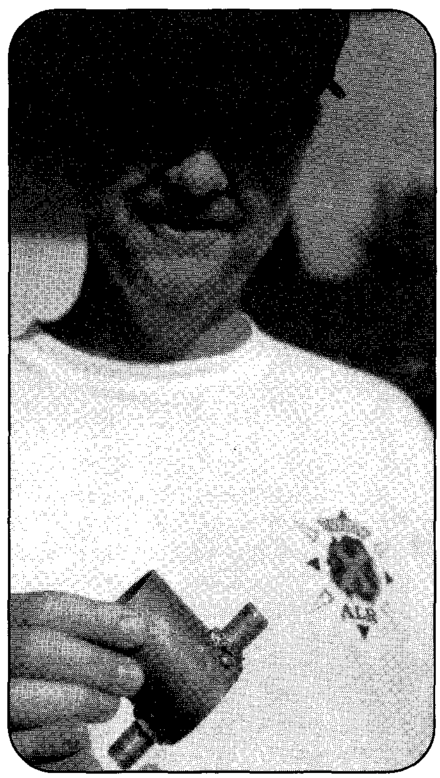
Build a 2-Meter Intermod Notch Trap

Bothered by intermod from high-powered pagers? Trap their signals before they reach your receiver with this build-it-yourself notch filter.

By Jim Ford, N6JF*

If you've heard a grumbling tone on your 2-meter rig, chances are you've become a victim of *paging intermod.* In case you haven't noticed, pagers have become a ubiquitous consumer device. Since they're very small and normally sit next to your body, they have very inefficient antennas. The paging companies make up for this with lots of transmit power and many transmitter sites. Herein lies the problem for hams: their frequency band is close to our 2-meter band (roughly 152.4 MHz for the Southern California area).



The author with the completed 2-meter helical notch filter. Tuned to 152.4 MHz, it "notches out" interference from nearby pager transmitters. (Photos by Gordon West, WB6NOA)

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Intermod Reduction Techniques

The effects of intermod, or intermodulation distortion, are heard when two or more strong off-the-air signals create additional signals inside your receiver. The fact that these additional signals are not really there is little comfort to the person receiving the interference. What causes the "phantom" signals is *non linearity* of the receiver itself. All receivers have it to some extent, but some are more prone to problems than others.

There are three common methods of reducing intermod problems.

1. Strengthen receiver front end (RF stage, mixer, and IF)
2. Add a bandpass filter
3. Add a notch filter

Let's briefly look at each of these, starting with the front end.

Receivers today are often designed with more emphasis on price than on big signal performance. For example, many receivers use dual gate MOSFET transistors as first mixers. These transistors are good considering their price, but are not so good when encountering big signals such as the pagers.

A more expensive but "bulletproof" mixer is a *diode double-balanced mixer.* These are immune to interference, but they have loss instead of gain and require much more local oscillator power to drive them. This requires two additional amplifier stages, one to make up for the lost gain in the mixer and the second to amplify the local oscillator signal. This, of course, raises the price. Finally, IF (intermediate frequency) amplifiers that are designed for big signals are generally current hogs with more power supply drain than other devices, and perhaps even require a small heat sink. Good RF front end design can reduce both in-band (144 to 148 MHz) and out-of-band intermod. But receiver front end redesign is a major project, and not our emphasis here.

Bandpass Filters

Bandpass filters are a good way to reduce intermod caused by out-of-band signals (*for more on bandpass filters, see "Sniffing Out 'Birdies' on Your Radio,"* CQ VHF, *September, 1996.—ed.).* But the most common paging frequencies are just slightly out-of-band, in percentage terms, to 2 meters. A bandpass filter will have to work hard to eliminate the paging signals. Getting the necessary level of rejection often requires more than one stage—and that, again, means a greater expense. To its credit, a bandpass filter will reduce interference caused by any-

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Top view of the filter. Note that there is no top connection for the helical coil. Solder blob indicated is the connection point for the bottom end of the coil. See text for attachment details.

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thing outside of the band, including mixer images. But that also means you'll need to bypass it if you want to listen to anything outside the 2-meter band, such as aircraft or weather. And, generally speaking, the bandpass filter needed to eliminate paging signals from a 2-meter receiver will have more loss than another alternative, which *is* the focus of this article. Enter...the notch filter.

Take a Notch out of Intermod

The final common method of reducing paging interference is a *notch filter*. A notch filter blocks all signals from a narrow frequency band. It does not need to be bypassed when listening outside the 2-meter band (unless you like to listen to pager signals). And a notch filter generally has less loss than a bandpass filter. The only disadvantage is that it eliminates interference from only a very narrow group of frequencies. Is this a problem? Only if your interference comes from a variety of sources on many different frequencies.

One of the ads from a notch filter manufacturer states that 99% of intermod comes from the paging frequencies. I don't know if this is true for everyone, but I know that paging transmitters cause the majority of *my* intermod problems.

I recently had a chance to test a bandpass filter by DCI and a notch filter by Par Electronics. Both of these products are excellent, and I'd recommend them wholeheartedly. However, if you want to brew your *own* notch filter that has very low loss, excellent VSWR, and can handle the power of a 50-watt transceiver, then read on—this project's for you.

What You'll Need

This notch filter is basically a helical resonator hooked up as a "suck-out trap" with a tuned coupling loop as an input/output. The design uses a 2-inch copper water pipe (type M) available from many plumbing supply houses. It should be 2.65 inches long (being off by a 1/10 of an inch should cause no problems). I had to buy a minimum length of 12 inches for just under $10, but it was good to have extra pipe, since I tried two versions of this project.

While a hacksaw will work, I got a much cleaner cut by premarking the length and having the local plumbing supply house cut it for me with its large tubing cutter. They charged me $2 for this service. You'll also need:

- Three feet of bare #10 copper wire for the coil. Actually, this is enough for two coils in case you make a mistake.
- About 6 inches of #12 enameled wire for the coupling loop. You can use the #10 wire for this as well, but it's harder to work with.
- A loop tuning capacitor. I used a 15-pF, 100-volt disc ceramic (Digi-Key part number 1328PH). A silver mica or a chip capacitor should work at least as well.
- Some sort of feedline connector (two of them). The type you use is your choice, but I used two SO-239s.

Building the Filter

The helical coil should be 1.1 inches in diameter, 1.625 inches long, and about 5.75 turns. I say *about* 5.75 turns because it will vary according to your exact diameter, pitch, and centering in the tube. I'd start with 6.25 turns and a length of 1.66 inches, then tune it by cutting the top with stout wire cutters (more on this later). I used a piece of 3/4-inch Schedule 40 PVC tubing as a form to wind the coil. It has a diameter of 1.05 inches, and the coil diameter was just right after I removed the PVC. If you don't have a 1.05-inch form, then use a 1-inch form with two or three turns of black tape on it. Wind the helical coil as tight and close as you can on the form. It's easy to stretch the coil to the right length but harder to get good form if you have to squeeze the loops back together.

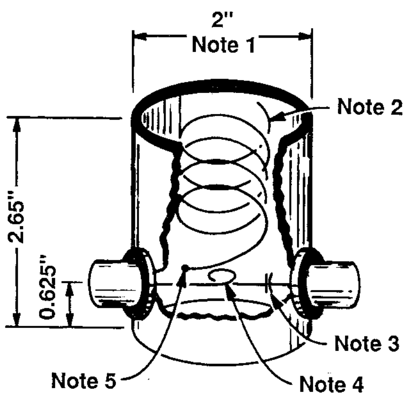
The coupling loop is 1-1/2 turns close wound on a 5/8-inch form. It should be parallel to the larger coil, but shouldn't touch it, and in the same plane as the connectors. The smaller coil should be centered in the tube and wound in the same direction (clockwise, for example) as the main coil for maximum coupling.

The 15-pF capacitor is soldered directly between one of the connectors and the 1-1/2-turn coupling loop. I didn't like an unsupported connection at the coil, but thought more hardware in the RF field inside of the tube would create more problems than it would solve.

Connecting the Connectors

I found that a regular SO-239, connected to the copper tube with two brass nuts and screws, was the easiest approach to connecting the coax. The start of the helical coil and both connectors are .625 inch from the bottom of the tube (see Figure). I used a 5/8-inch chassis punch to make the connector holes on my second version. The chassis punch slightly flattens the copper tube, but that isn't a problem. The connectors should be mounted directly opposite each other. The flange on the SO-239 should be mounted on the *outside* of the tube because, otherwise, the connector would protrude too far into tube and interfere with the helical coil. In fact, you'll still need to file off about half of the connector pin to avoid being too close to the helical coil, but there will be enough pin left to make a solder connection.

In addition to the holes for the connectors, you'll need to drill a 7/64-inch hole about 3/4 of an inch away from one of the connectors (technically, it should be measured in degrees, but this is close enough). This is where you'll connect the helical coil. The #10 wire is almost exactly .100 inch in diameter, so the nearest fractional drill bit for the hole is 7/64, which is .109 inch. Insert the end of the coil in the hole and solder it, both on the inside and



Notes
1. 2-inch (type M) copper water pipe
2. Helical coil made from #10 bare wire, 1.1-inch diameter, 1.65 inches long. Start with 6.25 turns, then trim to match specific notch frequency (approximately 5.75 turns; see text), then squeeze or compress coil for fine tuning
3. 15-pF, 100-volt capacitor (disc ceramic or silver mica)
4. 1.5 turns #12 enameled wire, 5/8-inch diameter, close-spaced. Wind coupling loop in the same direction as the large coil (e.g., clockwise) and position for maximum coupling or *worst* SWR at 152.4 MHz
5. 7/64-inch hole spaced 3/4-inch from connector and 0.625 inches from bottom (same as center point of connectors). Insert bottom end of coil and solder inside and out with propane torch, using silver solder if possible (see text). Do this *before* attaching the connectors.

Figure. Parts layout of the helical trap (notch) filter. See notes and text for construction details.

Bottom view of the filter. The author suggests attaching the coax connectors to the tube with brass screws and nuts, rather than trying to solder them on, as he did. Note the smaller coupling coil and capacitor connected between the coax connectors.

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the outside, using a propane torch (see instructions below). Do this *before* you put in the connectors to avoid burning them. The inside connection is the most important, electrically, as most of the RF is on the inside of the tube. The outside solder connection is for added strength.

Attaching the Main Coil

First, brighten the end of the #10 wire with some steel wool (*without soap)* or sandpaper, and pre-tin (coat with solder) about an inch of the end with regular 60/40 solder. Leave a little extra on the end so you can grab the wire from the outside of the tube *with pliers* to rotate the coil inside the tube if necessary, before soldering. You can then hang a pair of "Vise Grip"-type pliers on the wire to help hold it in place during soldering. Solder the coil on the inside of the tube with 60/40 regular solder.

After soldering the coil, I suggest you *resolder* the connection with silver solder (you can get a small roll of it at most hardware stores for about $2). Silver solder is much stronger and will hold the coil much better without the danger of it breaking off because of vibration. Silver solder does require a higher temperature, but a propane torch (or soldering gun when not soldering such a large mass) has more than enough heat. The amount of silver in the solder is small and doesn't help conductivity much, but it does add strength. (The reason for soldering first with regular solder is that it seems to adhere better. Perhaps the 60/40 solder has a more active flux. In any case I've had better luck with this method.) There is no connection at the top of the coil.

As always, safety comes first. I use a flame tip for soldering and not a soldering tip attachment, so I also use safety glasses, hat, and gloves for a project like this. Consider doing the same.

Tune Up

The best way to tune the filter is to terminate either connector with a 50-ohm resistor or dummy load and connect an SWR analyzer to the other connector. If you don't have an SWR analyzer, such as the MFJ 259, borrow one if you can (next to a multimeter, I believe these are the most useful pieces of test equipment a ham can own). Tune the SWR Analyzer from about 100 to 150 MHz. There should be a marked increase in SWR at some frequency which should be *lower* than the frequency you want to notch out, since the coil should be a little too long at this point. What you want is to have the worst SWR fall out at roughly 152.4 MHz. Cut a maximum of 1/4 inch off the top of the helical coil and remeasure the worst SWR frequency. It should have moved higher. If you overshoot the desired frequency, don't worry because you can compress the coil slightly to lower the frequency. You can change the frequency by as much as a couple of MHz by expanding or compressing the coil, but it is best to keep this to a minimum since the length of the coil was calculated to give maximum Q (approximately 1200) and performance. (*"Q" is a measure of efficiency of a coil or tuned circuit.—ed.*)

If you can't get your hands on an SWR analyzer, an alternative tuning method is to hook up a signal generator to one connector and use a 50-ohm terminated oscilloscope as a null detector on the other connector to determine the best "suck out" frequency.

No Covers Needed

There are no top or bottom covers on the trap because they generally aren't needed. I tested it with and without covers and found no difference in performance, except that the covers lowered the resonant frequency by a MHz or more.

There are, however, two situations in which you might want to put on covers. Without covers, the resonant frequency of the trap will change if the top is within 3/4-inch or the bottom within 1/2-inch of a metal surface. Mine sat on a nonmetallic operating table, so it wasn't an issue for me. Another reason might be RFI from a computer in the same room. I ran a before-and-after test with a handheld using low power and a dummy load in the same room as the computer. The signal was about 10 dB louder with the covers off, suggesting a slight loss of shielding without covers.

If you want to put covers on the trap, first tune up the filter *without* any covers attached. Next, solder on a bottom cover. Then temporarily hold on a top cover and find the new lower frequency. Slowly

Resources

Most of the parts for this filter can be purchased at a local plumbing supply house or home center. Contact information for the manufacturers/dealers mentioned in this article is as follows:

DCI Digital Communications, Inc., Box 293, 29 Hummingbird Bay, White City, SK S0G 5B0 Canada; Phone: (306) 781-4451 or toll-free from the U.S.: (800) 563-5351

Digi-Key Corp., 701 Brooks Ave. S., P.O. Box 677, Thief River Falls, MN 56701-0677; Phone: (800) 344-4539; Fax: (218) 681-3380; Internet: <http://www.digikey.com>

MFJ Enterprises, P.O. Box 494, Mississippi State, MS 39762; Phone: (601) 323-5869; Fax: (601) 323-6551; Internet: <http://www.mfjenterprises.com>; for the location of a dealer near you, call (800) 647-1800.

PAR Electronics, 6869 Bayshore Dr., Lantana, FL 33462; Phone: (561) 586-8278; Fax: (561) 582-1234; e-mail: <par@magg.net>

trim the coil until it's resonant at the desired frequency. Once that adjustment is made, the final cover soldering operation (the top cover) shouldn't change the resonant frequency.

Results

This filter has eliminated over 95% of my intermod. The VSWR across the 2-meter band is an excellent 1.1:1, or better. The loss is also very low, at .1 dB, which is better than most commercial vendor specs. The 152.4-MHz null is 18 to slightly more than 20 dB, which is less than the commercial vendors who advertise over 30 dB.

At first I was disappointed, but it did the job very well and with very little loss. I think the reason has to do with intermodulation theory. Remember that the intermod interference you hear is a product of at least two signals. When you reduce the strength of one of the signals by 1 dB, the product (your interference) goes down by at least 3 dB. So by reducing the strength of your paging signal by 10 dB, the interference is reduced by a whopping 30 dB!

Really Stubborn Cases

Getting more reduction generally costs you more insertion loss. If you have an extreme case of interference and need more rejection, there is one thing you can try. Increase the inductance of the coupling loop by increasing either the diameter or number of turns. You'll then have to reduce the value of the capacitor to compensate for the increased inductance. I was successful without this change and hope you are, too.

Tuning Out

Once the completed filter is in line between your radio and your antenna, you should find a dramatic decrease in the amount of pager intermod, if not a complete elimination of the problem. I'd like to acknowledge Wes Hayward, W7ZOI, for his helpful suggestions concerning this project. ■