The NVARC “Ugly” Filter Project

By Bob Reif W1XP and Stan Pozerski KD1LE

Introduction

First, this is not a construction article. This article describes a project we undertook for the Nashoba Valley Amateur Radio Club (NVARC) to build sets of band pass transmitting filters for reducing the interference between HF transceivers operated in close proximity. If after reading the article you wish to build one or more of the filters, there are parts lists, schematic diagrams, and pictures available on the Club web site. There are also notes on several aspects of building the filters. This article traces the thoughts of the team that came up with the project and designed the filters. After the filters were designed a set of test filters was built from the plans. Then multiple sets of filters for use at our field day site were built by a group of volunteers. The filters have been used since 2005 in our field day set up and have performed very well. We are making the plans available on our club web site for anyone that may wish to build the filters. To include all the information in this article would lead to a very lengthy article. We hope this method of presenting the material will meet the needs of both the filter builder and those that are interested in the process.

Background

Other authors have used the term “Ugly” to refer to non-standard ways of doing things. The expression “Ugly Construction” has been credited to Wes Hayward W7ZOI for the many projects he has built over the years using components to support themselves. The “Ugly Amplifier” term used to refer to the unusual construction techniques used by Rick Measures AG6K in power amplifier projects. There is even “An Ugly Transformer” project in the 2005 ARRL Handbook for Radio Communications. So therefore why not an “Ugly” Filter project?

As a bit of background, the Nashoba Amateur Radio Club has for some years operated field day from a local apple orchard. It is a lovely spot in several ways and gives some meaning to the “field” part of Field Day. We set the stations up amongst the trees and enjoy the advantage that we can spread the antennas out to reduce the inter station interference. The operation has grown from a single transmitter QRP operation to 2A on CW and SSB and then to 2A with a GOTA (Get On The Air) station and VHF/UHF plus satellite station.

With the increase in activity level at the site the inter station interference has also increased. Several years ago it was proposed to increase the number of active HF transmitters to four (4) (SSB, CW, and digital mode, plus the GOTA station). This caused the specter of inter station interference to rise over the horizon. We had suffered some interference with just the SSB and CW stations. We have always tried to locate the antennas for minimum coupling. That and not operating the same band by more than one station at a time had kept the interference problem tolerable.

With more stations on the air it seemed that even more interference problems would occur. For one thing the antennas were going to be closer together. We could not spread the operation over an even larger area since we were already near the contest limit of a 1000 ft. diameter circle for the antennas. Our operating positions are grouped more closely together in the center to maximize social interaction and to keep AC power wiring and computer network interconnections as short as possible. You could consider it a star configuration. This was going to make it harder to find locations that had minimum coupling between the antennas.

The suggestion was made that we could use some band pass filters to increase the isolation between the stations. The transmitter phase noise in adjacent bands was a big source of the interference. Band pass filters after each transmitter can help suppress this type of interference. A search for possible filters identified several that could either be purchased or built from articles.[0]

We considered the cost of purchasing four sets of filters and that motivated us to consider building our filters. A search for a satisfactory design left us with the feeling that we might want to design our own. Some of the designs seemed inadequate. In particular some designs gave good specification at the next harmonic but due to the sub harmonic separation of the 20, 15, and 10 meter band, the performance at the next band is much poorer. Some designs seemed to be almost as costly as buying commercial filters. So our filter project was born.

In the early phases of the project we considered using toroidal core inductors. Toroidal cores have advantages when used to build inductive filter elements. The main advantage is compact coils that do not interact with each other or the surroundings. The cost of the cores is one big disadvantage when you have a lot of filters to build. There was a lot of exchange of ideas between the principals in the project on what to use for inductors. The discussion went back and forth several times between powdered iron toroidal cores and air core solenoids. This flip-flopping at this point in the project was probably good. It allowed us to really decide what we wanted the project to look like. During this phase we decided to write an article on the filter project and the resulting filter design. This decision more than any other probably drove the design into the “ugly” form of construction.

We had chosen a filter specification and now we needed to fully develop the philosophy of the filter design. This is really where the ‘Ugly Filter’ was born.

The three parts of the filters, coils, capacitors and cases all seemed likely to be costly items. So we decided to see what we could do to reduce the costs of these items. First we considered the costs of the coils. Study of the requirements indicated we needed at least three coils per filter. With twenty filters to build (originally we only considered 80, 40, 20, 15, and 10 meters) the number of cores was not enough to get a saving on a quantity discount. Different core types are required for the different bands so no one type was required in large enough quantity to save on the cost. More study indicated we should be able to use air core designs of close wound wire on PVC forms and meet the requirements. While we were considering the coils we thought we were still going to have to buy expensive capacitors and cases. So we decided to build the filters with inductors of air core hand wound solenoid coils to minimize cost in this area.

We were still searching for suitable high voltage capacitors. A study of the requirements indicated we needed a three-pole filter design. That meant there were at least three and probably more capacitor elements per filter. We were beginning to think that the capacitors might be even more costly than the use of powdered iron cores. Then we found a source of ceramic high voltage capacitors. They looked as if they could do the job and sample parts were ordered for evaluation. More on the capacitors later.

So the case was the final item. Some of the filter designs we had looked at used expensive cast aluminum boxes. Certainly a quality way to go but with the quantity of filters required we wanted to look for other options. Another design had all the filters mounted in one large enclosure. We rejected this approach because upon studying the published response curves it seemed to suffer from coupling between the filters. With the decision to use air core coils the possibility of coupling between the filters was even greater. So we were looking for a suitable case for the individual filters. Individual filters also meant you could build only what you needed and place them where convenient. It was obvious that the cost of enclosures for twenty (20) filters (four stations at five or more filters each) was going to be a considerable expense by itself. Now we are not the cheapest or poorest organization, but we did want to keep the costs low. It was suggested that PC (personal computer) power supplies are failing every day and that they are replaced and the old power supply is thrown out. Each power supply has a metal case that could be used for the filter enclosures and they are available for FREE. (That is the magic word to any ham.) So we took a look at what could be done with this as a possible filter case. Another advantage is that this choice is environmentally friendly. Recycle those old PC supplies and save a landfill! Another benefit of recycling the old power supplies is they are a source of switches, capacitors, coils, line filters, heat sinks and other goodies you can recover.

One of the driving requirements of the project was to come up with a filter design and construction method that could be duplicated by the average ham on the kitchen table and made to work with little or no test equipment. Maybe a design that was not optimum in the electrical sense, but provided a satisfactory level of performance that was repeatable to build, reliable, and not too expensive. The filters were required to be built with parts and material that were readily available. We then settled on a general set of requirements. The requirements have two tiers of performance, goals and specifications. Goals set the higher level of performance. Specifications are the minimum acceptable limit of performance.

- Insertion loss of 0.5 dB or less, goal, and 1.0 dB max. Spec.
- Stop band attenuation of 40 dB or more at the adjacent ham band edge, goal and 30 dB or more. Spec.
- 100 watts power key down no time limit
- 2 to 1 load SWR operating limit
- No tune design
- Simple construction
- Readily available parts
- 160, 80, 40, 20, 15, and 10 meter designs
- Keep the design as uniform as possible band to band
- Full band coverage with one filter

Table 1, Goals and Specifications

In general the ugly filters meet all the specifications and most of the goals. Like any design there have been tradeoffs between the various conflicting requirements, but the resulting filters are a very satisfactory compromise. The response of a typical filter is shown in figure 1 and figure 2 is a photo of the filter with the case open.

Mkr1 4,000,000 Hz.
S21Mag: -41.0 dB.
S21Phs: -133.3 deg.

Mkr2 7,000,000 Hz.
S21Mag: -0.6 dB.
S21Phs: 19.4 deg.

Mkr3 7,300,000 Hz.
S21Mag: -0.4 dB.
S21Phs: -17.0 deg.

Mkr4 14,000,000 Hz.
S21Mag: -47.5 dB.
S21Phs: 108.3 deg.

Start Frequency 3,000,000

Stop Frequency 15,000,000

Tx Level, dB. 0

Ref. Level, dB. 10

Figure 1: Typical Ugly Filter response [full resolution image]

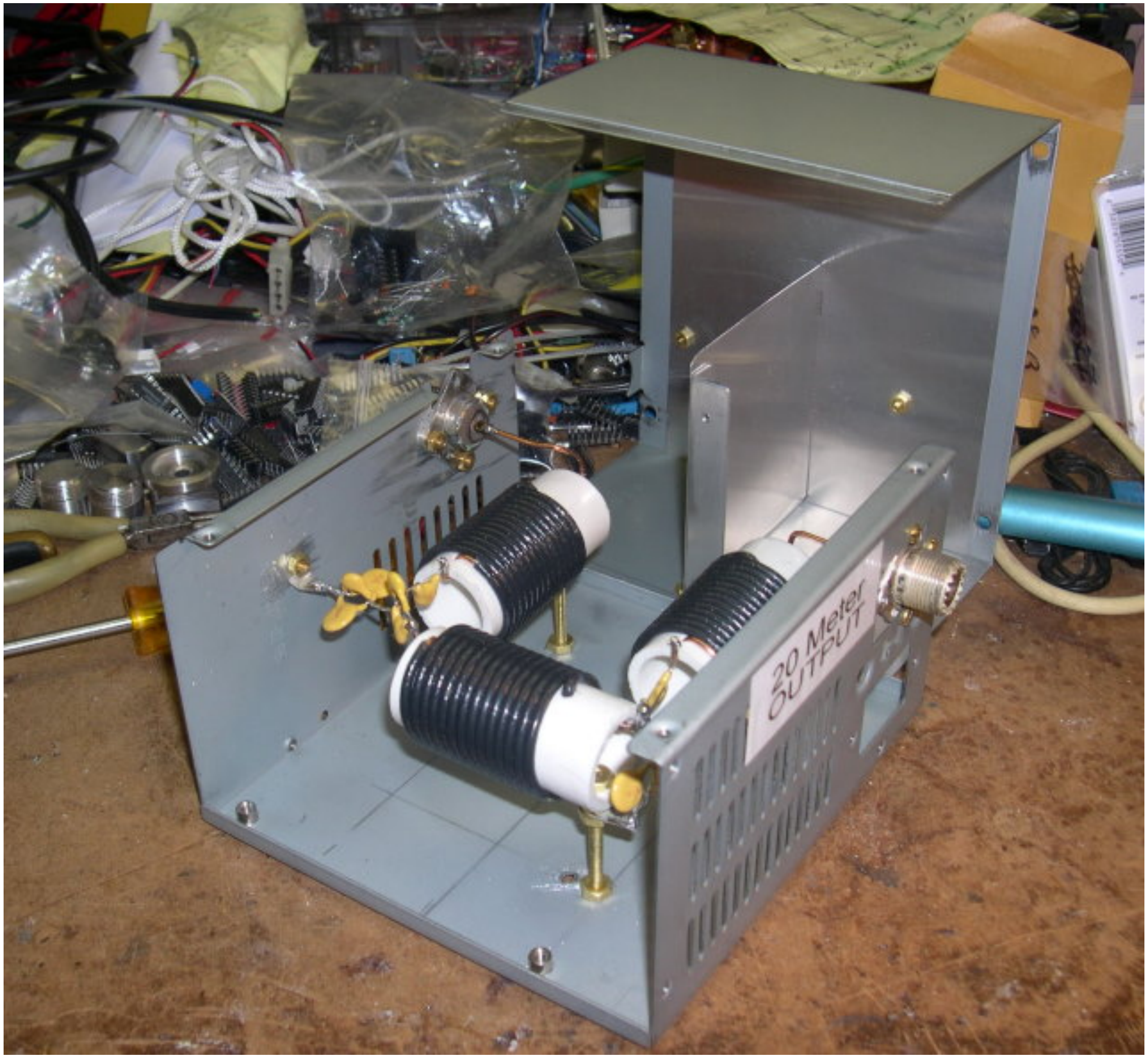
20 Meter
OUTPUT

Figure 2: Typical Ugly Filter construction

Detailed Design

All of the filters use the same filter prototype circuit. See figure 3. This circuit was chosen for several reasons. First, the values of inductance are reasonable to realize in solenoid coils with acceptable Q’s. To maintain a more symmetrical stop band response in some of the filters both coupling coils and coupling capacitors are used. The coupling elements are the shunt elements between the series resonators. The type of coupling element, capacitor or inductor, shape the stop band response because of the reactance of the coupling element at zero and infinite frequency. The filter loaded Q was kept as low as possible to keep the pass band losses low while providing the desired stop band attenuation. This was accomplished by making the filter pass band as wide as possible and still achieve the desired stop band attenuation at the adjoining contest ham band. This also adds to the uniformity of response in the desired pass band. The resulting design is also more tolerant of variation in component values. In the case of the 80/75-meter filter, due to the wide percentage bandwidth it was necessary to go to four (4) poles. All of the other bands use three (3) pole filters. For this reason and because the coils required are large in inductance, the 80 meter filter is built in a double sized enclosure made by joining two (2) PC power supply cases. Likewise the 160-meter filter requires even larger inductance coils. For this reason it is built into three PC supply cases. The filter for 160 meters also uses a toroidal core coil for one of the coupling elements. In the end it was the simplest way to fit it all in the enclosure.

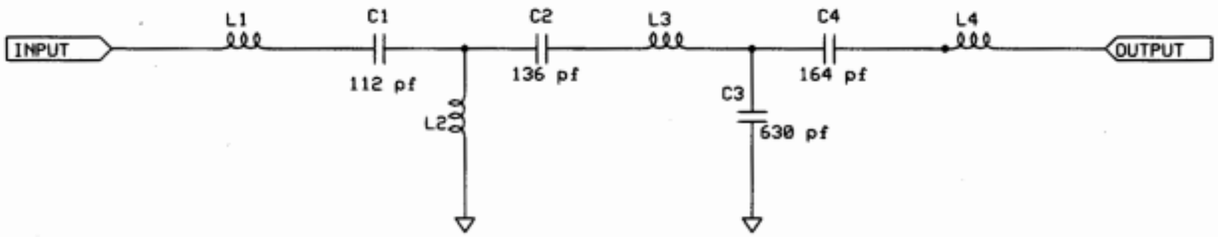

Figure 3: Typical Ugly Filter schematic

All of the filters use series tuned resonators and shunt coupling elements. These series circuits seem desirable to help reduce the possibility of damage to the filters by transmitting out of band signals into them since the input impedance is high out of band. This reduces the out of band input currents and reduces the possibility of damage to a filter. This series design is just one of the steps we took to make the filters as rugged as possible. We also decided to use two or more capacitors in parallel for each capacitor value in the circuit. This shares the current between the two (or more) parts to improve the reliability by reducing the stress in the individual components. In most cases three thousand volt breakdown capacitors are used. Because of the paralleling of capacitors we did not make an effort to force the design to standard value capacitors. The parts chosen are Panasonic KGE type available from Digikey. (See the individual parts list for each filter for the required parts). They are not available in five percent values although the parts are specified at five percent tolerance. The range of capacitance values is also somewhat limited to just over a decade. The range is 12 pF to 150 pF in the 3 KV parts. Because of the limited range available it is necessary to parallel more than two capacitors in many cases but this should only help the reliability by reducing the current stress in the individual parts. The cost of the parts is low enough that this is not a real cost disadvantage. Again the exception to the basic design is at the limits of the range. The filter for ten meters is the exception to the parallel capacitor goal. In this filter we had to use series capacitors to achieve the small value required from the limited range of values available. Again the stresses are shared between two components.

One of the key requirements was a way to wind the coils on air core forms that would be reproducible by different builders. It is well known that space wound coils can provide higher coil Q’s than close winding. Higher Q means lower loss. We chose close winding because we felt that would be more repeatable and easier to wind. Magnet wire with thin enamel insulation might be preferred but we chose solid copper PVC covered wire stripped out of regular Romex house power wire. The magnet wire would cool better but heat is not a problem in the coils. The house wire is available at any hardware or electrical store. This solid wire spaced by the heavy PVC insulation gives good Q values at the frequencies of interest. We chose standard schedule 40 PVC water pipe for the coil forms because it is readily available and the outside diameter is well controlled. It has low loss at HF frequencies. It is also inexpensive and easily worked with hand tools. The turns on the coils are close wound with each turn wound tightly against the previous turn. The spacing between the turns is controlled by the thickness of the PVC insulation on the wire. The turns are terminated by close fitting holes in the PVC form. The wire is passed through the holes and the wire crimped tightly against the inside of the form after being pulled tight. The excess wire is used for the coil leads and as tie points for connecting the capacitors. This gives it the Ugly Construction rating. See the photos on the construction web pages for details of the coil construction. The winding procedure will be described in detail later. The coils are mounted on single long bolts that support the coils in the center of the case compartments. The mounting hardware is brass because it is non-magnetic. This is necessary because the coils have large external magnetic fields that can be disturbed by the metal of the cases or by coupling between the coils. For this reason it is necessary that the filters be built as shown so that the performance of the coils is not disturbed. It is also necessary to add a shield partition to the box to achieve the ultimate stop band attenuation. This is one unfortunate aspect of using the PC power supply case. Note that all shields and case covers must be in place to achieve full filter performance.

Before we proceed let’s review a few basic filter terms and properties. The pass band is the part of the filter response through which the desired signal passes. It is desirable that the losses in this part of the response be as low as possible. It is usually defined as that part of the response between 3 dB loss limits. In our application we want the losses in the desired amateur band to be less than 1.0 dB and ideally 0.5 dB. So the pass band of the filters (in 3 dB terms) is much wider than the amateur band. The stop band attenuation is the amount of rejection to out of band signals. In general it is not a fixed amount but increases as the frequency of the response moves either above or below (in band pass filters) from the 3 dB cut off frequencies. In practical filters this attenuation increases till secondary effects limit it. These effects are due to the parasitic inductance in the capacitor leads, and the ultimate shielding of the case. The slope of this response is directly related to the number of tuned circuits (poles) in the filter. More tuned circuits produces a filter with a steeper slope and more attenuation. The downside to more poles besides more parts is that the filter is more critical to tune. More parts also have more loss in the pass band. These are all elements of the design tradeoffs that have to be decided.

The approach we took to the design of the filters was to use as wide a pass band as possible and still meet the stop band attenuation requirements at the adjoining band edges. This design approach provides a low pass band insertion loss (our goal was 0.5 dB). It also provides a design tolerant of small errors in construction and component tolerances. This is the “no tune” design. We chose a Butterworth design over a low ripple Chebychev as early study indicated more desirable component values with the Butterworth design.[1]

The requirements of each filter in terms of pass band bandwidth, and stop band attenuation vary from band to band. For example the 80/75-meter filter has the widest required percentage bandwidth; thirteen point four percent (13.4%). The fifteen-meter filter has the narrowest percentage bandwidth (of the Field Day bands); two point one percent (2.l %). The filters for these two bands were the most difficult to design for different reasons. The 80/75-meter filter required an extra pole (tuned circuit) to provide a flat pass band response over the large bandwidth and still provide enough attenuation at the edges of the adjoining bands. In the end the specification was relaxed a bit to keep this design simple to build.[2]

The fifteen (15) meter filter has the disadvantage of being only a half octave away from either the twenty 20 meter or the ten (10) meter band. This same close spacing affects the design of the twenty (20) and the ten (10) meter filter. The separation between the other ham bands is one octave. We are not including the 60, 30, 17, and 12 meter bands in the filter specifications. The general design philosophy was to make the pass bandwidth as wide as possible while still meeting the stop band attenuation desired at the adjacent band edges[3]. To help meet these goals the coupling elements within the filter prototype were chosen to tailor the stop band response. In this way the designs of the filters from band to band are different. Some filters use two capacitive coupling elements and some use two inductive coupling elements. Some of the filters use one of each. We used a computer program[4] to evaluate each design before it was built. A scalar network analyzer was used to measure the response of the filters. The element values were tweaked and designs changed to achieve the final result. A version of SPICE[5] was used to investigate component stress under various mismatch conditions.

Lumped element filters are made up of inductors and capacitors. We had decided to wind our own coils and after some more experimentation and discussion the solenoid coils had been chosen for the inductive reactance elements. We had also started a search for a suitable capacitor. There were several candidates for the capacitors but most were very costly and/or not available in high voltage rating. We found a series of high voltage ceramic capacitors that looked like a reasonable choice. Some parts were obtained and tested in a filter for Q and stability. The capacitors have a small positive temperature coefficient. Considering the limited temperature range and the low loaded Q of the filters it was felt that the fact that the capacitors were not NPO temperature characteristics would not be a problem. We also chose to use two or more capacitors to reduce the heating of the capacitors and improve the stability. Testing on the first filter built has indicated that this is indeed the case. The down side to the parts is that although specified at +/- 5 %

tolerance the only values are the 10% values. For example 100 pF, 120 pF, 150 pF is the sequence of values available. The lowest capacitor value available is 12 pF at 3 KV and the maximum value is 470 pF at 1 KV breakdown voltage. The decision had been made to parallel two or more capacitors to reduce the current stress and reduce heating in the parts for each capacitive element in the filters. This was done to improve reliability and stability. This approach also allows the paralleling of parts to achieve the required value of capacitance even if it was not in the range of values available. Since the unit cost of the parts is under a dollar this has not been a large cost disadvantage. Some of the lower band filters do require a large number of capacitors in parallel to achieve the required large value of capacitance. This has not been a disadvantage to the filter performance. Some of the shunt coupling capacitors are made up of 1 KV rated parts. This allows taking advantage of the larger range of parts available in the 1 KV breakdown rating range. The working voltage across these shunt coupling elements is low so this is a sound design choice. The capacitors in the series tuned circuits undergo the highest voltage stress and these parts are selected from the 3 KV rated series of parts.

Along with the choice of the case, the decision to use air core coils has the biggest impact on the filters. Powdered iron cores have the advantage that if you can count and use the right core it is relatively easy to duplicate the required inductance. The same cannot be said for air wound coils. The inductance of an air wound coil is a function of the geometry of the conductor in the coil. That includes the size of the wire, the diameter of the turns, the number of turns and the spacing between the turns. The challenge of the design was to come up with a coil that could be easily replicated by different builders with relatively simple instructions. First of all we needed to choose materials that were available to the average builder. That led us to choose #14 AWG solid wire with PVC insulation. This is the standard house wiring wire. We also chose PVC pipe for the forms. The third part of the coil design is to close wind the turns with the spacing between the turns determined by the thickness of the wire insulation. These decisions have caused some compromise in the Q of the coils, but the fact that four sets of filters have been built by different Club members with no problem in the reproducibility of the coils attests to the soundness of the design. The close spacing between the coils and the case walls also affects the loss in the coils and the inductance of the coils. For these reasons the filters should be built exactly as described or you can expect to have to tweak the coils to get the inductance correct. The coil designs were adjusted in the case. That is why the inductance values of the coils listed should only be a guide. If you use the correct form and wire, count the turns correctly, and wind the wire tightly on the form, you will have satisfactory coils. It’s that simple. You should be prepared to wind a coil more than once. This is especially true when you are starting out if the winding of coils is new to you.

When you are finished winding a coil the turns should not move when pushed with your fingers. If the turns of the coil move on the form in any way either tighten the turns or remove them and rewind the coil. The other rule is “if your fingers don’t hurt you aren’t winding the coil tight enough." A detailed procedure for winding the coils is included in the construction notes.

It is probably necessary to say a few words about the cases. The cases are obtained by removing the guts of a failed PC power supply. If you are planning to build the filters you probably need more than one case. The full range of filters for one station (160 to 10 meters) takes a total of nine power supply cases. That is because 80 meters takes two cases and 160 meters three. So you have some scrounging to do. We passed the word around our radio club and they started showing up from everywhere. You may have to take a few computers to get the supply but don’t worry we may think of a use for those cases. Proprietary power supplies are often of non-standard sizes. But most are the size and shape defined by a PC industry specification and separate into two U shaped halves. Remove any hardware that is part of the case, including the line filter/power plug. Save any of the screws. The fan opening will have to be closed with a piece of thin aluminum held in with screws or pop rivets. There may be other large openings that you will want to cover in the same way. You may want to plan out and drill any additional holes for screws to hold the case closed before you start assembling the filter in the case. It is important that the halves of the case make good electrical contact and be held together firmly when assembly is completed. You may also want to sort the cases for the various bands. It is especially necessary with the 80 and 160 meter filters that the cases all fit together properly. It is a good idea to go through the cases before starting the filters. Where the fan holes and other holes are located in the case may make the filter assembly difficult or easy. Study the pictures and drawings before beginning construction. Plan ahead.

Tools Required

You will need a few hand tools to be able to assemble the filters. A hand drill or a small drill press is required. The small drill press is preferred as it is necessary to drill holes in the case to mount parts and secure the case after filter assembly. The coil forms also require holes for mounting and terminating the windings. So a hand drill or drill press and set of twist drills are a necessary. A center punch and accurate scale or tape measure are also necessary. A file is good for deburring holes and cleaning up the edges and for removing the protective finish on the cases to provide good ground connections. Sand paper and/or steel wool are also good for this purpose. You will also need the usual array of screwdriver, pliers and wire cutters. The wire cutters need to be heavy, as you will be cutting a lot of #14 wire if you build all the filters. A hacksaw or other fine-toothed saw is needed to cut the PVC pipe for the coil forms. A medium duty soldering iron is also required.

Filter Construction

This is not a project for a beginner. You need to be able to work from pictures and drawings and not a set of step-by-step instructions. If you have not successfully built projects with these level of directions, then find someone that can coach you through it. This is mainly a mechanical construction project. There is very little electronics. Only point to point wiring of the capacitors and coils is required. The coil leads and coax connectors provide the tie points.

There is no alignment. Testing is as simple as measuring the SWR in the pass band before using. If you have duplicated the coils, followed the lay out of the filter and used the correct values of capacitors in the corresponding place, the filter will work. If you have access to a network analyzer or other means of measuring the response of the filter then do so by all means, but it is not necessary. Four different people built filters and the first author has measured each of the assembled filters with a network analyzer. The difference between them is very small. In some cases the filters built by the test group are better than the original design model, but you really have to look closely to see the difference.

Using the filters.

For field day operation the filters are used in banks that are cabled up with coax switches or relays so that the proper filter can be selected for the band in use. This can be as big a project as building the filters. If you use dedicated stations per band the wiring is easy. There is just one filter in the antenna lead. Remember the filters are rated at 100 watts, NO MORE! Although considerable effort has been made to design a rugged and reliable filter, I have faith that any ham can blow one out. Do not exceed the rating. They are intended to go between a 100-watt transceiver and a reasonably matched antenna or the input of a linear amplifier. DO NOT use an internal antenna tuner to try to match a high SWR antenna through the filter. Disable any antenna tuners in the transceiver. Place an antenna tuner after the filter. This way the SWR shut down in the transceiver protects both the filter and the transceiver.

Remember these are “good neighbor” filters. The advantage to the filters is your filter reduces the interference to other radios due to the phase noise floor from your radio. It reduces the possibility of the overload of your radio by adjacent band strong signals. The amount of attenuation will probably not eliminate harmonic interference. For example the second harmonic of an 80-meter CW station may still be heard in the 40-meter phone band. The filters will do nothing to reduce the interference between radios in the SAME band. We have used the filters at our multi transmitter Field Day site since 2005 and the feeling is that we do not have interference between stations in different bands. We have not had any filter failures. This has been a very worthwhile project and it has also been fun.

Disclaimer

The filters described here are a compromise design. Anyone who knows something about filters will see possible changes and improvements to the filter designs. That’s OK. After all, that is how we got started on this project. We did try to come up with a reproducible design given the cost and case constants. We view the web page construction files as a living site so suggestions are welcome, but we probably are not going to change the designs or update the filters. Lastly you use the designs at your own risk. We warrantee nothing other than we tried to do the best job we could. We do consider the designs and construction information copyrighted but anyone is welcome to use it for non-profit use.

73 The Ugly Filter Team.

Acknowledgements

de Bob W1XP

I would like to thank the other members of the team that helped get this project together and on the web for others to use. Especially Stan KD1LE (the other coauthor) who was the motivating force and bankrolled the parts needed for the design phase and collected and stripped the power supply cases. He also built the first set of test filters and put together the documents that the beta test filters were built from. Those documents

have become the web pages for the building of the filters. Les N1SV did the schematics and mechanical drawings. And Ralph KD1SM has put it all together on the web site. Beta test filters used for our field day operation have been built by KD1LE, N1SV, KD1SM, and Larry KB1ESR. Thank you all for your effort and support. Bob

de Stan KD1LE

This project took many NVARC members to bring to fruition. But special credit goes to Bob W1XP who took all of the specifications, goals, and restrictions on cost and turned it into a set of designs that could be readily built. Bob's extensive RF design background and cellar development and testing laboratory was what made this project feasible. See Bob at our 2006 Field Day CW station next to our “secret weapon”. The preassembled unit put an antenna, filter, and tuner combination in service by selecting an antenna/band from a desktop selector switch at the operating position. Stan

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Footnotes

[0] Sources we investigated included, in no particular order:

Narrow Bandpass Filter article in QEX by William E Sabin W0IYH
http://www.arrl.org/tis/info/pdf/001009qex013.pdf

Clean Up Your Signal with Band-Pass Filters By Ed Wetherhold, W3NQN 1998, 2 parts [part 1, part 2].
http://www.arrl.org/tis/info/pdf/9805044.pdf
http://www.arrl.org/tis/info/pdf/9806039.pdf

QST Product Review of Dunestar commercial filters
Dunestar Model 600 Multiband Bandpass Filter, QST March 1995
http://www.arrl.org/members-only/prodrev/pdf/pr9503.pdf

RF Filters, ARRL Technical Information Service page with filter definitions and article references
http://www2.arrl.org/tis/info/rf-filter.html

Band-Pass Filters for HF Transceivers by Lou Gordon K4VX QST September 1988
http://www.arrl.org/tis/info/pdf/8809017.pdf

Inexpensive Interference Filters by Alan Bloom N1AL, QST June 1994

K2TR Coax Stub Filters
http://www.k1ttt.net/technote/k2trstub.html

Array Solutions commercial filters based on W3NQN QST article June 1998
http://www.arraysolutions.com/Products/wx0bbpf6.htm#200W

Industrial Communication Engineers LTD, ICE commercial bandpass filters
http://www.iceradioproducts.com/filtersrf.html

[1] For those that may not be into the mathematics of electric filter design, Butterworth and Chebyshev refers to the mathematician who’s polynomial expressions describe the locations of the poles and zeros (we are using an all pole design) that establish the frequency response of the filter. The Butterworth filter has a flat pass band and uniform slope stop band response.

[2] The high end of the 160-meter band is only 1.5 MHz away from 3.5 MHz. Couple this with the requirement that the maximum pass band attenuation at 3.5 MHz has to be 1 dB or less, it is necessary to have additional slope to the filter skirt response. So a fourth pole was added to the filter. It was still necessary to relax the attenuation specification at 2 MHz.

[3] The filter specifications are only concerned with the Pass band response and stop band response in the six contest bands.

[4] Elsie

[5] A computer program for circuit analysis developed at Berkley some years ago.

Web formatting by Ralph KD1SM
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