SNA … Tune an 80 meter Bandpass Filter

K1TRB 5/6/17

The response of an existing bandpass filter was measured in another experiment. That experiment answered the question: What is the performance? In this experiment, I've set out to actually do something, not just observe the results. That is a bandpass filter will be tuned up. (Pictures are of the Yana prototype.)

I prefer triple tuned bandpass filters over double tuned because they cut off more rapidly providing better selection. However, tuning a triple tuned filter can be a challenge using the "watch the bandpass as I twist this adjustment" method. Dishal devised a method of tuning using reflections from the end of a filter that is quite useful and rather easy for a triple tuned bandpass filter. That is the method that will be displayed in this experiment.

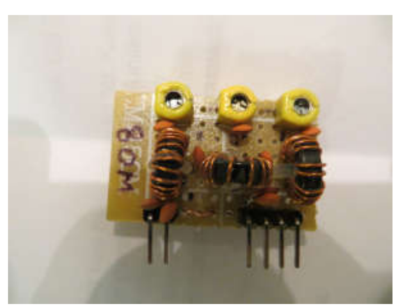
I have not had great success with parallel tuned filters. Mine seem to end up with high insertion loss. I've found series tuned filters work for me, though they have a distinct tune-up disadvantage. In a parallel tuned filter, the screw adjustment on trimmer capacitors can be grounded so that a steel screwdriver can be used to tune the filter.

In a series tuned filter, both ends of the tuning capacitors are floating. So, sticking a steel screwdriver into the slot completely detunes the filter. This can be overcome by adjusting the trimmers a tiny bit at a time and observing the result with the screwdriver removed. This is painful and slow.

I purchased a couple ceramic tuning screwdrivers cheaply on eBay. Ceramic is not flexible, not strong, and has a tendency to shatter when overstressed. If you read reviews of these screwdrivers, you will see that many people say they are junk. These reviewers are the "muscle tuners" among us. No matter what the required torque, they twist anyway, and, of course, the screwdriver shatters.

I always turn a trimmer adjustment around with a steel screwdriver to get it loosened up. Sometimes a dab of silicon lubricant is needed. If the trimmer cannot be loosened up a bit, I set it aside and use it in a parallel tuned circuit where the adjustment screw can be grounded and a steel screwdriver will work.

I have never had to replace any ceramic screwdrivers (but, of course, there is always a first time).



I purposely detuned the filter at the right so that I could adjust it for this experiment. The filter was designed to have its 3db points located at the band edges of 80 meters (i.e. 3.5MHz and 4MHz). The bandwidth is determined by the parallel coupling capacitors which were carefully selected for value and are not adjustable. Thus, I really have no control over the bandwidth of the filter if it is properly tuned.

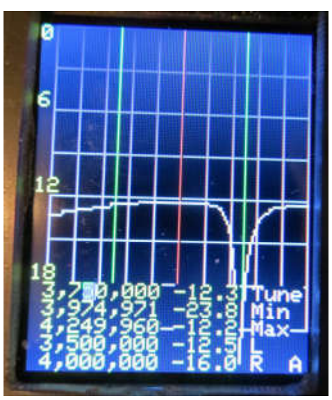
The picture at the left shows how Yana is connected to the filter through the bridge. This connection was exhibited for illustration in the experiment on filter bandwidth, but now measuring reflections will be of some use. (I forgot to terminate the “far end” with 50 ohms.)

Yana is set up in Center/Radius mode with the center tuned to 3.75MHz (center of the 80 meter band). The radius is set to 500KHz so the bandpass and skirts of the filter can be seen. The markers are set at the band edges (250KHz in each direction from 3.75MHz). The tuning will display centered on the screen.

The Dishal method tunes up each LC combination sequentially: beginning with the one closest to the output connected to Yana. For a triple tuned circuit, the two end LC circuits are tuned by reversing the connection of the filter to Yana. In particular, the center circuit is the only one left untuned by this first “tune the end circuit step.”

Tuning proceeds from the Yana connection and moves toward the terminated end of the filter. Each LC circuit is tuned in succession. At the midpoint, the filter is flipped end for end and tuning proceeds from the new end. For a parallel tuned filter, when tuning a LC circuit, the next LC combination is shorted. For a series tuned filter, the next LC combination is opened. Generally I’ve found both of these steps impossible because shorting changes the filter due to the proximity of the short to the LC circuit I’m tuning, and opening a connection is generally not possible. But never fear, Dishal tells us what to do.

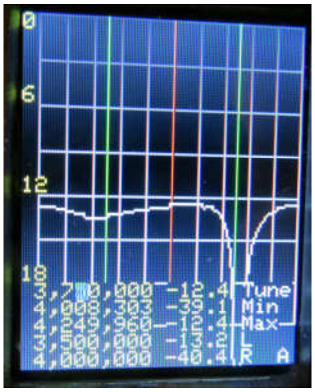
For a triple tuned parallel filter, the trimmers should be maximized (moves resonance down in frequency), which is the closest we can make the trimmer to a short. For a series tuned circuit, the trimmer is minimized (moves resonance up in frequency) to get the capacitor as close to an open circuit as possible. Dishal tells us that this detuning should move the resonant frequency of the detuned circuit about 10 passband widths away from the center frequency: not a chance!



In this filter I used trimmers of fairly small value and put a fixed capacitor in parallel. Thus the adjustment is not huge. No way could I get 10 passbands of detuning. But amazingly, the Dishal method still works even with this limitation on capacitance adjustment. I think an adequate requirement is that the center tuned circuit should be at the edge or outside the edge of the passband. If this adjustment can be made, then the method still works pretty well.

a. Step One: Tune the center circuit up in frequency as far as possible.

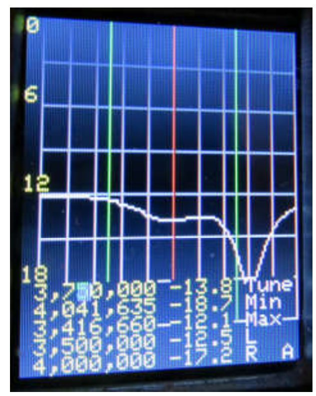
The picture on the previous page shows how far I could get my center LC circuit tuned up in frequency: not too far, sort of at the band edge.



To make certain that this "tuning up" strategy is best, I modeled tuning down then tuning: not a good move. Dishal knows what he's doing, and there are good theoretical reasons for the choice.

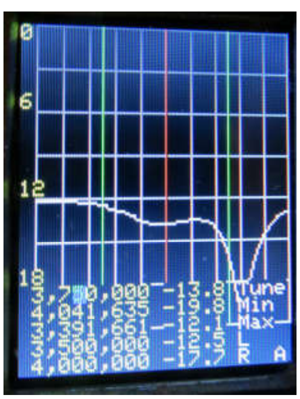
b. Step Two: Tune the end closest to Yana to center the depression.

Now tune the LC combination closest to Yana. The picture at the upper left shows the result. As I tuned, a downward dent appeared on the left side of the screen. Yours may appear in another place, depending on how the filter is detuned. Just keep twisting the adjustment and the dent will move back and forth.



Yana is scanning in centered mode so the red vertical line is the center of the band. The object of tuning is to move that depression so that its center is right in the middle of the screen: symmetrical around the vertical red line. The picture at the right shows this complete. Now you see why detuning the center circuit is important. The large center circuit dip makes it difficult to center the end tuned circuit dip. If I had been able to tune that center LC combination higher (maybe even off the screen) then the centering would have been more obvious.

c. Step Three: Disconnect Yana and reconnect to the other end. Do the same centering adjustment at this end.

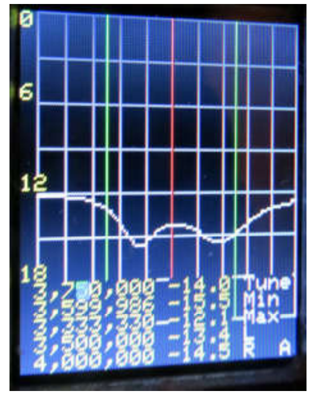


Now disconnect the filter and reconnect to the opposite end. Do exactly the same thing: center the depression. The picture at the left shows this depression centered.

Believe it or not, the two end circuits are now tuned up. It doesn't look much like a bandpass, does it? That's because we're looking at the reflection from the end of the filter, we are not looking at transmission through the filter.

We're ready now for the final adjustment: the middle circuit.

d. Step Four: Adjust the center circuit until the two downward lobes are equally downward.



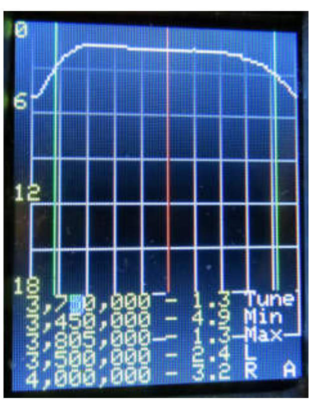
The final adjustment is simple. Just crank the middle trimmer until the two downward lobes are equally placed with respect to the center. The result should look fairly symmetrical with respect the vertical red line.

You'll see I didn't get it quite right. There are two reasons for this. First, the center LC detuning was not far enough from the bandpass. Second, I should have connected a 50 ohm load to the output of the filter (the end furthest from Yana) so the filter is properly loaded. Third, I didn't get those first two LC cicuits adjusted just right.

But never fear. This filter is better tuned than the "twist and check" procedure usually can achieve. Dishal's method is very robust. It worked even when I couldn't properly detune the circuits and forgot to terminate the far end of the filter in 50 ohms. Now that's a good method.

e. Step Five: Check the bandpass and tweak the result.

The picture at the right shows Yana connected to measure the filter bandpass: just as was done in the experiment on the 6 meter filter response. I set the scan radius at 300KHz so that the top of the passband would be exhibited. Further, I set Yana for 3db steps so I could clearly see the 3db points on the passband. The picture below and left shows the filter passband top.

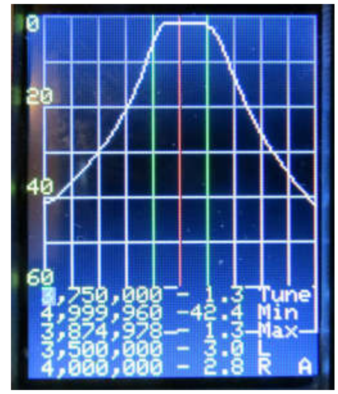


First, I tweaked the middle LC circuit tuning so that the points at which the trace crossed the green lines are at equal heights. I then used graph tuning to check the band edges.

I found that at the top end, the attenuation was about 4db and at the bottom it was just more than 2db. I tweaked the center circuit until both ends were 3db or less. If the attenuation could not be set at 3db on both ends, I would have gone back and redone the Dishal tuning. I would have put a 50 ohm load on the filter output and checked the final downward lobes for symmetry.

Even with imperfect tuning, things came out very well. Attenuation in the passband is mostly around 1.5db as I can check by graph tuning. The passband may not look perfect, but a fraction of a db hardly matters. This filter is well-tuned at this point.

Just to check things out, I increased Yana's sweep radius to 1.25MHz. The picture at the right shows the final filter shape: not too shabby. Before I stumbled across Dishal's article, I used the "twist and check" tuning method and never got results this good.



f. Theoretical Stuff

The design values for the 80 meter filter are shown in the table. These filters are described in Hayward, Campbell, and Larkin, "Experimental Methods in RF Design," p. 3.11. I designed this filter using Williams and Taylor, "Electronic Filter Design Handbook, 2nd ed." p. 5-20.

I often use AADE Filter Design, a free windows program that really does the job. In the help screens is a write-up describing the mathematical procedures used in Filter Design.

http://w1hue.org/filter.html

Neil Hecht wrote this program for us and designed the very useful LC Meter IIb. I use his program and his meter for my filter design steps. My primary frequency counter is also one of his. It is sad that he is now a Silent Key. He is missed.

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> #  (80m) 3.75 MHz,  BW = .6MHz 18turns: ft37-61 11" wire
> #  C1(pF) L12(uH) C12(pF) C2(pF) L23(uH) C23(pF) C3(pF) L34(uH) C34(pF) C4(pF)
> #  105.2  17.4    118.7   918.1  17.4    133.7   918.1  17.4    118.7   105.2
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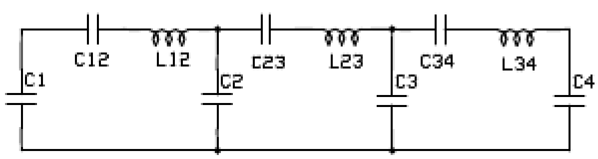
The schematic for the filter is shown at the below.



I wound the coils on FT37-61 cores with #26 enameled wire. I had to slide the turns a bit to get the right inductance. I then used coil dope (you can use clear nail polish) to fix the turns in place. Even so, the inductances are approximate (close but not equal).

The trimmers are eBay specials. I think these are factory rejects since the tuning slots are a bit wonky (like they're not much of a slot at all). But they were cheap and seem to work quite well. The fixed capacitors are from a kit of disk ceramics I got on eBay supplemented with standard values bought from Tayda. The cores I bought from kitsandparts.com.

The filter is assembled on perfboard and the toroids are held down by zip ties. I've settled on pin headers for connections off-board. It is easy to connect headers to thin coax (RG-174) for RF connections between boards. This kind of connection seems perfectly fine for HF work.

Filter synthesis (design of filters) is a pretty mathematical process (which makes us thankful for powerful programs like Filter Design). Hence, most journal papers on filter design are pretty technical. Dishal's paper on his tuning method is an exception. It is worth reading. Unfortunately I can't find it on the web. If you have friends at a university, they can get a copy through interlibrary loan. The reference is:

Dishal, M., "Alignment and adjustment of synchronously tuned multiple-resonant-circuit filters ," Proc. IRE, Vol. 38, No. 11, 1448-1455, Nov. 1951.

Dishal's method is mentioned in EMRFD. It is described on p. 95 in

Hayward, Wes, Introduction to Radio Frequency Design, Prentice Hall (1982).

There is a website describing the method with emphasis on laser trimming parts (which can be ignored). However, the authors only model the method, they don't actual "do it." But there are some nice graphs.

http://www.johansontechnology.com/dishal-bandpass-filter-tuning-using-lasertrim-chip-caps