

Practical HF Bandpass Filter Tuning

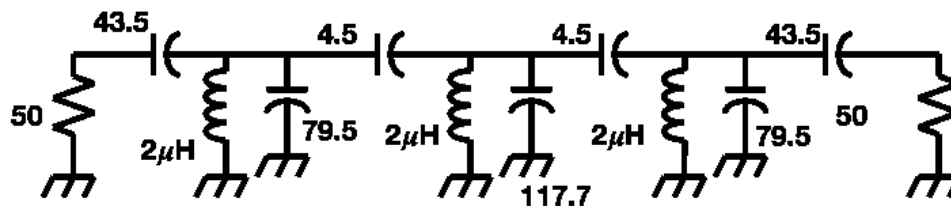
Wes Hayward, w7zoi, 25 March 2021

A common question I hear from readers and experimenters regards a method to tune or align a LC bandpass filter. This is especially significant for bandpass filters with 3 or more resonators.

Let's start with the short answer: Once the filter is designed and built, a signal source is attached to the input. The output is attached to a 50 ohm terminated oscilloscope or similar instrument. An AD-8307 based power meter would also work, although a linear instrument such as the 'scope provides more sensitivity. **Set the source generator to the desired filter center frequency and leave the generator at that frequency during tuning.** Tune the resonators, looking for a maximum response at the detector.

Let's now expand upon the short answer with an example, a third order LC bandpass filter with 10 MHz center frequency and a bandwidth of 0.5 MHz. This 5% bandwidth represents a filter Q of 20. We use good cores such as the Micrometals FT-50-6 to realize unloaded Q_u of 250, or more. The insertion loss should be low with this high unloaded Q. We pick an inductance of 2 microhenry and arrive at the schematic shown below.

Initial Design, 10 MHz center, 0.5 MHz BW, $Q_u=250$ for inductors

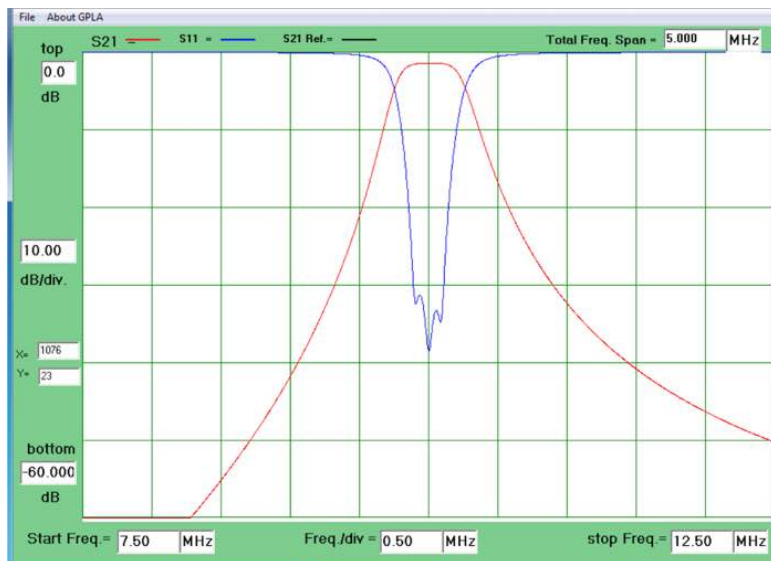


One of the 50 ohm terminations is a load across an oscilloscope input, or is the actual input impedance of a power meter. The termination at the other end of the filter is usually an integral part of the signal source. If you are unsure of the generator's source impedance, insert a 10 dB attenuator or pad at the generator output. Use 50 ohm coax cables for interconnects. More will be said later about a test set.

The filter shown above is already tuned to the desired 10 MHz center frequency.

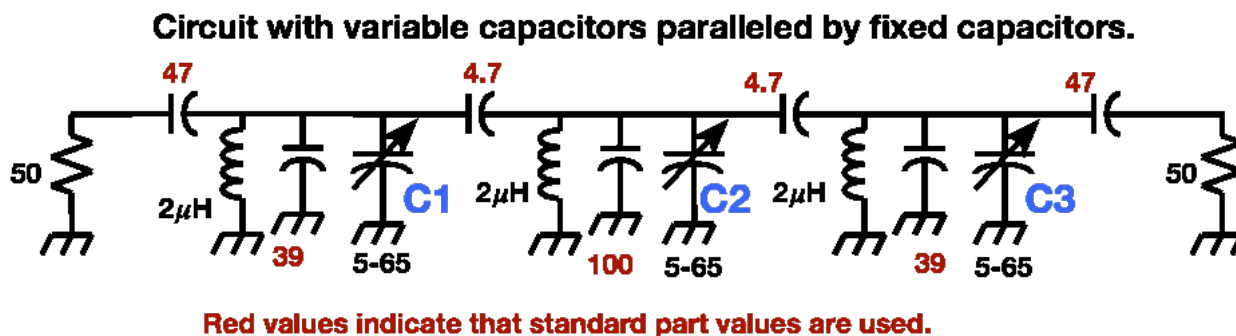
Proper tuning resulted from the mathematics integral to the design. The design is detailed in Chapter 3 of Experimental Methods in RF Design (ARRL, 2003.) This

particular filter was designed with the program TTC.exe, which was included with early printings of EMRFD. Any other filter design method would do as well. The response for this filter is shown below:



Case 1. The red trace is the "gain" for this circuit. This is a passive filter, so gain is always negative. The response at the center frequency represents an insertion loss of a little over 1 dB.

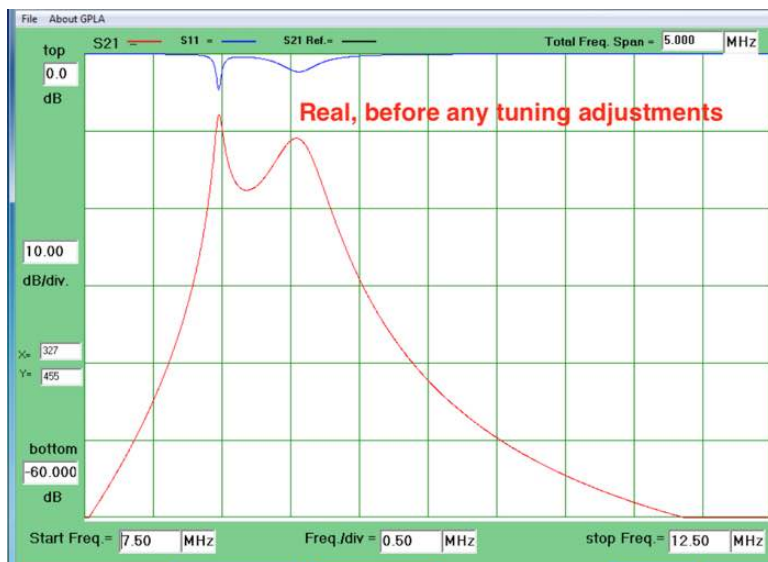
It's possible, at least in concept, to build this filter with no adjustable elements. But "no-tune" filters can be very difficult. The more practical, and common approach is to design the filter, and then replace the large capacitors paralleling each inductor with a combination of a fixed capacitor and a variable trimmer. The two capacitors with value 79.5 pF in the original filter (above) are replaced with fixed 39 pF paralleled with 5-to-65 pF trimmers. The 117.7 pF fixed capacitor in the filter center is replaced with a fixed 100 pF paralleled with another 5 to 65 pF trimmer. The modified filter is shown below.



This is the modified circuit with trimmer capacitors, marked here as C1, C2, and C3. An additional minor refinement replaces fixed capacitors in the original design with

standard values of 47 and 4.7 pF. These are marked with values in red.

The response for this filter is shown below with all three trimmers set to the maximum C of 65 pF.



Wideband response with all trimmers set at 65 pF. Clearly, this is not yet a practical filter.

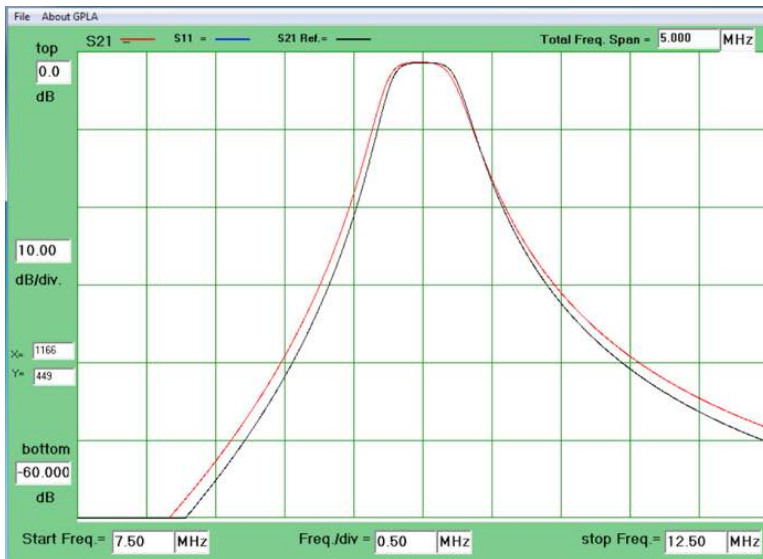
We now wish to adjust the trimmers for the desired response. This is done with a signal generator with **frequency fixed at the filter center**, 10 MHz for our example. The software I use to simulate this includes the ability to tune individual components, producing exactly the same result that one would see with physical hardware. Before any of the three trimmers are tuned, the gain at 10 MHz is -42.3 dB.

C1 Tune: The first adjustment we do is to C1 in the schematic above. We see a maximum **at 10 MHz** when C1=36.9 pF, yielding a gain of -30.4 dB.

C2 Tune: Next, we tune the middle trimmer, C2. At 18 pF, the filter gain is now -8.4 dB.

C3 Tune: Finally, we tweak trimmer C3. When it reaches 38 pF, the 10 MHz gain is -1.34 dB.

Having tuned the filter with only excitation at the center frequency, we now examine the wideband response from 7.5 to 12.5 MHz. The result is shown below where the tuned filter is compared with the original computer design.



The red curve is the response after tuning C1, C2, and then C3. The black curve is the original filter that was designed with the program TTC.exe. The blue curve is just a repeat of the original sweep, but does not show the impedance match (S11) through the filter.

In a practical, experimental environment, we would go back through the process again. But with just one pass through the tuning, we are nearly as good as the filter is going to get.

It's important to keep the single frequency source in place during adjustment. The mathematical design process yields element values to force each node in the filter to be resonant at the filter center. Hence, this is the way we tune it in practice.

Note: I went through a simulation procedure as a way to produce curves for this report. That's not what the user/experimenter would do. He or she would design the filter, perhaps going so far as an initial simulation. The filter would then be built, and then would be tuned with a single frequency drive at the center frequency. If the insertion loss is consistent with the initial design, the filter should be done and ready for use in a larger project.

