Great Noise Figure, but still can't hear?

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Most of us have taken preamps to a conference to measure noise figure. Sometimes we are disappointed, but most recent devices provide very good measured noise figures. Then when we get home, they don't improve things as much as we had hoped.

Early GaAsFET preamps provided good noise figure with a terrible input match, very critical tuning, and sometimes marginal stability. Connecting a real antenna could produce different results and even oscillations. Modern designs tend toward unconditional stability and better matching, so that real world performance is good.

At VHF and UHF frequencies, MMICs are available with excellent noise figure with no tuning, making broadband preamps possible with minimal effort. Except for EME, there seems to be little need for anything fancier.

What's the problem?

I designed a new 432 MHz transverter[1] in 2018, and was pleased with the performance. The front end was an untuned MMIC, followed by two printed combline filters separated by a second-stage amplifier to provide good bandpass characteristics. It worked very well for a couple of years.

Activity in this area is sporadic, so I leave the rigs monitoring beacons – for 222 and 432 MHz, VE2FUT/b at 195km distant is weak but solid, a good performance monitor. Sometime last year, the 432 beacon became hard to find; perhaps I should have been concerned. Then in the 2022 January VHF contest, I found that the background noise was very high to the east, so that I was unable to make any contacts in that direction. I suspected that a neighbor had gotten a new gadget and I would have to chase it down when the weather got warmer.

During the 2022 Spring Sprints, N1JEZ complained of overload from me on 222 MHZ. Afterward, we ran some tests; his mast-mounted preamp plus new transverter had too much gain – easily fixed. Then we ran a quick test on 432, and I couldn't hear him. Something was seriously wrong.

After tests confirmed that the problem was the transverter, I opened it up and started tracing signals using a TinySA[2] spectrum analyzer, probing with a 470 ohm resistor with short leads on an SMA connector, in Figure 1. The resistor minimizes loading on the circuit and only reduces signal level by perhaps 10 dB – not a problem for a sensitive spectrum analyzer. I quickly found that the front-end MMIC was not amplifying. I also noticed the fairly strong digital TV signals in Figure 1 being picked up by the short probe, roughly -80 dBm around 470 and 509 MHz.

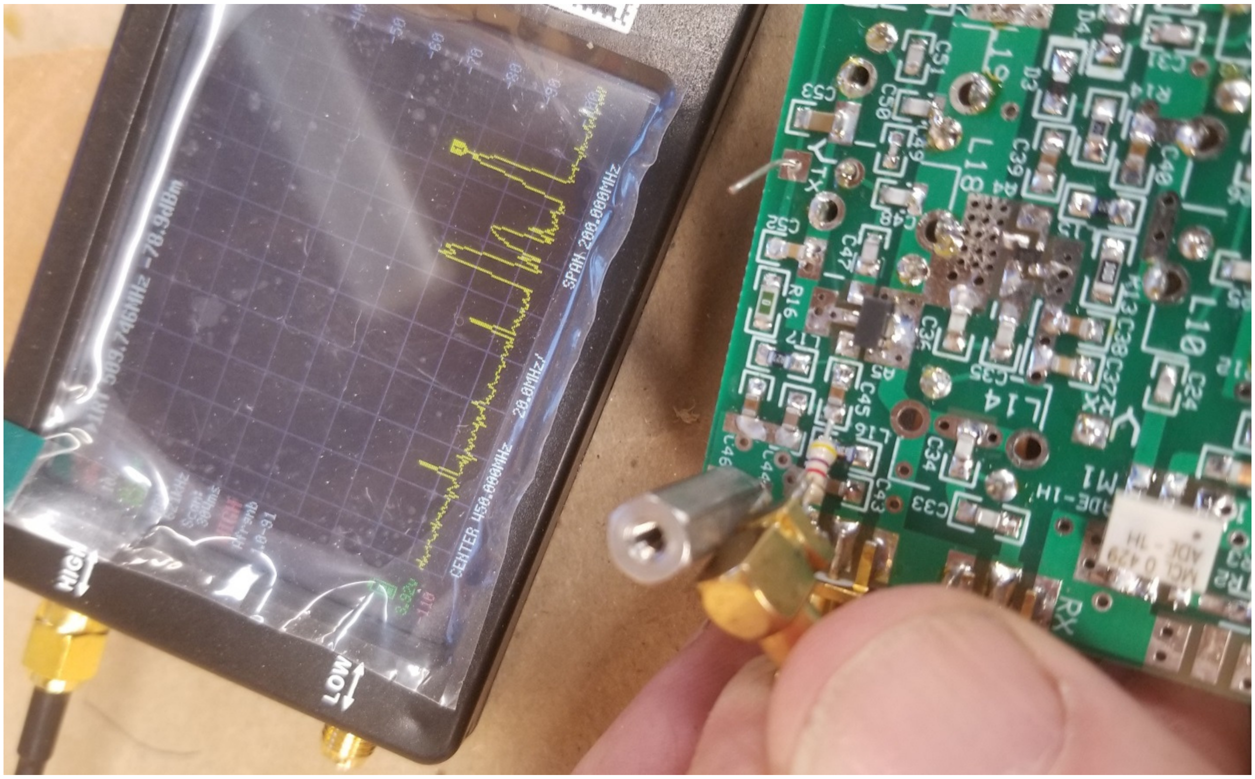

Figure 1 – Probing RF circuit with Spectrum Analyzer thru isolating resistor

The failed front-end MMIC was a Minicircuits PSA4-5043. I replaced it with a PGA-103, which is slightly larger and draws more current, but still has a low noise figure; I thought it might be more robust than the one that failed.

After things were back together, I connected the antenna and still couldn't hear the beacon. The noise floor seemed high and rose much higher with the antenna to the east. Maybe that TV signal was adding noise.

I dug out a combline filter[3] that I built several years ago to see if it would help. It has about 2 dB loss, but 470 MHz is 52 dB down. Putting it in front of the transverter reduced the noise floor by 20 dB and eliminated the additional noise to the east. And the beacon popped right up in the panadapter.

What is going on?

Obviously, the problem is caused by out-of-band signals that the filter attenuates enough. My QTH is line-of-sight to all the TV broadcast transmitters – I can see the towers, 42km away, out the shack window. I connected the TinySA spectrum analyzer to a WA5VJB[4] log-periodic antenna for 400 to 1000 MHz, took it outside, and pointed it at the towers (283 degrees). The 470-476 MHz TV channel peaked at -32 dBm, with additional channels at 482-488 MHz and

506-512 MHz nearly as strong. The TinySA display in Figure 2 shows the DTV signals filling the 6 MHz channels.

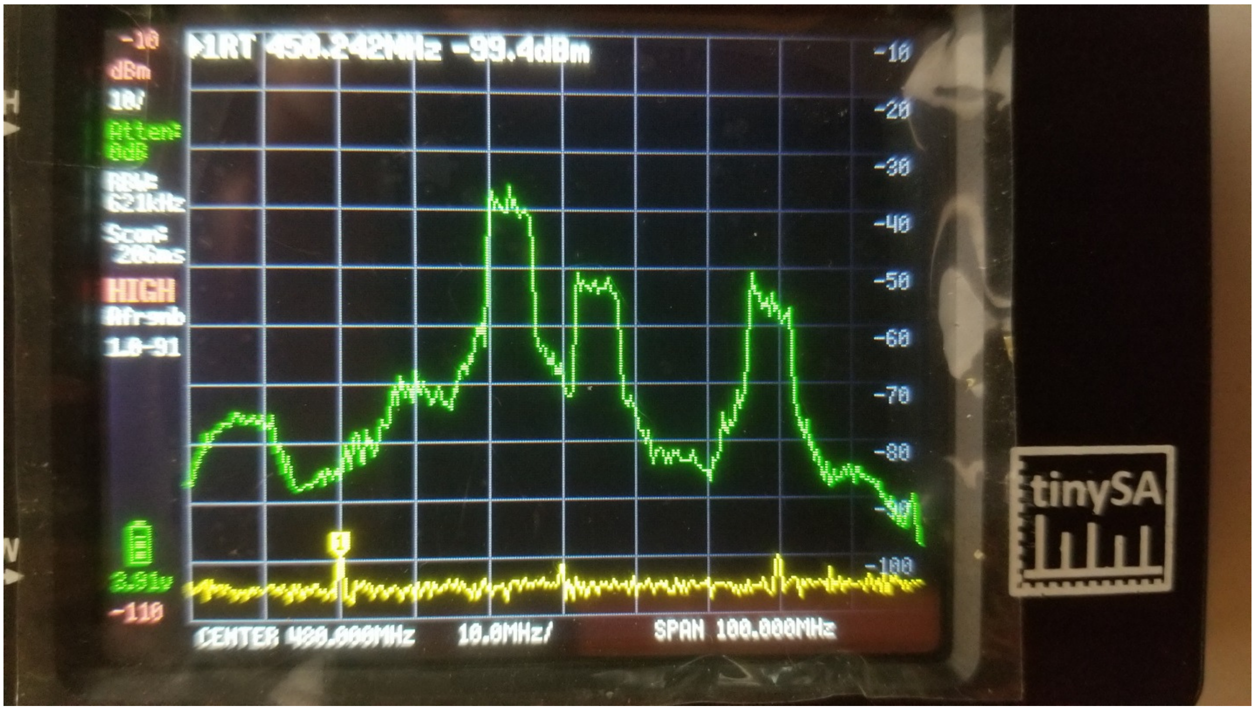

Figure 2 – DTV signals received on log-periodic antenna

How much of this power gets into the 432 MHz yagi?

HEADING	308°	270°	90°	103°(back of Yagi)	
470-476	-52	-54	-48	-44 dBm	WCAX ch3
482-488	-64	-62	-52	-51	WFFF ch44
506-512	-50	-53	-42	-40	WPTZ ch5
578-584	-64				WETK ch33
174-180	-66			-72	WVNY

The highest power into the Yagi is off the back. This is not surprising – at frequencies above the operating frequency, the directors on the Yagi act as multiple reflectors, while to the rear there is only one reflector.

A year or so ago, the FCC reshuffled the DTV channels, moving several of them closer to 432 MHz. I had to rescan the TV set, but hadn't noticed any immediate effect on 432 – I wasn't paying close enough attention.

Intermod

A DTV signal is spread out over the entire 6 MHz channel, as seen in Figure 2. To a narrowband receiver, it is 6 MHz noise source. If we just consider the fundamental signals, the sum and difference frequencies cover the range of 6 to 42 MHz; if the DTV signals get into the mixer, any common IF frequency would suffer.

If the third-order intermodulation products[4], 2F1 – F2 and 2F2 – F1, are considered, the result is even worse. The combination of the strongest channel 506-512 MHz with either 470-476 MHz or 578-584 MHz results in IM products from 428 to 446 MHz, effectively wiping out the entire 70cm band. The untuned front end of my transverter adds another 20 dB or so to the signal levels in the table above, enough to cause intermod in almost any semiconductor device. For a device with a high IP3 (third order intercept point), the calculated intermod level might be 100 dB down, but that is still above the noise floor.

Solution

Clearly, the solution is to keep the DTV signals out of the front end. The comb-line filter[2] has about 2 dB loss, increasing system noise figure by 2 dB, but it is 52 dB down at 470 MHz, with rejection increasing at higher frequencies. With the filter, the noise floor dropped by roughly 20 dB, and is low in all directions. The beacon popped right up at the expected level, so the filter has cured the problem without significantly affecting sensitivity. Better to lose a small amount than not to hear anything.

I had previously noticed the need for a filter on 222 MHz, after a DTV station was moved to Channel 13 (210-216 MHz). The filter here reduced the noise floor by at least 6 dB. I haven't checked recently, but the table above shows nothing on Channel 13. The station that had been there is now on 482-488 MHz. The new station on 174-180 MHz has a signal level of -51 dBm on the 222 MHz antenna.

Having a filter before the front end should be adequate for anything but EME. Some EME stations use cavity preamps – a good one should keep the DTV noise down and have excellent noise figure.

Summary

All sorts of new electronics devices are generating increased RF noise. Broadcast signals were pretty stable for 50+ years, so they could be dealt with once, but today things are shifting around. Whatever the source, it pays to keep track of your noise floor. Monitoring the noise floor and the signal level of beacons on a panadapter makes accurate comparisons possible. Don't trust your ears – noise increases are often small and insidious.

The morning after I finished the first draft of this paper, I noticed that the noise floor on 222 MHz had increased by 5 or 6 dB, not noticeable by ear. Since the beacon level can vary by 30 dB from day to day, that is a poor indicator. Swinging the antenna around found that the increase was mainly in the direction of the TV towers; something had changed. It appears to have gone back down after a day or two.

But that evening, the noise floor on 432 jumped about 15 dB, with dirty signals wandering through the passband. Rotating the antenna made no difference, so I suspect it is some new gadget in the house. This one went away after a bit, so I'll have to chase it down.

So keep an eye on your noise floor. If you wait for a contest or opening, like I did, you might get an unpleasant surprise and miss some QSOs.

Notes

1. Paul Wade, W1GHZ, "432 MHz Transverter for an SDR." http://www.w1ghz.org/xvtr/432MHz_Transverter_for_an_SDR.pdf
2. www.tinysa.org
3. Paul Wade, W1GHZ, "Combline Filters for VHF and UHF." http://www.w1ghz.org/filter/Combline_Filters_for_VHF_and_UHF.pdf
4. www.wa5vjb.com
5. https://www.everythingrf.com/community/what-is-intermodulation-distortion