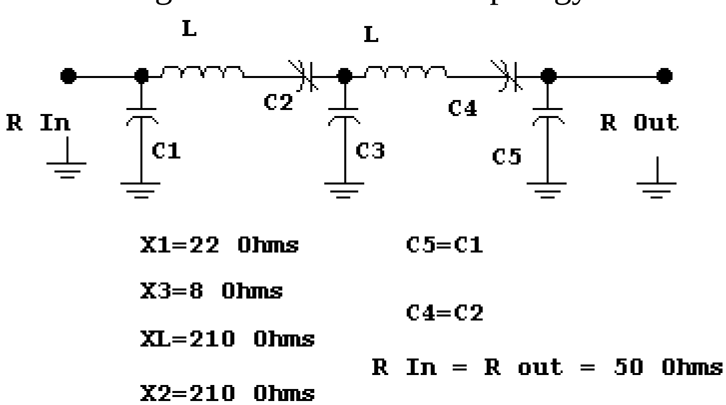
A Simple VHF Filter

19 June 04   w7zoi

This note describes a vhf bandpass filter of a form that is easy to design and realize with the design tools incorporated in EMRFD.   It is a double tuned circuit, but uses series resonators rather than the more traditional parallel tuned circuits.   This particular example is placed at 72 MHz, but the ideas can be expanded to cover about any center frequency within the HF or VHF spectrum.

We are concerned here with two factors.   First, we wish to generate a schematic that is easy to implement and to tune.   Second, we wish to present a method for transferring the on-paper schematic to a filter that can be built with a clean response throughout the VHF spectrum.

The first figure shows the basic topology of our filter.

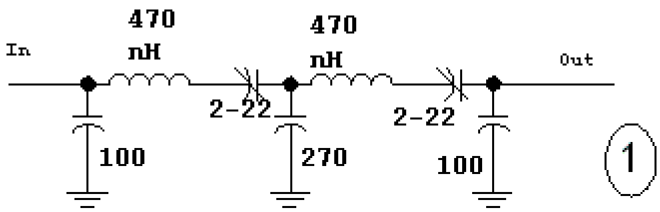


It is a symmetric design with symmetry about capacitor C3.   Two variable trimmer capacitors are used, and they are NOT grounded. This is a slight disadvantage.   An insulated tool must be used for adjustment.   The advantage of a filter topology using series tuned circuits instead of the more common parallel resonator is that the circuit degenerates into a low pass filter in the stopband.   As such, it offers better suppression of spurious responses at higher frequency.   But short lead lengths in the shunt capacitors C1, C3, and C5, are vital.

Approximate design equations are presented with the figure, all in terms of reactance of the L and C values at the filter center frequency.   For example, a 22 Ohm reactance capacitor at C1 occurs with 100 pF for f=72 MHz using the usual equations.

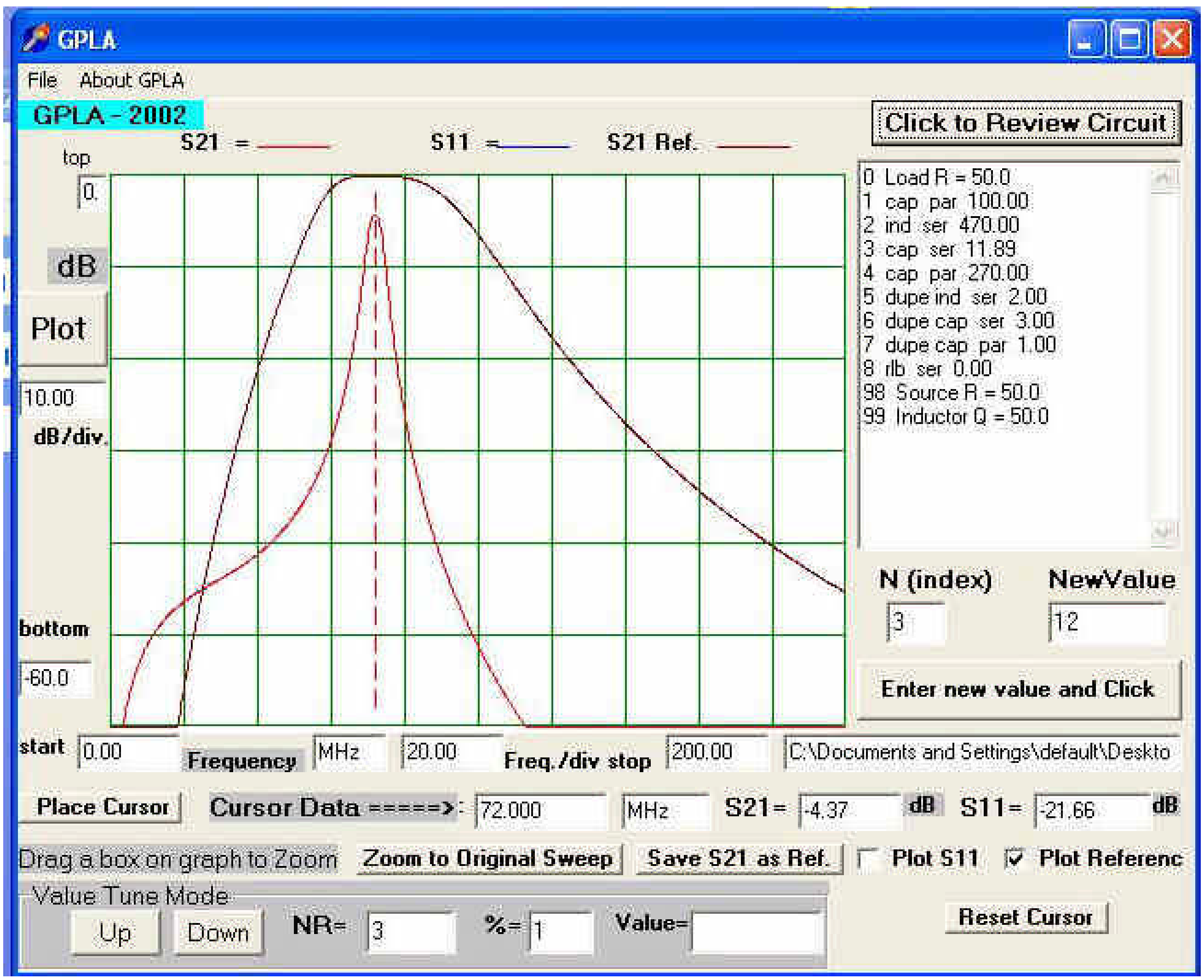
The inductors have relatively high X values compared with the shunt capacitors.   The tuning capacitors C2 and C4 then have a reactance value that is nearly the same as that of the inductors.

A 72 MHz version of this filter is shown below.



Simple bandpass filter. F=72 MHz, BW=4.2 MHz. Inductor Qu=50.

The large, circled “1” indicates merely that this is the first in a sequence of comments about this circuit.



The response of the above circuit.

The wide response is a reference from the cascade of a 5th order low pass and a 5th order high pass filter. The narrow bandpass is that of our filter and clearly has a much narrower bandwidth. The response in the figure is a calculated one, simulated with the program GPLA, distributed with EMRFD. Any of many such programs could be used for this simulation.

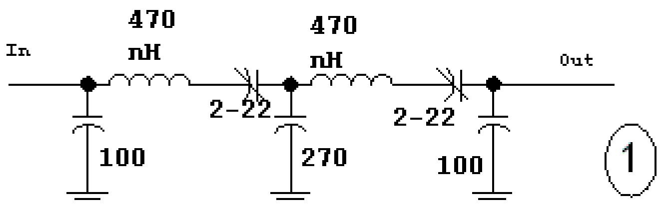
The filter was realized with a constraint that the inductor unloaded Q be 50. If the Q is higher, the insertion loss will be less than the 4.4 dB now shown. A Q of 50 can be obtained with off the shelf molded chokes.

This particular DTC (double tuned circuit) can be expanded to narrower bandwidth if desired. To do this, increase C1 and C5 to alter the "end section Q," increase C3 to decrease coupling between sections, and increase the unloaded Q of the inductors to keep the insertion loss within reason. The 3 dB bandwidth of the filter as shown is 4.2 MHz.

This filter has a pronounced single peak. A flat top response may be possible if higher Qu inductors are used. The flat top response is then obtained with tighter coupling between resonators which is realized by decreasing C3. Computer tuning is useful, but eventually one may wish to play with a real circuit.

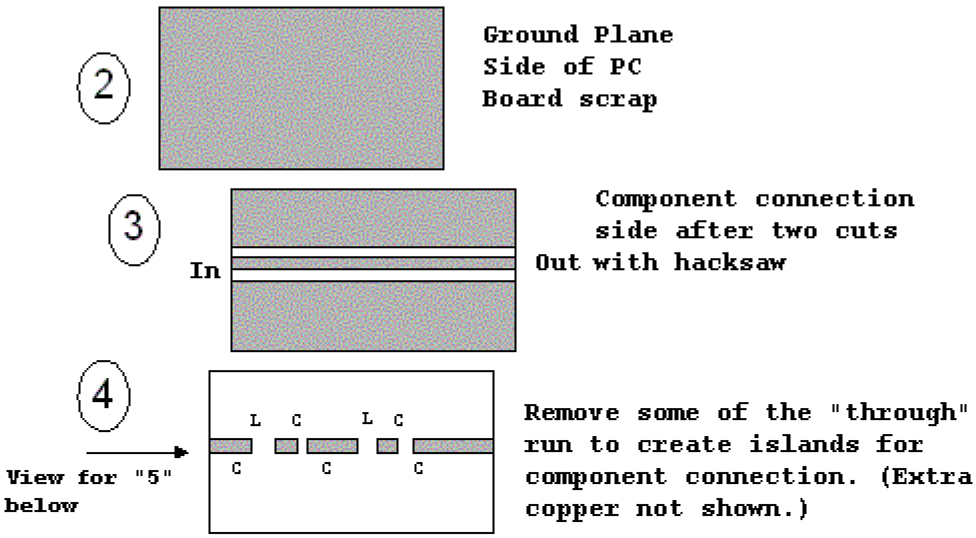
How do we build it?

Some design details have been presented, and we now wish to build one. There are numerous ways to do this. We will present but one of these, a scheme we have used with many filters of this sort. Step 1 begins with the basic circuit:



Simple bandpass filter. F=72 MHz, BW=4.2 MHz. Inductor Qu=50.

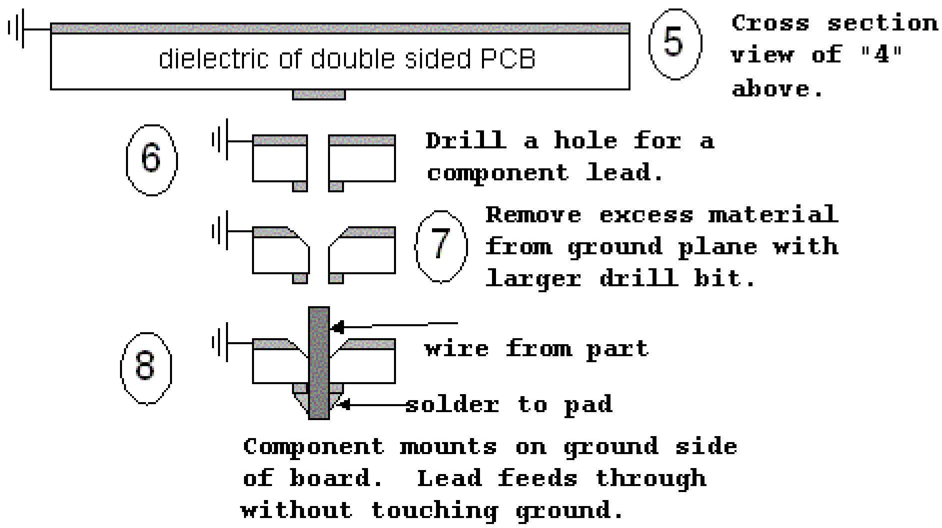
We wish to build this on printed circuit board material. We start with a scrap of double sided PCB stock, step 2, with solid copper on both sides of the board.



Step 3 now begins to create some "islands" on the back side of the board. The board is clamped in a vice and a hacksaw is used to make two cuts in the board, creating a long strip across the board. The hacksaw cuts can be fairly wide, for we don't really want much capacitive coupling from the center run to the large areas on the sides.

Step 4: In this drawing, for clarity we show only the center run. The long run is cut with an X-Acto tool to isolate small islands where parts can eventually be soldered. Fig 4 above is labeled with the parts that will fit. The series parts are "above" the run while the shunt ones are below. Once the X-Acto cuts have been made, a section of run can easily be removed with the knife and a soldering iron. The iron is placed on the copper to tin it, aiding heat transfer, and the knife is slipped under the copper pad.

We now need to get some holes in the board for the components. This uses the following sequence:



Step 5 shows a cross section of circuit board material. The continuous ground foil is on top while the "run" is on the bottom. Only one pad or run is shown.

6: Here we drill a hole between the pad and the ground plane, starting from the pad. Use a small drill, commensurate with the size of the wires to be inserted. The variable capacitors in the filter, C2 and C4, are quite a bit larger than the other parts.

7: If a component wire was inserted here, it would short to the ground foil. So, we must remove some ground foil. This is done with a drill bit that is quite a bit larger than that used for the original hole. Take care to not drill too far into the board.

8: Parts can now be placed into the board and soldered. There is no need to drill any holes for the ground end of the grounded parts C1, C3, or C5. Rather, the leads can merely be soldered directly to the found foil. The large areas of copper under the board should be grounded, or ideally, removed. (If there is a substantial gap between the "pads" and the adjacent grounded material, we have simulated a microstrip environment here. But if the gap is small, we simulate a structure called coplanar waveguide.)

Testing

We now need to tune and test the filter. If we used standard 1/16 inch circuit board material, we could slip SMA or SMB coax connectors onto the edges of the board. The connectors would be soldered in place and coax cables would be attached. An input cable would go to a 50 Ohm signal generator while another would route to a 50 Ohm detector of some sort. This could be a power meter, spectrum analyzer, or 50 Ohm terminated oscilloscope (with the terminator at the 'scope and not the filter!) The signal generator is set to 72 MHz and the two capacitors in the filter are tuned for maximum output response. The tuning will be sharp. After alignment, the signal generator is tuned while observing the output. The generator should be tuned over a substantial range on either side of 72 MHz to be sure that there is but one peak. This is a vital step. (See my QST paper, Dec, 1991.)

We may not wish to use coax connectors on the filter. We can, instead, come in with small coax on either end. The ground foil is soldered to the ground plane while a center line attaches to in input or output run. Keep the loops related to these connections as small as possible.

A coaxial "through" connector can be used to measure insertion loss. Once a filter is aligned, set the generator to the center frequency and note the response. Then remove the filter and replace it with the "through." The response will be larger with the difference being the loss of the filter.