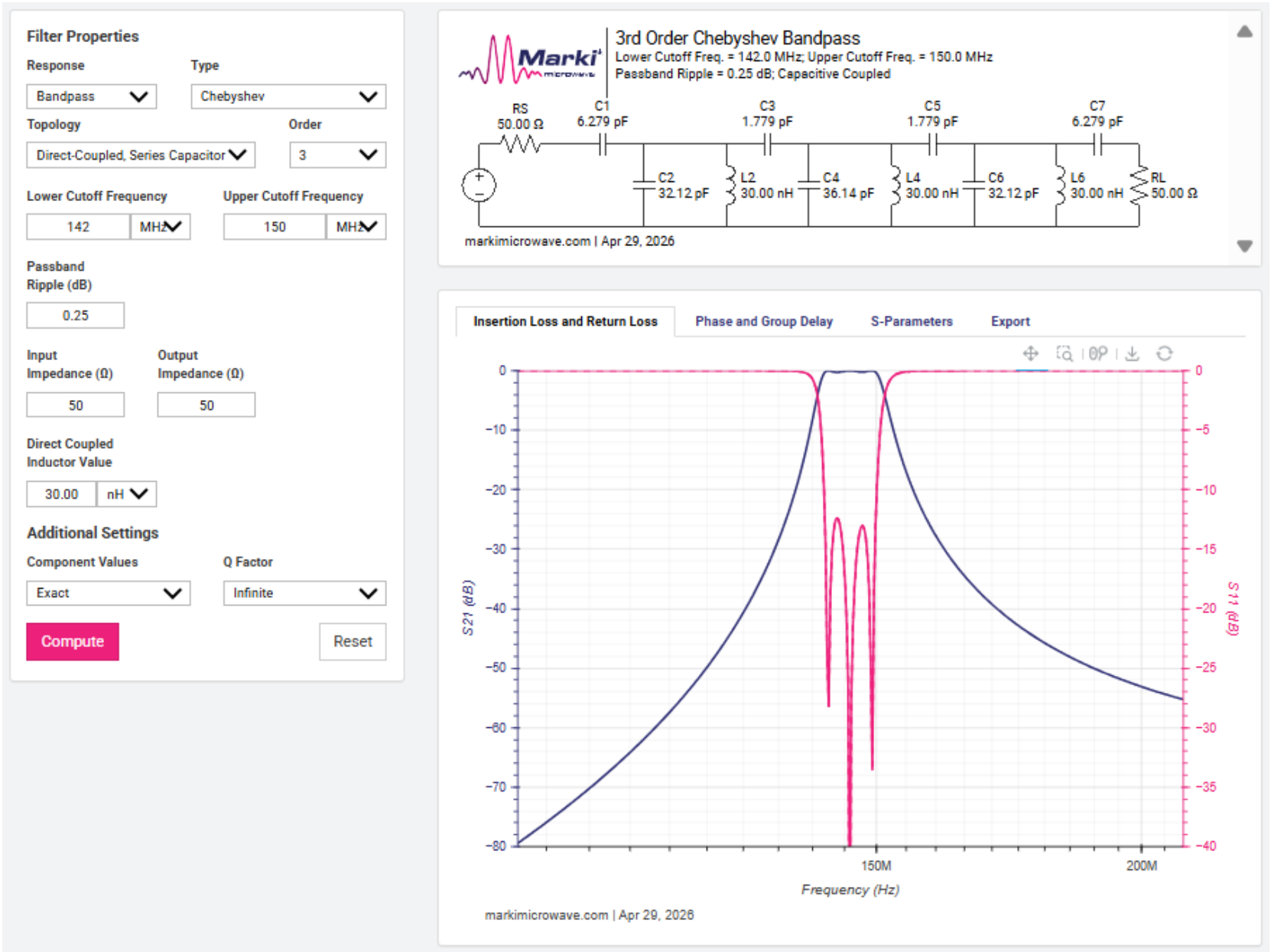
FM broadcast

2m Amateur band

Design your own filter!

markimicrowave.com

Beware – real components are not ideal and real printed circuit boards have their own contributions.



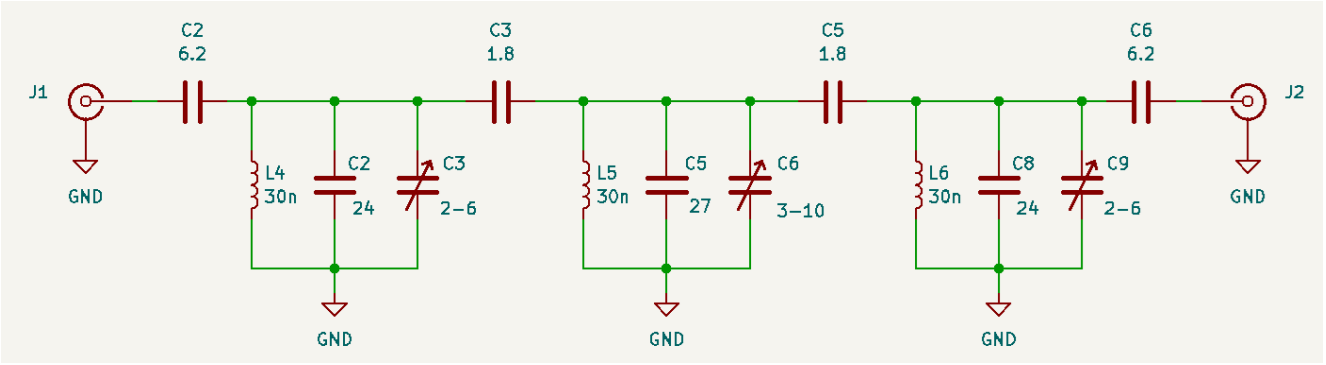
Tradeoffs – no design is perfect

An ideal filter would do its job perfectly, with no loss in the desired range, and infinite rejection everywhere else.

Real bandpass filters have practical limitations

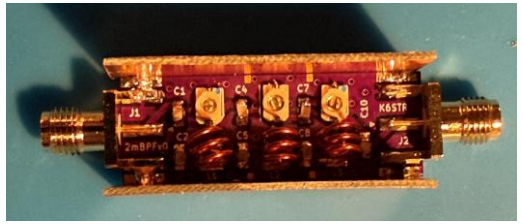
Our design goals:
- excellent rejection of FM broadcast
- good rejection of higher frequencies
- acceptable loss for in-band signals

Factors considered:
- component cost and availability
- size
- part tolerances
- ease of tuning
- power handling
- insertion loss
- out-of-band rejection at various frequencies

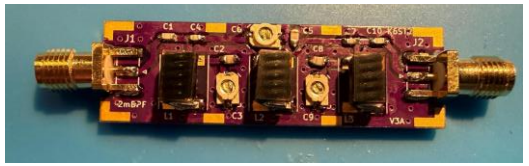


Final component values

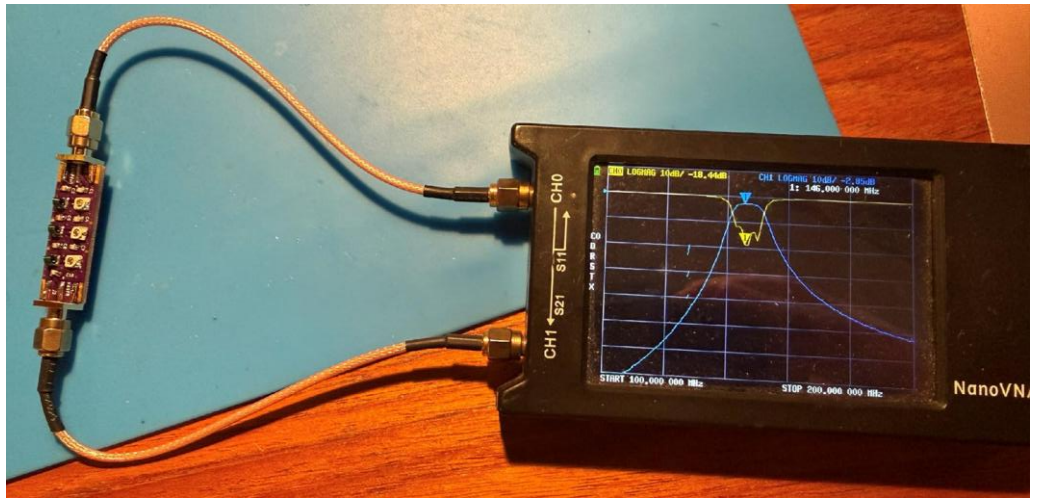
Prototypes



First prototype
Homebrew inductors



NotTiny

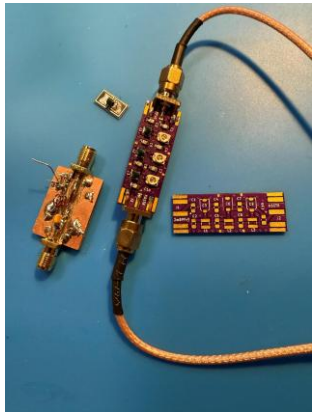


Good performance with commercial inductors
Initial testing at home with nanoVNA











Lots of iterations!

Testing prototype filters is fun!

Especially with friends



Contacts with Jon NT6E and many others!



W6LOR and N6AN



Chasing Max KI6SYD

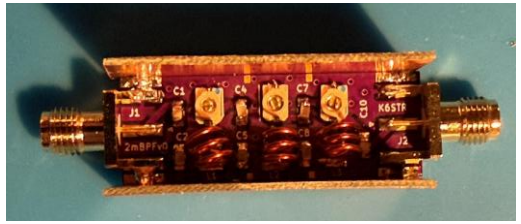


W6LOR

Turning the prototype design into a real product …

Where can I help?

- Mike had a fantastic design, could be made a kit already
- Goal: “Make it fun!”
- My Focus Areas
  - **Customer experience**
    - Connectors
    - Size (go tiny!)
    - Rugged (enemy of size and cost)
    - Easy to build
    - Cost
  - **Performance**
    - Shielding
    - Component variation
  - **Scaling**
    - If successful, we need to be able to scale production with minimal risk (supply chain, production time, etc)
    - Requires PCB revisions, experimentation, iteration, beta testers
    - Manufacturing
  - **Promotion**
    - YouTube, Podcasts, Friends with YouTube and Podcasts, BKG



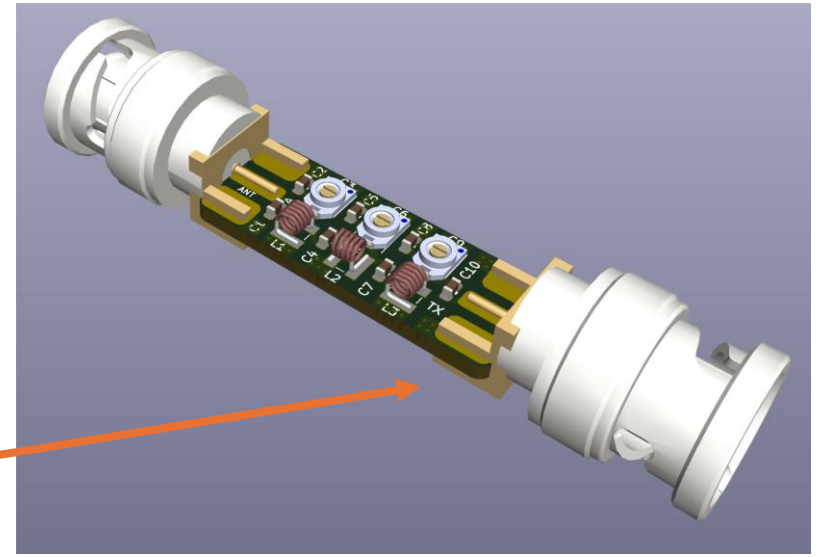
Prototype

???

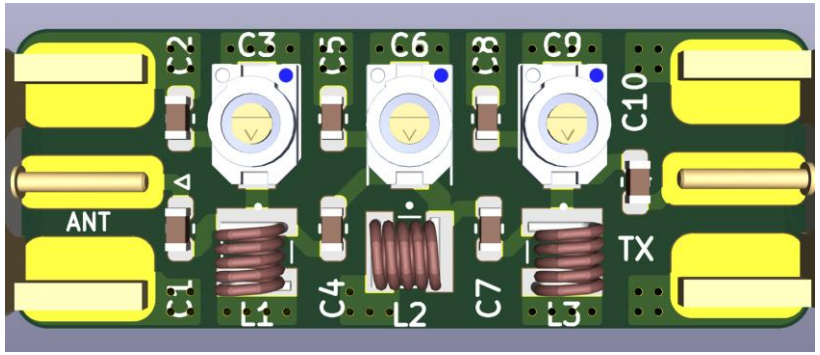


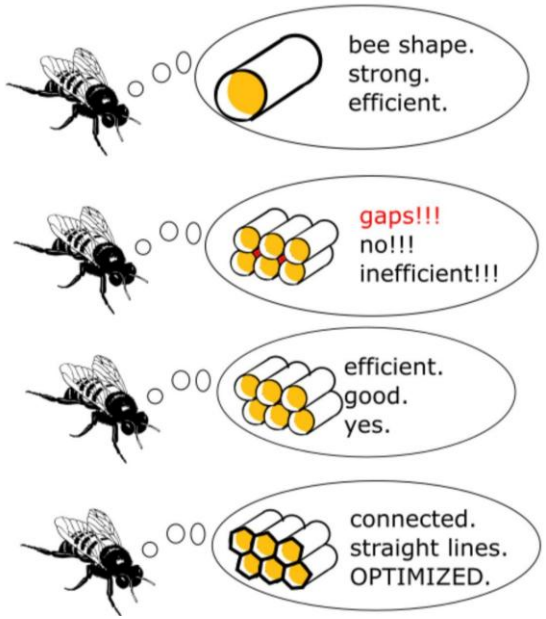
Production

Customer Experience



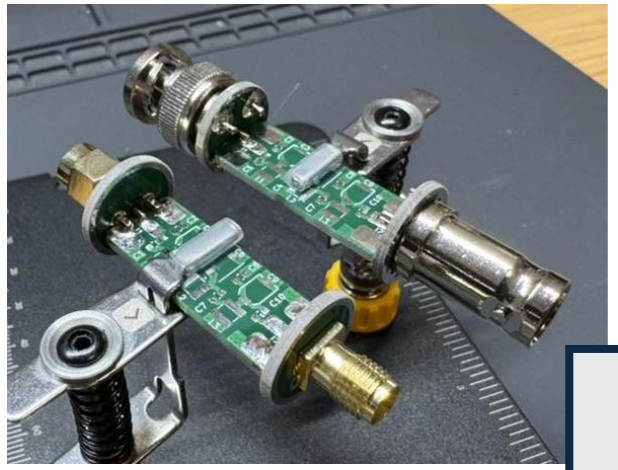
- **Core Principle:** The designer and production engineer should be the customers of their own product
- **Connectors**
  - HT Radios come in BNC and SMA connectors; accommodate both
  - One PCB design to rule them all
  - Customizable
- **Size (go tiny!)**
  - Pick the smallest *readily available* components within part requirements
  - Squish components close together
  - Forget hand assembly of SMT components
  - Cross coupling

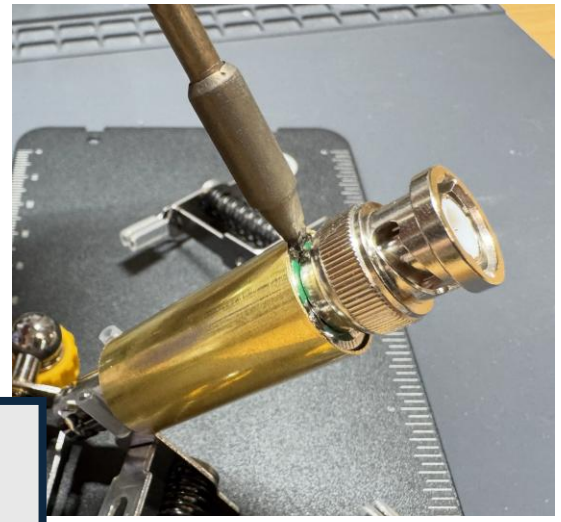


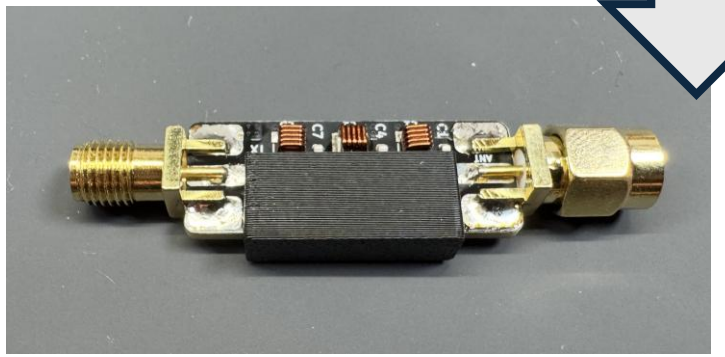


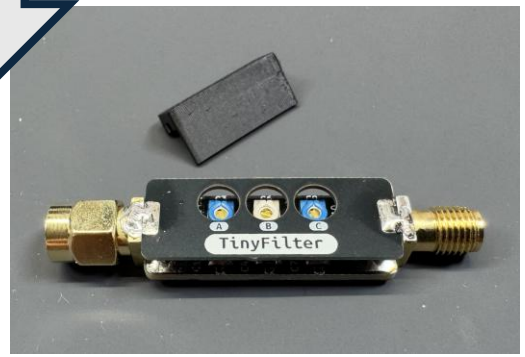
Customer Experience

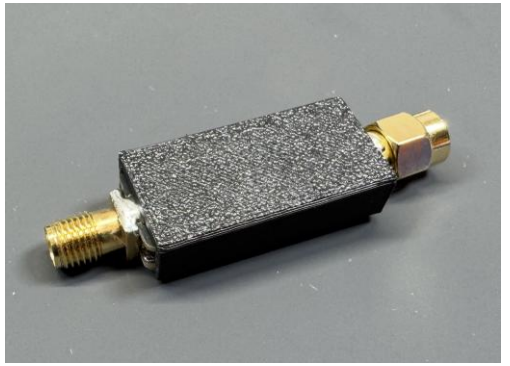
- **Rugged Design**
  - Ruggedization is often the enemy of size and cost
  - SOTA is rough on gear, gear breaks
  - Heavy Antennas and lever arm
  - Protect
    - Internal components, external connector
    - Housing/packaging
- **Easy to build**
  - Should be available as *both* kit and assembled
  - Ideally, requires no special tooling
  - Provide tooling if necessary
  - Good assembly instructions
- **Cost**
  - Select the lowest cost components
    (without compromising quality where it matters)
  - Tolerances affect yield, yield affects cost
  - PCB Assembly for SMT*
  - Manual labor for connectors and shell
    - Good design has very few manual steps







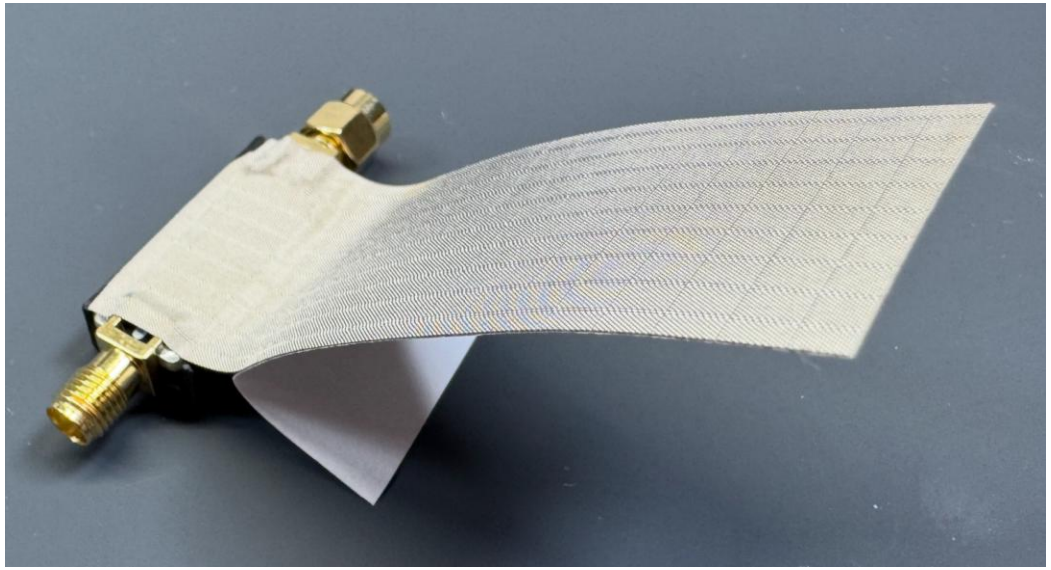






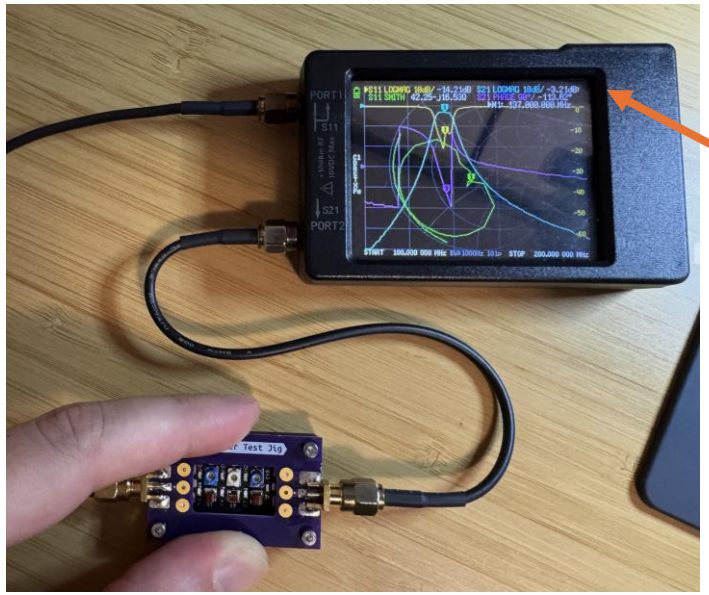
Performance

- **Shielding**
  - Originally didn’t think we needed it
  - Mike demonstrated the value near Mt Wilson
  - Tried the brass metal tube, difficult to build
  - Tried conductive tape around bare PCB
    - Worked to shield
    - But detuned the circuit due to eddy currents
  - Settled on a 3D printable spacer with conductive tape
  - Looks matter, added custom printed heat shrink



- **Component variation**
  - Electronic components have tolerances
  - PCB parasitics
  - Tolerances can stack up -> out of spec filter
  - Out of spec = bad yield = cost go up

- **Beta Testers**
  - Send small batches of product to real world
  - Get feedback!



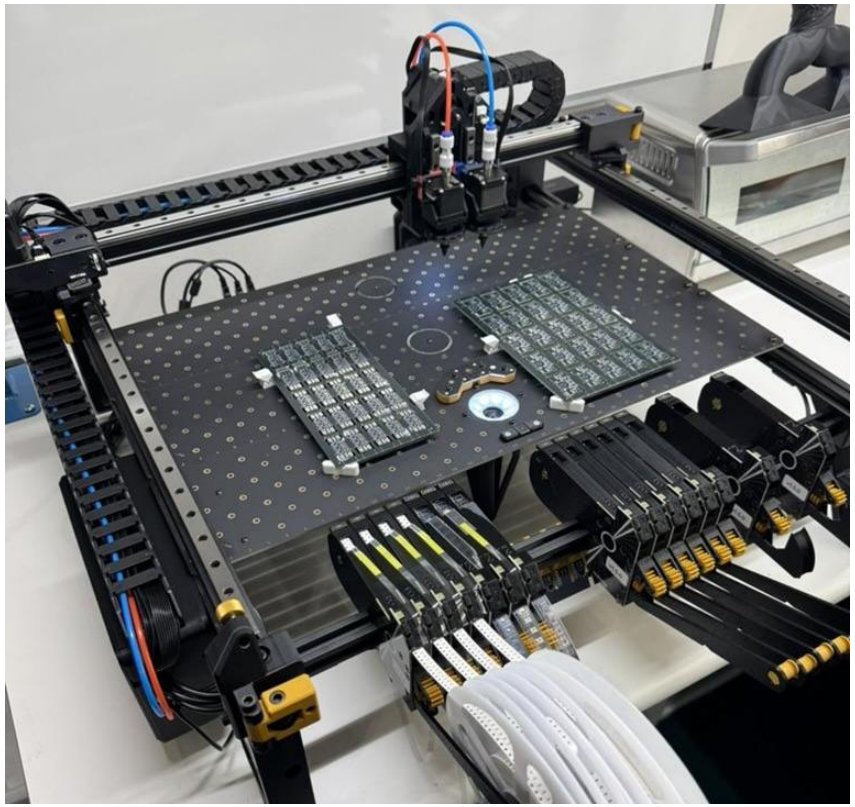
Expected Insertion Loss Range: **2.6-2.8dB**

Measured Insertion Loss: **3.2dB**

FAIL!

Scaling

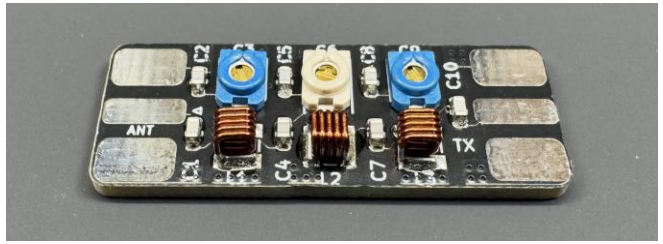
- Assembling one of something is easy, many is tricky
- Demand was predicted to be high (spoiler: it was…)
- Tuning, Connectors soldering, Overwrap
  - Specialized, must do In-House
- PCB Assembly for SMT Components:
  - Pick and Place Machine

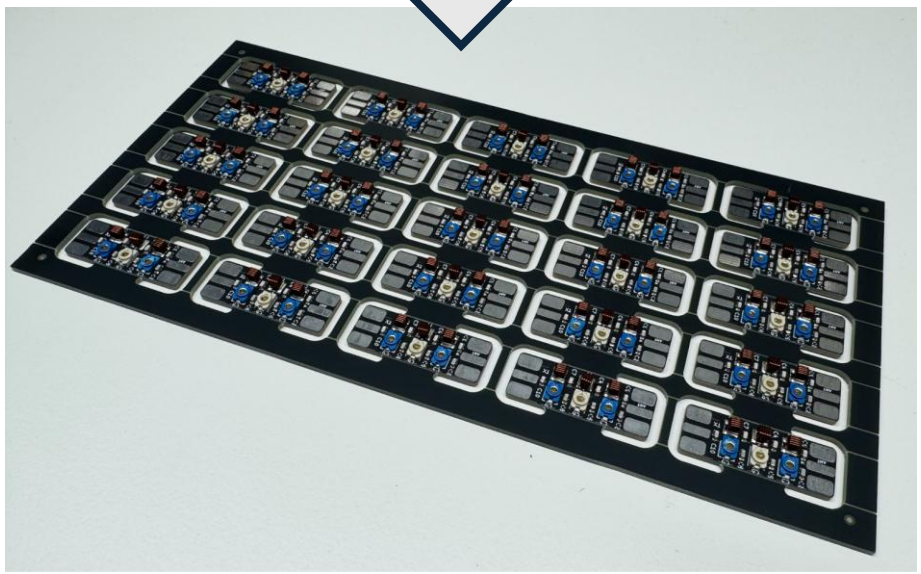


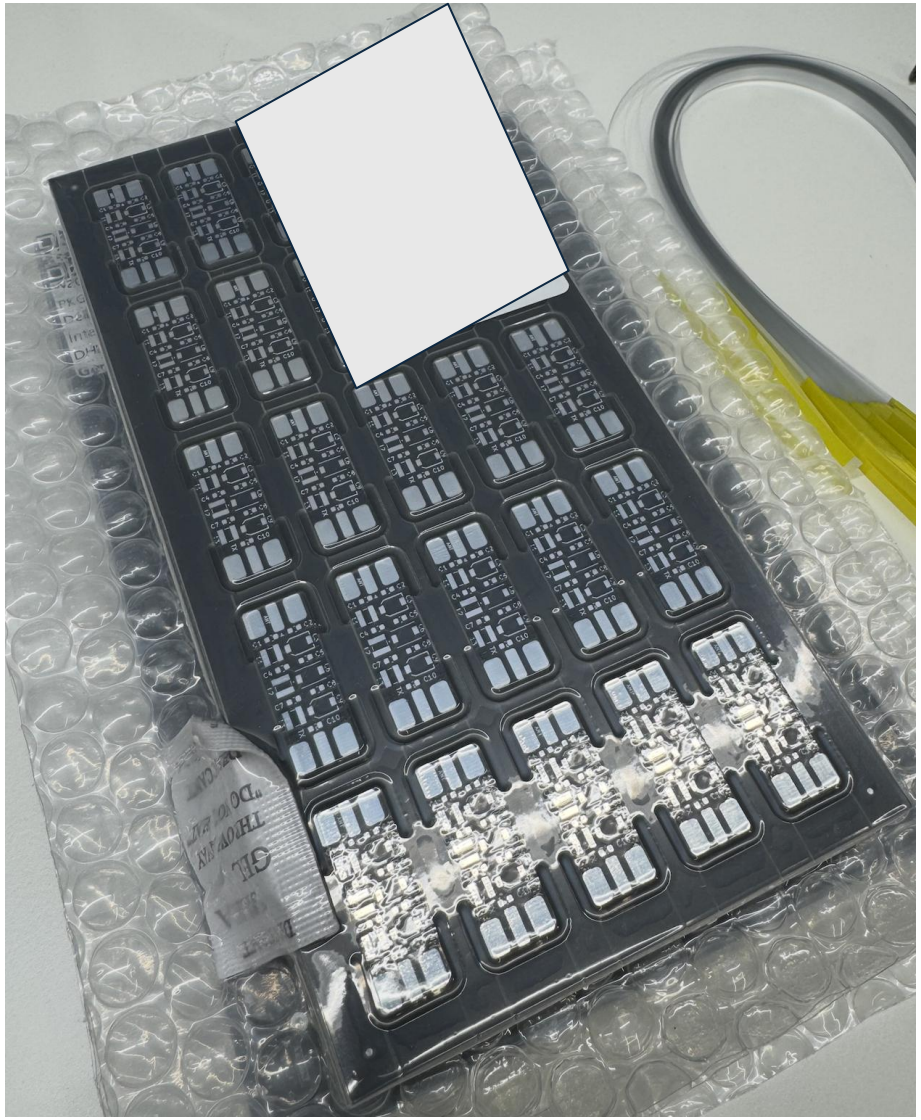
Out-of-House		In-House	
Pros	**Cons**	**Pros**	**Cons**
• Save me time • Better yield	• Costly • Tariffs, Import Duty/Tax • Shipping • Not Flexible • SLOW (weeks/months)	• Low Cost • FAST (hours/days) • Agile/Flexible • MFG in USA	• Initial time and cost investment • After setup, still requires time

In-House PCB Assembly

1. **Panelize PCB**
2. Stencil
3. Solder paste
4. Opulo LumenPNP
5. Reflow Oven
6. Visual inspection
7. Break, tune, record







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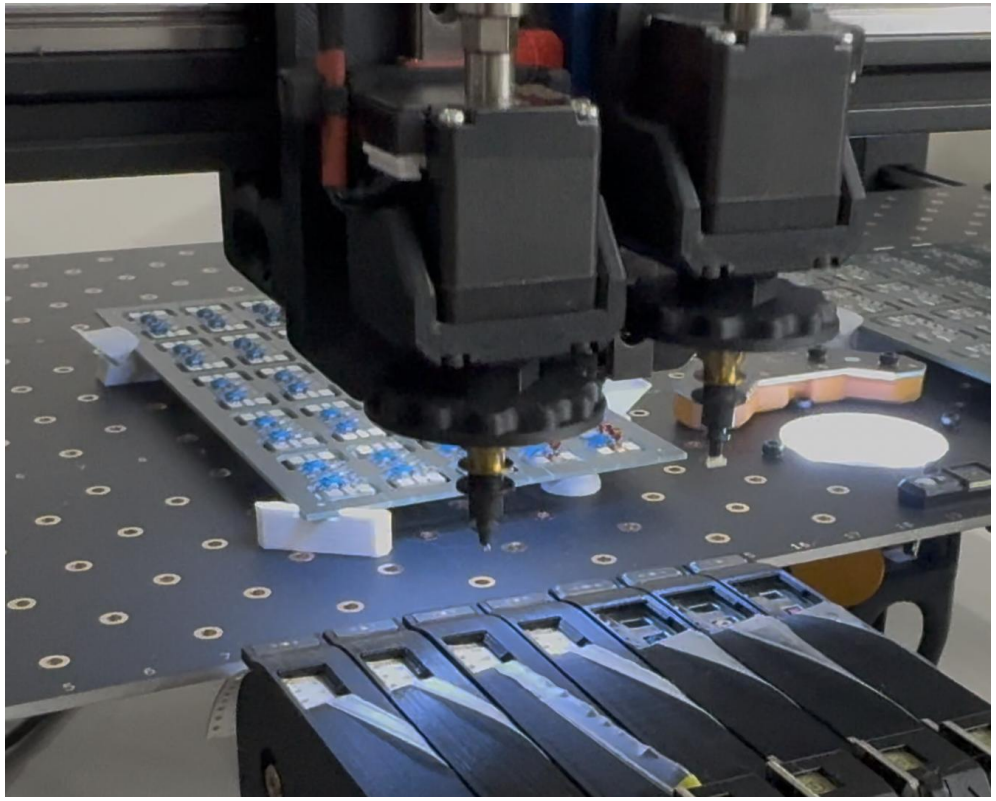


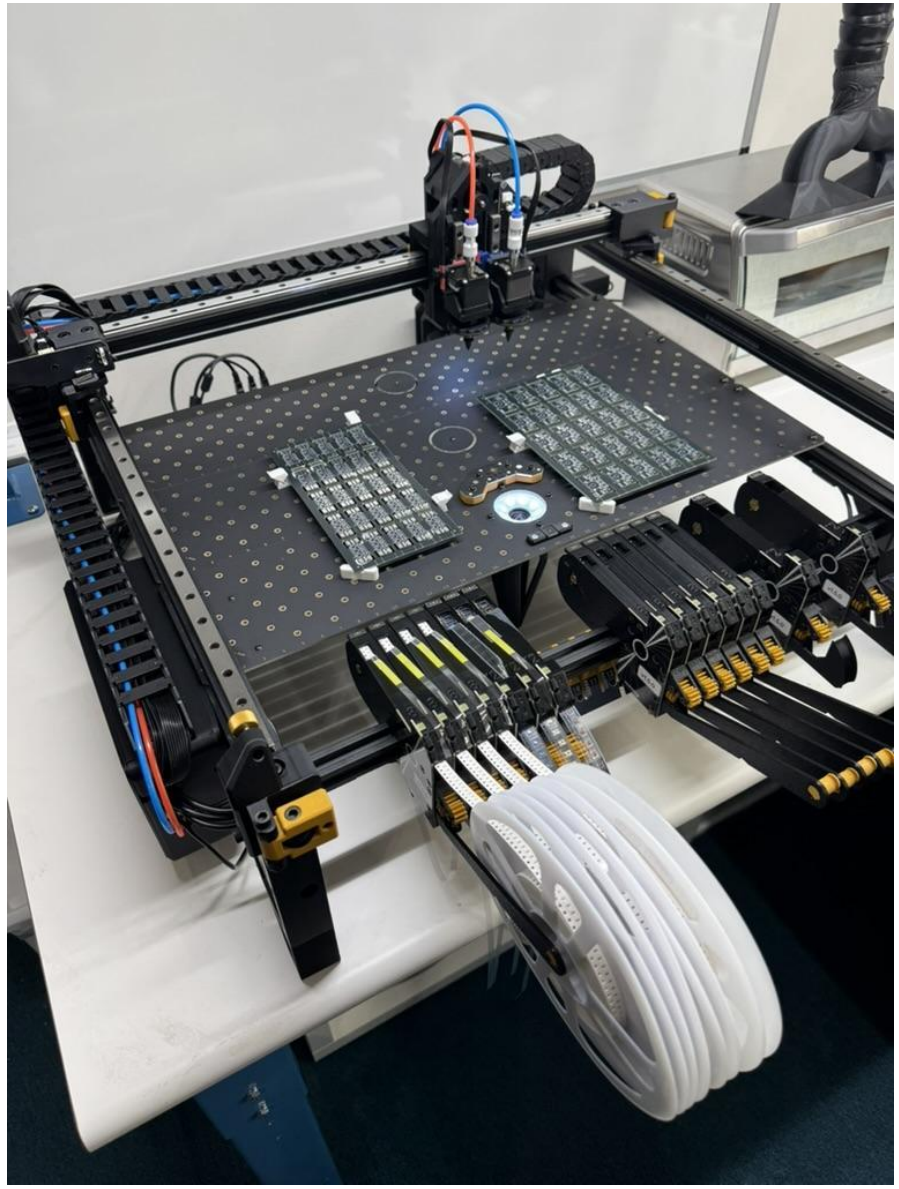


Lead Free Solder Paste

In-House PCB Assembly

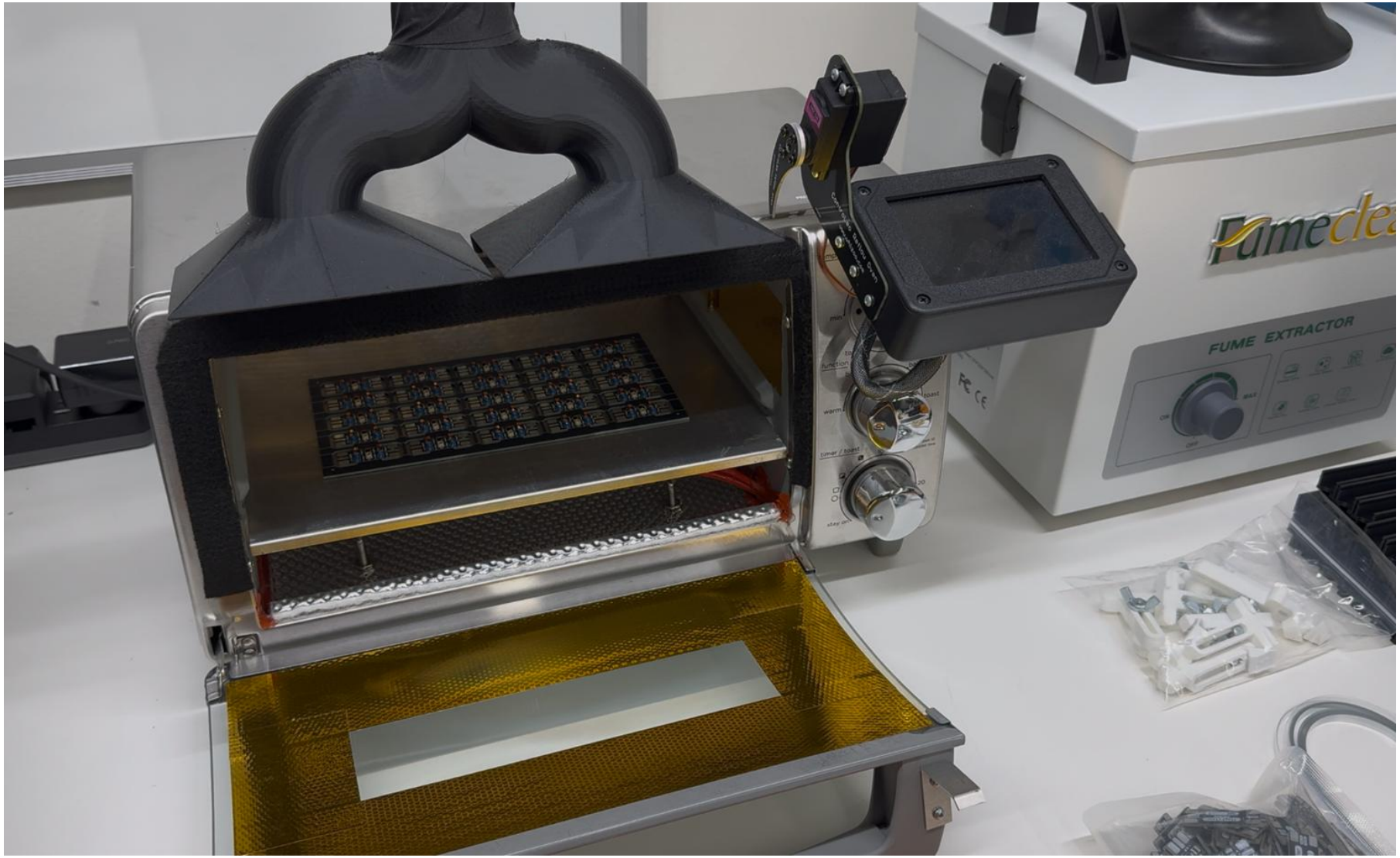
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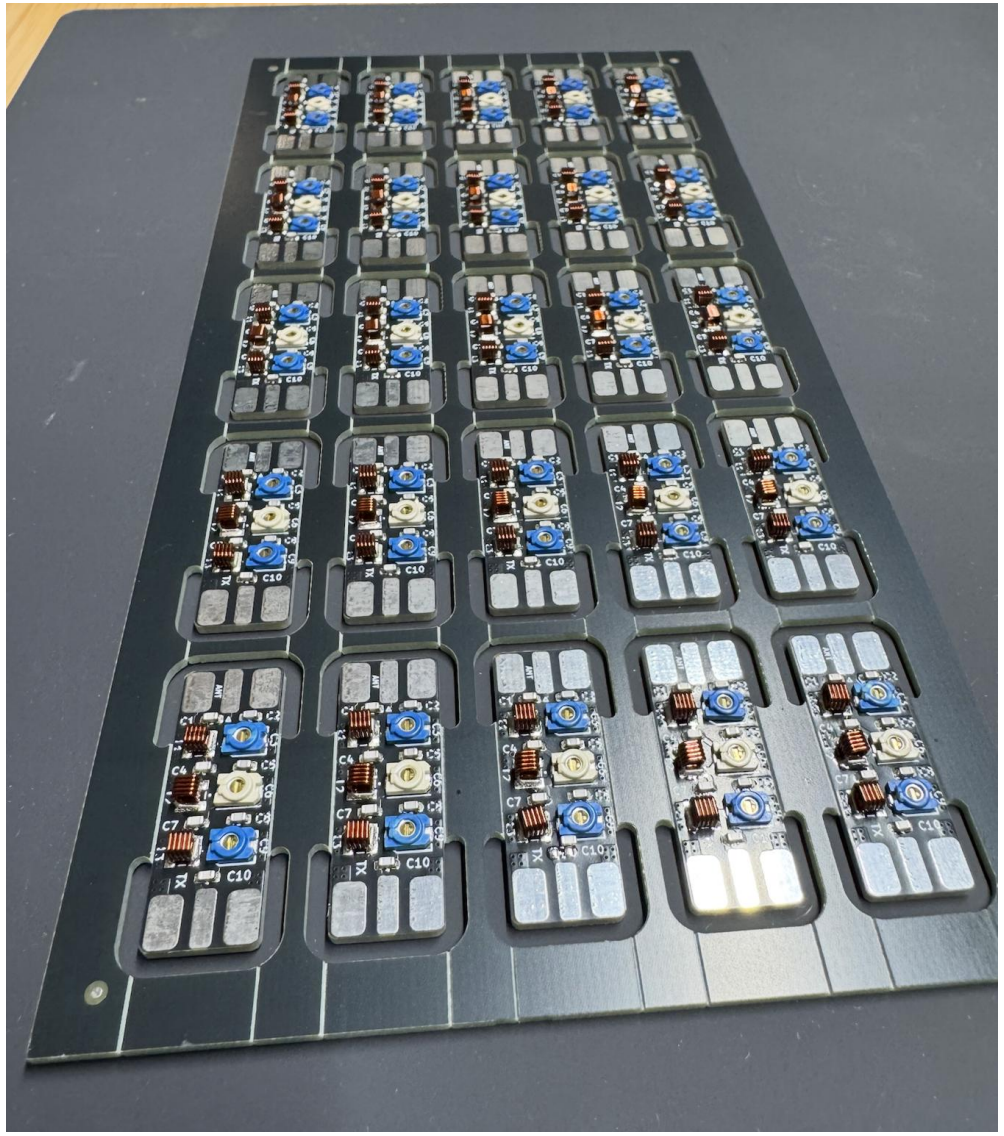
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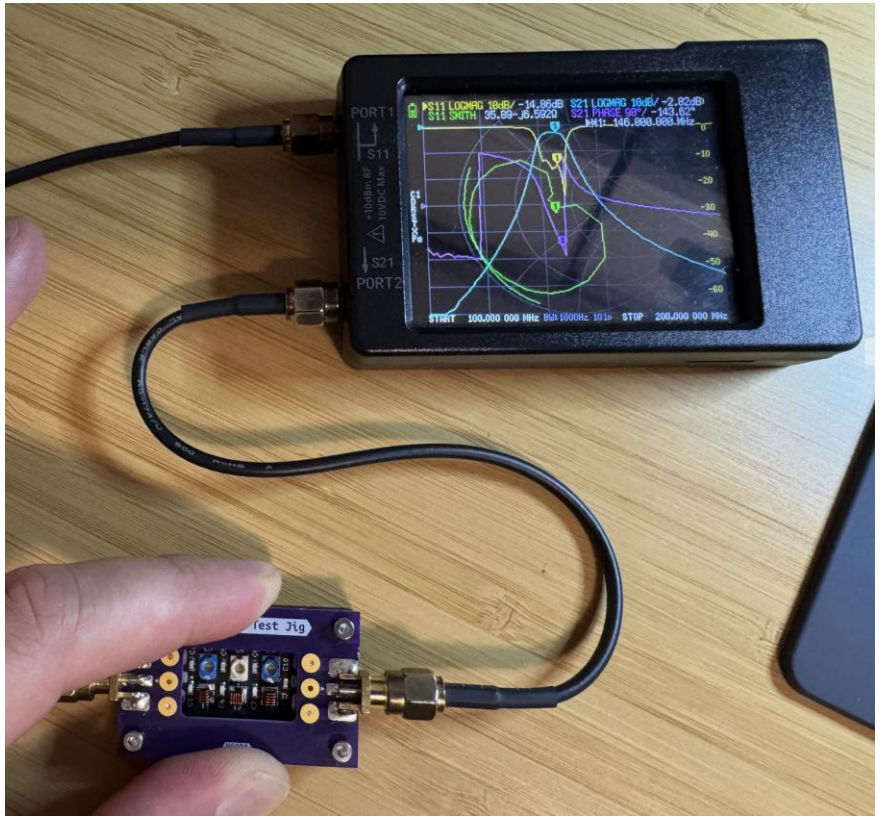
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In-House PCB Assembly

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7. **Break, tune, record**





The community is embracing it!

YouTube
- N6ARA Electronics
- Sofas on the Air (SOTA+)
- Ham Radio Crash Course
- Forrest KI7QCF

BKG
- Quanshengs + CW
- SOTA 2M Challenge
- Perfect timing

Build a good product.
Folks will make videos.









Conclusion and what are we up to next?

- The TinyFilter has found a useful spot in the ham radio world
- Adding the filter to a cheap HT can often outperform an expensive HT without one!
- Also useful to attenuate harmonics at the HT output.

Ara - Build fun products that people love. Focus on the customer experience. Not everything has to be about optimizing for profits. Build, field test, iterate!
N6ARA.com

Mike – I strongly believe that spending time in nature, connecting with others, and building something yourself make the world a better place. I'm beginning to try to write about some of this on a blog:



soldertosummit.com