A VHF Bandpass Filter for the QST Spectrum Analyzer

w7zoi; 17August 2012, 19Jan2016, 11Aug2016, 18March2021

VHF N=3 Bandpass Filters

First, if you are building the QST Spectrum Analyzer, you may be asking *why not just build the original filter*. Click here to see a comparison between the two filters.

A filter that has been of considerable interest is a three resonator bandpass at VHF or UHF. This filter form is especially useful for image stripping filter applications in high performance receiver front ends or for use in the first IF of RF instruments. A specific application was the 110 MHz bandpass filter in the first IF of the DC to 70 MHz spectrum analyzer that K7TAU and I described in QST in August and September of 1998. A filter was designed with the methods outlined with the circuit shown below.

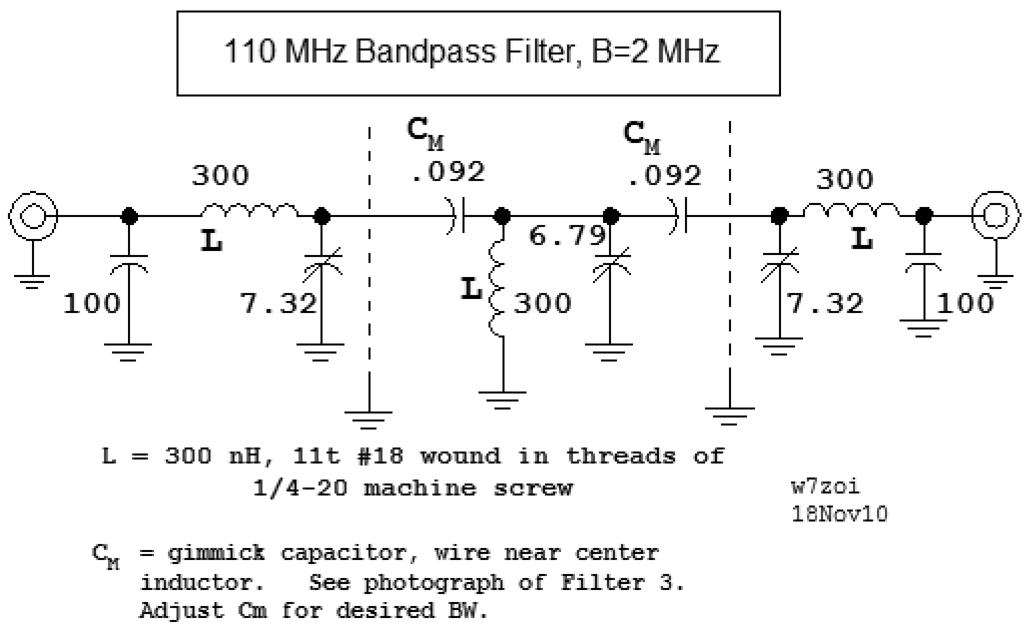

Fig 1. A bandpass filter at 110 MHz using the mixed format.

The reader should not be overly concerned about the exact value of the coupling capacitors Cm, shown as .092 pF. That value was generated by a computer program that used a network of ideal elements. The filter we will build is much less ideal, but more interesting. More discussion is found below regarding the small valued coupling capacitors. The reader is also referred to a QST article about the double tuned circuit. See QST for December, 1991, page 29. That paper shows how to build and measure such circuits with emphasis on the way to adjust the coupling and end resonator load to get a desired response.

Three versions of the filter of Fig 1 above were built. The only major difference between them is in the variable capacitor type used.

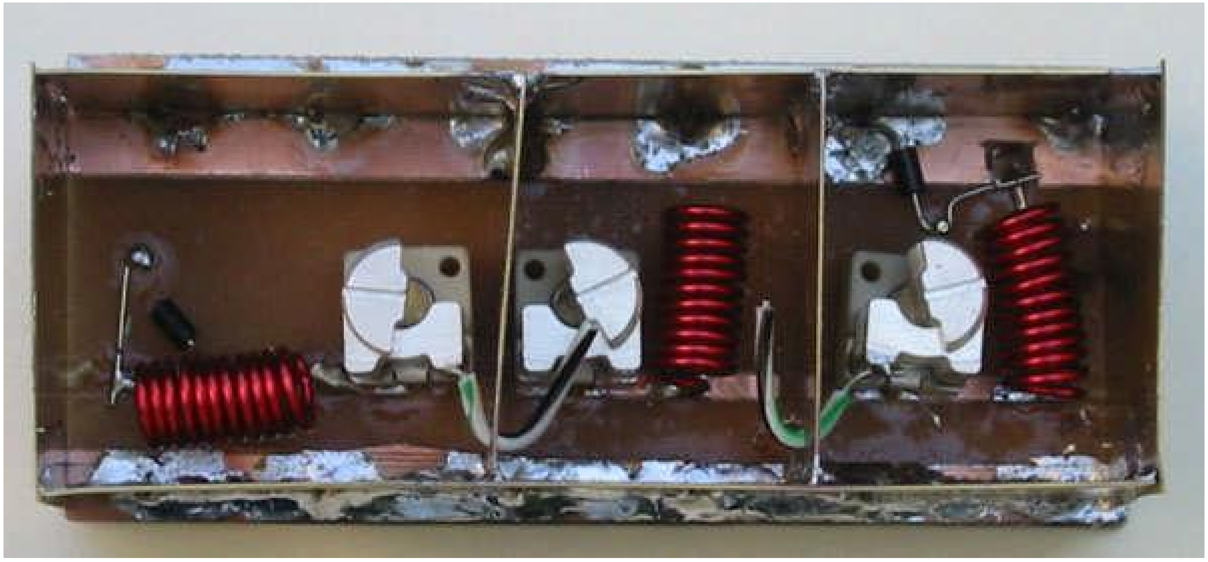

Fig 2. Inside view of "Filter 1," which used air dielectric 2-10 pF trimmer capacitors (ceramic insulation), leaded 100 pF ceramic shunt end capacitors, and "gimmick" capacitors from the end resonators into the middle. The coils are wound with #18 wire and consist of 10.5 inches of wire wound into 11 turns on a ¼-20 machine bolt. SMB coax connectors extend through the base, which is circuit board material. The walls and shields between resonators are 1 inch brass strips from a Hobby Shop. This filter is "semi-ugly." That is, it is a breadboard, but has a pattern on the side of the board containing the components. This was cut by hand. The other side serves as the circuit ground.

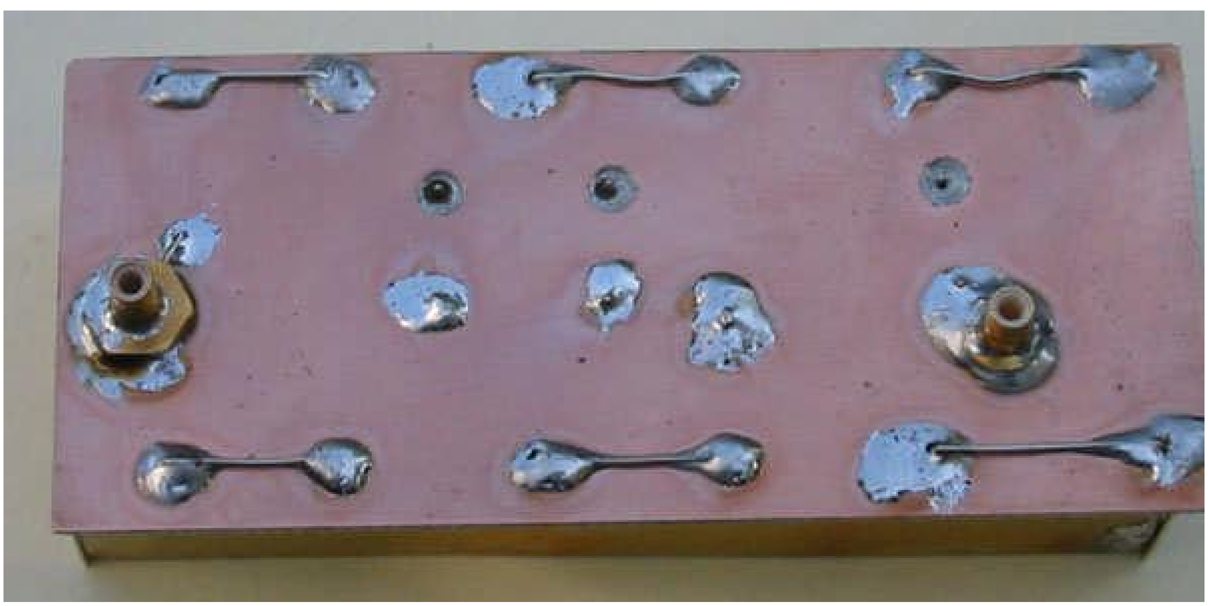

Fig 3. Outside view of "Filter 1." The coax connectors and the trimmer capacitor terminals can be seen sticking through the board. The wires are connections to grounded foils on the other side of

the board where brass walls reside.

Filter #2 was similar. The inductors were like those used in the first filter. However, plastic insulation trimmer capacitors were used with
completely ugly construction. This filter is shown below:

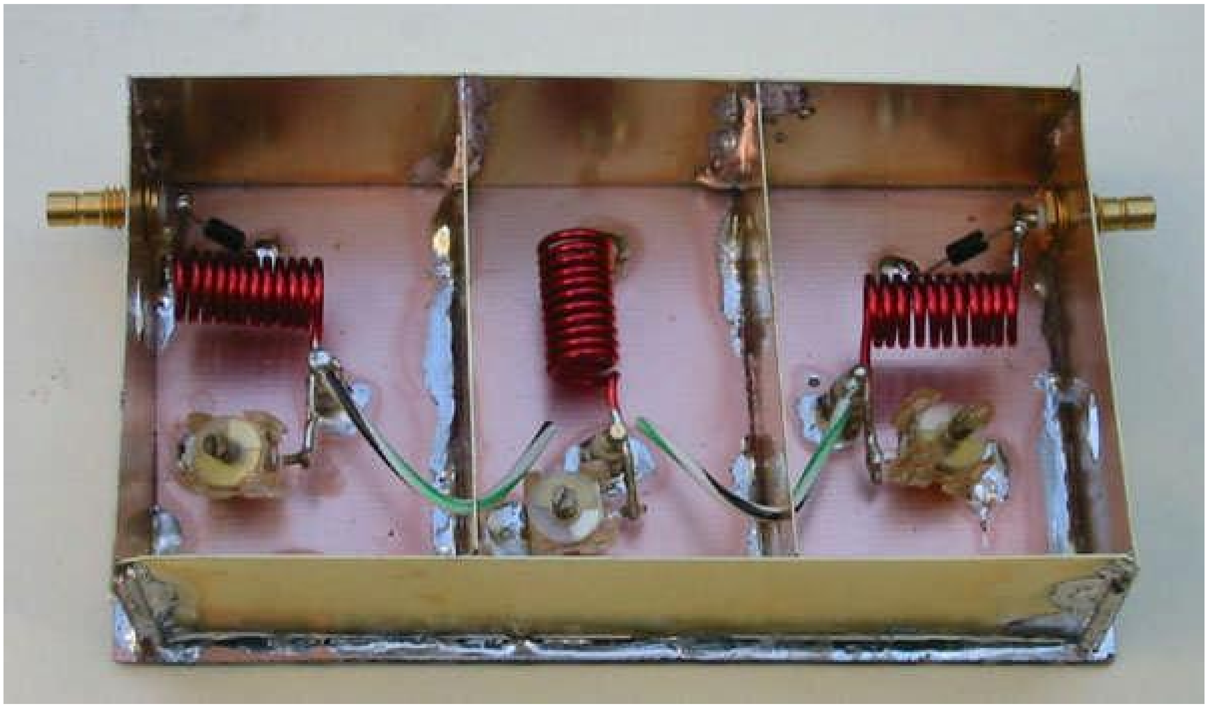

Fig 4. VHF bandpass "filter 2." This circuit uses plastic trimmer capacitors. Small Teflon standoff posts were used at the critical nodes, mainly as mechanical support. Without these, the filter was subject to vibration problems. The circuit is otherwise exactly the same as the first filter.

Filter 1 seemed marginally better with a slightly lower insertion loss. Filter 1 with the higher quality capacitors was easier to tune. Both filters are in the vicinity of 5 dB loss with a 2 MHz bandwidth. The shapes are excellent with good compliance with the computer simulated responses.

A third filter was built much later than the first two. "Filter 3" used glass piston trimmers and is shown in the figure below.

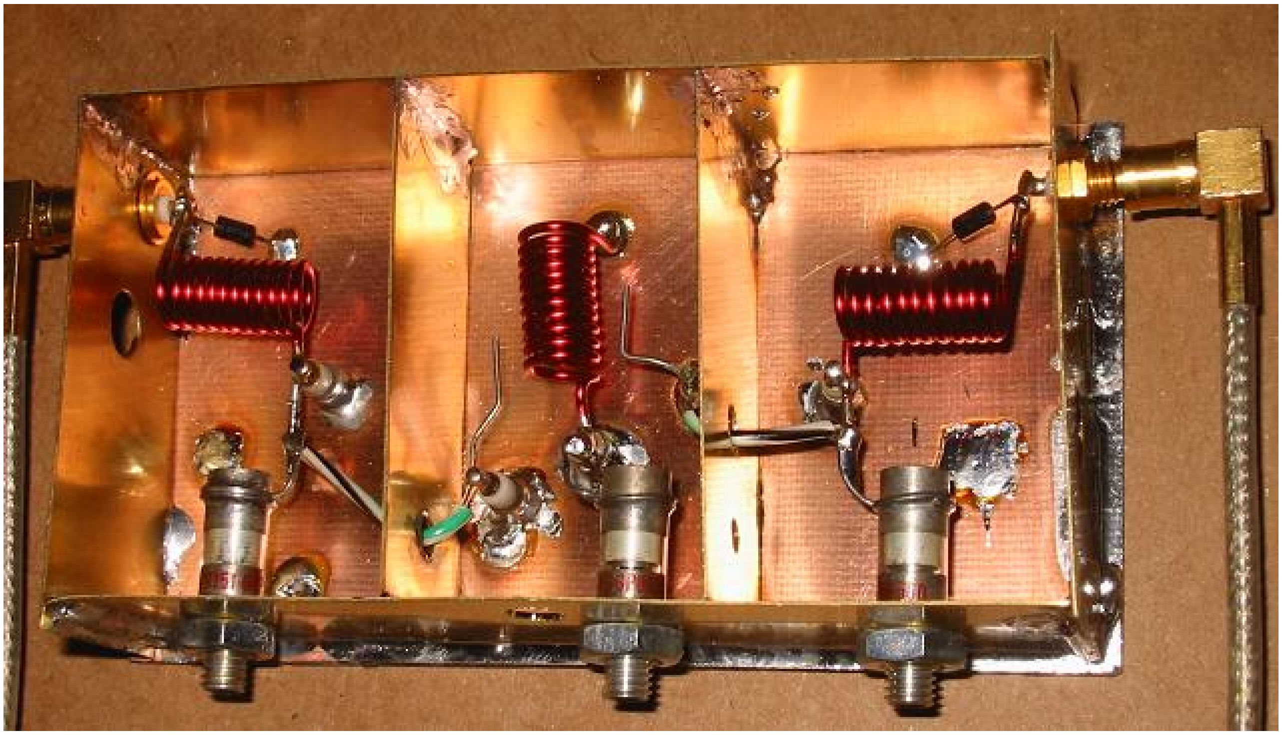

Fig 5.

(Also see Fig 6 below.) The performance of this filter is the best of the three and is now the recommended filter for the 1998 QST spectrum analyzer. The earlier (1998) filter design without shields between resonators is not recommended, owing to problems with UHF stopband attenuation. (A comparison is found by clicking here.) The insertion loss for the filter shown was the lowest of the three, yet the filter was an easy one to adjust. The box shown again uses 1 inch hobby store brass on PC board to form a box that is 1.9 x 3.7 x 1 inch, although slightly smaller dimensions could be used. After alignment, including adjustment of the coupling "capacitors", a lid can be soldered to the top of the hobby store brass, followed by a final alignment. This filter happens to use the new "mixed" topology, but this particular VHF filter is narrow enough that there is little difference compared with a more traditional circuit. The "mixed" form becomes more significant with filters with a wider bandwidth. The Teflon insulated standoff insulators may be difficult to find. K5IRK used Nylon machine screws and nuts with solder lugs as a replacement. Indeed, it may be worthwhile to try 1 Megohm resistors. Experiment.

The coupling capacitors in the VHF filter are very small at less than 0.1 pF. One cannot purchase capacitors of such small value, but they can certainly be built. The easiest way to do this is with small pieces of wire, as shown in the figure above. Click here to see a detailed discussion of these capacitors and some hints on filter alignment.

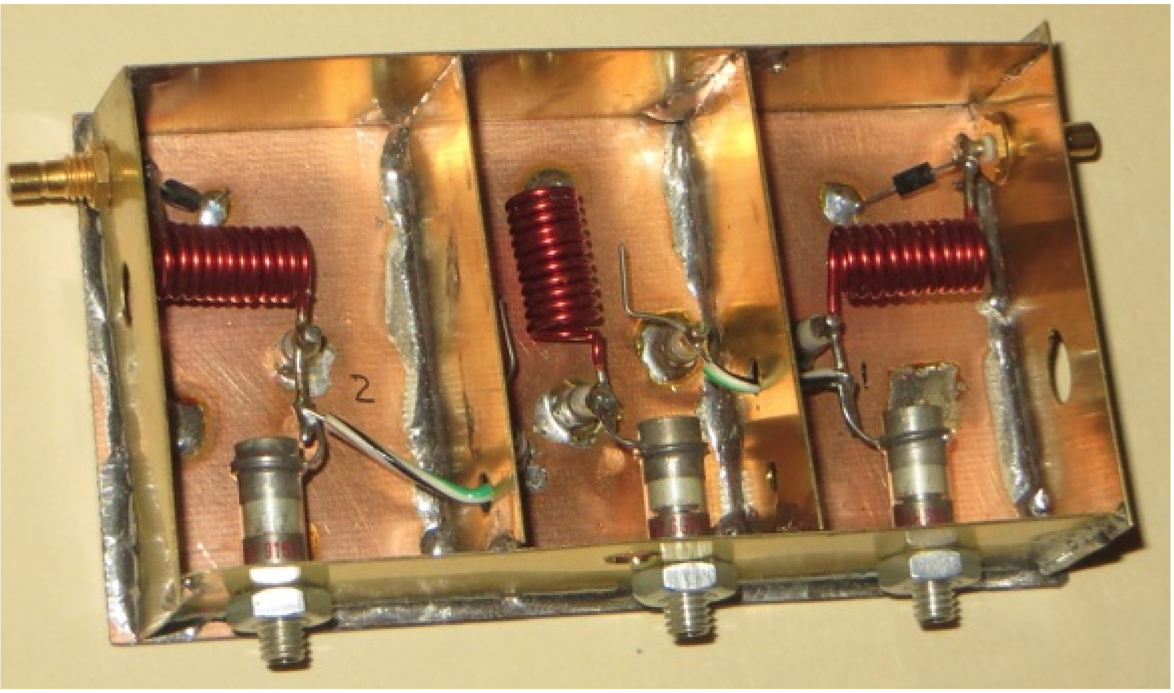

Fig 6. **This view presents the same filter that was shown in Fig 5, but the camera angle is slightly different. This view emphasizes that the brass shield sections that separate the resonators are indeed soldered to the circuit board filter bottom plate. It is only necessary to solder one side of the brass strip. If the walls are built from double sided circuit board material, it may be useful to solder both sides.**

Notice in Figures 5 and 6 that there is no lid in place. Placing a lid close above the filter, but not touching the brass can severely upset the performance. One resonator induces a signal in the "floating" lid that then couples to the adjacent resonator. But when the same lid is forced to make good contact with the brass, the undesired coupling disappears. It will then be necessary to re tune the three capacitors. Note also that there are three extra holes in the brass. These have very little impact on the filter performance. The fields inside the filter will urge the current flowing in the wall to sneak around the hole, but to remain on the inside of each resonator. Little current will flow on the outside of the brass sheet as a result of high currents inside. I'm often amazed at the number and size of the holes that can be placed in a *shield* without killing the effectiveness. But the holes must be small.

It is often helpful to adjust our thinking when we deal with structures like this filter. It's a collection of LC resonators. Current flows through the L and the C, changing direction at a rate commensurate with the resonant frequency. For that current to flow there must be a well defined path from the "grounded" end of the inductor to the grounded end of the capacitor. That path is a vital part of the resonator. The current will flow in the surface metal, urged by the adjacent electric field. The flowing current will generate a magnetic field that supports the electric field. It's useful to try to envision where the fields will be and where the resulting currents will flow.