

Receiver Band-Pass Filters Having Maximum Attenuation in Adjacent Bands

Third-order Cauer filters can boost performance of multi-transmitter, multi-operator contest stations to the “next level.” The filters are practical and you don’t need expensive test equipment to align them.

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In a recent *QST* article,¹ I explained how to design, assemble and test six three-resonator band-pass filters (BPFs) for attenuating the phase noise and harmonics of the typical 150-W transceiver, both on transmitting and receiving. In this article, I will explain how to design, assemble and tune smaller-sized four-resonator BPFs having maximum attenuation in the two ham bands adjacent to the band being received. The BPFs are intended for connection to the 50- Ω RF input terminals of a receiver. They are especially useful for the multi-multi

contester, where six receivers and six high-power transmitters are in simultaneous operation, and the receivers need preselection filtering to prevent front-end overload.

Several receiving band-pass filter designs are in current use by the multi-multi contest fraternity, but they are either difficult to assemble, have insufficient attenuation, or lack design information so the interested reader can confirm the correctness of the design or try a different design. For example, an article in *CQ CONTEST Magazine*² described a group of band-pass filters for the multi-multi operator station. Although the BPFs had exceptional stop-band attenuation (on the order of 80 dB in adjacent bands), the number of components (seven inductors and seven capacitors) was

more than really needed, and the construction was difficult. The author made a passing reference to Zverev’s *Handbook of Filter Synthesis*³ as a source of the designs, but no explanation of the design procedure was included; consequently, none of the BPF designs could be confirmed. Other receiver BPF designs used over the past 15 years by the better-known multi-multi operators used a capacitively coupled three-resonator design with capacitor input and output. The attenuation of low-frequency signals was very good because of the capacitive coupling, but the high-frequency performance was poor. In addition, the tuning procedure was difficult unless you used a network analyzer.

In comparison, the new four-resonator receiver BPFs described below

¹Notes appear on [page 33](#).

need only four inductors and four capacitors for each BPF. Preliminary tuning of the four resonators requires a signal generator and detector, with final tuning using the return-loss test described in a previous article.⁴ Stop-band attenuation of 60 to 80 dB is obtained in the center of the bands adjacent to the passband. The four inductors and capacitors of each BPF can be mounted on a piece of 1×1½-inch perf-board and installed in a 2½×1½×3½-inch aluminum Minibox. The design procedure is fully explained. Anyone having a computer can duplicate the designs and confirm the correctness of each design by means of free software that is available.

Whether you want to update your receiver BPFs for better selectivity, or design different BPFs, this article will show you how to do it.

Background

Some previously published designs used two or three top-coupled resonators, such as the N1AL designs,⁵ or the W3LPL designs.⁶ K4VX used three-resonator Butterworth designs for his BPFs,⁷ and the most-selective BPFs by N6AW used seven resonators in a series-parallel configuration (See Note 2). I elected to base my BPF designs on the four-resonator, third-order Cauer. The input and output shunt resonators are tuned to the center frequency of the passband and the two series-connected resonators are tuned to the center frequencies of the adjacent bands. The intent is to have one more resonator than used in the simpler designs while getting maximum attenuation in the adjacent bands by having two of the resonators tuned to the frequencies where maximum attenuation is needed.

Although the stop-band attenuation of the third-order Cauer may be less than that of the N6AW seven-resonator design, the less-complex Cauer has less passband insertion loss, and is easier to assemble and tune. The design procedure to be explained shows how to confirm each BPF design and how to calculate other designs having different center frequencies or bandwidths. The computer used for designing needs only a DOS operating system. The computer I used has a 386SX microprocessor operating at 20 MHz with MS-DOS Ver. 4.01.

In addition to a computer, you need filter-design and analysis software. Normally, such software would cost more than \$100, but for you to design, analyze and plot the responses of any

third-order filter, the software costs nothing! This unusual offer to the Amateur Radio fraternity is made by Jim Tonne, president of Trinity Software.⁸ Jim's intent is that those seriously interested in filter design and analysis—either for amateur or professional purposes—should have the opportunity to become familiar with his *ELSIE* (LC) filter-design and analysis software. He is therefore offering a demo disk of his DOS-based *ELSIE* software to anyone who asks. Although the program on the demo disk is limited to filters of the third order only, all options of *ELSIE* are available for use. These include plots and tables of all parameters, *ELSIE* can design filters, and tune the designs.

Those interested in either duplicating these third-order Cauer BPF designs or designing other third-order BPFs for different bands may obtain *ELSIE* software on a 3½-inch floppy disk by writing to Jim. In your letter, please include a description of your intended application and your filter-design background.

BPF Design and Confirmation Procedure

The design of these third-order Cauer BPFs involves discovering the optimum values of many parameters, such as passband and stop-band widths, center frequency, stop-band attenuation, passband return loss, and impedances of the input and output resonators. Finding the optimum values of all these would have been impossible without the help of *ELSIE*. My *ELSIE* designs

for the 160, 80, 40, 20 and 15-meter BPFs are shown in Table 1. With these data, you can assemble and tune a set of BPFs with confidence.

Fig 1 shows the schematic diagram and the L, C and frequency values of the 40-meter BPF. As specified in rows 4, 5 and 6 of the 40-meter data in Table 1, inductors L1 and L4 each have five quintifilar turns of #18 and #20 magnet wire wound on T94-6 powdered-iron cores. A tap at the fifth turn above ground serves as the input and output connection to a 50-Ω source and load. The other BPFs are wired in a similar manner, except the 160 and 80-meter BPFs use quadrifilar windings for L1 and L4 instead of quintifilar windings.

Using quadrifilar or quintifilar windings on L1 and L4 results in an interleaving of all turns, with a correspondingly greater coupling between turns than that obtained with the more-customary single continuous winding. The inter-winding coupling reduces leakage inductance while optimizing the filter performance. This same winding technique was used in the wiring of the input and output resonators in the transmit BPFs discussed in an earlier article (see Note 1).

It was necessary to connect resonators 2 and 3 of the BPFs to taps on L1 and L4 at ¼ or ⅕ of the total turns so that the component values of resonators 2 and 3 would be practical. For example, the inductive reactances of L2 and L3 in the 40-meter BPF design are 413 Ω and 391 Ω at 14.287 and 3.734 MHz, respectively. These reasonable reactances can be achieved

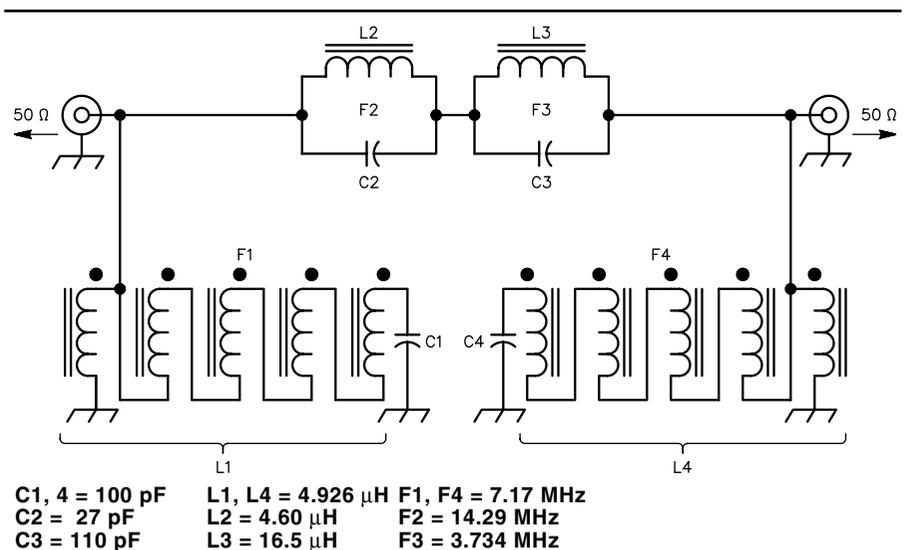


Fig 1—Schematic diagram and component values of the 40-meter receiver band-pass filter. The diagram is representative of all receiver BPFs, except for the 160 and 80-meter BPFs, which have quadrifilar windings for L1 and L4. See Table 1 for the component values and coil-winding details.

Table 1—Design Parameters For 160, 80, 40, 20, 15-Meter Receiver Band-Pass Filters

Parameters	160-Meter (1.8 to 2.0)	80-Meter (3.5 to 4.0)	40-Meter (7.0 to 7.3)	20-Meter (14.0 to 14.4)	15-Meter (21.0 to 21.45)
F_c , BW, Stop-Band Width (MHz)	1.897, 0.222, 2.22	3.74, 0.82385, 5.2256	7.17, 0.779, 10.127	14.2, 0.7137, 11.6377	21.2, 1.83, 19.484
A_s (dB), RL (dB), Z (Ω)	60.2, 23.84, 800	52.0, 20.10, 800	64.0, 26.89, 1250	64.0, 32.8, 1250	60.0, 25.67, 1250
L1, L4 (μ H); Qu & XL (Ω) @ F_c	11.17, 120, 133	8.965, 122, 211	4.926, 200, 222	1.570, 150, 140	1.281, 120, 171
Core & A_L (nH/N ²)	T94-2 (Red), 8.4	T94-2 (Red), 8.4	T94-6 (Yel), 7.0	T94-17 (Blu/Yel), 2.9	T80-17 (Blu/Yel), 2.9
Turns	9 Quadrifilar	8 Quadrifilar	5 Quintifilar	4 Quintifilar	4 Quintifilar
Turns, Wire Length & AWG	36: 9T, 13" #18; 27T, 32" #20	32: 8T, 12" #18; 24T, 29" #22	25: 5T, 8.3" #18; 20T, 26" #20	20: 4T, 7" #18 16T, 21" #18	20: 4T, 5" #18 16T, 16" #20
L2 (μ H), F2 (MHz)	14.17, 3.60	4.72, 7.085	4.596, 14.287	2.11, 21.1	0.9228, 28.84
XL (Ω) @ F2 (MHz), Qu	321, 210	210, 240	413, 80	280, 150	167, 200
Core (Color) & A_L	T94-2 (Red), 8.4	T94-6 (Yel), 7.0	T94-6 (Yel), 7.0	T94-17 (Blu/Yel), 2.9	T80-17 (Blu/Yel), 2.2
Turns, Length & AWG	40T, 45", #22	26T, 29", #20	24T, 28" #21	25T, 29", #20	18T, 20" #18
L3 (μ H), F3 (MHz)	53.39, 0.984	19.4, 1.880	16.51, 3.734	11.0, 7.23	2.46, 14.21
XL (Ω) @ F3 (MHz), Qu	330, 170	229, 250	387, 200	500, 140	220, 115
Core (Color) & A_L	T94-2 (Red), 8.4	T94-2 (Red), 8.4	T94-2 (Red), 8.4	T94-2 (Red), 8.4	T80-6 (Yel), 7.0
Turns, Length & AWG	38.5 Bifilar, 45", #24	47T (2-layer), 56", #20	44T, 49" #23	35T, 41", #20	22T, 24" #18
C1, C4 (pF)	630 = 620 + 10	202 = 180 + 22	100	80 = 33 + 47	44 = 22 + 22
C2 (pF)	138 = 82 + 56	107 = 68 + 39	27	27	33
C3 (pF)	490 = 470 (+20 interwinding)	370 = 270 + 100	110 = 100 + 10	44 = 22 + 22	51 = 33 + 18

TABLE NOTES:

- The first two rows list *ELSIE* parameters of center frequency, ripple bandwidth, bandwidth between upper and lower stop-band frequencies, attenuation depth in the stop band, minimum passband return loss and the impedance level of resonators 1 and 4, respectively. See the article text for explanation of the 160 meter C3 capacitance value of 490 pF.
- Most of the capacitors are obtained from the PHILIPS 680 Series because of its low K (high Q), 2% tolerance and 100-V dc rating. See the FARNELL/NEWARK electronic components catalog (March/September 1998, p 62). The 630-pF value of C1 and C4 in the 160-meter BPF design is realized with a paralleled 620-pF dipped silver-mica cap and a Philips ceramic cap, both selected to realize the design value within one percent. The 620-pF, 5% mica capacitor is available from Hosfelt Electronics, 2700 Sunset Blvd, Steubenville, OH 43952; tel 800-524-6464, fax 800-524-5414; hosfelt@clover.net; <http://www.hosfelt.com/>.
- MICROMETALS cores (for RF applications) are used in all the BPFs.
- The odd-numbered wire sizes are AWG equivalents of SWG wire sizes obtained from FARNELL/NEWARK. See the March/September 1998 FARNELL catalog, p 865.
- The minimum return-loss values listed above were obtained from the computer-generated data of the *ELSIE* filter design/analysis software. The return loss of the assembled BPF as measured with a network analyzer may be different.
- For frequencies less than 3 MHz, resistive considerations outweigh capacitive considerations; consequently, multiple-layer windings are acceptable to reduce resistive losses and improve Q. Above 3 MHz, single-layer windings provide maximum Q.

with toroidal powdered-iron cores. If these resonators had been connected to the tops of resonators 1 and 4, the reactances would have been impractical at 25 times greater; that is, at 10.3 k Ω and 9.7 k Ω .

If resonators 1 and 4 had been designed for an impedance of 50 Ω at the start, this would have eliminated the need for taps, but then the inductance and reactance of L1 and L4 would have been much too low at 0.197 μH and 8.88 Ω to realize these inductance values with acceptable Q. The procedure to obtain optimum component values for all resonators is to design resonators 1 and 4 for an impedance equal to the square of 2, 3, 4 or 5 times 50 Ω , and then to connect the center resonators between 50- Ω taps on L1 and L4.

Whether a quadrifilar or quintifilar winding is used for L1 and L4 depends on the BPF percentage bandwidth. For example, the percentage bandwidth of the 80-meter BPF is $(100 \times BW) / F_c = 82.385 / 3.74 = 22\%$. This is a relatively broad bandwidth, and a quadrifilar winding is satisfactory. In comparison, the percentage bandwidths of the 40, 20 and 15-meter BPFs are 11.3%, 5.0% and 6.8%, and quintifilar windings are more appropriate. The 160-meter BPF has a relative percentage bandwidth of 11.7%, and either quadrifilar or quintifilar windings could be used.

The BPF designs listed in Table 1 may be confirmed in two ways. The simplest way is to use the analysis option of *ELSIE* wherein the listed component values are entered at the *ELSIE* prompts, and the insertion loss and return-loss response plots are viewed to confirm that the design is satisfactory. However, a minor correction to the tabular data for resonators 2 and 3 must be made before entering their component values at the *ELSIE* prompts because *ELSIE* is not capable of evaluating tapped inductors. Consequently, the two series-connected resonators 2 and 3 must be moved to the tops of resonators 1 and 4, and the component values of resonators 2 and 3 corrected to account for the change in impedance level. This is accomplished by multiplying and dividing the tabular inductance and capacitance values, respectively, of resonators 2 and 3 by a factor equal to the impedance of resonators 1 and 4 divided by 50, or $1250 / 50 = 25$. Fig 2 shows the schematic diagram and component values of the 40-meter BPF in a corrected form suitable for *ELSIE* to analyze the design and plot the attenuation and return-loss responses.

The attenuation peaks should fall in the center of the 80 and 20-meter bands, and the minimum passband return loss should be 30 dB.

The BPF designs may also be confirmed by letting *ELSIE* assist you in designing a BPF. At the *ELSIE* prompts, enter the width of the passband, the center frequency, the stop-band width, the depth of the stop-band attenuation and the impedance. *ELSIE* will then design a BPF to meet these requirements. The design values to use are listed in the first two rows of each column in Table 1, except for the passband return loss, which is not needed by *ELSIE*, and is included only for reference.

After reviewing the attenuation and return-loss response plots, you then manually tune the design so the attenuation peaks fall at the center of the bands adjacent to the passband. This is done by varying the C and L values of resonators 2 and 3 while maintaining a passband return loss greater than 20 dB. Additional minor adjustments can be made to the center frequency so that the values of C1 and C4 are convenient. For example, the center frequency of the 40-meter BPF was increased slightly from 7.15 MHz to 7.17 MHz so C1 and C4 would become exactly 100 pF instead of the original nonstandard value.

When you are satisfied with the tuned design, the impractical component values of resonators 2 and 3 are scaled from the design impedance to 50 Ω . The 50- Ω taps on resonators 1 and 4 serve as the BPF input and output connections. Fig 1 shows the schematic diagram of the completed design of the 40-meter BPF.

The third-order BPFs designed by *ELSIE* originated as classic Cauer designs, where the minimum stop-band attenuation both below and

above the passband are identical. However, after the modifications, the lower and upper-frequency minimum-attenuation levels are no longer identical, thus showing that the design is no longer a legitimate Cauer. For this reason, these modified Cauer designs cannot be duplicated using the published Zverev tables. For our purposes, this is of no concern as long as the attenuation peaks are in the center of the adjacent ham bands, and the computer-calculated minimum passband return loss is greater than 20 dB. By using *ELSIE* to design these third-order Cauer designs, what before was impossible now becomes simple!

BPF Assembly and Tuning

Fig 3 shows the 40-meter BPF assembled on a piece of perfboard installed in an LMB 873 aluminum Minibox. The toroidal inductors are secured to the perfboard by passing their leads through the holes in the perfboard, then sharply bending the leads sideways. All capacitors are connected to the inductor leads under the perfboard. A cardboard strip insulates the capacitor and inductor leads (under the perfboard) from the bottom of the aluminum box. The #18 wire leads of L1 and L4 connect at each end of the assembly to the center pins and ground lugs of the phono connectors. These four #18 leads provide sufficient support to hold the assembly in place. The other BPFs are assembled in a similar manner.

The assembly of the BPF components is greatly simplified by the omission of shielding partitions between stages. The lack of any shielding apparently had no effect on the BPF stop-band performance, since attenuation levels greater than 80 dB were noted in the upper frequencies in all the BPF tests.

Because resonators 1 and 4 must be

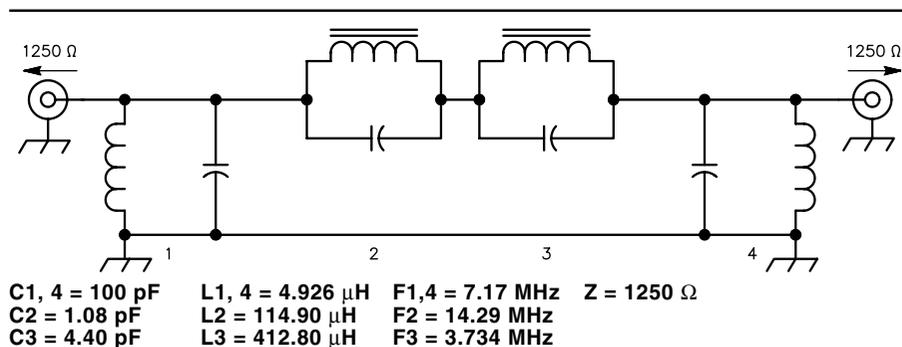


Fig 2—Schematic diagram of the prototype third-order Cauer 40-meter BPF before resonators 2 and 3 are moved to the 50- Ω taps on L1 and L4. Use these component values if you want *ELSIE* to analyze the BPF performance.

tuned to the same center frequency, successful tuning depends on using precisely matched capacitors, preferably both having the same value, and within one percent of the design value. For the 40-meter BPF, this frequency was 7.17 MHz, so C1 and C4 could be standard values of 100 pF. Capacitors 2 and 3 can be within two percent of the design values. Sufficient room should be left on the T94 cores so the windings can be squeezed or spread to fine tune each resonator. This is important so that all resonators can be tuned either to the center of the BPF passband, or to the center frequency of the adjacent amateur bands.

Initially, tune each resonator before installation on the perfboard. First, pass a single-turn wire loop from a signal generator through the center of the inductor. Then put a second loop through the inductor, and connect it to a sensitive wide-band detector. Vary the signal-generator frequency until you see a voltage peak on the detector output meter; that indicates circuit resonance. Measure the generator frequency with a frequency counter, then squeeze or spread the inductor turns until a resonance peak is obtained at the design frequency. After this, install the resonator on the perfboard without disturbing the turns on the core. A final check on the BPF tuning is made with the return-loss response test as explained in the referent of [Note 4](#). After the final check, the inductor turns may be secured with a coating of polystyrene Q-dope.⁹

Special Tuning Considerations

To find the optimum parameters for the 160-meter BPF, I used *ELSIE*'s "tune" mode to find convenient capacitance values while keeping the upper-frequency attenuation peak in the center of the 80-meter band and while keeping the minimum passband return loss greater than 20 dB. The placement of the lower-frequency attenuation peak, established by resonator #3, was not critical, and the C3 and L3 values were varied until a convenient C3 value of 470 pF was obtained with a computer-calculated minimum return loss of more than 20 dB. However, when the design was assembled and final tuning adjusted by observing the measured return-loss response as seen on an oscilloscope, I discovered that the optimum return-loss response occurred when resonator #3 was tuned to 0.984 MHz, *not* to the original frequency. The measured return-loss response of the assembled

BPF could be duplicated with an *ELSIE* analysis only when C3 was made equal to 490 pF instead of the 470-pF value, and F3 was 0.984 MHz.

The actual value of C3 is 20 pF greater than the 470-pF capacitor installed on the perfboard because of the inter-winding capacity of L3. Con-

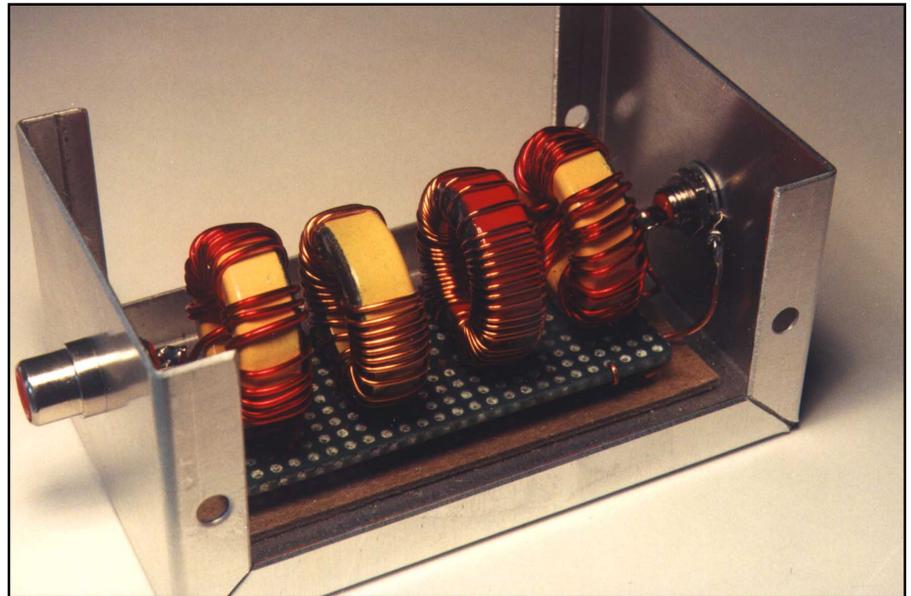


Fig 3—The photo shows the 40-meter BPF assembled in an aluminum Minibox 3 1/2×2 1/8×1 1/8 inches (LMB 873). The T94 cores are installed on the top of a piece of perfboard (1×2.6 inches) with the prepunched holes on a 0.1-inch grid. All capacitors are mounted under the perfboard. A strip of cardboard glued to the inside of the box bottom provides insulation between the BPF leads and the aluminum box. The BPF input and output leads that are connected at each end to the phono-connector center pins and ground lugs are stiff enough to hold the assembly in place.

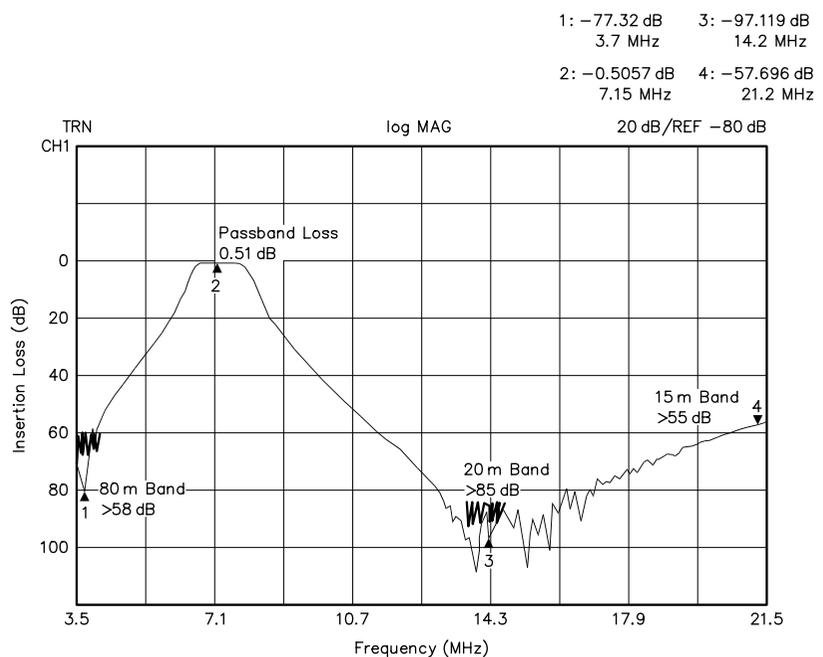


Fig 4—The plot shows the insertion-loss response of the 40-meter BPF as measured with a network analyzer. The attenuation of signals in the adjacent 80 and 20-meter bands is greater than 58 and 85 dB, respectively. The passband loss is about 0.5 dB and the passband return loss (not shown) is greater than 20 dB.

sequently, when assembling the 160-meter BPF, use a 470-pF capacitor for C3; when analyzing the design with *ELSIE*, use a 490-pF value. The additional 20 pF caused by the L3 winding capacitance is indicated by the designation “+20 interwinding” in the 160-meter BPF column for C3 in [Table 1](#).

Because of the unknown effects of stray variables associated with these BPFs, it is important to final tune each BPF using the return-loss-measurement procedure so you have assurance that the BPF is correctly tuned.

Insertion Loss and Return-Loss Performance

[Figs 4](#) and [5](#) show the measured responses of the 40-meter BPF insertion loss and return loss after the BPF tuning was completed. The insertion-loss response, obtained with a network analyzer and plotter by Tim Duffy, K3LR, shows that the stop-band attenuation is maximum at 75 and 85 dB at the centers of the 80 and 20-meter bands, respectively. The passband loss is about 0.5 dB. The stop-band and passband losses of the other BPFs are similar to those of the 40-meter BPF, with the greatest passband loss being 0.55 dB in the 15-meter BPF.

The decrease in insertion loss above 15 MHz is attributed to imperfect coupling in the windings of L1 and L4, and this same anomaly was noted in the transmitter BPFs described in the referent of [Note 1](#). Although the insertion loss decreases above 15 MHz, this should cause no problem because the attenuation in the 15-meter band is still substantial, at more than 55 dB.

The return-loss response of the 40-meter BPF is shown in [Fig 5](#). This figure is a photograph of the scope waveform obtained with the return-loss test setup described in the referent of [Note 1](#). Two important additions to the equipment shown in [Note 1](#)'s [Fig A3](#) should be noted, however. (1) A seven-element, 50-Ω low-pass filter with a cutoff frequency equal to about 1.3 times the upper cut-off frequency of the BPF being tested should be connected directly to the 50-Ω output of the voltage-controlled oscillator (VCO). (2) A 50-Ω, 6-to-10-dB pad should be connected between the low-pass filter output and the RF-IN port of the return-loss bridge.

The 50-Ω pad provides a well-defined 50-Ω source impedance for the return-loss bridge and eliminates any minor impedance variations that might be present at the filter output port. The low-pass filter prevents har-

monics of the VCO from distorting the waveform of the return-loss response. If the VCO harmonics are not sufficiently attenuated, the sharp peaks of the return-loss response may be completely missing, and it may be difficult to determine when the BPF is correctly tuned. BPF tuning is accomplished by squeezing or spreading the turns on inductors L2 and L3 until the three peaks are obtained on the return-loss response and the minimum return-loss levels are identical. Sometimes it may be necessary to remove or add a turn to L2 or L3. You can see whether this is necessary by the effect on the return-loss response when squeezing or spreading the turns of L2 and L3. Do not touch the turns on L1 and L4 since they need no adjustment.

Correct tuning of the BPF is indicated when you get three distinct peaks in the return-loss response and the two minimum return-loss levels between the peaks are identical. In the 40-meter BPF, the measured minimum return-loss level was a few decibels above 20. A 20-dB reference level was established on the oscilloscope screen by replacing the 50-Ω terminated BPF with a 61-Ω resistive load. A 61-Ω load on the return-loss-bridge “load” port produces a straight line on the display that is equivalent to an SWR of $61/50 = 1.22$, which is equal to a return loss of 20 dB. For the 160 and

80-meter BPFs, the minimum return loss was a decibel or so below the 20-dB reference level.

The 40-meter passband width can be measured from the return-loss response by subtracting the lower frequency from the upper frequency on the return-loss response curve where the curve crosses the minimum return-loss level. In the case of the 40-meter BPF, the measured passband width was about 0.79 MHz, which closely approximates the design value listed in [Table 1](#).

As viewed on a network analyzer or in the *ELSIE* plot of return loss, the return-loss response increases in a downward direction. However, I prefer to see return loss increasing upward. I accomplished this reversal of return-loss direction by using the scope **INVERT** switch on the Y-channel input.

160-meter BPF Performance Under Operating Conditions

An indication of the usefulness of these receiver BPFs under actual operating conditions was provided by Tony Kazmakites, N2TK/V26AK. He used both the transmit and receive BPFs in the operation of V26B during the 1998 CQ Worldwide Sideband Contest, in the multi-multi category. Tony reports that originally, with the old-style three-resonator capacitive-coupled BPF on the 160-meter re-

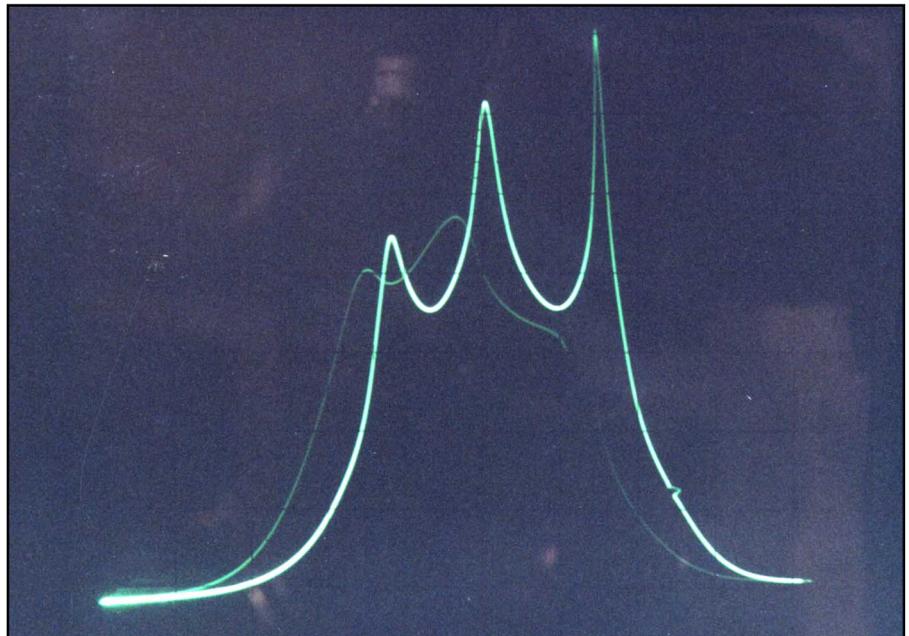


Fig 5—The photo shows the return-loss response of the 40-meter BPF obtained with the test equipment described in the text. The center peak of the return-loss response is at 7.17 MHz, which is the center frequency of the tuned 40-meter BPF. The frequencies at the beginning and end of the 40-meter passband (7.0 and 7.3 MHz) are to the left and right of the center peak in the valleys of the response curve. The BPF minimum return-loss level is greater than 20 dB.

ceiver, nothing on the 160-meter band could be heard because of noise from the 75-meter station. After the old-style BPF was replaced with the new third-order Cauer 160-meter receive BPF, the entire problem on 160 meters was solved. The 160-meter operator wanted to buy the filter on the spot! Tony further reports that "...the W3NQN transmit and receive filters have taken us to another level of improvement in multi-transmitter operations." Tony says he will be using these BPFs again at V26B for the 1999 CQ Worldwide Sideband Contest.

Summary

The deficiencies of LC BPFs currently being used to prevent receiver overload were discussed. A previously unused BPF type—the third-order Cauer—was introduced. The Cauer is easier to assemble and tune than other filter types, and it provides maximum attenuation in the adjacent amateur bands. This filter type was not previously considered because it was impossible to calculate the component values for the special stop-band response that was desired. However, free filter-design and analysis software makes it possible for anyone with a computer to design and analyze any type of third-order passive LC filter.

Those interested in only building new third-order Cauer BPFs, can do so from a table of values for the 160, 80, 40, 20 or 15-meter bands and the tuning procedure described. To demonstrate the performance typical of all the BPFs, the insertion and return loss of a 40-meter BPF was evaluated and its response curves are shown in two figures. An

explanation was included for those who wish to confirm the tabulated designs or design BPFs having different parameters. Those wishing to obtain any of the assembled and tested BPFs should send an SASE (business-sized envelope) to the author for details.

Radio amateurs now have access to free LC filter software that allows them to design and analyze any type of third-order passive LC filter. This new and powerful capability should help to advance the state-of-the-art in Amateur Radio filter design.

Acknowledgements

The author is grateful to Jim Tonne, WB6BLD, for making his *ELSIE* filter-design and analysis software available for use in this project. Thanks also to Tim Duffy, K3LR, for his comments on the receiver BPF performance and for plotting the insertion and return-loss responses using a network analyzer. The report provided by Tony Kazmakites, N2TK, on his experiences in using the receiver BPFs is gratefully acknowledged.

Notes

¹E. Wetherhold, W3NQN, "Clean Up Your Signals with Band-Pass Filters," *QST*, 1998, Part 1 May, pp 44-48 and Part 2 Jun, pp 39-42.

²J. Perkins, N6AW, "Band-pass Filters for the Serious Multi-Operator Station," *CQ Contest*, Jan 1996, pp 14-17.

³A. I. Zverev, *Handbook of Filter Synthesis* (New York: John Wiley and Sons, 1967).

⁴See [Note 1](#): Appendix of Part 2, pp 41, 42 and Fig A3.

⁵A. Bloom, N1AL, "Inexpensive Interference Filters," *QST*, Jun 1994, pp 32-36.

⁶Description of W3LPL receiver band-pass filters from notes of K3ND, provided to the author by Tony Kazmakites, N2TK.

⁷L. Gordon, K4VX, "Band-Pass Filters for HF Transceivers," *QST* Sep 1988, pp 17-28.

⁸Trinity Software, 7801 Rice Dr, Rowlett, TX 75088, Jim Tonne, WB6BLD, President, tel 972-475-7132.

⁹Q-dope, 2 oz bottle with brush, part #10-3702, \$3.75; Ocean State Electronics, PO Box 1458, 6 Industrial Dr, Westerly, RI 02891; tel 1-800-866-6626, 401-596-3080, fax 401-596-3590; <http://www.oselectronics.com/>.

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Ed has written many articles on simplified filter design that have been published in the electronics trade and Amateur Radio journals, such as Interference Technology Engineers' Master (ITEM), QST, QEX, CQ and Practical Wireless, and in professional EMC journals and Amateur Radio Handbooks. For example, The 1998 ARRL Handbook contains Ed's SVC filter design tables and an explanation of how to design passive LC filters.

Ed obtained his Amateur Radio license in 1947, while serving in the Air Force as a radio mechanic instructor at Scott AFB, in Illinois. Since 1977 he has been a Technical Advisor to the ARRL on passive LC filters. He may be contacted at his home at 1426 Catlyn Pl, Annapolis, MD 21401, or by telephone at 410-268-0916. □□