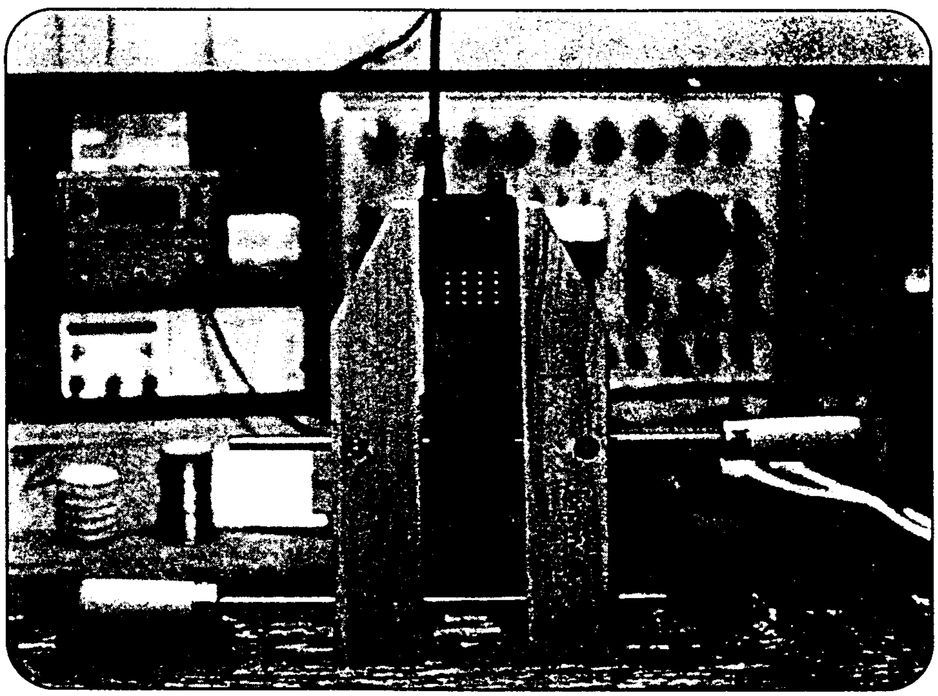
Very Converting to ^ Narrow Band

Commercial FM users are squeezing more channels into available UHF spectrum by reducing their bandwidth to 12.5 and even 6.25 kHz. Here's how we can do the same on our 440-MHz band.

By Rod Wheeler, WA6ITC*

Editor's Note: When we printed WA6ITC's "Op-Ed" promoting narrower FM bandwidths in the December, 1996, issue of CQ VHF, *we also challenged him to show us how to do it. He met the challenge. Here's how.*



How do you squeeze more channels into our crowded repeater subbands? You could try this approach, but a narrower IF filter could be much more effective—and less expensive! (Photos by Joel Gelfand, KD6BRI)

With more and more amateurs joining our ranks, and it's well over half a million now, we're going to have to use our precious spectrum of frequencies more efficiently.

In reading through the 1984 *Radio Amateur's Handbook* (now *The ARRL Handbook*), I found "The Amateur's Code," right in the front, next to a picture of Hiram Percy Maxim. Point #3 of the code says "The amateur is progressive....He keeps his station abreast of science. It is well-built and efficient. His operating practices are above reproach." On the same page, under Technical Developments, it says that the "ever-growing Amateur Radio continually overcrowds its frequency assignments, spurring amateurs to the development and adoption of new techniques to permit the accommodation of more stations." This need for additional channels on which we can operate will lead to ever narrower channel spacing and bandwidths to more efficiently use our limited radio spectrum.

We've done a lot to improve this situation on the HF bands, where the use of single sideband transmission has given us a three-fold increase in usable "channels" over the days of AM. For some reason, we haven't done the same in the VHF and UHF spectrum. On 440 MHz, for example, we stopped at 25-kHz channel spacing while the commercial operators went to 12.5-kHz and are now heading for 6.25-kHz spacing.

Maybe it's time to start converting our old 440-MHz FM radios to take advantage of 12.5-kHz channel spacing. The radios will still work fine on the current repeaters but will have sharper IF selectivity. It's like working on the HF bands, but when the bands gets busy, you'd simply switch to narrower filters to help block out adjacent stations.

It's Not Really Difficult

A simple switch of the IF filter in your radio and the implementation of CTCSS encode and decode will open up a lot of new channels for all of us. Old amateur equipment from the '70s and '80s was

**Rod Wheeler, WA6ITC, has been a ham since 1959 and has been involved with repeaters since 1964, including two 12.5-kHz bandwidth machines in the Los Angeles area. Professionally, Rod is the Radio Shop Foreman at Disneyland.*

Converting Surplus GE Repeaters to 12.5 kHz

Many amateurs use the General Electric MASTR II, Executive II, and MVP series radios as the building blocks of their repeaters. The 150- and 450-MHz versions of this radio use an 11.2-MHz IF system. Narrow filters at this frequency are difficult to find. But Communication Specialists (see "Resources") has an abundance of 10.7-MHz filters with a bandwidth of 3.75 kHz, so I thought it might be possible to modify the GE radio to a 10.7-MHz IF system.

I replaced the 11.2-MHz filters with the 10.7-MHz narrow filters, realigned the IFs, and it worked! The receiver now had a true 12.5-kHz bandwidth and worked just fine—and all with a few dollars worth of filters. There will be one additional expense: a new receive crystal. Since the IF was changed, I'll have to order crystals .5 MHz higher than I want to listen to in order to end up on the right frequency. Changing the 10.7- or 21.4-MHz IF filters ahead of the 455-kHz filters will improve the overall receiver operation and avoid relying on one filter for all bandpass requirements.

designed for 25 kHz channels because the commercial equipment back then also used 25 kHz separation. Today's amateur FM equipment is a lot better, but it can still be narrowed with little effort and cost. Turning down the transmitter's deviation is even easier, and, if everyone used ± 2.5 kHz, it would allow for a little extra adjacent channel spacing.

I found CTCSS encode and decode capability to be the single greatest help in rejecting adjacent channel interference, with different tones reducing adjacent channel interference by as much as 40 dB. So, by using narrow filters *and* CTCSS encode/decode, we could double, and someday quadruple, our channels on the 440-MHz band. Applying the same concepts to the 2-meter and 222-MHz bands could help solve overcrowding there, too.

Don't Panic!

Now don't panic over the thought changing our current 25-kHz channel spacing to 12.5 kHz on the 440 band. The commercial users did it in the early '80s and found it worked very well. Even changing to 10-kHz spacing on 2 meters and 222 MHz isn't that big of a deal; it's like changing from AM to SSB was on HF. In fact, you don't even need a schematic to modify most FM radios. And, if you do the work yourself, the cost should be about $10. Now that shouldn't wipe out anyone's bank account.

A Bit of Theory, or... Why Bother?

What's the point in changing to a narrower bandwidth if none of the repeaters in your area are doing the same? First, you'll have a tighter receiver that's less prone to interference. Second, you'll be able to use spectrum more efficiently. But how does all this work?

Let's take a look at where selectivity in a receiver is achieved. There are three basic areas of selectivity in the receiver. First is the *front end,* where the input frequency is selected. However, the filter here is usually a bandpass type of filter and the selectivity is designed for a whole band, not a particular frequency. Second is the *Hi IF* Here we find the 10.7 MHz or similar frequency amplifiers and filters. These add greatly to the receiver's selectivity, but only bring it down to the ± 30 kHz range. In some radios (notably the GE MVP and Executive II radios used for many repeaters), you can add filters

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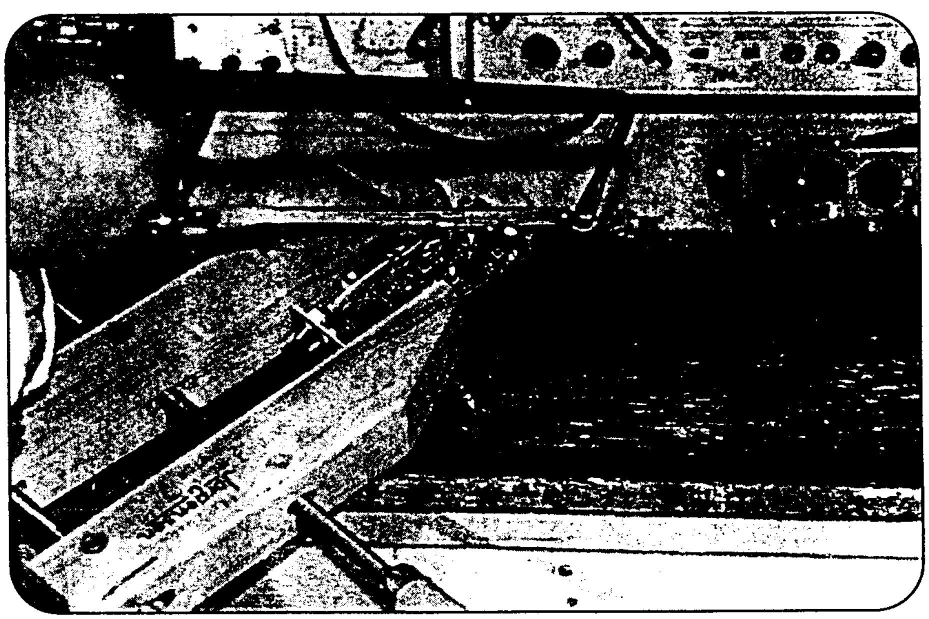
in this area to improve selectivity. Finally, there's the *Low IF,* generally 455 kHz, which is where most radios get their real selectivity, mainly because it's easier and less expensive to do it at 455 kHz than at higher frequencies (see Figure 1).

The Low IF filter is located near the receiver's discriminator or audio detector (sometimes, there's more than one filter, as shown in Figure 1). The vast majority of radios use filters made by muRata. These look like small black cubes with either "455" or "55" written on the top followed by a letter; that letter tells you how selective your radio is (see Figure 2). The filters are very inexpensive and readily available (see "Resources").

Open Up That Case

To sharpen the selectivity of your radio, you'll need to find out which filter you have and which one you need. Take your radio apart and find the receiver board and locate the 455-kHz IF filters (see photo).[1] (Remember the letter after the "455" or "55" tells you the bandwidth



No, this won't narrow your bandwidth, although it WILL significantly reduce your deviation level! Again, a narrower IF filter might be a better option.

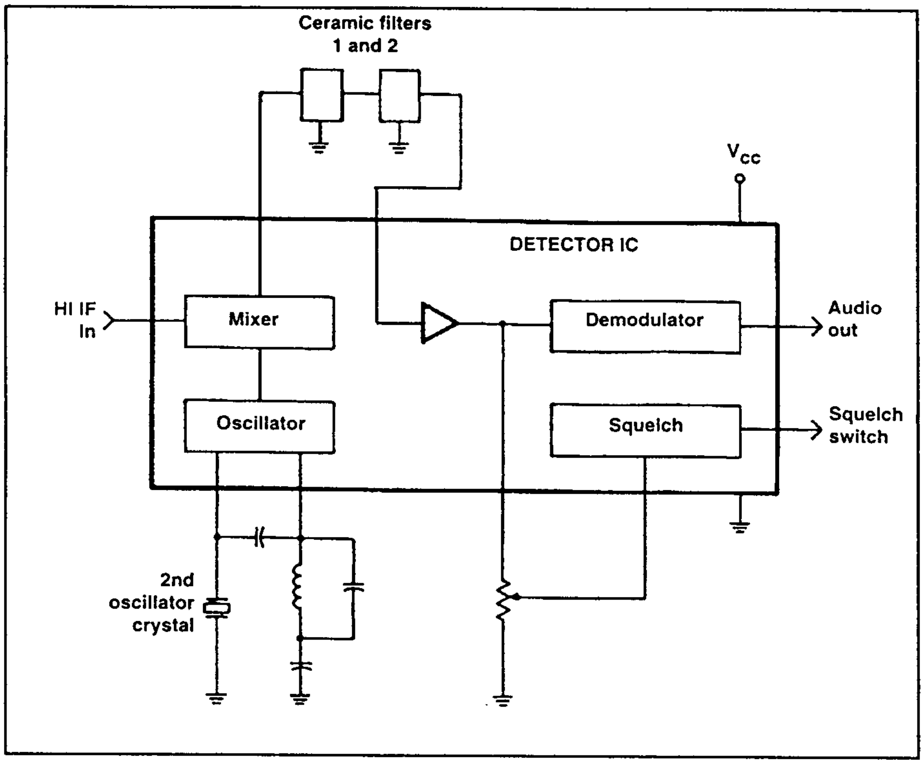


Figure 1. A basic IF detector circuit. Note that some use only one filter; others use more than one, as illustrated above.

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of the filter.) The most commonly used filters are designated A, B, C, D, E, F, and G.[2] Some radios have one filter and some two. There is also a double filter that's about twice as wide. They all do the same thing, though, so you just need to use the chart in Table 1 to determine which filter you have and what you need to get.

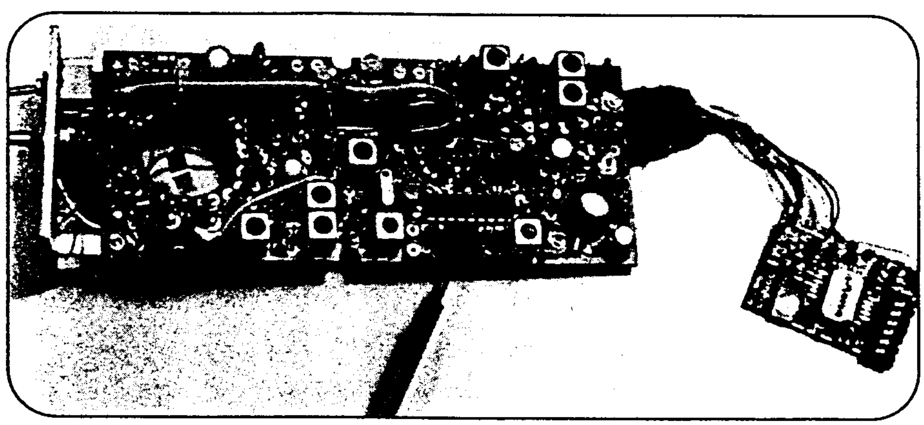
I personally use the "G" filters or ±4.5 kHz bandwidth at -6dB. This gives me the best adjacent channel rejection and still maintains the necessary bandwidth for all current repeaters. For instance, most radios have a "D" filter, or ±10-kHz bandwidth. These filters are too wide for the demands of 12.5-kHz channel spacing and should be changed.

To determine the necessary bandwidth for a given transmitted signal you can use the following formula (assuming a maximum modulation frequency of 3 kHz):

2 (deviation in kHz) x 2.4 = bandwidth in kHz[3]

For instance, with ±5-kHz deviation, you have (2 x 5) x 2.4 = 24-kHz bandwidth. So even though you only deviate ± 5 kHz, your signal takes up more actual spectrum. Your receiver only needs to hear the major portion of the transmitted signal in order to give you readable copy, which is why ±10-kHz IF filters work for ±5-kHz deviation. Now, if you reduce your deviation to ± 2.5 kHz, it changes things to (2 x 2.5) x 2.4 = 12 kHz.

Again, because the receiver doesn't need to "copy" all of the transmitted signal, you can use a ±3.75-kHz IF filter with a 7.5-kHz bandwidth to copy a signal with 2.5 kHz deviation and a 12-kHz bandwidth. Now, if you take two of those 12-kHz-wide signals and put them next to each other, you've got two discrete channels in a space now occupied by one—*doubling* the current number of channels (the roll-off of the filters provides the necessary separation between the channels).



No joking. This is what the 455-kHz IF filter in a radio typically looks like. You'll need to replace it in order to narrow your bandwidth.

Table. The Basic Filter Bandwidths (at -6 dB)

A= ±17.5 kHz	F= ±6.0 kHz
B= ±15.0 kHz	G= ±4.5 kHz
C= ±12.5 kHz	H= ±3.75 kHz
D= ±10.0 kHz	I= ±2.0 kHz
E= ±7.5 kHz	

I've found that, in practice, a tighter filter than calculated can be used without noticeable deterioration of signal quality. This is probably because most conversations are not at full deviation, and the filters don't have straight slopes on there bandpass. In addition, as noted earlier, using CTCSS encode and decode all the time further eliminates adjacent, and even some co-channel, interference.

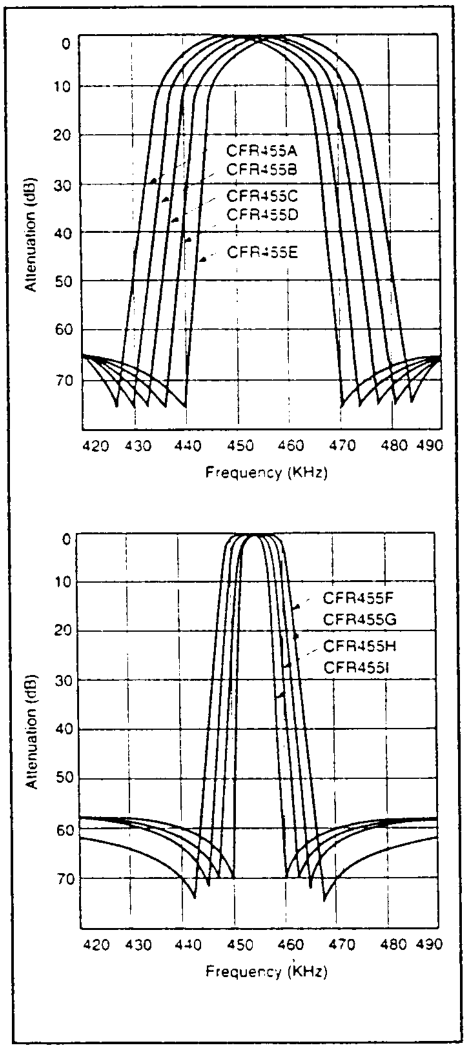


Figure 2. Typical response curves for muRata 455-kHz IF filters. Note the difference between the bandwidth of the filters in Figure 2a (bandwidths A–E; most 70-centimeter ham rigs use "D" filters) and those in Figure 2b (bandwidths F-I; the author recommends going to ±3.75 kHz "H" filters for reduced bandwidth. (Courtesy muRata)

Can You Squeeze It Tighter?

Now, if you want to experiment with *really* narrow operation, you can use the "I" filter at ± 2.0 kHz. Using this filter, you could start approaching the 6.25-kHz channel spacing the commercial operators are trying to attain. If you run 6.25 kHz through the formula, the deviation gets really narrow—1.25 kHz. I believe it's possible to use ± 2kHz at 6.25-kHz channel spacing and still have the radio work fine. One side note: when you reduce the deviation, the recovered audio will be reduced as well. So you'll need to turn up the volume on your receiver.

Done and Done

So that's all there is to it: find the 455-kHz filter and change it. Be careful, and if you're not confident doing the work, find a technician who can do it for you.

We need to continue experimenting to see what else we can work out and improve upon. If we all changed to the narrower filters, we could greatly increase the number of usable FM channels in our VHF and UHF bands—and we could all use that. Don't wait, let's all get on the narrow bandwagon now! ■

Notes

1. If your radio doesn't have a 455-kHz IF (as is the case in some commercial equipment), contact the manufacturer for possible factory modifications for 12.5-kHz operation.

2. Filter data courtesy of muRata.

3. FM and repeaters for the Radio Amateur, *ARRL, 1972.*

Resources

Narrow-bandwidth 455-kHz IF filters are available from:

muRata, 2200 Lake Park Dr., Smyrna, GA 30080: Phone: (770) 436-1300

Communication Specialists has a large inventory of IF filters for certain other frequencies, such as 3.75 kHz, 10.7 MHz, 21.4 MHz, and 21.8 MHz). If you can't find these parts locally, call them directly at (800) 854-0547.