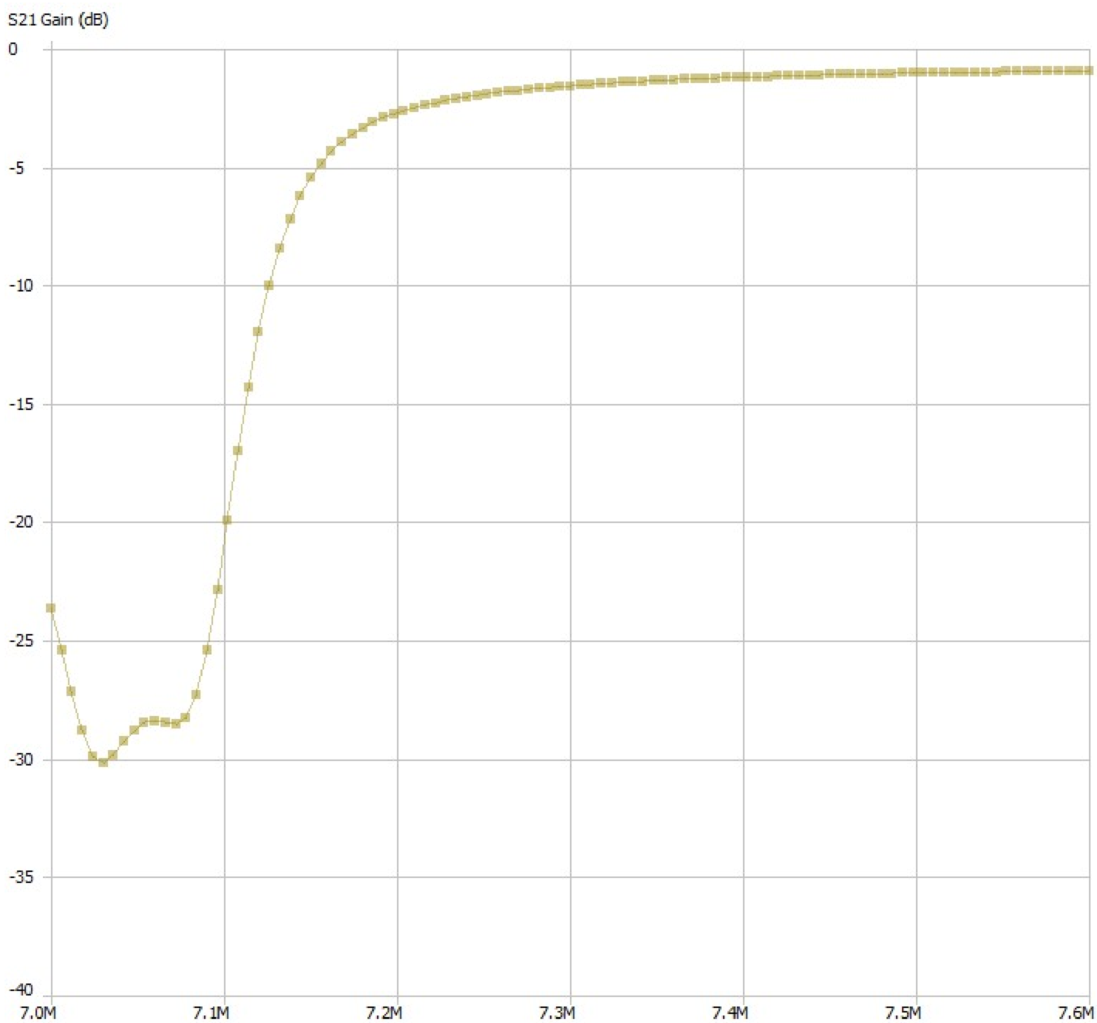
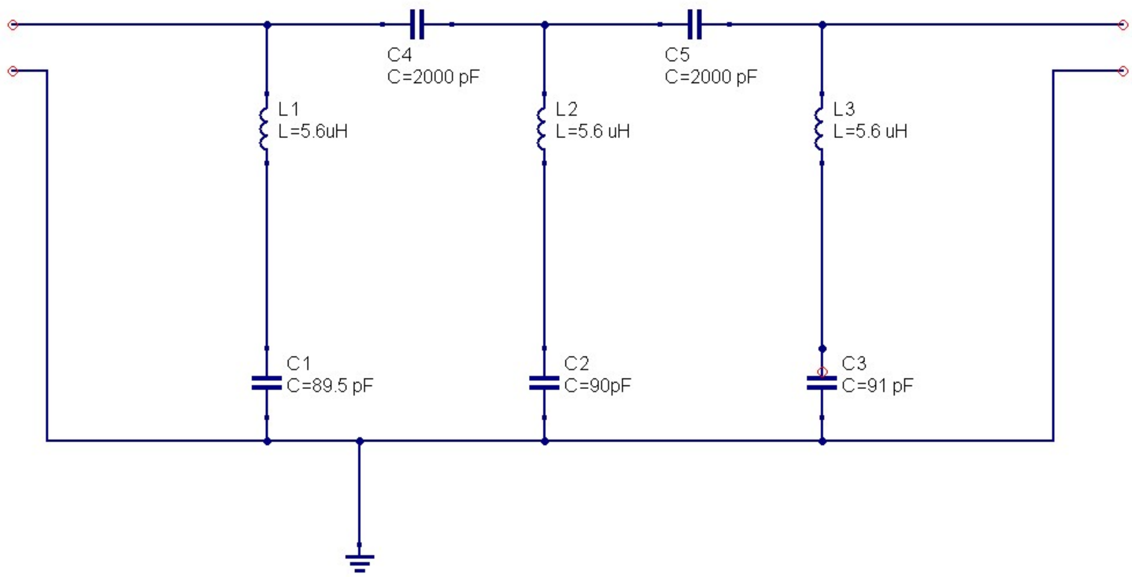
Field Day Ultra-Sharp RX Filters

Interference between phone and CW/digital operations on Field Day when using the same band with multiple rigs can be particularly challenging where the signals are separated by as little as 50 to 100 KHz. Interference between operations on different bands can be readily addressed with low-loss TX/RX band-pass filters that both suppress out-of-band TX emissions and prevent RX overload and inter-mod from out-of-band signals. Avoiding paths of interference coupling other than through the antennas is also important such as over power cables or with coupled grounding arrangements. Antenna placement and design is one key tool to address Field Day interference for operations with multiple rigs, especially same band interference problems. Another tool for Field Day is the use of Ultra-Sharp RX filters (USRX filters) that operate in front of the receiver directly at the operating frequency that can handle and suppress high power interference that is in the same band separated by as little as 50 to 100 KHz from a desired RX signal. Techniques to address this problem are discussed in this paper to protect the receiver front end from overloading from nearby signals.

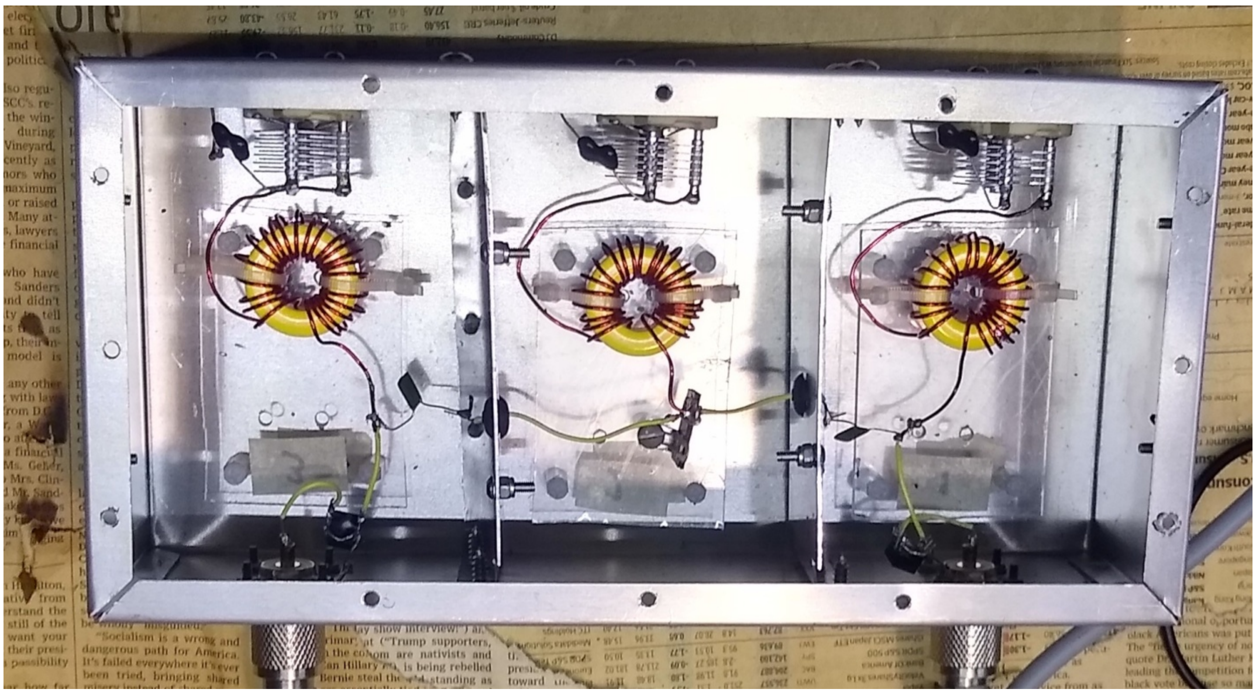


This is the response of a USRX filter for 40 meters phone measured with a nanoVNA, and which is discussed in this paper. No tuning is needed during operations. It suppresses most of the CW band (7.0 to 7.1 MHz) by 25 to 30 dB, while passing the phone band (7.15 to 7.3 MHz) with only 2 to 3 dB of loss except near 7.15 MHz where the loss is a few dB more. The suppression of the CW band only needs to be great enough to avoid overloading the front end of the phone rig's receiver, and 25 to 30 dB of suppression of the 40 meters CW band combined with good antenna isolation should give the 40 meters phone receiver good protection. The USRX filter would be bypassed during TX operations with relays. Power is provided by a 12 VDC power plug to operate the TX/RX relays, and a cable plugs into the rig to tap the linear amplifier control output to operate the TX/RX relays. The USRX filter is simple in design and fairly easy to build. It operates at 50 Ohms input/output impedance with input/output 4:1 matching RF transformers by Coilcraft from 50 Ohms to 12.5 Ohms. The USRX filter does require careful/precise tuning, and using a nanoVNA is very desirable for the tuning process. Filter designs for phone and CW operations for 80, 40, 20 & 15 meters are discussed.

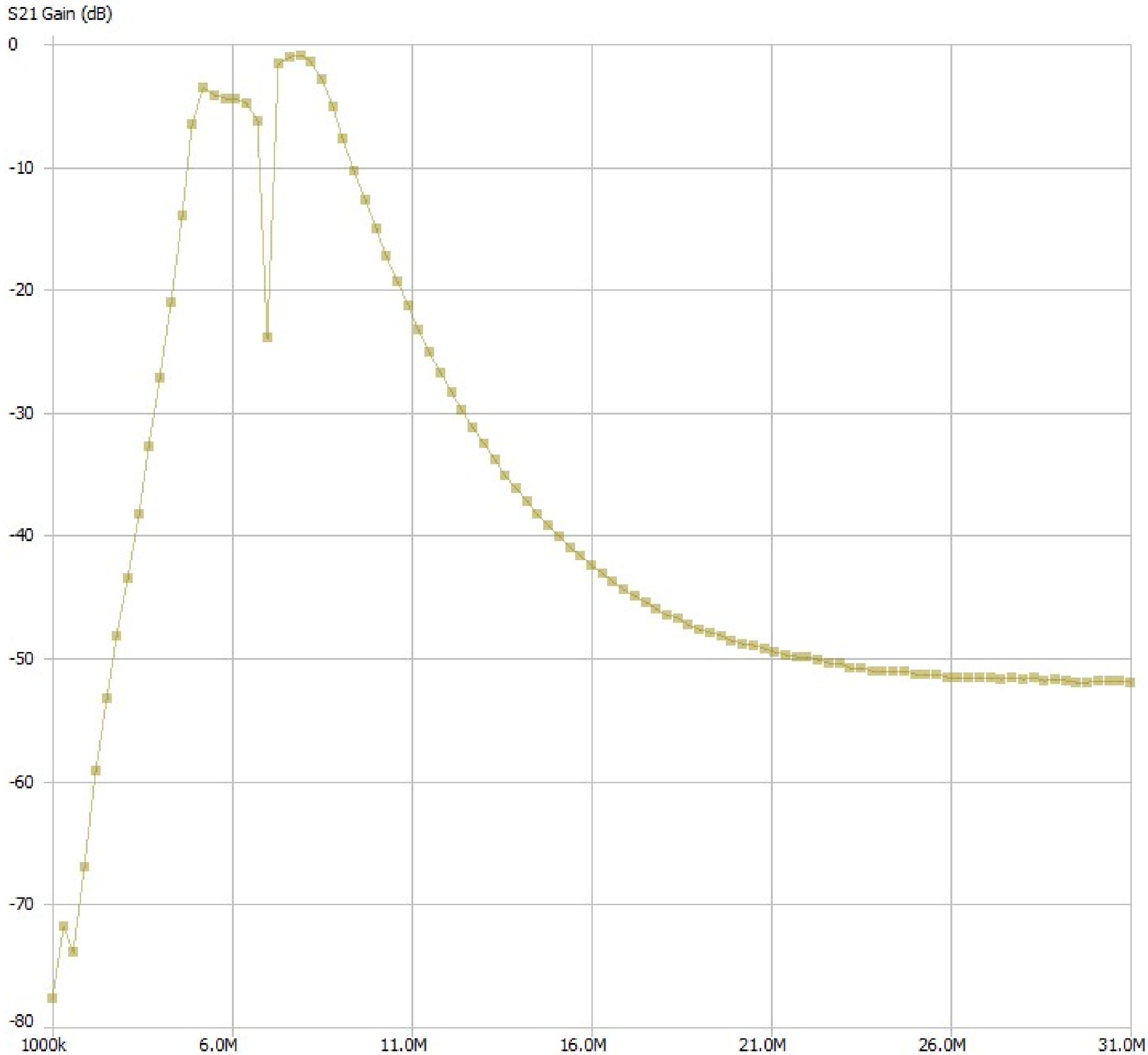


This is a schematic of the basic filter with values for 40 meters phone operation with a 3-stage band-stop design on the CW band (not shown are 4:1 input/output RF transformers). For tuning purposes, C1, C2 and C3 are implemented with a fixed silver mica capacitor plus a 3 to 30 pF trimmer capacitor. Filters for 80, 40, 20 and 15 meters use the same basic design. Appropriate values for the L's and C's are used for each band. Toroid core coils are used for 80 and 40 meters, and air core coils are used for 20 and 15 meters. The filter is very simple, but careful/precise selection of components is important, and the mechanical design is also important for final performance. This filter uses capacitive coupling between stages to provide a band-pass bump above the stop-band and is appropriate for phone operation to suppress CW signals. For CW operation to suppress phone signals, the coupling capacitors are replaced with small inductors to create a band-pass bump in the CW band below the notch band on the phone band.

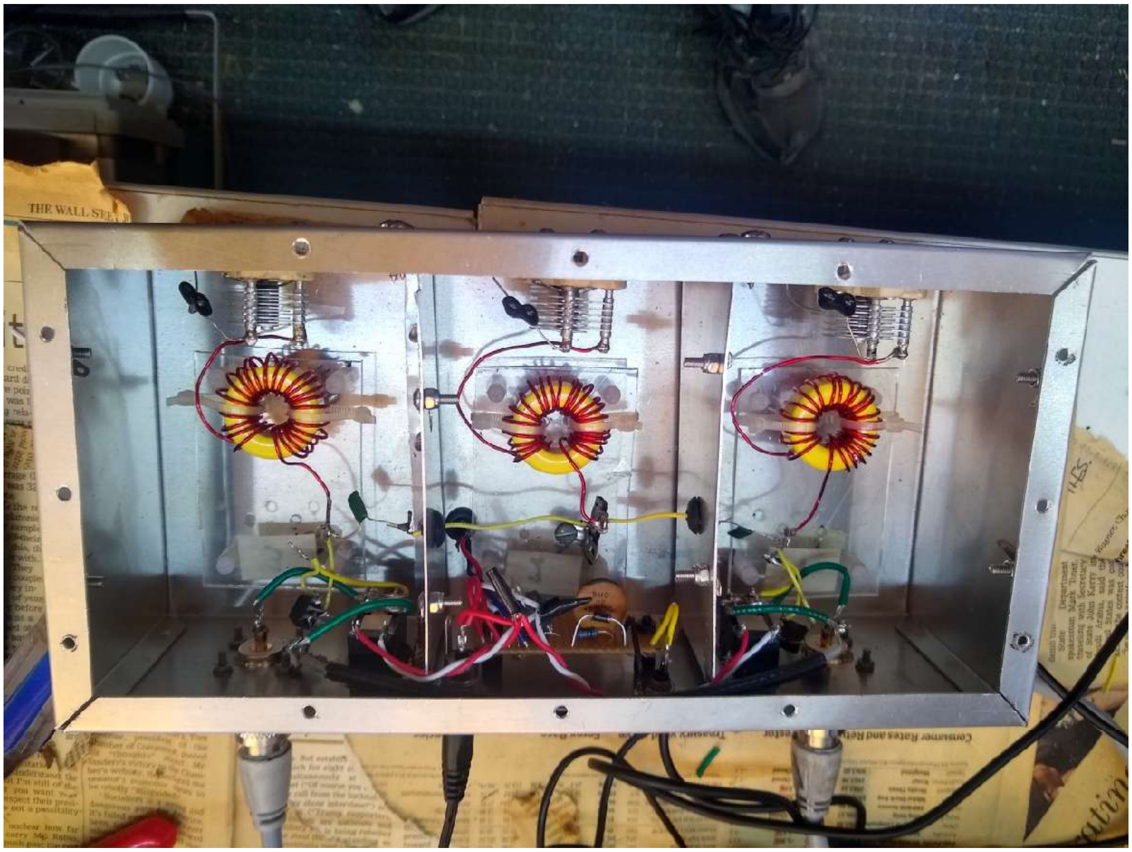
In operation, this USRX filter reduces S9 CW signals between 7.0 and 7.1 MHz to S4 to S5 signals and they may disappear into the atmospheric noise. Or S9 + 30 dB signals become only S9 signals. For phone signals above 7.15 MHz, there is only small attenuation, and an S9 signal becomes about an S8.5 signal in the 7.2 to 7.3 MHz range. A toggle switch can be used to disable the USRX filter by engaging the TX/RX bypass relays when there is no local/strong CW interference on 40 meters or if there is a very weak phone signal that is received better without the small loss of the USRX filter.



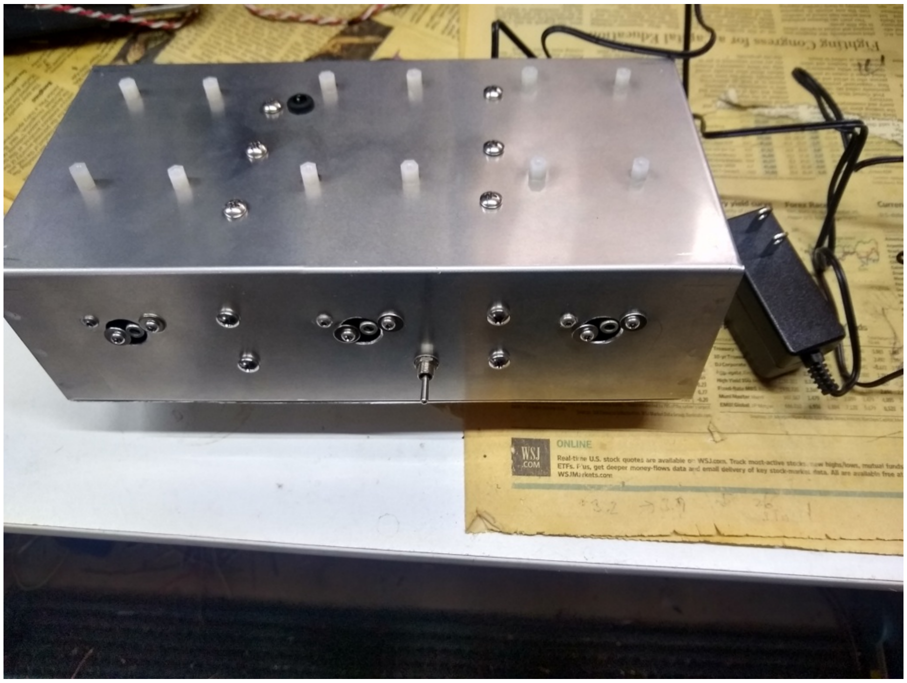
This is a picture of the USRX filter for 40 meters. Each of 3 filter stages are conventional series L/C circuits providing 3 notches in the CW band using inductors optimized for high-Q and air variable capacitors to tune the filter. Capacitive coupling between the stages is selected to optimize a band-pass bump in the phone band. The mechanical design considers stability as well as minimizing stray capacitance and stray inductance. The Coilcraft RF 4:1 WB4-6L transformers are visible (they are fairly small) near the coax connectors, and they match 50 Ohms external impedance to 12.5 Ohms impedance for the filter with only about 0.5 dB loss each. Small slot Johnson tunable variable air capacitors are placed in parallel with silver mica fixed capacitors. This makes the filter easy to tune on the bench and prevents disturbing the tuning during operation with a bit of care. The toroids use T106-6 cores (slightly over an inch in diameter) at 22 turns to provide 5.8 uH with a fairly high Q near 300 for 7 MHz operation. The aluminum shields between stages are cut from 0.032 inch thick aluminum sheets which is easily cut with tin snips and fairly easy to bend into shape. Stainless steel #6 x ½" sheet metal screws are used.



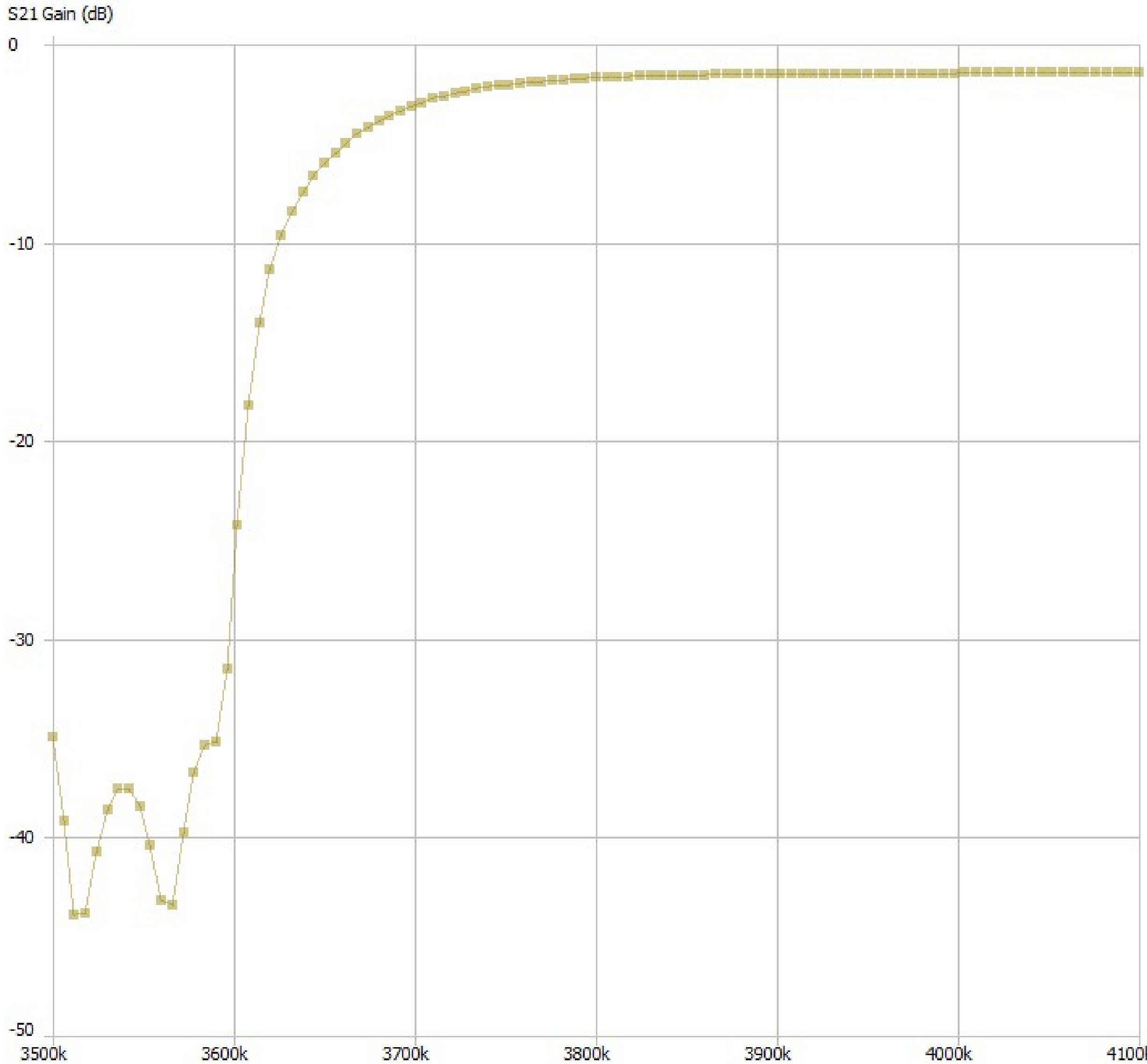
This is the measured response of the USRX filter for 40 meters in series with the low-loss band-pass filter for 40 meters (used for both TX and RX) using the nanoVNA. There is no noticeable interaction between the filters. The USRX filter appears to be a very sharp notch around 7 MHz while the band-pass filter has a broad response and suppresses the 80 meters and 20 meters through 10 meters bands. The combined filter response is intended to deal with the very strong nearby ham radio signals from the other Field Day transmitters, including CW signals from 7.0 to 7.1 MHz as well as the other HF ham radio bands, but it does not suppress other signals near 40 meters such as at 6 MHz or 8 MHz.



This is the 40 meters USRX phone filter with the bypass relays and relay control board installed during a final step in construction. There are 2 SPDT relays. A relay is next to each coaxial connector glued to the back side of the chassis with Coilcraft RF transformers visible nearby.   A short coaxial cable carries the signal between relays to bypass the USRX filter. The relay control board is mounted in the center back of the chassis, and it's operation is discussed later. An LED indicator is located near the relay control board and is mounted in the top side of the chassis. When the relays are pulled into the USRX position, the LED will light. A toggle switch on the front of the chassis can be used to force bypassing the USRX filter, and a TX control signal from the rig (linear TX/RX relay control) also places the relays in bypass. When +12 VDC power is not available, the relays bypass the USRX filter.



These are pictures of the completed 40 meters USRX filter. The toggle switch on the front of the chassis is used to bypass the filter. The 3 slots for the variable air capacitors are visible on the front. On the back of the chassis are input/output UHF connectors, a 12 VDC jack with the 12 VDC power plug, and a phono jack for the TX/RX control cable to the rig. An LED to indicate status is on the top of the chassis in a rubber grommet.



This is the measured response of the 80 meters USRX filter. The CW band is suppressed by about 35 to 45 dB, but the phone band only sees 1 to 2 dB of loss over most of the band. The 3 notch filter resonance points are visible between 3500 and 3600 KHz with one at about 3580 KHz that forms a shift in the curve, and the other 2 forming clear sharp notches around 3510 and 3560 KHz.

Jack Lau, W1VT, published designs for high performance band-pass filters for 80 meters and 40 meters in QEX in 1998 in the Sept/Oct and Nov/Dec issues. He mentions the possibility of using them for Field Day to protect Phone and CW rigs from each other operating in the same band. These band-pass filter designs do indeed show the feasibility of USRX filters for Field Day operations, although notch or band-stop filters can often achieve a sharper response to eliminate Field Day interference. The Jack Lau designs use toroid inductors for 80 meters and air inductors for 40 meters with Q's around 300 and 700 respectively. They appear to be designed for input/output impedances of thousands of Ohms, but this is not detailed in the papers. Matching into 50 Ohms can be done with RF transformers, by tapping the coils of the input/output stage inductors or by capacitive dividers, depending upon the architecture of the RF filter. These designs are 2-stage LC filters with a small coupling capacitor between the hot sides of each stage.

William Sabin, W0IYH, published design information also for high performance band-pass filters for HF operation in QEX in Sept/Oct, 2000. He used toroids with a 2-stage design. The input/output impedances were matched from several thousand Ohms used in the internal filter designs to 50 Ohms using capacitive dividers on the inputs and outputs. He recommends type 2 or type 6 powdered iron-core toroids.

Clinton Turner, KA7OEI, has implemented helical notch and band-pass filters for 20 meters targeting Field Day problems with CW and phone interference built in paint cans: https://ka7oei.blogspot.com/search/label/20%20meter%20filter. These are impressive filters with very high Q that have only about 1 dB of loss and can be used for TX as well as RX and can be configured as band-pass or band-stop filters. They have a very narrow bandwidth of only a few 10's of KHz which is an advantage for separating closely spaced signals, but it also means that operation (at least for CW in this case in a band-pass configuration) requires retuning the filter to move across the entire CW band. The filters discussed here are simpler L/C filters with lower Q than KA7OEI's helical filters, but they are designed to cover the entire CW and phone bands without retuning by the use of an ultra-sharp transition design between the CW and phone bands which is possible with high-Q L/C filters using multi-stage notch designs with a band-pass bump. The helical filters provide about 20 dB of peak loss using 2 stages of notching for 20 meters in the center of the CW band. The filter discussed here is able to achieve over 40 dB of loss using 3-stages of notching over most of the CW band. The helical filters have only 1 dB or less loss in the phone band while the filter here has 2 to 3 dB of loss around 14.3 MHz in the phone band tapering down to 6 dB around 14.2 MHz and the then 10 dB of loss at 14.15 MHz at the lower edge of the phone band.

KA7OEI also implemented a sharp band-pass filter for 40 meters to reject nearby broadcast signals: https://ka7oei.blogspot.com/search/label/40%20meter. It uses a combination of band-pass and notch stages. The implementation and construction have some similarities to the filters discussed here. It has a total of 7 stages (3 band-pass and 4 notch). It has a total insertion loss of about 15 dB which probably would be high for normal Field Day operation.

KA7OEI mentions the TX phase/amplifier noise is also a problem. This can be addressed by using rigs with excellent TX phase/amplifier noise performance combined with adequate antenna isolation.

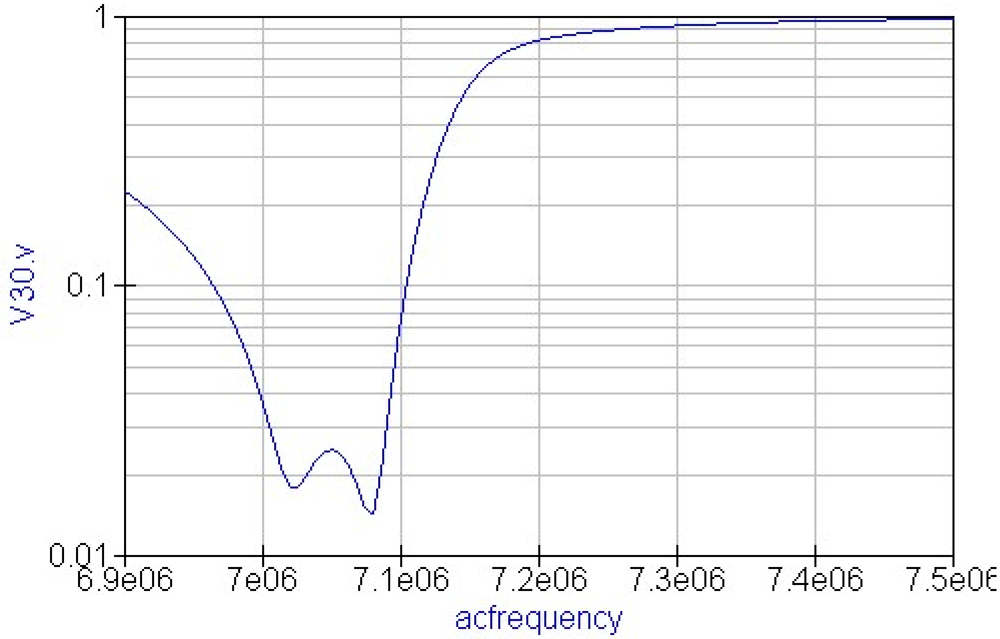
KR6X mentioned in 2001 that antique Drake R4B receivers worked well for operating on the same band on Field Day due to having high performance multi-stage front-end pre-selector filters with bandwidth as small as 25 KHz. He also mentioned that he once built tunable rejection filters for Field Day operation and that it did help. He also mentions using separate generators and separate ground systems for intra-band interference problems. https://www.contesting.com/forums/tips/148

OE3HKL has built a series of extreme notch filters for HF amateur radio bands for test purposes. These are used to attenuate a TX signal with a very deep and very narrow notch to allow sampling and measurement of TX phase/amplifier noise near the carrier. These filters use a number of crystals and achieve notches over 100 dB deep in some cases and only a few KHz wide. They are not tunable, and they are actually much too narrow for our purposes, but the designs are interesting due the very high performance and excellent quality. These filters use input/output RF transformers with trifilar toroid windings that match external 50 Ohm interfaces to 450 Ohm internal impedances. This suggests that input/output RF transformers to optimize the internal impedance of a USRX filter could be important. Also, these filters carefully shield the input/output RF transformers.

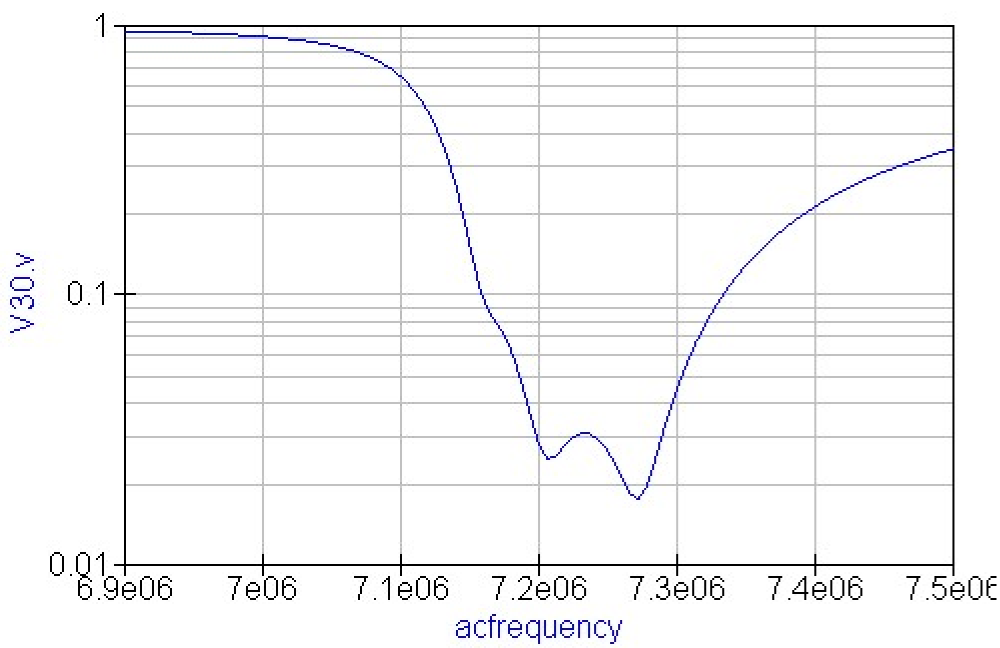
http://www.oe3hkl.com/hf-measurements/npr-messplatz-rauschgenerator/q-notch-20m-cw-1khz-100db.html

John E Portune, W6NBC, published online design information for VHF/UHF cavity filters for repeaters: https://www.w6nbc.com/articles/duplexer.pdf. Cavity filters typically combine 2 stages of notch filtering plus 1 stage of band-pass filtering for the RX filter and similarly for the TX filter. The TX filter very strongly notches TX phase noise at the RX frequency and also attenuates wideband noise, spurs and harmonics. The RX filter very strongly notches the TX signal and also attenuates out-of-band signals. This article also explains that cavity filter notch stages are typically designed to include an upper or lower frequency band-pass “bump”. Capacitive coupling between filter stages with appropriate values can create a band-pass bump above the notch frequency and inductive coupling between filter stages with appropriate values can create a band-pass bump below the notch frequency. This architecture works for HF L/C filters as well as for cavities, and it can create a band-pass that is very near a deep notch frequency with an ultra-sharp frequency transition band.

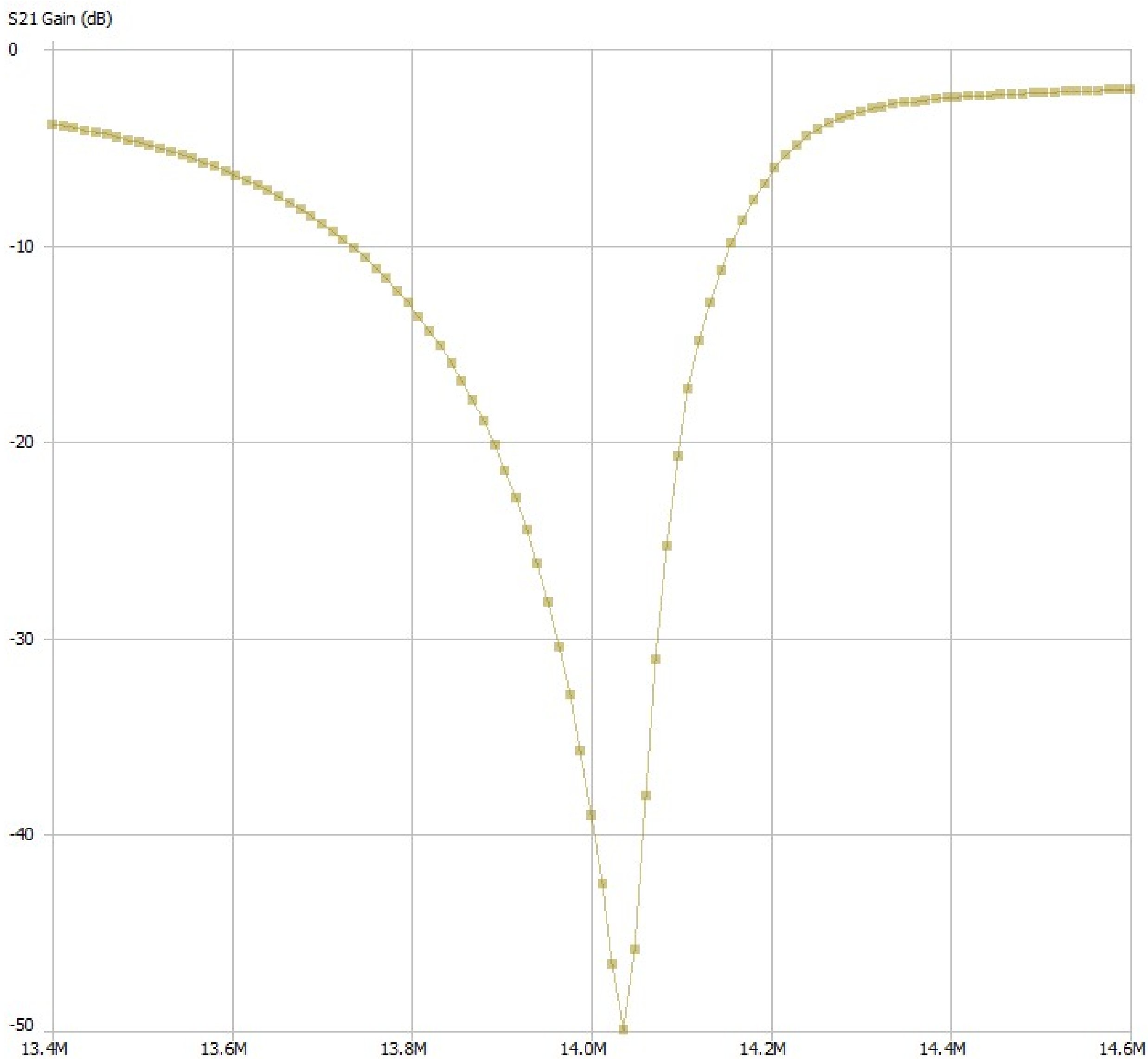
In this work to separate very close parts of a single HF amateur radio band, ideas used in VHF/UHF cavity filters for repeaters are instructive such as using very high-Q notch filters with bump band-pass design. But since cavity filters are not practical for the HF bands, the ideas from existing work on high-Q HF filters are also important to achieve practical designs. A typical repeater cavity filter combines 2 stages of notching with 1 stage of band-pass. In the HF filter work in this paper, 3-stages of notching (the USRX filter) are combined with 3-stages of band-passing (a conventional low-loss HF TX/RX band-pass filter). The high-Q inductors with Q’s of 200 to 300 used for these filters are significantly lower in Q than cavity filters which can be 1000’s, so this is partially compensated by using more stages of filtering than in a cavity filter. Another critical factor is accepting a bit higher RX band-pass loss than in a repeater cavity filter, and then using input/output RF transformers to optimize impedances.



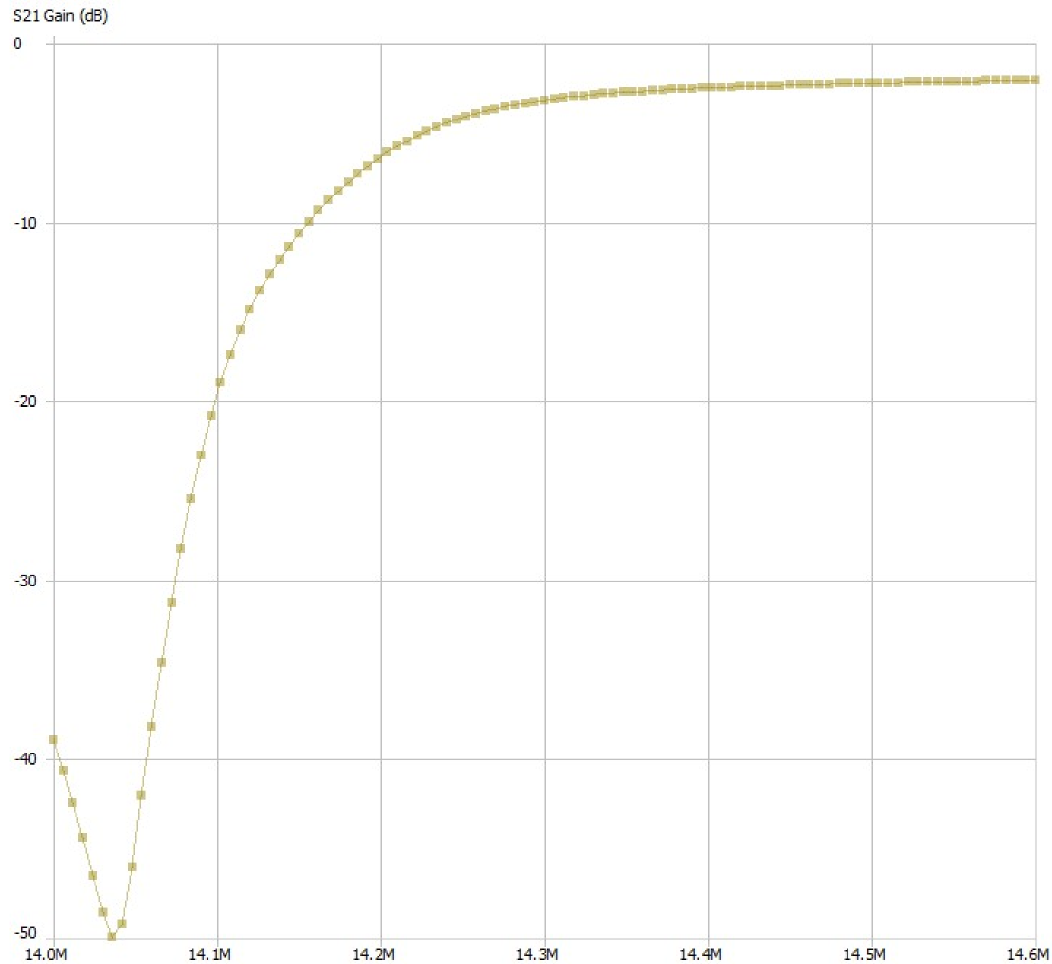
This is a 40 meters USRX filter response (simulation) from 6.9 to 7.4 MHz for phone operation with a notch on the CW band and a band-pass bump on the phone band. The band-pass bump and ultra-sharp transition are clear on the upper side of the notch going up in frequency from the CW band to the phone band. This filter uses capacitive coupling between 3-stages of notching.



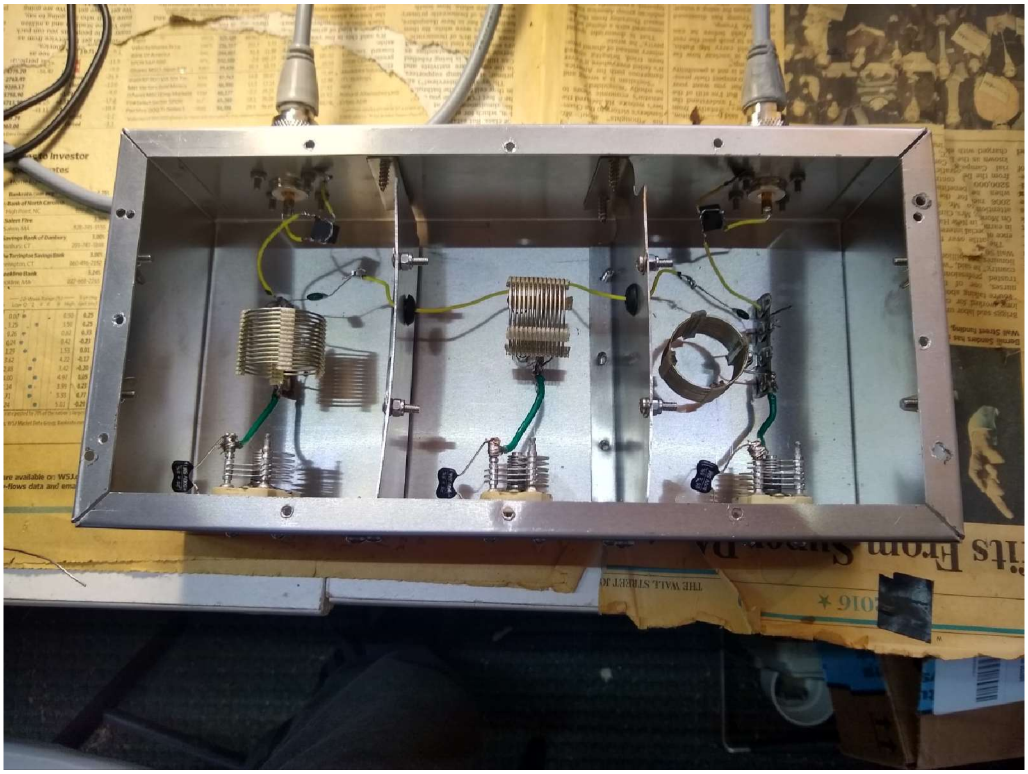
This is a 40 meters USRX filter response (simulation) from 6.9 to 7.5 MHz for CW operation with notches on the phone band and a band-pass bump on the CW band. The band-pass bump and ultra-sharp transition are clear on the lower side of the notches going from the phone band down in frequency to the CW band. This filter uses inductive coupling between 3-stages of notching.



This is a measurement of the 20 meters USRX phone filter from 13.4 to 14.6 MHz. The dots are spaced by 12 KHz. Around 14.1 MHz at the transition from the CW band to the phone band, the slope is as high as 6 dB in 12 KHz. On the lower side of the filter the slope is only about 2.5 dB in 12 KHz at the sharpest point. So the sharpness of the filter is clearly due to designing with a band-pass bump on the high side of the band-stop region using capacitive coupling between the 3 notch filter stages. As a result, over 40 dB of attenuation is provided for the CW band from 14.00 to about 14.06 MHz, and then it tapers to about 20 dB at 14.10 MHz. For the phone band, only about 3 dB of attenuation occurs from about 14.25 to 14.35 tapering to about 6 dB at 14.20 MHz and to about 10 dB at 14.15 MHz.



This is the measured response for the 20 meters filter for phone operation measured from 14.0 to 14.6 MHz.



For the 20 meters USRX filter, air core inductors are used to achieve high Q.   Slot tunable surplus Johnson air capacitors are used to tune the filter in parallel with fixed silver mica capacitors. It is quite sensitive to tuning, but with a nanoVNA running in continuous sweep mode and some patience, it can be tuned up fairly quickly. Besides shielding 3 chambers for each notch filter stage, the coils are oriented along 3 different axis to minimize any residual mutual coupling. The depth of the band-stop is improved by adding the bottom plate to the chassis, and the measurements were done with the bottom plate installed.   Small rubber grommets in the shields pass the wires to connect the signal between the stages of the filter.

Some high-end rigs ($3000 + range such as the Yaesu FTDX-101D, the ICOM IC-760 and the Kenwood TS-990S) have internal sharp RX pre-selectors which provide some ability to separate CW and phone signals on the same bands, but low-end and mid-range rigs do not have this feature. These internal pre-selectors do not include notch filters which can provide significant advantages, and the internal pre-selector filters do not have very steep skirts. Measurements on a Yaesu FTDX-101D and on the older MTU option show -6 to -10 dB from a desired frequency on 40 meters at 100 KHz separation. This could be helpful, but the attenuation between CW and phone portions of the band is small.

Filter design or synthesis software that I was able to find did not prove to be effective for this type of filter design although some programs might be helpful. Partly this is due to the architecture of capacitive coupled notch filters not being very common. On the other hand, filter analysis or simulation software was critical. I used QUCS to analyze filter performance and to guide optimization.

Achieving USRX filter response for 80/40/20/15 meters comes with some considerations. Firstly, inductors with a high Q factor (ratio of inductive reactance at the operating frequency to the effective resistance at the operating frequency) are important. Q-factors for good quality RF capacitors are typically 3 to 10 times higher than for the inductors. Q-factors in the 200 to 400 range for inductors are practical for 80/40/20/15 meters with careful selection of toroid cores or air core inductors and the inductor values for a required operating frequency. Here is an online source providing good detail on toroid inductor core Q:

https://52ebad10ee97eea25d5e-d7d40819259e7d3022d9ad53e3694148.ssl.cf3.rackcdn.com/UK_MIS_Q%20Curve%20for%20iron%20powder%20cores_TN.pdf

For 80 meters, a Q of about 375 is achieved with a toroid and for 40 meters a Q of about 350 is achieved with a toroid with inductances in the 5 to 10 uH range using T106-6 cores. At these frequencies, air core inductors need to be quite large to achieve much better Q factors than toroids. For example, achieving a Q of around 600 for an air inductor in the 5 to 10 uH range at 7 MHz requires coils around 2" in diameter. Also Q factors of 350 to 375 allow excellent response shapes for USRX filters for 80 and 40 meters although the high Q's possible with large air core inductors should improve performance. For 20 and 15 meters, air core inductors start to look more attractive than toroids. Air core inductors only 1 inch in diameter and about 1 inch long can achieve a Q of 500 to 600, and for the 20 and 15 meters bands, that higher Q is desirable. The air core inductors are much more susceptible to stray inductive coupling than toroids, so good shielding is critical for 20 and 15 meters USRX filters.

Secondly, these filters are highly sensitive to certain stray capacitances and stray inductances. To address this problem, it is necessary to carefully understand these sensitivities. The filter architecture and component selection combined with component placement and shielding must be designed to control the most sensitive stray capacitances and inductances so that impact on the overall performance is modest. To help minimize the impact of stray capacitance, both the Phone and CW filters use only shunt resonant circuits. This also allows the variable capacitors to be grounded on one side and hence mounted directly on chassis ground. Using low impedance circuits can reduce the impact of stray capacitance, and impedances of 12.5 (50/4) and 5.5 (50/9) Ohms are used in the filters.

There are other considerations. The ultra-sharp filter response means that the exact values of the inductors and capacitors will be very critical, so mechanical stability is important for filter stability. Variable capacitors are required to tune each filter stage to its exact frequency within a few KHz or about 1 part in 1000. To make this most practical, fixed value capacitors are used for 50% to 75% of the required capacitance, and variable capacitors are selected to operate near their mid-points. This results in sensitive but practical operation to tune the filters. Silver Mica RF capacitors are used for good stability and Q-factor as is typical for HF RF applications.

Simulations of the USRX filter show that stray capacitance between several key points need to be reduced to extremely small values to avoid compromising performance. Across the inductors, the stray capacitance needs to be less than about 1 pF for 40 meters to avoid significant compromise in performance which corresponds to a self-resonance frequency of about 92 MHz for the 5.6 uH inductors. Using Micrometals RF toroid analysis tool, it was found that the 40 meters 5.6 uH notch filter toroid would have an equivalent parallel stray capacitance of about 0.8 pF. This is acceptable but not with much margin. It means that added stray capacitance due to leads must be minimized and preferably less than about 0.2 pF. Simulations also show that any stray capacitance between the stages at the connection of the inductors to the variable tuning capacitors is very sensitive. The impact on 80 meters of stray capacitance is smaller, but of course is more severe for 20 and 15 meters.

The filter is NOT very sensitive to stray capacitance between the input and ground; the output and ground; the input and output; across the variable capacitors; and from the center point of the 2 inter-stage coupling capacitors to ground. It is also not very sensitive to impedance matching or SWR at the input/outputs, so it is fine in series with TX/RX band-pass filters and with antenna SWR's up to 3:1 or so. Stray capacitance needs to be minimized among the inductors and the hot sides of the tuning capacitors and between the inductor windings and ground. To minimize stray capacitance effects, a 10" x 5" x 3" aluminum chassis is divided into 3 chambers (one for each filter stage) and shields are inserted between each stage as well as a bottom plate. This minimizes stray capacitance between filter stage inductors and the hot sides of the tuning capacitors. The inductors are mounted away from the chassis by ¾" to 1" on plexiglass boards for the toroids and on terminal strips for the air core inductors to minimize stray capacitance distributed over the inductor wire to ground. Stray capacitance from connecting wires to ground is generally not a problem.

These filters are sensitive to stray inductance in the coupling circuit between the filter stages. For a practical circuit, both the signal wires connecting filter stages will have stray inductance and even the chassis ground connection will have some small stray inductance although it may be 1/5 to 1/10 the value of the signal wires. Tuning the value of the coupling capacitors can compensate, at least partially, for these stray inductances. Simulations show that the inductance of the wires connecting one stage of the filter to the next stage of the filter is significant and must be modeled and included in the design to achieve good results. With 3" or so of wire connecting each filter stage, this is roughly 100 nH. The coupling capacitors need to be reasonably close to their optimal values to peak the band-pass response. I was able to choose fixed capacitors for the 20 meters filter of about 700 pF that worked well, but using variable mica compression capacitors might be a good alternative to peak the performance. The Q of the coupling capacitors is not highly critical, so air capacitors are not necessary.

Toroids can be sensitive to temperature. For these filters, we need to set the resonant frequencies to about 1 part in 1000 to achieve the desired performance or to within about 10 KHz at 10 MHz. The T106-6 cores used in these filters designs have very low temperature sensitivity at about +35 PPM/degree-C. The silver mica capacitors typically have about +50 PPM/degree-C drift. Assuming the filters are tuned at room temperature of about 25 degrees-C, then the drift is only about ½ to 1 part in 1000 for +- 15 degree-C operations or from 10 to 40 degrees-C which is 50 degrees-F to 104 degrees-C. Operation should be OK over temperatures from about freezing to 125 degrees F.

Phone filter details with 3 notch stages in the CW bands with capacitive coupling between stages:

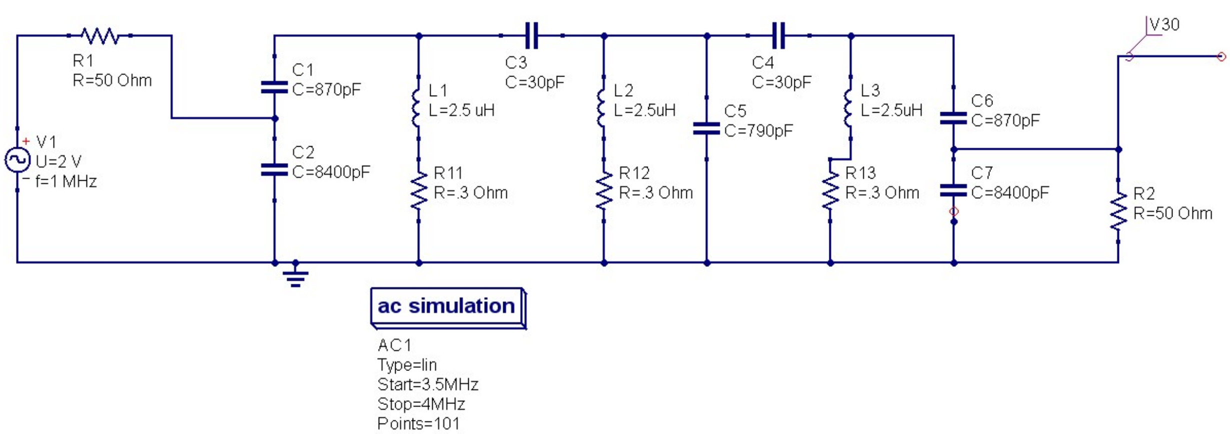
- Use fixed silver mica in parallel with a trimmer cap
  - (~300 pF total) 250 pF fixed in parallel & 4.6 to 75 for variable 80 meters
  - (~75 pF total) 50 pF fixed in parallel & 3 to 30 for variable for 40 meters
  - (~31 pF total) 25 pF fixed in parallel & 2 to 18 pF for variable for 20 meters – use a 3 to 30 pF cap and remove 2 of 5 fixed plates
  - (~ 28 pF total) 20 pF fixed in parallel & 2 to 18 pF for variable for 15 meters (remove plates)
- Use T-106-6 toroid cores for 80/40 meter inductors with #18 wire
  - 5.6 uH for 80 meters, 22 turns
  - 5.6 uH for 40 meters, 22 turns
  - ~4 uH for 20 meters air core inductor is 13t of 3015 Miniductor with 1 inch dia at 16t/inch or 7/8 inch in length which provides 3.74 uH
  - ~2 UH for 15 meters air core inductor is 9t of 3015 Miniductor with 1 inch dia at 16t/inch or 0.56 inch in length which provides 1.95 uH
- Coupling caps between filter stages
  - 3000 pF on 80 meters
  - 2000 pF on 40 meters
  - 700 pF on 20 meters
  - 300 pF on 15 meters
- RF input output transformers
  - 4:1 for 80, 40 and 20 meters –filters operate at 12.5 Ohms
  - 9:1 for 15 meters – filters operate at 5.5 Ohms

CW filter details with 3 notch stages in the phone bands with inductive coupling between stages

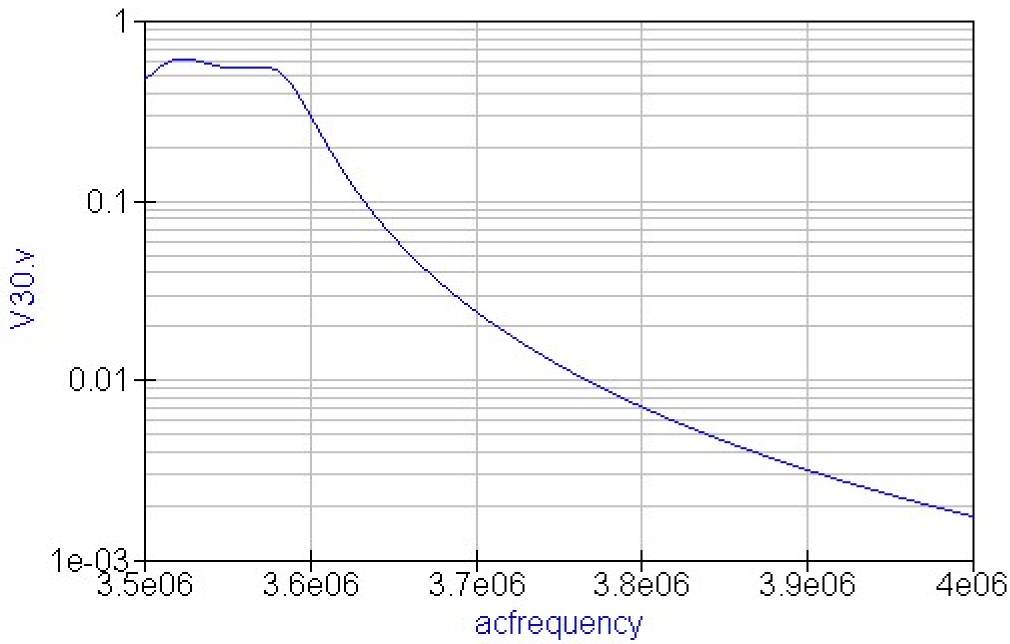
- Use fixed silver mica in parallel with a trimmer cap
  - (~300 pF total) 250 pF fixed in parallel & 4.6 to 75 for variable 80 meters
  - (~75 pF total at resonance) 50pF fixed in parallel & 3 to 30 for variable for 40 meters
  - (~31 pF total) 25 pF fixed in parallel & 2 to 15 pF for variable for 20 meters (remove 2 of 5 fixed plates)
  - (~ 28 pF total) 20 pF fixed in parallel & 2 to 15 pF for variable for 15 meters (remove 2 of 5 fixed plates)
- Use T-106-6 toroid cores for inductors with #18 wire
  - 5.6 uH for 80 meters, 22 turns
  - 5.6 uH for 40 meters, 22 turns
  - 4 uH for 20 meters miniductor
  - 2 UH for 15 meters miniductor

- Inductive coupling between filter stages
    - 1.5 uH for 80 meters -3.5 inch connecting wire plus 1.4 uH
    - 400 nH for 40 meters – 3.5 inch connecting wire plus 300 nH
    - 200 nH 3.5 inch connecting wire plus 100 nH between stages for 20 meters
    - 80 nH 3.5 inch connecting wire between stages for 15 meters – may need some parallel wire or heavy wire
- RF input output transformers
    - 4:1 for 80, 40 and 20 meters – filters operate at 12.5 Ohms
    - 9:1 for 15 meters – filters operate at 5.5 Ohms

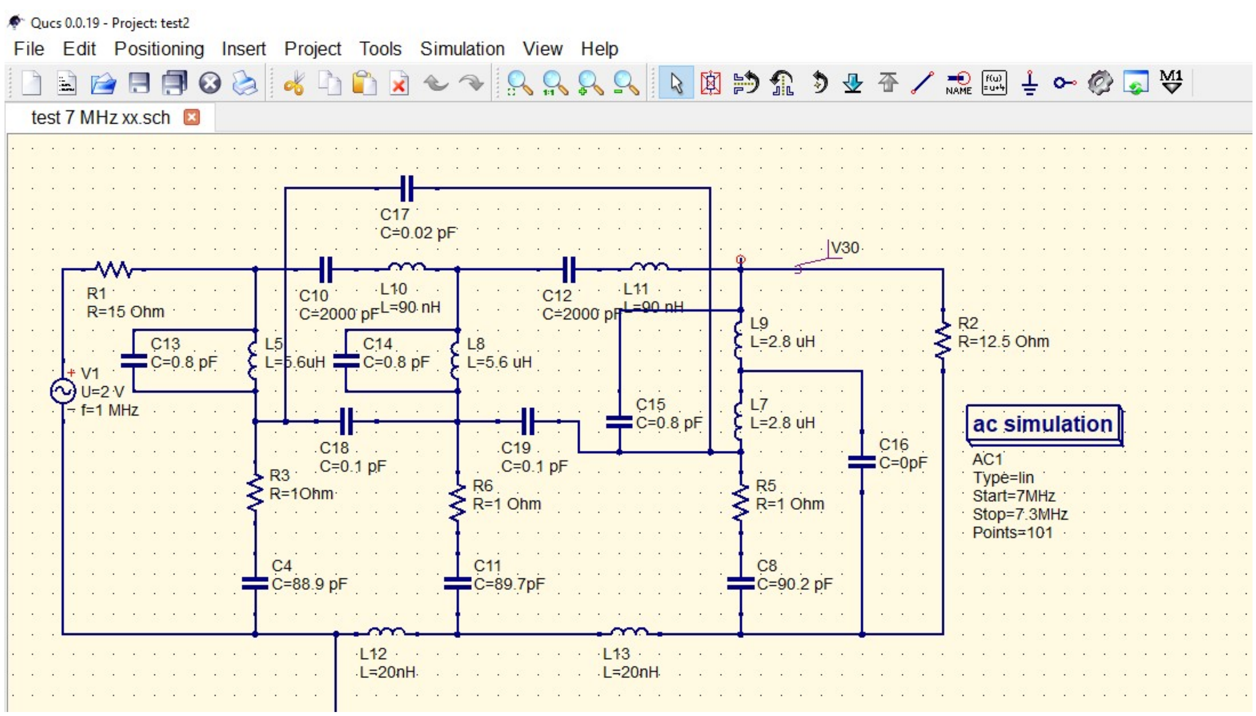
For phone filters for 80, 40, 20 and 15 meters, a 3-stage notch filter spread over the CW band with a band-pass bump in the phone band provides an ultra-sharp transition band, and is much sharper and more effective than a band-pass filter. A multi-stage notch filter or band-stop filter is very effective to use for phone operations and to suppress CW, because the CW bands are fairly narrow. But for a CW filter for 80 meters, it appears that a 3-stage band-pass filter can do a good job. This is primarily due to the phone band being very wide as a percentage of the frequency for 80 meters compared to 40 and 20 meters. But for 40, 20 and 15 meters, a 3-stage notch filter performs better than a 3-stage band-pass filter for CW operation where the phone band is suppressed since the phone bands on 40, 20 and 15 meters are relatively narrow as a percentage of the frequency.



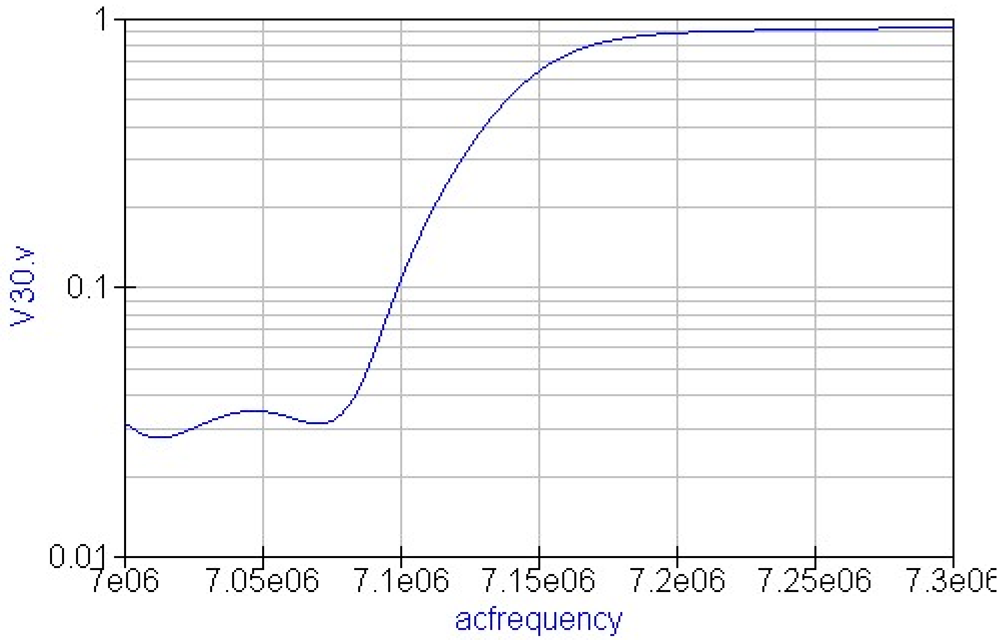
This is a schematic for a 3-stage high-Q preselector for the 80 meters CW band (R11, R12 and R13 are models for the resistance of the inductors). The internal impedance is about 5000 Ohms, and capacitive dividers at the input/output provide matching to 50 Ohms. C1, C5 and C6 can be composed of a fixed capacitor in parallel with a trimmer capacitor to support precise tuning.



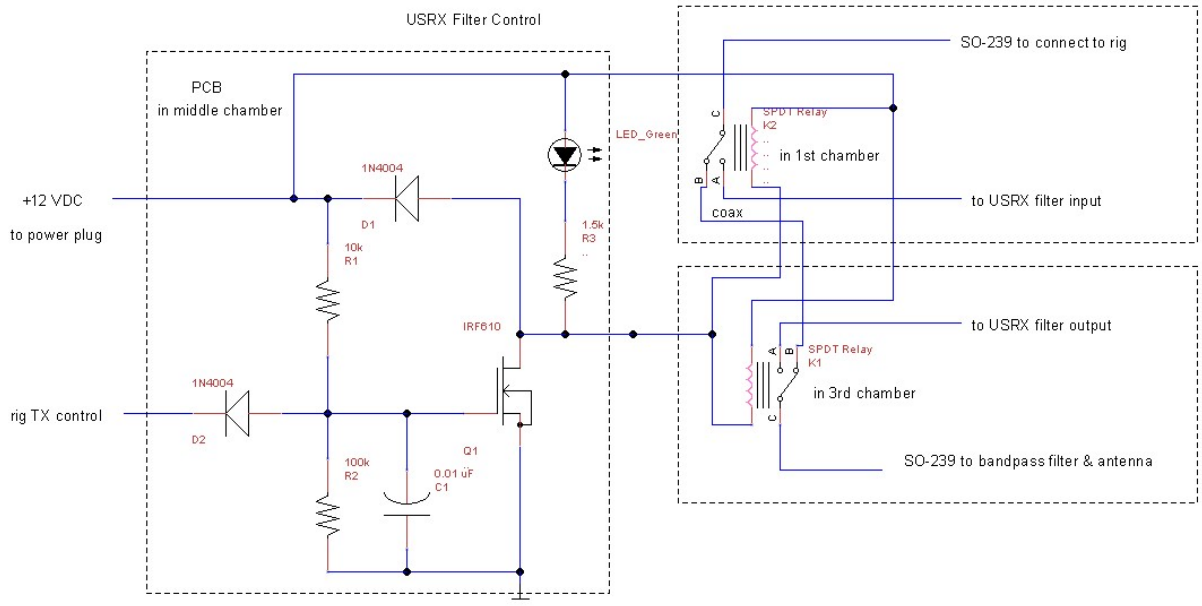
This is the response of the 3-stage pre-selector for the 80 meters CW band from QUCS simulation/analysis. There is 4 to 5 dB of insertion loss in the CW band. The loss in the phone band reaches 30 dB at about 3.680 MHz and ramps to almost 60 dB at 4 MHz.



This is a model of the 40 meters USRX filter with resistors added to model inductor Q, and stray capacitance and stray inductance added to generate accurate results and to clarify mechanical design issues affecting performance.



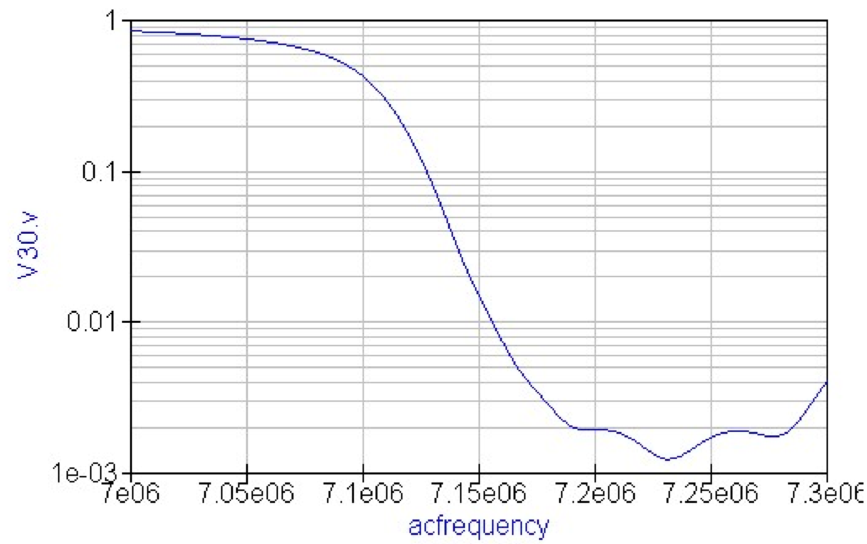
The simulation result with detailed modeling shown here is fairly close to the measured result shown early in the paper for the prototype filter. About 1 dB of loss should be added to account for the RF transformers which results in a good match from 7.2 to 7.3 MHz of about 2 dB of loss. And the loss in the CW band is about 27 to 31 dB with measured results of 25 to 30 dB.



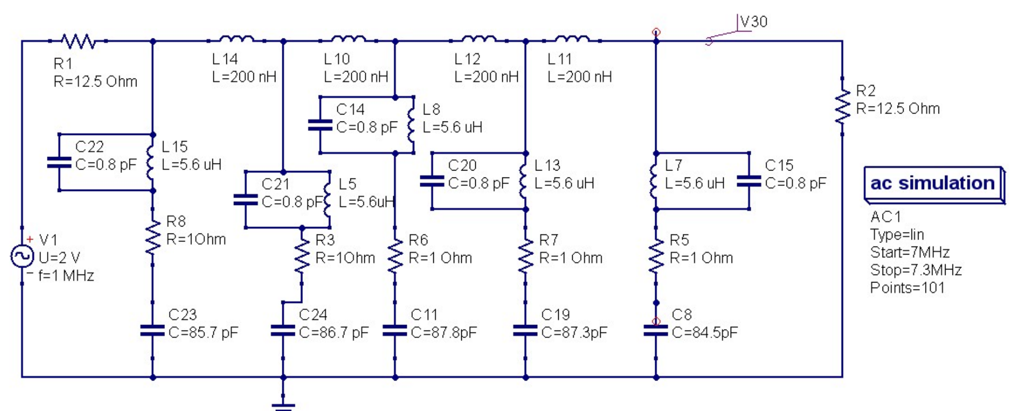
This is the schematic of the TX/RX bypass relays and control for the USRX filter. It is designed with a failsafe feature for the 12 VDC power supply. If there is no power, the TX/RX relays default to the TX or bypass position. The relays and small control PCB are located inside the USRX filter chassis against the back side near the RF input/output SO-239 connectors with the PCB in the middle filter chamber. The relays are part number RTD14012F by Potter and Brumfield. The RF transformers in the USRX filters are only rated at ¼ watt, so if they are exposed to TX energy, they will fail. If a conventional TX/RX relay configuration is used, failure to bypass the USRX filter will occur if either the power for the relays fail (such as unplugging power to the filter) or if the TX/RX control signal from the rig fails. With this failsafe design, the TX/RX relays default to bypass mode when the power to the filter is OFF or fails, but if the TX control signal from the rig fails, overloading the USRX filter is still possible. Some TX/RX accessories also employ a TX signal detector that triggers with a few watts of RF power and set the relays to bypass to provide an additional layer of protection. That mechanism was not added here. An LED indicates when the power is available and when the relays are in the RX position. The LED should go out when the TX is enabled, so this provides a visual check that the relays are in the correct position (bypass) for TX operations.

A 5-stage USRX for 40 Meters CW

The USRX filter design can be extended from 3 to 4 or 5 (or even more) notch filter stages to achieve even deeper undesired signal suppression and band-stop performance or wider band-stops with minimal impact on pass-band losses. Here a 5-stage filter is designed for 40 meters for CW operation that suppresses the phone band about 50 dB.



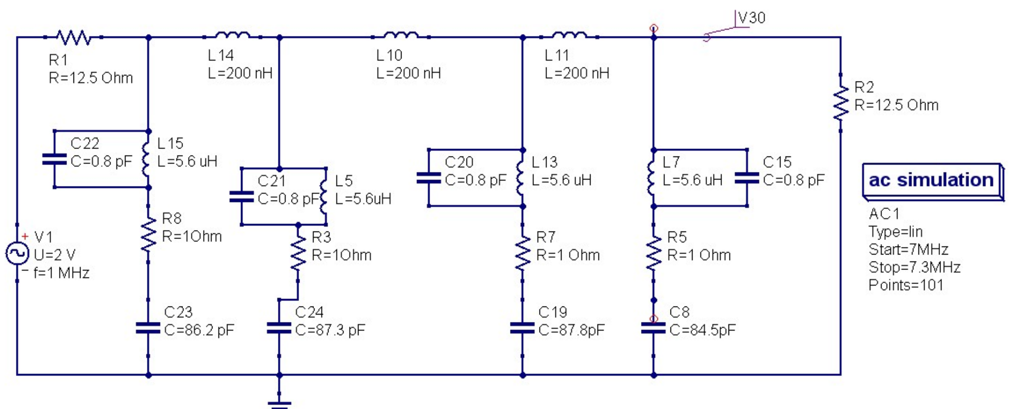
This is the simulation result for a CW filter with a 5-stage notch design which achieves around 50 dB of suppression over most of the phone band with only several dB of loss over most of the CW band.

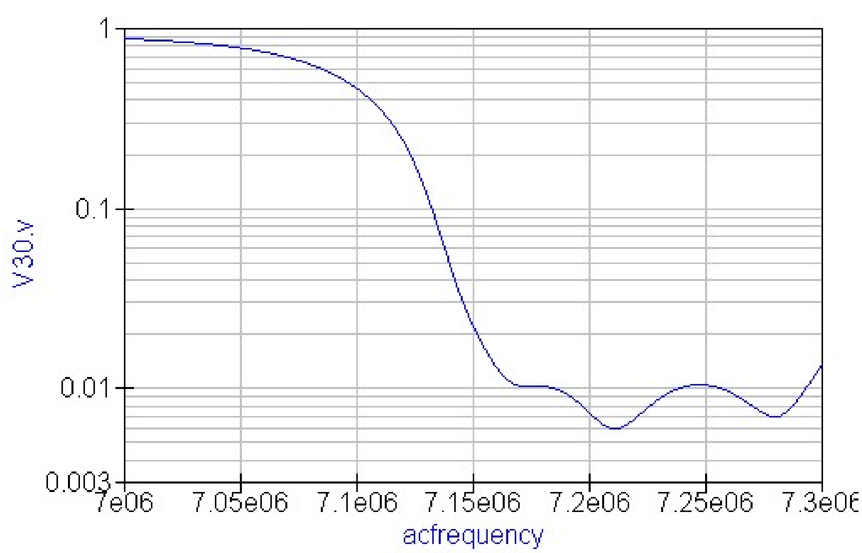


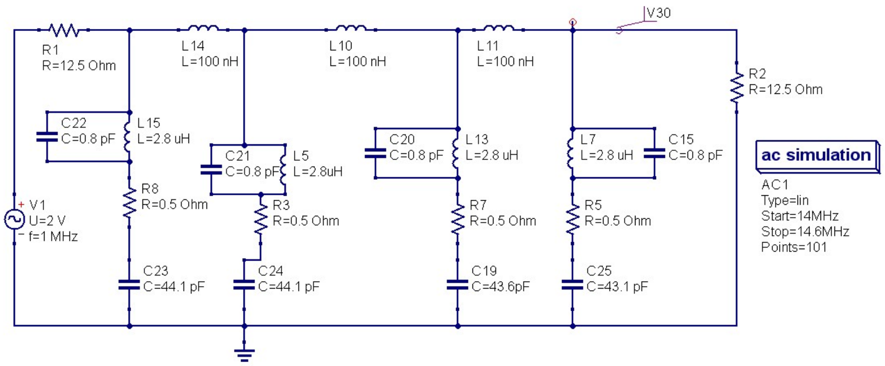
The schematic of the 5-stage notch filter shows 12.5 Ohms input/output impedances which would be matched to 50 Ohms with RF transformers. Small inductors of 200 nH couple the stages to provide a band-pass bump below the stop-band.

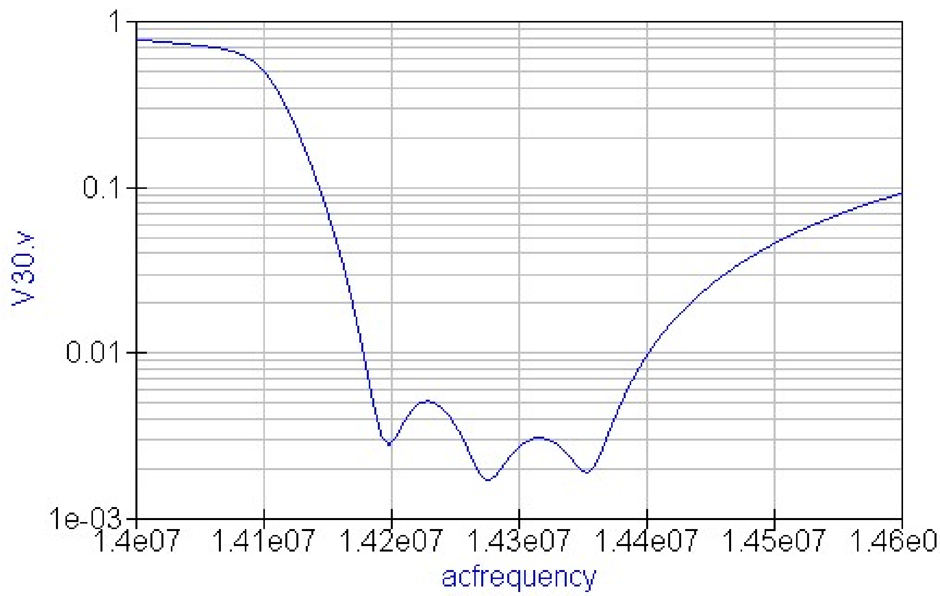
CW Dual Band 40 and 20 meters 4-stage USRX Filter

A CW dual band 40 and 20 meters USRX filter was designed with 4-stages. The CW station operates on 80, 40, 20, 15 and 10 meters for the ARA at Field Day, but 40 and 20 meters are usually the most productive. So, a switchable filter for 40 and 20 meters is a good fit. Since the phone bands are wider than the CW bands, 4-stages helps to suppress the entire phone band with good attenuation. The inductors, tuning capacitors and coupling inductors are separate, and switching is performed between the filters with just 2 SPDT relays with one at the input and one at the output. The chassis in 15” x 7” x 3” with the 40 meters filter running at the front of the chassis and the 20 meters filter running at the back between 4 isolation chambers. The input/output 4:1 RF transformers are shared as well as the bypass relays and input/output connectors and other components. One toggle switch selects 40 or 20 meters and a second toggle switch sets the filter to bypass mode.






V30
R1
R=12.5 Ohm
L14
L=100 nH
L10
L=100 nH
L11
L=100 nH
R2
R=12.5 Ohm
C22
C=0.8 pF
L15
L=2.8 uH
C21
C=0.8 pF
L5
L=2.8uH
C20
C=0.8 pF
L13
L=2.8 uH
L7
L=2.8 uH
C15
C=0.8 pF
ac simulation
AC1
Type=lin
Start=14MHz
Stop=14.6MHz
Points=101
V1
U=2 V
f=1 MHz
R8
R=0.5 Ohm
R3
R=0.5 Ohm
R7
R=0.5 Ohm
R5
R=0.5 Ohm
C23
C=44.1 pF
C24
C=44.1 pF
C19
C=43.6pF
C25
C=43.1 pF


1
0.1
0.01
1e-03
V30.v
1.4e07
1.41e07
1.42e07
1.43e07
1.44e07
1.45e07
1.46e07
acfrequency

Conclusion

The USRX phone filters look like they should provide a good tool to minimize CW signals on 80, 40 and 20 meters overloading and interfering with the phone rigs for Field Day nearby in frequency on the same band. They will also protect the phone rigs from digital transmissions which are in the upper portion of the CW band or just above it. No tuning is needed during operations. The filter is simply inserted in-line with the antenna coax and a band-pass TX/RX filter, and a 12 VDC power plug provides power for its TX/RX relays which are controlled by a cable to the rig's linear amp control output. For 40 meters, signals in the CW band from 7.0 to 7.1 MHz are suppressed by 25 to 30 dB while signals in the phone band from 7.15 to 7.3 MHz are passed with only a few dB of loss. This type of filter will not provide protection between CW and digital operations generally since these operations are even closer in frequency. Clean TX operation (low phase/amplifier noise and spurs) must be separately addressed and is most readily addressed by choosing rigs with clean TX operation.