RF Filters for Multi-Station Operation

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When several Amateur Radio stations operate in close proximity, cross-station interference can occur. Nearby transmitted signals, even at modest power levels (100 watts), can cause serious receiving difficulties for nearby stations. This situation has been most acute during our annual Field Day operations.[1]

Modern HF receivers can detect usable signals at power levels less than 10^{-15} watts. The standard S-meter reading for a "strong" signal (S-9) is often set at an input of 5×10^{-11} watts, or fifty thousand times the power of the weakest detectable signal. Most receivers, though, can handle power levels that exceed S-9 by more than a million-fold. In top-of-the-line receivers this *dynamic range*—the power range over which signals are detectable—can extend ten billion-fold or more from weakest signal to strongest.

The FCC specifies that out-of-band emissions from amateur radio transmitters must be reduced, relative to the transmitter's carrier output, by a factor of a hundred thousand or better. Among the most significant of the unwanted signals are *harmonics*, integral multiples of the transmitter's main signal frequency. All modern transmitters incorporate ouput filters that attenuate these harmonics. But a typical 100-watt signal can still be (legally) accompanied by unwanted harmonic radiation at levels as great as 10^{-3} watts. Radio signals at this power level can potentially damage a nearby receiver's sensitive input circuitry.

Unwanted signals like these are of little concern when our nearest ham radio neighbor is several miles away. But when stations are close by, as in a Field Day operation, the out-of-band signals can become a serious impediment to communication. We can reduce the problem somewhat by spacing and orienting station antennas to minimize cross-station pickup.[2] Though this will decrease unwanted signal levels a thousand-fold or more, we may still be left with interference that can be thousands of times stronger than the usual S-9 signal.

Even if the unwanted signals do no damage, RF energy at these levels can still seriously impair receiver performance. Strong signals will activate the receiver's automatic gain control (AGC) system, and decrease receiver sensitivity. This can happen even when the frequency of the unwanted signal lies far outside the receiver's passband. Adjacent signals can also combine with the receiver's own internal oscillator signals to generate so-called mixing products at multiple frequencies. In addition, transmitted signals are accompanied by *phase noise*, the result of tiny frequency perturbations present in all oscillators. These too can mix with internal receiver signals and cause broad spectrum interference.[3] All these cases point to the need for additional filtering of both transmitted and received signals when multiple stations operate from a single location.

Commercial bandpass filters for multi-station application are widely available, and filter designs for home construction have been described in amateur radio publications.[4-8] The filters attenuate the harmonics and other spurious emissions that accompany transmitted signals, often by many orders of magnitude. Installing filters at every station in a multi-station operation can improve matters further. Yet when filters are needed by a participating group solely for its once-a-year Field Day weekend, as in our case, the investment in filters and the accompanying switching systems for each station can stretch financial resources. With five or six bands per station, and $100 or more per filter per band, costs can quickly mount.

This article describes six high-performance filters designed to attenuate unwanted adjacent band emissions from nearby transmitters. The filters can handle a full 100-watt signal when matched to a non-reactive 50-ohm load, and function in both receive and transmit. The filters are inexpensive, use standard-value capacitors and readily fabricated inductors, and are relatively easy to build and adjust. We estimate that a set of five filters (80m, 40m, 20m, 15m, 10m) can be assembled for about $130. By supplementing component purchases with materials on hand, our cost was less than $80. A manual band-switch system comprised of two multi-position coaxial switches brought our cost to $220 per station. A relay-based switching system would significantly reduce this figure.

Filter design

Bandpass filters for multi-station, multiband operation often employ a single filter topology. Once a successful filter design for one band is found, scaling the circuit to other frequencies is straightforward. This approach allows for a common physical layout independent of frequency, and may facilitate manufacturing efficiency. Our Field Day operations have customarily involved four or fewer stations, some operating on single bands only, and a full filter set for every station has not been needed. The limited capability of our test equipment has also led us to tailor our filter designs for each amateur band without concern for mass production, but rather for ease of construction, testing and adjustment. Our filters' performance compares favorably with that of many commercial designs. In the following descriptions, we consider in detail the design and performance of each filter.

80-meter filter. The circuit of our 80-meter filter is shown in Figure 1. In engineering lingo, this is a fifth-order Cauer low-pass filter.[9] We chose a low-pass design since we were not concerned with operating on 160 meters, nor with interference from nearby AM broadcast stations. The two parallel L-C pairs function as traps at 7 MHz and 14 MHz. The bandwidth is about 4.5 MHz and the stopband is 7 MHz, with a stopband depth of about 55 dB. When we initially tried these parameters in our design software, we encountered unacceptable passband ripple and return loss.[10] The optimization feature of the *Elsie* software, however, allowed us to find a design with greatly improved performance. In this case, we set the optimizer to request a return loss of 20 or better for 3.5 to 4 MHz, and to ignore filter performance below 3.5 MHz. With these simple adjustments, the Cauer topology works well. The filter has only two inductors and five standard-value capacitors.

Figure 2 shows the 80-meter filter's computed response. The filter's attenuation in decibels (dB) is plotted as a function of frequency in MHz ("M"). The vertical bars mark the frequencies of the flanking amateur bands, and the extent of each bar shows the intended filter attenuation (– 45 dB) specified in our filter-design software. This filter can be expected to substantially attenuate signals in the amateur bands above 4 MHz. [Proposed designs for an 80-meter bandpass filter, and for a 160-meter low-pass filter, are described in a later section of this paper (Figures 13-16).]

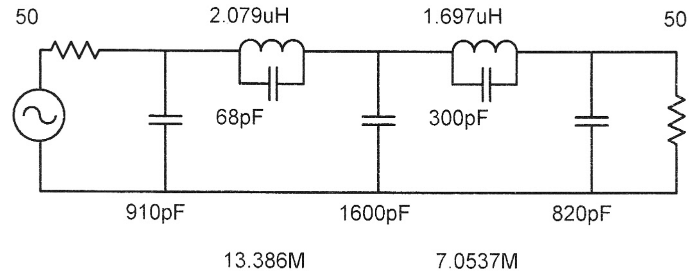

Figure 1. *Circuit of our 80-meter low-pass filter.*[9] *The inductance values, generated by Elsie, need not be precisely duplicated in actual construction. The resonant frequencies in MHz ("M") of the parallel L-C traps are given below the diagram.*

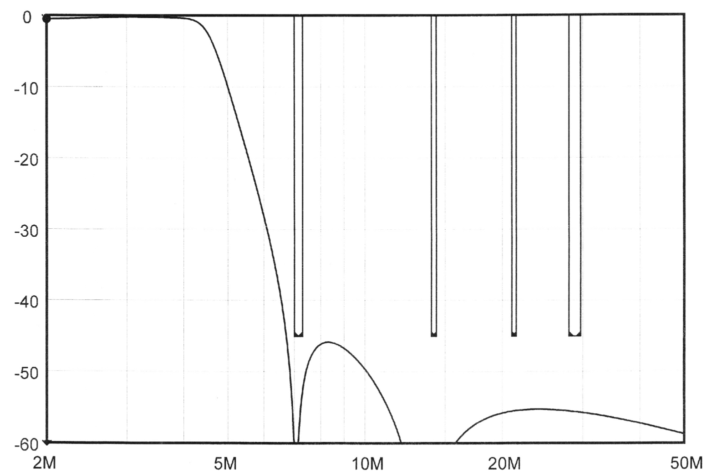

Figure 2. *Computed frequency response of our 80-meter low-pass filter. Attenuation in decibels (dB) is plotted against frequency in MHz ("M"). The vertical bars mark the frequencies of adjacent amateur bands, and indicate the intended, or target, attenuations (– 45 dB) of the filter design.*

40-meter filter. For our 40-meter filter we needed significant attenuation both above and below the passband frequency, and a bandpass design was called for. The basic Cauer topology again served our purposes. As in the 80-meter filter, attenuating traps furnished significant band-specific attenuation, in this case on 80 meters and 20 meters. We again used standard-value capacitors instead of actual computed values. This required only minor adjustments in inductance values to maintain resonant frequencies, and caused only minor departures from the filter's ideal performance. The circuit of our 40-meter filter is shown in Figure 3 (p. 3), and Figure 4 shows the filter's frequency response. Attenuation in adjacent bands more than meets the –45 dB design targets indicated by the vertical bars.

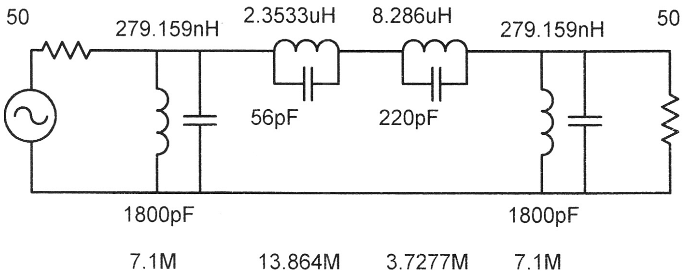

Figure 3. *Circuit of our 40-meter bandpass filter. The inductance values are those generated by Elsie.*

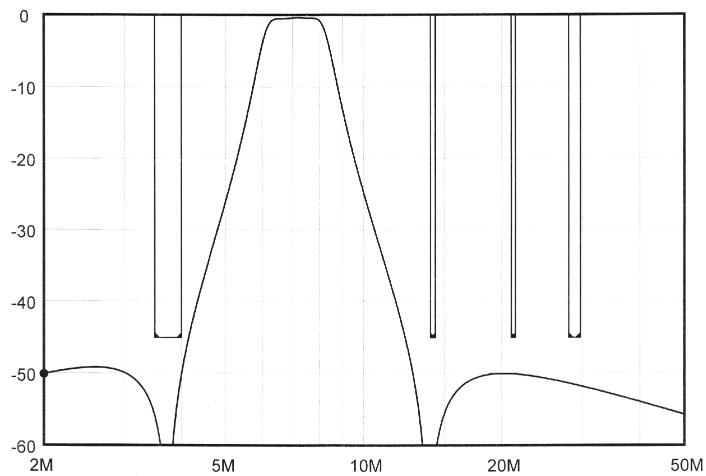

Figure 4. *Computed frequency response of our 40-meter bandpass filter. Attenuation is plotted against frequency in MHz ("M").The vertical bars mark the frequencies of adjacent amateur bands, and indicate the intended attenuation (– 45 dB) of the filter design.*

20-meter filter. Like the 40-meter filter, the 20-meter filter is a Cauer bandpass design (Figure 5). The resonant frequency of the first harmonic trap, however, was shifted downward to increase attenuation in the 15-meter band. This modification accounts for the reduced, but still satisfactory, attenuation in the 10-meter band (Figure 6). The *Elsie* optimizer function was again employed to find this design solution. Attenuation at 7 and 21 MHz exceeds our design targets, but falls a bit short at 28 MHz (– 42 dB).

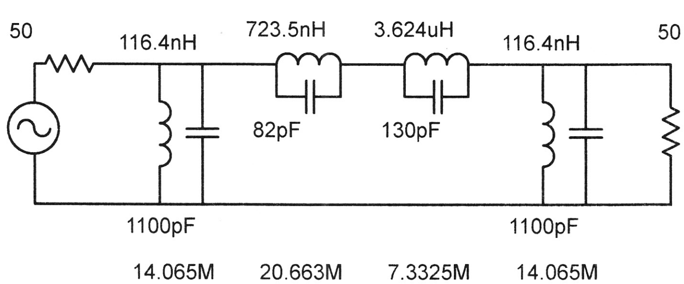

Figure 5. *Circuit of our 20-meter bandpass filter.*

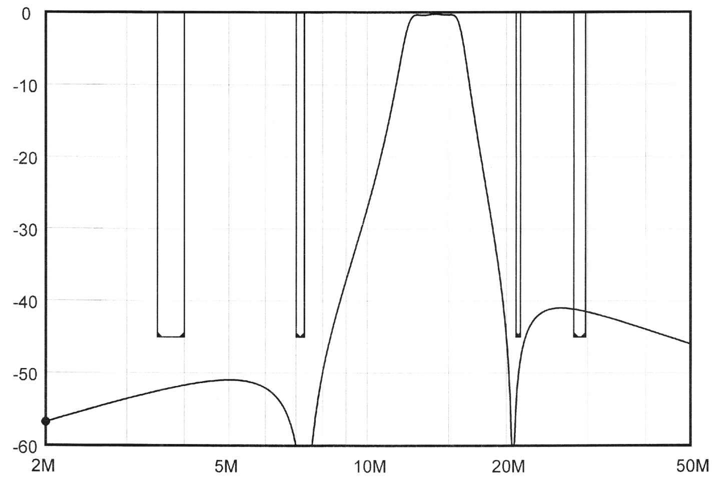

Figure 6. *Computed frequency response of our 20-meter bandpass filter. Attenuation is plotted against frequency in MHz ("M"). The vertical bars mark the frequencies of adjacent amateur bands, and indicate the intended attenuation (– 45 dB) of the filter design.*

15-meter filter. For this filter (and for our 10-meter filter) we chose a different design, composed of four parallel-resonant L-C pairs cascaded in series, with coupling capacitors to achieve proper bandpass function and impedance terminations. As shown in Figure 7 (p. 4), the four inductors are nearly identical, and the design again uses standard-value capacitors.

Figure 8 shows the computed response of the 15-meter filter. The adjacent-band attenuation notches of the 40-meter and 20-meter Cauer filters are not seen here. Nonetheless, attenuation is substantial (about – 70 dB) in the 20-meter band, and adequate (about – 40 dB) in the 10-meter band. The Cauer topology would have provided better performance on 10 meters, but at these frequencies the inductances required by the design lay below the measurement capabilities of our test equipment. We appreciate also the practical considerations imposed on filter design when the filters are expected to be constructed by mere mortals.

10-meter filter. This filter is identical in design to the 15-meter filter described above. The filter's circuit is shown in Figure 9 (p. 4), and the filter's response is shown in Figure 10. Attenuation is – 60 dB or better at frequencies below 20 MHz. The filter also meets the design target (– 45 dB) set for the 6-meter band.

6-meter filter. For this filter we selected a simple high-pass design, since our Field Day VHF station operates on only one band (6 meters or 2 meters) at

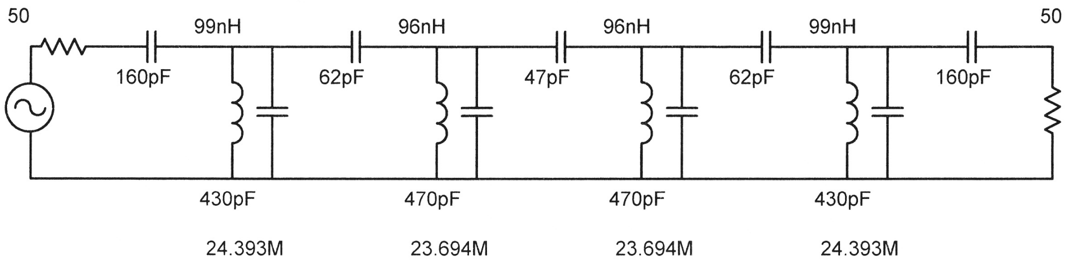

Figure 7. *Circuit of our 15-meter bandpass filter.*

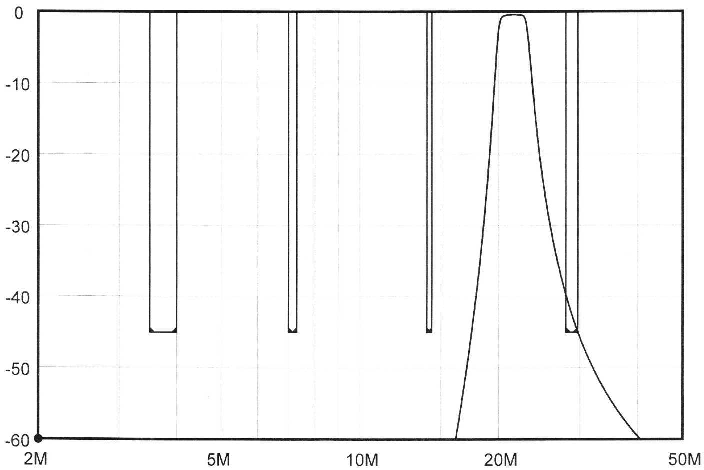

Figure 8. *Computed frequency response of our 15-meter bandpass filter. Attenuation is plotted against frequency in MHz ("M"). The vertical bars mark the frequencies of adjacent amateur bands, and indicate the intended attenuation (– 45 dB) of the filter design.*

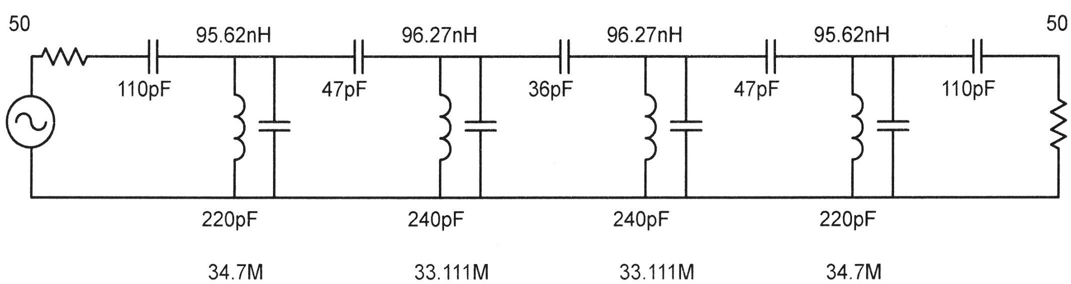

Figure 9. *Circuit of our 10-meter bandpass filter.*

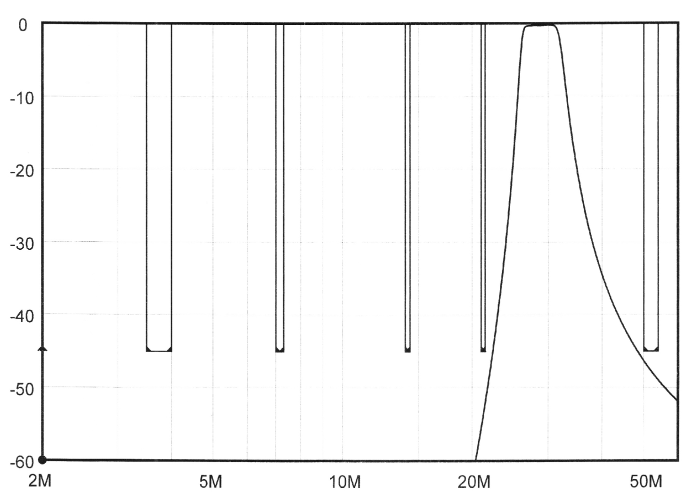

Figure 10. *Computed frequency response of our 10-meter bandpass filter. Attenuation is plotted against frequency in MHz ("M").The vertical bars mark the frequencies of adjacent amateur bands, and indicate the intended attenuation (– 45 dB) of the filter design.*

a time. Hence, we were not concerned with interference on 2 meters from our 6-meter signal, nor with interference on 6 meters from our 2-meter signal. The circuit of the 6-meter filter is shown in Figure 11, and Figure 12 shows the filter's response. Attenuation at 28 MHz is better than – 45 dB, and exceeds – 60 dB at 25 MHz and below. We again made use of *Elsie*'s optimization function to improve filter performance in the passband area, even at the expense of poor return loss in the region above 60 MHz.

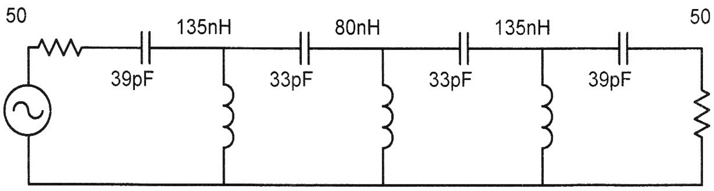

Figure 11. *Circuit of our 6-meter high-pass filter.*

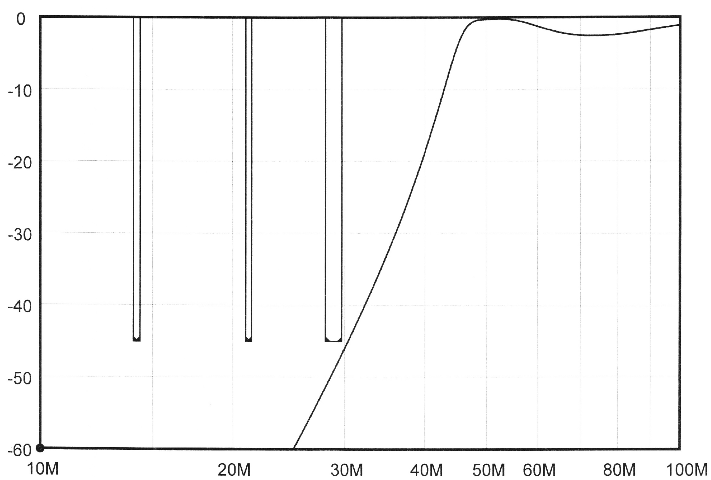

Figure 12. *Computed frequency response of our 6-meter high-pass filter. Attenuation is plotted against frequency in MHz ("M").The vertical bars mark the frequencies of adjacent amateur bands, and indicate the target attenuations (– 45 dB) of the filter design.*

80-meter bandpass and 160-meter low-pass filter designs. We have customarily excluded 160 meters from our Field Day operations, but we recognize that some readers may wish to operate on this band. Our low-pass filter for 80 meters (Figures 1 and 2) does not attenuate signals on 160 meters, and an 80-meter bandpass filter is called for. Similarly, a low-pass filter for 160 meters will protect stations operating on 80 meters and above, but may not suffice to prevent interference from nearby AM broadcasting stations. With these considerations, we describe below two filters designed for these purposes.[11]

The circuit of a proposed 160-meter low-pass filter is shown in Figure 13, and Figure 14 shows the filter's response. The filter attenuates signals on 80 meters and above by – 50 dB or more. This filter is a frequency-scaled version of our 80-meter low-pass filter (Figure 1), and is again a fifth-order Cauer design.

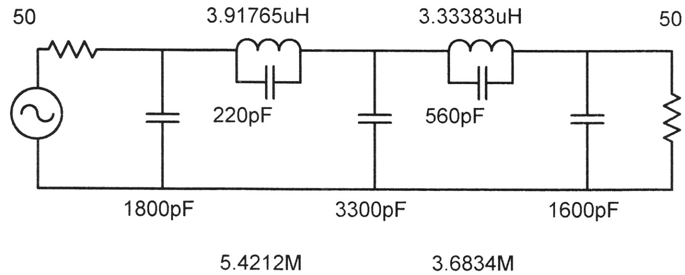

Figure 13. *Circuit of the proposed 160-meter low-pass filter.*

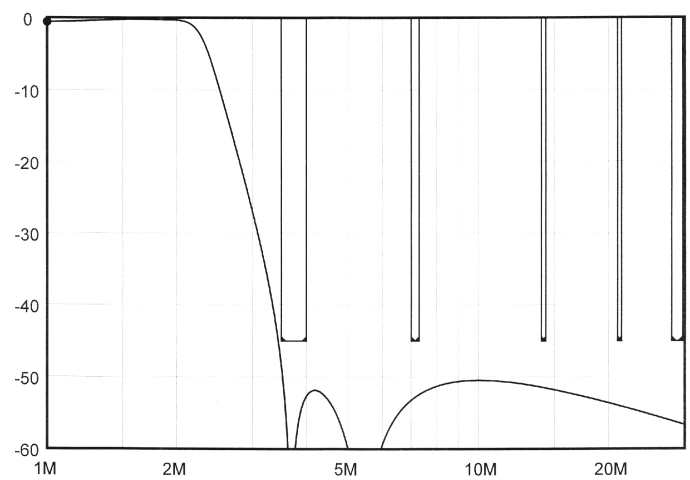

Figure 14. *Computed frequency response of the proposed 160-meter lowpass filter.*

Simultaneous operation on both 80 and 160 meters calls for an additional 80-meter bandpass filter that rejects 160-meter signals. A proposed filter circuit is shown in Figure 15 (p. 6), and Figure 16 shows the computed frequency response. This filter attenuates 160-meter signals by – 55 dB or better, as well as signals on 40 meters and above. The filter also exhibits good attenuation of AM broadcast signals. The filter design will be recognized as a frequency-scaled version of our 40-meter and 20-meter bandpass filters (Figures 3 and 5).

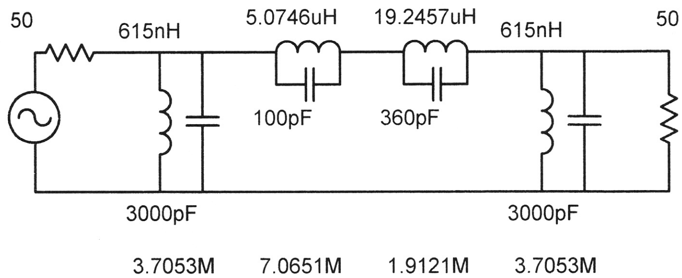

Figure 15. *Circuit of the proposed 80-meter bandpass filter.*

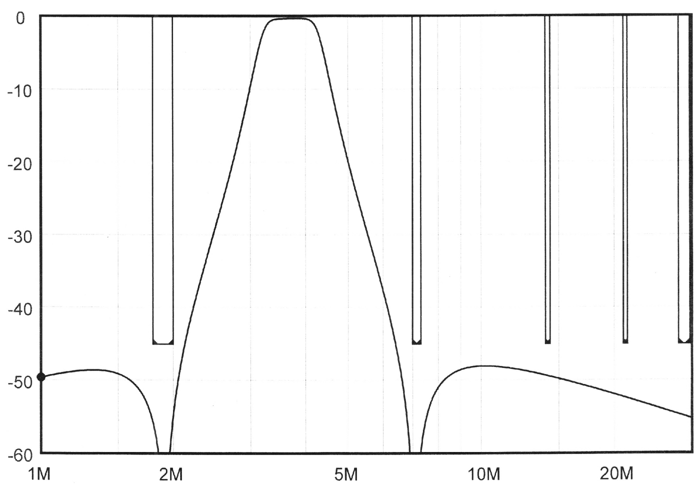

Figure 16. *Computed frequency response of the proposed 80-meter bandpass filter.*

Filter construction

In selecting components for any filter expected to tolerate transmitted RF power levels, the voltages and currents developed in the filter are a major concern. At 100 watts the filter's capacitors can be exposed to several hundred volts, and the inductors can carry currents of several amperes.[12] We used standard value dipped mica capacitors, rated at 500 volts or greater, not only because their use in filters of this kind is normal practice, but also because they are available with close (± 5%) tolerances.

Coils were wound with enameled or bare copper wire on wood dowels or threaded bolts. Wire gauges for the coils were chosen to accomodate computed currents at 100 watts: 14 AWG for currents greater than 6A; 16 AWG for currents in the 3-6 A range; 18 AWG and 16 AWG for currents less than 3 A. The larger wire gauges produced coils that were self-supporting. Some of the high-inductance coils were wound on powdered-iron toroids of appropriate composition.

We used *Elsie*'s coil-winding routine to find the physical parameters (length, diameter, number of turns) of our solenoidal coils, and we confirmed approximate coil inductances using the inductance function of an MFJ-259B antenna analyzer. We also used the analyzer to determine inductances by measuring the resonant frequencies of series L-C pairs with capacitors of known value. Resonances of parallel L-C pairs were determined using a grid dip oscillator.[13] In some cases, final adjustments of parallel L-C pairs were made after the filters had been assembled in their enclosures.

In all the filter designs, the lower rail in the circuit diagrams is seen as synonymous with chassis (enclosure) ground. This condition posed little problem in the 80-, 40- and 20-meter filters, and the small enclosures we used had little effect on filter performance. The 15-, 10- and 6-meter filters, however, were noticeably influenced by their enclosures, and the resonant circuits required closer attention to post-assembly adjustment. Note that the coils in these filters carry low inductances, of the order of 0.1 μH. We found that leads from resonant circuits to enclosure tie-points contributed additional (unknown) reactances that degraded filter effectiveness.

At first, we addressed this problem by installing a heavy ground bus, extending the length of each enclosure, to which the filter's circuit elements could be attached through shortened leads. This approach proved unsatisfactory in the 15- and 10-meter filters. Instead, we installed an additional ground plane of double-sided circuit board to which the resonant components were attached (Figure 17). Since the 15- and 10-meter filters now exhibited attenuation

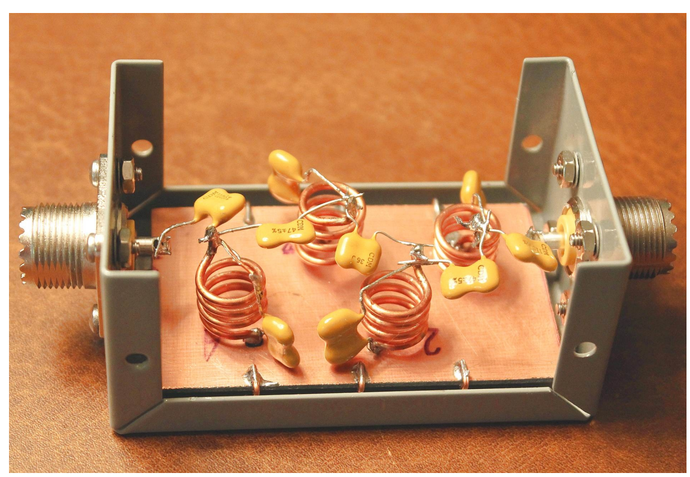

Figure 17. *Layout of our 10-meter bandpass filter, showing the added PCB ground plane.*

performance close to that predicted by computer analysis, we consider this construction modification a suitable compromise. We left the ground bus in place in our 6-meter high-pass filter (Figure 18), and were able to compensate for the stray reactances by coil adjustments. Clearly, at higher frequencies enclosure size affects filter performance in unpredictable ways, and needs to be kept in mind.

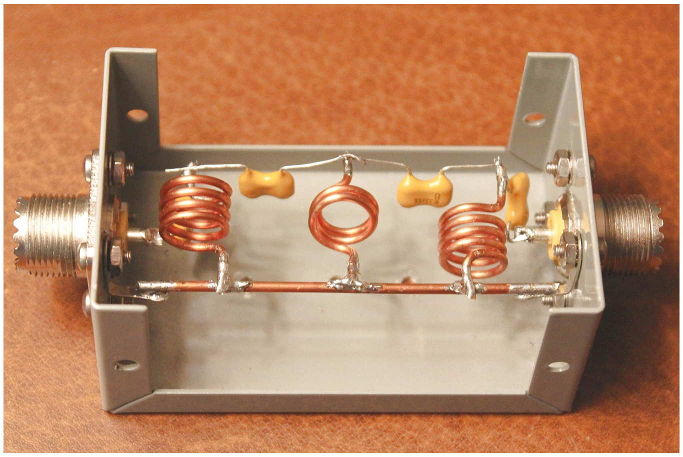

Figure 18. *Layout of our 6-meter high-pass filter, showing the added ground bus (12 AWG).*

Filter performance

With rare exceptions our experience has been that actual filter performance closely matches that computed by *Elsie*. Given the uncertainties in our resonance measurements, however, we felt the need to confirm this experience for our filters. Our test setup had a vintage HP-8640 RF signal generator, a homemade calibrated stepped attenuator, and a calibrated RF wattmeter incorporating the Analog Devices, Inc. AD8307 logarithmic amplifier, which converts RF energy over a 70+ dB range to DC voltage over a linear scale of several volts.[14] We determined filter attenuation in two ways: (1) by measuring output voltages from our wattmeter and finding attenuation by calculation; and (2) by adjusting the stepped attenuator in the absence of the filter to match these same voltages. The results found by the two methods were in close agreement.[15]

In testing our 40- and 20-meter filters, we found that our signal generator produced second-harmonic energy that caused anomalous readings when attenuation on 80 and 40 meters (respectively) was measured with our frequency-neutral wattmeter. We resolved this problem by using the 80-meter filter as a pre-filter when measuring 80-meter attenuation in the 40-meter filter, and using the 40-meter filter as a pre-filter when measuring 40-meter attenuation in the 20-meter filter.

Figures 19a-19f (p. 8) compare measured attenuation with computed attenuation for all six filters. The graphs again plot attenuation in dB on the vertical axis against frequency in MHz ("M") on the horizontal axis. The data for the 40- and 20-meter filters (Figures 19b, 19c) include the procedural modifications noted above. We describe here some properties of the individual filters.

Performance of the **80-meter** low-pass filter (Figure 19a) agrees remarkably well with that computed by *Elsie*. Attenuation in the 40- and 20-meter bands (for which the two attenuating traps were designed) exceeds – 60 dB. Attenuation above 15 MHz is better than – 70 dB, the sensitivity limit of our detector.

The **40-meter** bandpass filter (Figure 19b) also conforms well with the computed attenuation response. Mid-band attenuation on 80 meters exceeds – 70 dB. Attenuation in the 20-meter band exceeds – 60 dB, remains below – 55 dB from 15 MHz to 24 MHz, and exceeds – 60 dB at frequencies above 24 MHz.

The **20-meter** bandpass filter (Figure 19c) departs from the classic Cauer design to provide attenuation in the non-harmonic 15-meter band. Despite this modification, the filter performs well. Attenuation in the 40-meter band exceeds – 65 dB; on 15 meters atttenuation ranges from – 54 to – 70 dB. Attenuation in the 10-meter band is greater than – 48 dB.

The passband in the **15-meter** filter (Figure 19d) is about 1 MHz narrower than predicted by *Elsie*. We have no explanation for this difference, except to cite the influence of the filter's physical layout on circuit resonances. At frequencies below 16 MHz, and above 30 MHz, attenuation is better than – 60 dB.

The **10-meter** bandpass filter (Figure 19e) also has a narrower passband than predicted. Attenuation is greater than – 60 dB at frequencies below 22 MHz, and above 42 MHz.

The **6-meter** high-pass filter (Figure 19f) also performs as predicted. Attenuation reaches – 50 dB at 30 MHz, and drops below – 60 dB at frequencies less than 26 MHz. As we noted earlier, the 6-meter filter's performance would likely benefit from a grounded panel similar to those installed in the 15-meter and 10-meter filters (Figure 17).

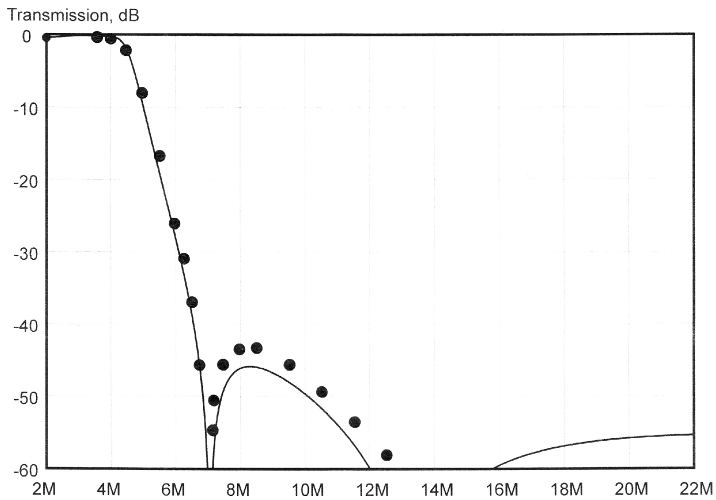

Figure 19a. *Comparison of computed 80-meter low-pass filter attenuation (continuous line) with measured attenuation (data points). "M" = MHz.*

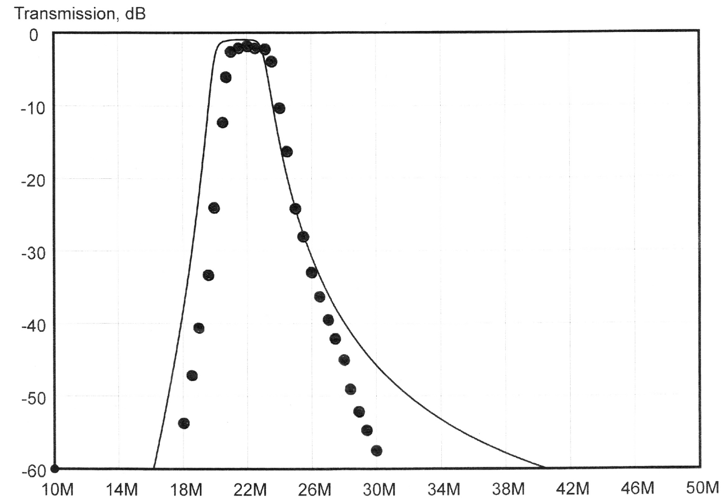

Figure 19d. *15-meter bandpass filter comparison.*

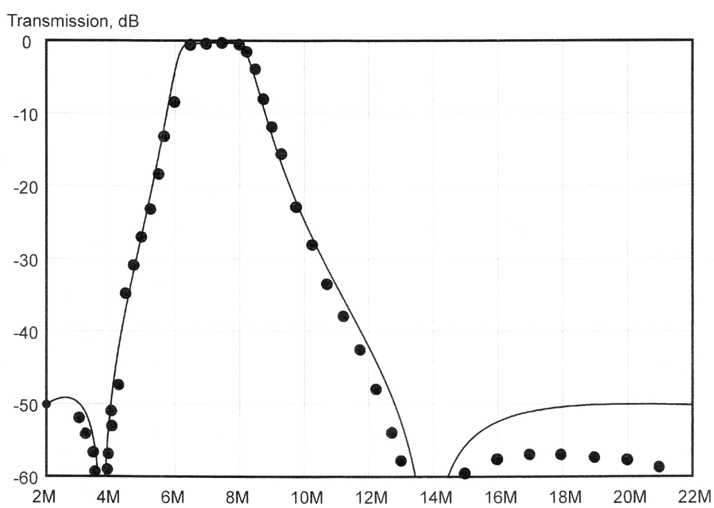

Figure 19b. *40-meter bandpass filter comparison.*

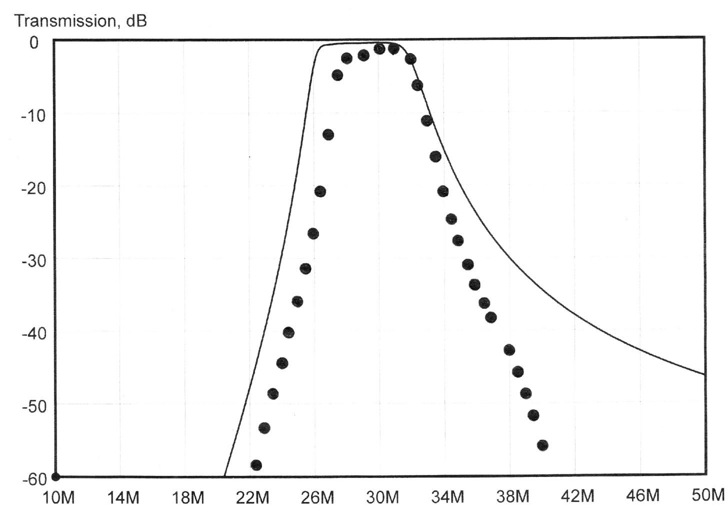

Figure 19e. *10-meter bandpass filter comparison.*

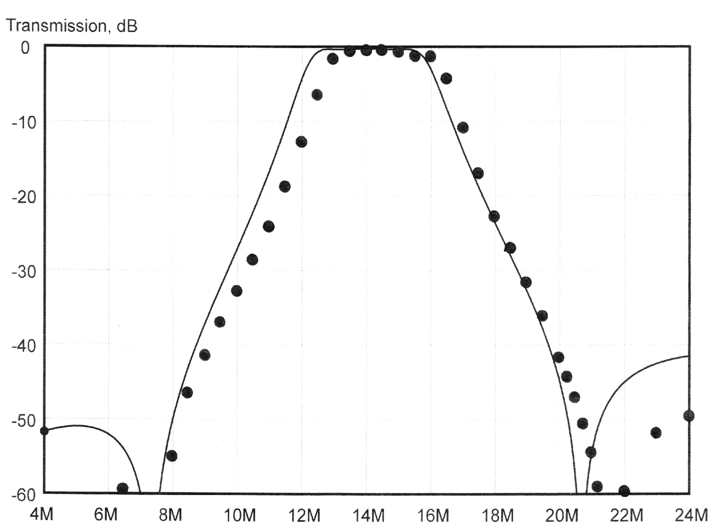

Figure 19c. *20-meter bandpass filter comparison.*

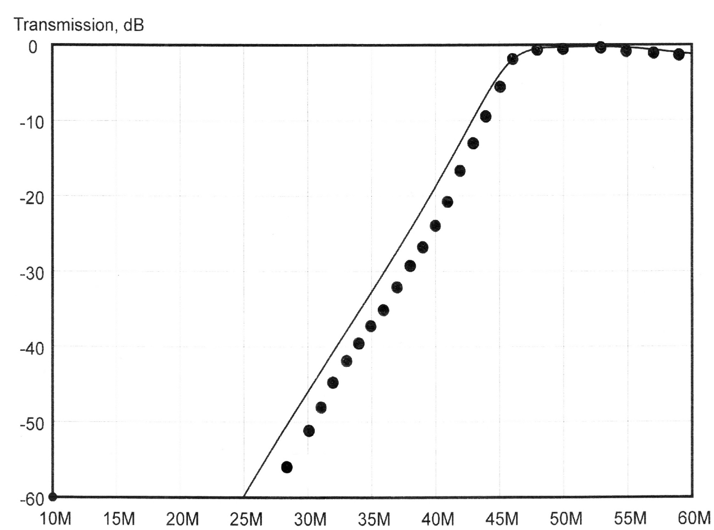

Figure 19f. *6-meter high-pass filter comparison.*

Discussion and conclusions

As the data in Figure 19 show, the filters described here provide significant improvements in attenuating out-of-band interference from nearby stations. In actual Field Day use we were able to simultaneously operate three stations (two HF; one 6m/2m VHF) using only a single bank of filters (80 meters through 10 meters) on one of the HF stations, and the 6m filter alone on the VHF station. A filter set for both HF stations would clearly be preferable.

A recently published description of a set of bandpass filters for multi-station operation differs from our approach by using a single filter topology for all bands.[5] These filters contain three identical series-resonant L-C circuits in tandem; desired signals pass through, and RF energy at adjacent frequencies is blocked. The filters appear to be optimized for ease of construction and reproducibility, and as such are well suited for a club project. *Elsie* modelling shows that the filters provide good attenuation (– 40 dB or better) in the nearest adjacent HF bands.

As with all retro-fit filters, our filters were designed to accomodate the 50-ohm output of an amateur transceiver, and to work into a 50-ohm resistive load. Positioning the filter(s) in the transmission line between the transceiver's output and the antenna will result in proper filter function *provided that* the antenna and feedline furnish a non-reactive 50-ohm load to the filter(s). On our Field Day weekends each HF station operates on several bands, in some cases using a single multi-band antenna. This arrangement means that the impedance match between transmitter and antenna system may not be ideal on every band, and a filter interposed in the transmission line may encounter impedances it was not intended for. This problem can be largely avoided by employing an antenna tuner, in which case the filter would be placed between the transceiver and the tuner. Even so, it is essential that the filter be bypassed while the tuner is being adjusted for a good impedance match. Failing to do so can expose the filter components to voltages and currents that may exceed the components' ratings, leading to possible filter damage.

In summary, we have designed, built, and tested a set of filters that have greatly enhanced our Field Day operations, as well as our club members' operating enjoyment. We believe the filters may also find application in multi-station contest and DXpedition operations. The filters are relatively inexpensive, and construction is straightforward. With no moving parts or active electronics, the filters can be expected to last a long time. As such, they represent a worthwhile investment that will serve our radio club for many years to come.

Authors' Notes:

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A condensed version of this article has also been published: Campbell, D., 2017 RF filters for Field Day. CQ 73 (6): 38-42 (June 2017).

A compendium of practical methods and techniques for filter construction and testing is provided at the end of this article.

References and Notes

1. The Oak Ridge (TN) Amateur Radio Club, Inc. participates in ARRL's annual Field Day exercise under our club callsign, K4PJ.

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5. Reif, B., and S. Pozerski, The NVARC "ugly" filter project. Nashoba Valley Amateur Radio Club, Groton, MA. www.N1NC.org

6. Tonne, J. L., 1998 Harmonic filters, improved. *QEX* (September) pp. 50-53.

7. Wetherhold, E. 1998 Clean up your signals with band-pass filters. Part 1. *QST* 82(5): 44-48 (May 1998). Part 2. *QST* 82(6): 39-42 (June 1998).

8. A detailed and informative review of available com-

mercial bandpass filters for multi-station use may be found at: www.audiosystemsgroup.com/bandpass filtersurvey.pdf.

9. In this and subsequent filter diagrams the signal source is shown at left. The 50-ohm series resistor is not part of the filter; it is an engineering convention representing the output impedance of the signal source and the input impedance of the filter. Similarly, the 50-ohm resistor at the filter's output represents the filter's load impedance.

   Wilhelm Cauer, a German mathematical physicist, developed the modern theory of network synthesis, and made seminal contributions to our understanding of filters and filter design. A technical biography is:

   Cauer, E., W. Mathis, and R. Pauli, 2000 Life and work of Wilhelm Cauer (1900-1945). Proc. MTNS-2000, Perpignan, France, June 19-23, 2000.

10. *Elsie*, the filter design and analysis program, is available at www.tonnesoftware.com.

11. We have not constructed and tested these two filters. In view of the close agreement between computed and measured reponse in our six tested filters (Figures 19a-19f), we have some confidence that the proposed designs shown in Figures 13 and 15 will perform as predicted.

12. We found expected voltages and currents in our filters by computer modeling, using files generated by *Elsie* for analysis by *LTspice*, available at www.LTspice.com.

13. At the risk of appearing hopelessly old-fashioned, we used the Measurements Corporation Model 59 "Megacycle Meter" grid dip oscillator to measure resonance of parallel L-C circuits. After minor restoration (P/S capacitor replacement), this otherwise unmodified test instrument from the 1940s proved to be remarkably stable and sensitive.

14. Hayward, W., and B. Larkin, 2001 Simple RF-power measurement. *QST* 85(6): 38-43. (June 2001). In our instrument an RF input of 20 dBm (0.1 watts) produced an output of about 6 VDC, as measured by a digital voltmeter. The amplifier's response was independent of input frequency in the range considered here (2 to 60 MHz). The amplifier's measured proportionality was 0.061 volts/dB.

15. Our stepped attenuator is of conventional design and covers a range of 81 dB. We combined carbon composition and carbon film resistors in each pi-network attenuator to duplicate as closely as possible the resistances calculated by the standard equations. We have routinely assessed the accuracy of our stepped attenuator by calculation from DC resistance measurements. The individual attenuators were within 0.01 dB of their nominal values for the –1 dB, –2 dB, and –3 dB attenuators; within 0.02 dB (–5 dB attenuator); within 0.07 dB (–10 dB attenuator); and within 0.4 dB (–20 dB attenuators). In strict terms, of course, these numbers apply only to measurements at low frequencies. The close agreement between the two measurement methods for determining filter attenuation leads us to believe that our stepped attenuator may retain its accuracy into the lower VHF range, and at least to 50 MHz or so.

Construction Notes for the ORARC Field Day Filters

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[*These notes supplement information in the articles on the ORARC website, and in CQ magazine, and are intended to assist those who are new to filter construction.*]

1. There is a typographical error in Table 1 of the *CQ* article (June 2017, pp. 38-42). The coil inductance values listed in the Table are in **microHenries** (µH), not in milliHenries (mH) as stated in the Legend. The website article has the correct values.

2. The filters described in the articles are tolerant of layout, and arranging the coils and capacitors is largely a matter of “what will fit where.” I built the 80-meter, 40-meter and 20-meter filters in boxes salvaged from commercial filters (nice box, basic filter). The 15m, 10m, and 6m filters were housed in new boxes [Mouser 537-TF-773(P)]. Photos of the 80-, 40-, 20- and 15-meter filters are shown below. The salvaged boxes are 3 in. square on the outside, 2-3/4 in. square on the inside, and 1-7/16 in. deep. The new boxes are 3-1/2 in. X 2-1/8 in. X 1-5/8 in. (length, width, depth). A sense of scale can also be gained from the SO239s.

The components in the 80m and 40m filters are a bit crowded, and bigger boxes would make layout options easier. A general rule is to space the coils as far apart as possible, but at the same time keeping the connections between components as short as possible. Obviously, both conditions cannot be met at the same time in the same filter. This is where the builder’s judgment comes in. In any event, it’s a good idea to orient the coils at right angles to one another in order to minimize mutual inductance. The toroidal coils in the 40m and 20m filters (8.3 µH and 3.6 µH) are self-shielding, and it probably doesn’t matter how they’re oriented. The coils in the 15m, 10m and 6m filters are spaced far enough apart (at least one coil diameter) that mutual inductance is minimal. The contribution to overall inductances solely from the lengths of connecting wires, though, becomes significant at these higher frequencies, and I plan to re-make the 15m and 10m filters with toroidal coils.

3. In the 40m and 20m filters, the L1/C1 and L4/C4 pairs (CQ article, Table 1) are soldered directly between the center stub of the SO239 and a nearby ground lug. In several cases the specified capacitances were achieved by combining capacitors in series or parallel. This tactic enabled me to use capacitors already on-hand, and would not be needed if the standard value capacitors specified in the designs are available.

4. I wound the coils according to the standard formulas found in the ARRL Handbook. [In my 2011 edition, the information is in Chapter 2, Section 2-12, pages 2-49 to 2-54.] The Elsie filter design program will also calculate the values of single-layer cylindrical (“solenoid”) coils from the standard equation. Since the equation allows for some flexibility in dimensions, a rule of thumb is to make the coils with diameter and length roughly the same, within a factor of two or so. The same section in the Handbook also provides procedures for calculating inductances of toroidal coils. In these cases, the size of the toroids is not critical, but only needs to be big enough to accomodate the wire gauge and number of required turns. Because even standard value capacitors are not always exactly what their labels say, the coil formulas will get you in the ballpark, but the coils will probably require some minor tweaking. This is where measuring the resonant frequencies of each L/C pair comes in.

5. For resonance measurements with the MFJ-259B antenna analyzer, I tack-soldered an L/C pair *in series* along with a 50-ohm resistor, and then soldered this assembly between the center conductor of the MFJ’s SO-238 output coax connector and the nearby ground post. Keep the lead lengths short. I found a short 1/8-in. rod or pin that fit tightly into the coax connector (Mouser 534-1601). I used a regular solder lug on the threaded ground post. The resonant frequency of the L/C pair is the frequency at which the SWR on the meter is minimum (close to 1.0), and the reactance is zero. (The resonant frequency is the same whether the L/C pair is in parallel (as in the filters) or in series (as for these measurments).) Adjust the coil of the L/C

pair to change the resonant frequency. The resonant frequencies specified in the articles don't have to be matched to the nearest Hertz, but try to get reasonably close. In the 40m filter, for example, L1/C1 and L4/C4 should resonate in the middle of the 40m band; L2/C2 around 14 MHz; and L3/C3 around the middle of the 80/75m band.

6. The large wire sizes mentioned in the articles are only necessary when filter currents are unusually high. For L1 and L4 in the 40m and 20m filters, the RF currents are about 8-10 amps. I used #14 copper wire for these coils, just to be safe. This is plain commercial insulated house-wiring wire from the electrical supply store, with the insulation stripped off. The wire is probably soft-drawn, but at #14 the wire is stiff and the coils are sturdy and self-supporting. Coils in the 15m, 10m and 6m filters were also made with #14 wire, though here the large wire size is probably unnecessary. For the other coils in the 80m, 40m and 20m filters, I used #16 and #18 enameled wire for the cylindrical coils, and #20 enameled wire for the toroidal coils.

7. I wound the cylindrical coils on wood dowels, following methods described in the ARRL Handbook. I made the dowels a foot or so long and drilled a little hole through the dowel near the center. I measured off the length of wire required for the coil, plus some extra, anchored one end of the wire to a sturdy support, and anchored the other end to the dowel by making a right-angle bend in the wire near its end and inserting this end into the hole in the dowel. Then I could hold the dowel in both hands, and wind the coil on the dowel by rotating the dowel while moving toward the wire's far anchor point. It's fairly easy to keep the turns tight on the dowel and close together. [I advise winding the coils with the turns closer together than the calculations specify. Springy coils have a tendency to rebound when squeezed.] When enough turns have been reached, the coil can be taped down at its ends if it tries to unwind, the unused wire cut off, and the bent end pulled out of the little hole. Now the the coil can be slid off the dowel. If the coil needs to be glued to hold the turns together (I used Duco cement), it's easier to leave the taped-down coil on the dowel until the glue is dry.

8. I hesitate to specify the dimensions of the coils in these filters, out of concern that builders will try to duplicate them exactly. Instead, I strongly suggest winding the coils according to your own calculations, and viewing the following numbers as rough guidelines only. In the 80m filter, L2 and L4 were close-wound on a 5/8 in. dowel with #18 enameled wire, and are about 5/8 in. in length. In the 40m filter, L1 and L4 were wound with #14 wire on a 3/8 in. dowel; L2 was close-wound with #18 enameled wire on a 5/8 in. dowel and is approximately 3/4 in. in length. In the 20m filter, L1 and L4 were wound with #14 wire on a 3/8 in. dowel; L2 was wound with #16 enameled wire on a 5/8 in. diameter ceramic form and is about 3/8 in. in length. All the coils in the 15m, 10m and 6m filters were wound with #14 wire on a 3/8 in. dowel. The two toroidal coils (L3 in the 40m filter, L3 in the 20m filter) were wound with #20 enameled wire on Type 2 powdered iron toroids (T94-2). In winding toroidal coils, it's best to use soft-drawn copper wire. With hard-drawn wire, the force required in winding the coil can break the ceramic toroid (Figure 5).

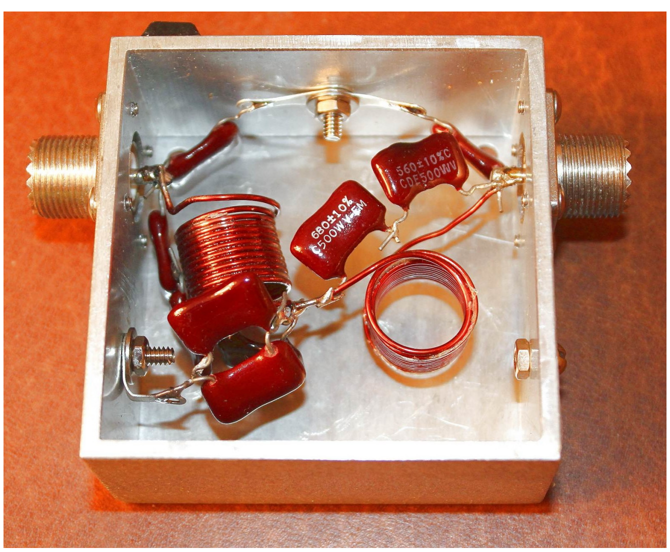

Figure 1. *FD80: 80 meter lowpass filter.*

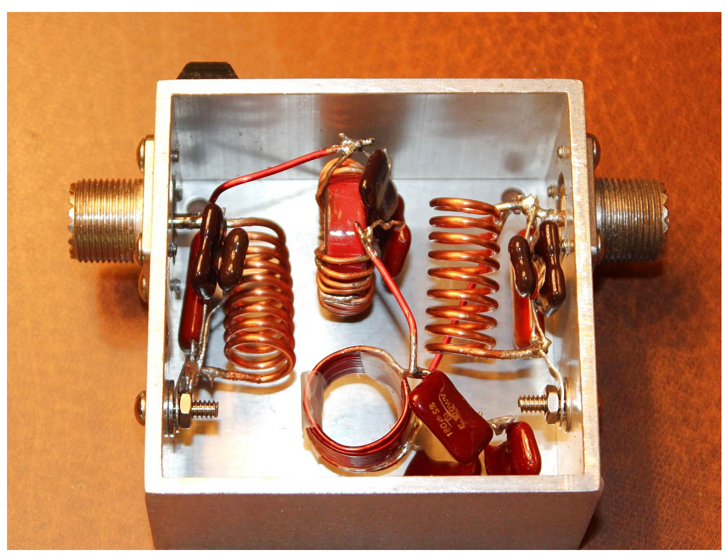

Figure 2. *FD40: 40 meter bandpass filter.*

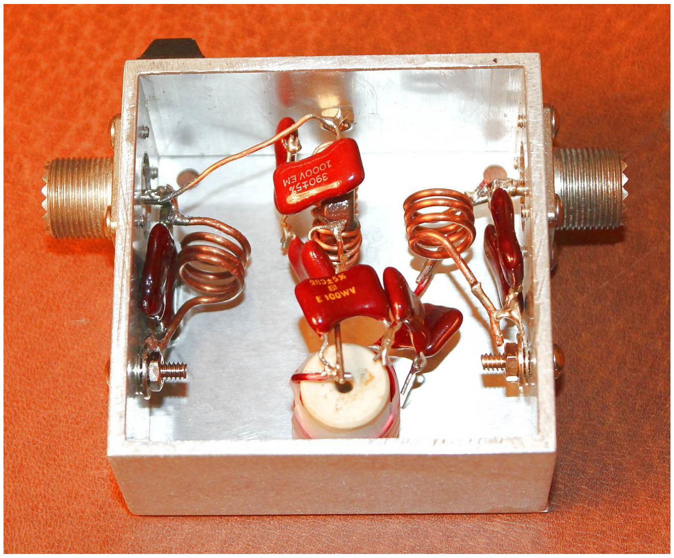

Figure 3. *FD20: 20 meter bandpass filter.*

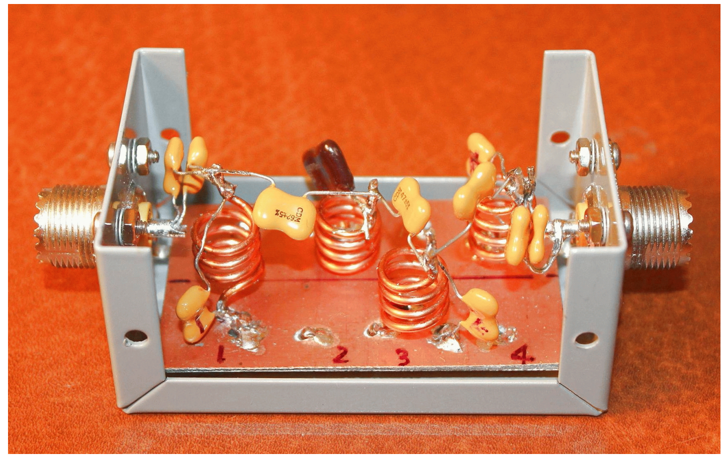

Figure 4. *FD15: 15 meter bandpass filter.*

Figure 5. *Toroid with hard-drawn copper wire.*