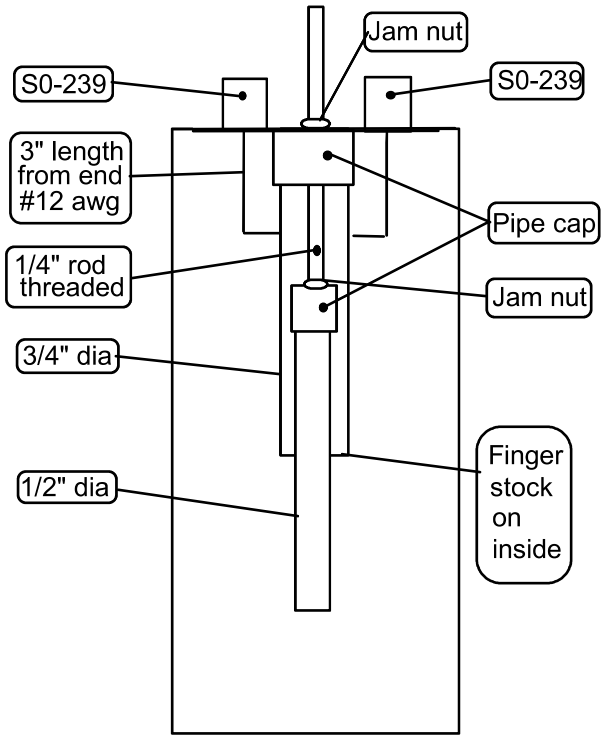
Jam nut
S0-239
S0-239
3" length from end #12 awg
Pipe cap
1/4" rod threaded
Jam nut
3/4" dia
Finger stock on inside
1/2" dia

Fig. 1

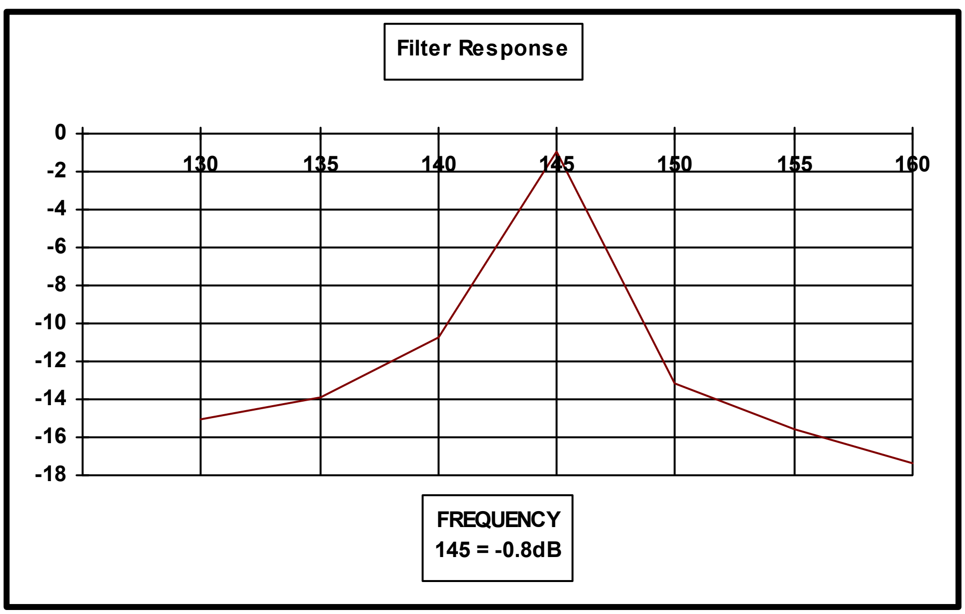
Filter Response
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
130
135
140
145
150
155
160
FREQUENCY
145 = -0.8dB

Fig. 2

VHF Intermod Filter

K4TAX
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Like most modern amateur operators today, we are commonly faced with various signals that seem to interfere with reception of desired signals on the 2 meter band. While most of these signals are not actually located within the 2 meter spectrum of 144 MHz to 148 MHz, they do appear to be received with today's "wide band" generation of receivers. Most often, signal sources such as paging, cellular phone, and other operations associated with fire, police and public service systems are located within a few miles, sometimes often less and within line of sight, from our home. These strong signals, regardless of frequency, saturate the front end of our receivers. This saturation causes the silicon devices in the receiver front-end to be biased to the non-linear portion of its operating curve. From semiconductor fundamentals, this bias condition is the basic requirement for a mixer. These multitudes of signals, along with our own local oscillator in the receiver, combine or mix to producing sum and difference products that fall within the IF pass band of our receiver. This is intermod.

It is often difficult to identify the offending sources. They frequently contain only "data" that is difficult to demodulate or further identify. Tracking down the offending frequencies, in an attempt to properly place a "notch" type filter at the receiver input, requires sophisticated equipment that is often well beyond the means of most amateurs. In any event, many of these so called ills are the result of our receiver's inability to provide ample "out of band" signal rejection. Actual field determinations indicate that most intermod contributors are from sources operating slightly above the 2 meter amateur band. The design and resulting shape factor of this filter does give greater signal attenuation on the high side the band. Making matters worse is our own desire for receivers that can operate outside the amateur bands. In most cases, the offending signals are operated strictly in accordance to the requirements of the licensing agency, the FCC. The fault is most often not the services in question, but that of our receivers. Granted, the manufacturers can produce better receiver designs that have additional selectivity. This then requires more sophisticated tuning efforts, on the part of the radio, to achieve broad band performance as well as space for the added electronics. These factors translate into larger size radios in our pockets and more dollars out of our pockets.

Having spent many hours of watching my PACKET station perform multiple retries and disconnects, I decided that it is time to put a stop to this unnecessary nonsense. Ideally, adding a band pass filter between the antenna and the receiver was the easiest way to solve the problem and requires no modifications to the radio. While this proved to be quite easy, several objectives must be considered. First, one must consider that a filter inserted in the receive line should have very low insertion loss. Additionally, the filter should have adequate selectivity to provide attenuation to the out-of-band signals. Finally, simplicity of construction and the cost of building such filter must be considered.

Reviewing several articles in QST and the ARRL Handbook on the subject of filters started the creative juices flowing. Having some prior experience with commercial filters used with repeaters, and duplexers both of the band pass and band reject design, led me to the "gallon paint can" design. Total cost of the project, buying all new materials at the local building supply house and Radio Shack, is under $25.00. A similar filter of a commercial design and performance will easily cost some 10 times that amount.

Construction materials consists of 3/4" and 1/2" rigid plumbing copper tubing, copper pipe caps, brass nuts, 1/4"X20 threaded rod, 2 -- SO-239's or BNC connectors, and 3 new 1 gallon paint cans. A few bits and pieces of hardware, pop rivets or screws and a 3" x 5" piece of 0.060" to 0.125" thick aluminum are all that is required. Tools can be basic plumbing tools, tubing cutter or hack saw, torch for soldering the copper and the cans, drills of the correct size and a file or hole punch. A well equipped home shop or tools will make this project a real snap to complete. Most of all, do obtain the permission of the XYL to use the electric can opener. This is necessary for a neat job of cutting the bottom out of the paint cans. Failure to get her permission to do this can result in being banished from the house or worse.

Basic construction hints.
After cutting the tubing or the drilling of holes, removal of burrs should be done to assure a smooth uniform finish. A round file or deburring tool will be of great value in this operation.

Several points on the 1/4 wave tunable assembly requires soldering. I can't say too much about the cleaning of the copper parts to be soldered. The parts must be polished to a bright shine, using fine steel wool or #200 grit paper at the points you intend to join. Ordinary plumber's flux and non-lead solder works well. A propane torch is required and provides more than enough heat. I won't go into the art of using a torch to solder plumbing parts, but too much heat is just as bad as not enough. Once a joint is soldered, do not move it for several minutes to allow the joint to cool and become rigid. Keep in mind that copper is a very good conductor of heat. It will get very hot several inches away from the point where heat is applied. Be careful with the fingers. OUCH!

CONSTRUCTION;
As the can bails are not needed, start by cutting the bails off the cans. This can be done using suitable wire cutters. Snip the bails close to the point where they enter the bail button on the side of the cans. If you should be lucky enough to obtain cans that do not have bails affixed, the better off you are. Following this, cut the bottom out of 2 of the 3 cans. Do not cut bottom out of 1 can. The kitchen can opener will do a great job and leave the inside reasonably smooth and free of sharp edges. In all 3 of the cans, leave the top ring, normally used to secure the lid, in place. This will add a bit of rigidity to the overall assembly. Start assembly by laying 2 cans horizontal end to end on the workbench, spot solder the two cans to form a can assembly that is "2 gallons tall". Add the third can, carefully lining up the cans and again spot solder in 2 or 3 places around the circumference. Once the assembly is "3 cans tall", check to see that the cans are arranged top to bottom and that no major gaps exist between the edges. As an aid to assist with alignment, I placed my cans on their side in a guide formed by laying 2 pieces

of scrap 2x4 spaced about 3" apart. To assure that the assembly is straight, it may be necessary to re-heat one or more of the spots to perform “minor alignment”. Once this is done, carefully using the torch, flux and lead-free solder, run a bead of solder around the joints of the cans. The cans are thin tin and very little heat is required. This completes this part of the assembly.

Preparation of the 3"x5" aluminum plate starts with the rounding of the corners with a file. The plate must fit on the underside of the lid, so as not to interfere with the installation of the lid on the paint bucket. Having this piece dimensionally a bit on the small side is better than it being too big. This plate will be attached later to the underside of the lid and will serve as the foundation for attaching the tunable 1/4 wave section, the input and output connectors and the tuning rod. Scribe a center line lengthwise on the aluminum plate. Find the center of this line and mark this point. This serves as the center of the assembly and, when drilled, provides a pass through for the tuning rod. Also the SO-239's or BNC connectors which will be mounted along this center line. Should you desire to use type N connectors, dimensions will need to be determined accordingly. The center of the connectors must be placed 3/4" from the outside circumference of the upper tube assembly. Typically this dimension is 1.125" from the center of the 1/4 wave section for SO-239 or BNC connectors. Mark these points, on the scribed line, to the left and right of the center point.

The 1/4 wave tuning section is made by using a 12" length of 3/4" diameter tubing and a 12" length of 1/2" diameter tubing and 2 mating end caps. Prepare each of the end caps by drilling a 1/4" hole in the center of each. A drill press and drill vise works well to hold the caps while drilling. Take care not to de-form the soft copper end caps. Temporarily, using a 1/4"x20 nut, thread it about 1/2" on one end of the threaded rod. Slide the pipe cap on the rod. Run a brass 1/4"x20 nut on the rod the tighten. This must be assembled so that the brass nut is on the inside of the pipe cap. Using the torch and applying heat to the outside of the end cap, carefully solder the brass nut to the inside of the cap. Perform this operation for both end caps. Once completed, solder the 1/2" cap on one end of the 1/2" tubing. It is suggested that the end cap is placed on the work surface with the open end facing up. Insert the 1/2" diameter tube vertically into the cap and solder the joint. If you attempt to perform this operation with the tube on the side, most likely the previously soldered 1/4" nut on the inside of the cap will be dislodged. As a precaution, temporarily, it is suggested that a short 1/4"x20 machine screw be run up snug through the nut from the outside of the end cap. This will assure that the nut on the inside will stay in correct position. Allow the assembly to thoroughly cool before examining the work.

Prepare the 3/4" end cap by drilling four 3/32" (0.09375") holes on the end of the end cap. The holes are to be located at 4 equal spaced places on either side of the brass nut. These holes will be used to attach the 1/4 wave tunable section to the top plate. Using the 3/4" end cap as a template, mark the location of the 3/32" holes, lining up the center of the 1/4" nut inside the end cap with the center mark previously made on the plate.

Prepare the top plate by drilling a 5/16" hole at the center mark. Drill a 1/8" hole at the four points marked at the sides of the center hole. The 3/4" end cap will be attached latter to this plate by using 4-- #6 x 1/2" thread cutting or sheet metal screws or pop-rivets.

Locate and drill the holes for the SO-239 or BNC connectors. Typically the connector center is 1.125" from the center of the 1/4 wave section tuning rod hole. The SO-239 connector requires a 5/8" diameter hole for the body to pass through while the BNC connector requires a 3/8" hole. The other connector mounting holes, if required, must be located and drilled according to the connectors you have chosen. Suggestion, bulkhead BNC type connectors only require one 3/8" hole for mounting. Locate and drill 4 -- 1/8" (0.125") holes approximately 1/2" from the outer edge, near the rounded corners of the aluminum plate. These holes will be used to attach the plate to the lid.

After checking to assure that one end of the 3/4" tube is free from burrs, carefully solder a length of finger stock around the inside of this end. This may appear a bit tricky, but tinning the inside of the tube first makes this operation a snap. Do not overheat the finger stock and use only a minimal amount of solder. The finger stock must be on the inside of the tube as it serves as the electrical contact for the movable 1/2" diameter section.

Cut the 1/4"X20 threaded rod to a length of 18". Dress the end with a file and turn a 1/4" nut about 1/2" on to one end of the rod. Thread this end into the nut previously soldered into the end cap of 1/2" tube assembly. Tighten the nut down securely against the end cap. Carefully insert this assembly into the open end of the 3/4" tube starting at the opposite end of the finger stock. Work the 1/2" tube assembly through the finger stock until it is protruding about 6". The threaded rod should extend from the open end of the 3/4" tube. Turn the 3/4" end cap assembly onto the threaded rod and into final position on the 3/4" tube. Once this is completed, check to see that the threaded rod turns freely and the 1/2" tube assembly rotates accordingly. If all is well, solder the 3/4" end cap to the 3/4" tube. Again the assembly should be in a vertical position so as not to dislodge the nut soldered in the end cap. (See Fig. 1)

Having completed drilling the holes in the aluminum plate, lay this plate on the inside of the paint can lid. Use the plate as the template. Mark all the holes onto the lid. Drill corresponding holes in the can lid. Also, once you have completed the lid, carefully check to see that all holes are in proper alignment. Dress all rough edges with a fine file. Take care as the edges of the lid around the holes will be sharp.

Attach the 1/4 wave tunable assembly to the aluminum plate using #6 x 1/2" thread cutting or sheet metal screws or pop-rivets. Use care so as not to over tighten and strip the soft copper end cap. Attach the aluminum plate to the lid using the 4 holes at the perimeter. I chose to "sandwich" the paint can lid between the SO-239 connectors and the aluminum plate. Install the SO-239 connectors from the lid side through the aluminum, plate. I have found that "pop rivets" work well for attaching the connectors and attaching the lid to the plate. You may elect to use #4 hardware, nuts and lock washers for connector installation.

Form the input and output coupling links by bending a 4" length of #12 AWG solid, tinned wire into "L" shaped forms. Legs are 1/2" and 3 1/2" respectively. Carefully mark and drill a hole 3/32" (0.09375") diameter on either side of the 3/4" 1/4 wave assembly. This hole must be located 3" from the mounting plate and on opposite sides of the assembly. Take care to align these holes with the center of the input and output connectors. The previously scribed line on the aluminum plate will aid in this alignment. Insert the long end of the "L" link into the center pin of the coax connector and insert the short end so that it just enters the 1/4 wave tube assembly. Some minor adjustment in length may be necessary as the connector center pin length may vary from manufacturer to manufacturer. Solder the end at the center pin of each coax connector. Adjust the "L" link position so that it is parallel with the 1/4 wave tube assembly. Spacing from the outer diameter of the 1/4 wave section to the #12 wire should be 3/16". Do not allow an excessive length of wire to protrude into the 3/4" section as it can interfere with the 1/2" center section and tuning rod rotation. Extra care in symmetry of the 2 input/output links makes for a good performing filter. Once this is achieved, solder the "L" link short end to the 1/4 wave assembly. (Refer to Fig. 1)

The 1/4 wave tunable assembly is now ready to insert into the "3 gallon can". Carefully place the lid on the can, using a block of wood, tap in place with a hammer. Run a 1/4" nut onto the threaded tuning rod down to the surface of the lid. A wing nut also works well for this application. This nut will be secured once the tuning to the desired frequency is completed. You may wish to dress the tuning rod by installing a knob on the upper end.

TUNING:

Assuming all dimensions are correct, attach a 50 ohm dummy load to one of the ports. Do not use an antenna for initial tuning as coax and reactance values may prove misleading. Connect the RF source (I used my 1 watt HT), selected to 145 MHz, to the SWR bridge and the bridge output to the other port. Apply the RF and adjust the tuning rod for minimum SWR. The system is now tuned. Typical SWR values are 1.3:1 or better.

As a secondary test, reverse the load and the input coax on the filter ports. Again apply the 145 MHz RF. There should be the same SWR reading as obtained before. If there is a difference, this indicates that the input and output links are not identical in length, or are at different points of attachment on the 1/4 wave section or the spacing between the links and the 1/4 wave section are not the same. Some very minor bending of the input/output links may be necessary to correct this problem. Remove the 1/4 wave assembly from the “3 gallon can” and make the necessary adjustments. ***CAUTION***: Do not apply RF with the assembly outside the can. A very high RF voltage appears at the end of the 1/4 wave assembly.

PERFORMANCE:
See Fig. 2 for typical results. Insertion loss was measured at 0.8dB at the center frequency. Rejection 5 MHz either side of center frequency is greater than 10 dB. This is more than adequate to eliminate or greatly reduce most 2 meter intermodulation distortion. Do not expect this filter to eliminate "in band" signals. This will require a much higher "Q" filter thus resulting in more insertion loss.

A word on operation. The filter should be tuned for your favorite frequency using the above method. If your antenna presents a low SWR is will not be necessary to use a dummy load for tuning purposes. Do not use the filter as a "matching device". The selectivity will suffer as well as the insertion loss will increase. If your are using the normal 600 KHz TX/RX offset for repeater operation, tune the filter for the transmit frequency.

A word on insertion loss, yes the filter presents the same loss in both directions. That is to say that received signals "on frequency" will be attenuated 0.8dB as well as your transmitted signal. There will be some loss of power on transmit. Typically, 10 watts into the filter will result in 8.32 watts out of the filter. That's 0.8dB loss.

I have used the unit with 150 watts being fed into the filter with no heating or other problem. Should you be running a higher power amplifier however, it is suggested that the filter be placed between the transceiver and the amplifier input. By using the filter in this mode, a secondary effect of cleaning up the transmitter output is also achieved.

<u>About the author:</u>
First licensed in 1960 as KN4TAX in Martin, TN, Bob McGraw has held K4TAX since 1961. He attended the University of Tennessee , with graduate studies at Vanderbilt University. He holds a Ph.D. in Electrical Engineering. Years following, he worked as a broadcast product evaluation engineer, an audio engineer and is presently with the manufacturing division of Sony Professional Products in Boca Raton FL. His ham interest stem from meteor scatter and EME work on VHF in the late 60's from Nashville, TN. More recently, he is devoting most of his time to UHF and VHF equipment building. In addition, he holds a 1st Class Radio Telephone license, an Advance class amateur license..