Number 11 on your Feedback card

CARR'S CORNER

Joseph J. Carr K4IPV
P.O. Box 1099
Falls Church VA 22041

Home-Brewing Your Own RF Filters

Radio frequency filters are inductor-capacitor networks that pass one band of frequencies, while rejecting all other frequencies. Hams use RF filters in a wide variety of applications: keeping harmonics at the transmitter, preventing out-of-band signals from getting into the receiver, etc. There are four basic types: low-pass filters (LPF), high-pass filters (HPF), band-pass filters (BPF) and rejection filters (called notch filters when the rejection band is narrow, and bandstop filters when the rejection band is wider).

The LPF and HPF frequency responses are shown in Figures 1A and 1B, respectively. In the LPF (Figure 1A), all signals from DC to some cut-off frequency (Fc) are passed, but above Fc the response falls off to the point where there is little signal passing. The cut-off frequency is usually defined as the point where the frequency response falls off -3 dB from the in-band response. The HPF characteristic is shown in Figure 1B, and is exactly the opposite of the LPF: It rejects all frequencies below its cut-off frequency, while passing all frequencies above Fc. Note that these curves are a bit idealized; real RF filters are not so smooth either in the passband or outside it.

If you start "raw" and design your own filter, then the task is daunting indeed. But if you use tables of values for "normalized" generic filters, then the job becomes a lot easier . . . and certainly falls into the "easily do-able" category. I recently tried my hand at a number of RF filters for different purposes, only some of which are related to ham radio, but all of which illustrate the principles involved. You can also use the same method to design filters for your own purposes.

> ***"The filter projects turned out so well that I am convinced it is another case of ' . . . the contriving of contrivances is a game for all.' "***

I had several projects in mind when I built some filters. First, I needed both HPF and LPF designs with overlapping cut-off frequencies of 3,000 kHz or so (the exact frequency was not critical). Second, I needed an 8,000 kHz LPF for a small 40 meter 1.5-watt power oscillator that I was building. Finally, I needed an LPF that would reject the AM broadcast band, while passing LF/VLF signals. For these projects I turned to the *ARRL Handbook* for the normalized tables. The circuits are found on page 2-51 in the 1993 edition, while the tables are found on pages 2-51 and 2-52. Figure 2 shows the basic LPF circuit, while Figure 3 shows the HPF case (both use the part designations found in the *ARRL Handbook).*

The tables give the values for the normalized case where Fc = 1 MHz; the inductances are given in microhenrys (µH) and the capacitances in picofarads (pF).

Table 1.

No. Elements	Ripple (dB)	C1	C2	L1	L2	L3
5	1	3473.1	3473.1	16.99	23.88	16.99
5	0.1	4364.7	4364.7	9.126	15.72	9.126
5	0.01	4153.7	4153.7	6.019	12.55	6.019

Example: The Low-Pass Case

In this example let's look at my 3,000 kHz LPF. It was used in a sweep signal generator that I designed for the AM broadcast band, and for common AM IF frequencies (e.g. 455 kHz). I needed it to facilitate a project that I am working on: a super AM DXer's receiver (sorry, no details as yet). A portion of the normalized 1 MHz data from Table 20, p. 2-52, is shown in Table 1.

The number of elements in the complete table varied from three to nine (odd numbers), but because this filter has two capacitors and three inductors, only the five-element data is reproduced (see the book for the complete table, as well as those for the HPF and other designs). The ripple data refers to the maximum ripple in the passband of the filter, and is expressed in decibels (dB). I selected the 0.1 dB figures.

The table data are normalized to 1 MHz, so to find the values of inductance and capacitance needed for the actual filter divide the values in the data table by the frequency in megahertz (MHz). To find the values for my 3,000 kHz (i.e. 3 MHz), 0.1 dB ripple LPF I divided the *ARRL Handbook* values by three:

C1 = C2 = 4364.7/3 = 1454.9 pF; L1 = L3 = 9.126/3 = 3.04 µH; L2 = 5.24 µH.

C1:	1454.9 pF
C2:	1454.9 pF
L1:	3.04 µH
L2:	5.24 µH
L3:	3.04 µH

The coils are relatively easy to come by: Wind them on Amidon Associates [2216 East Gladwick Street, Dominguez Hills CA 90220; phones: (voice) 213-763-5770, (Fax) 213-763-2250] coil forms. The T-50-2 (RED) cores have an AL value of 49, and op-

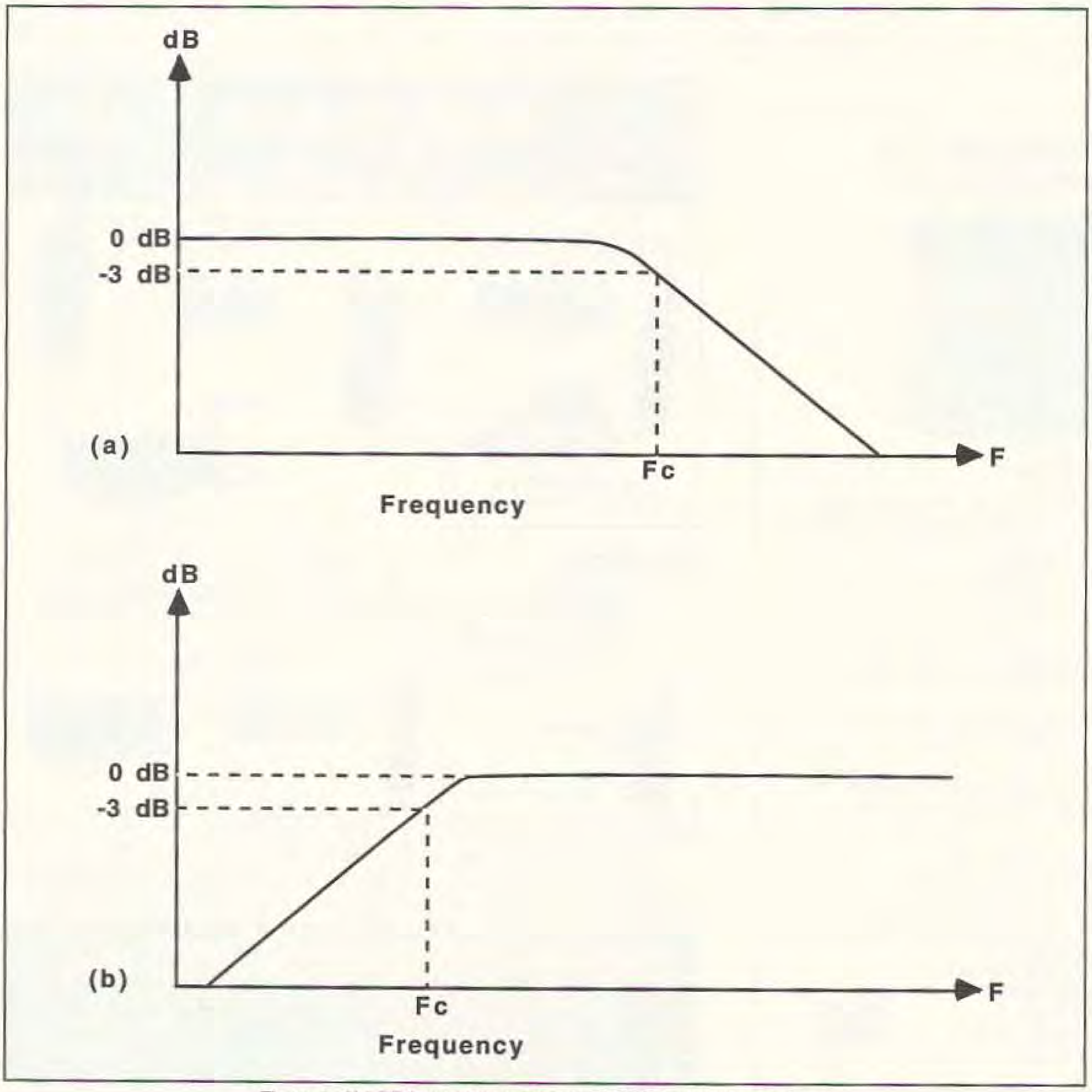

Figure 1. A) LPF frequency response; B) HPF frequency response.

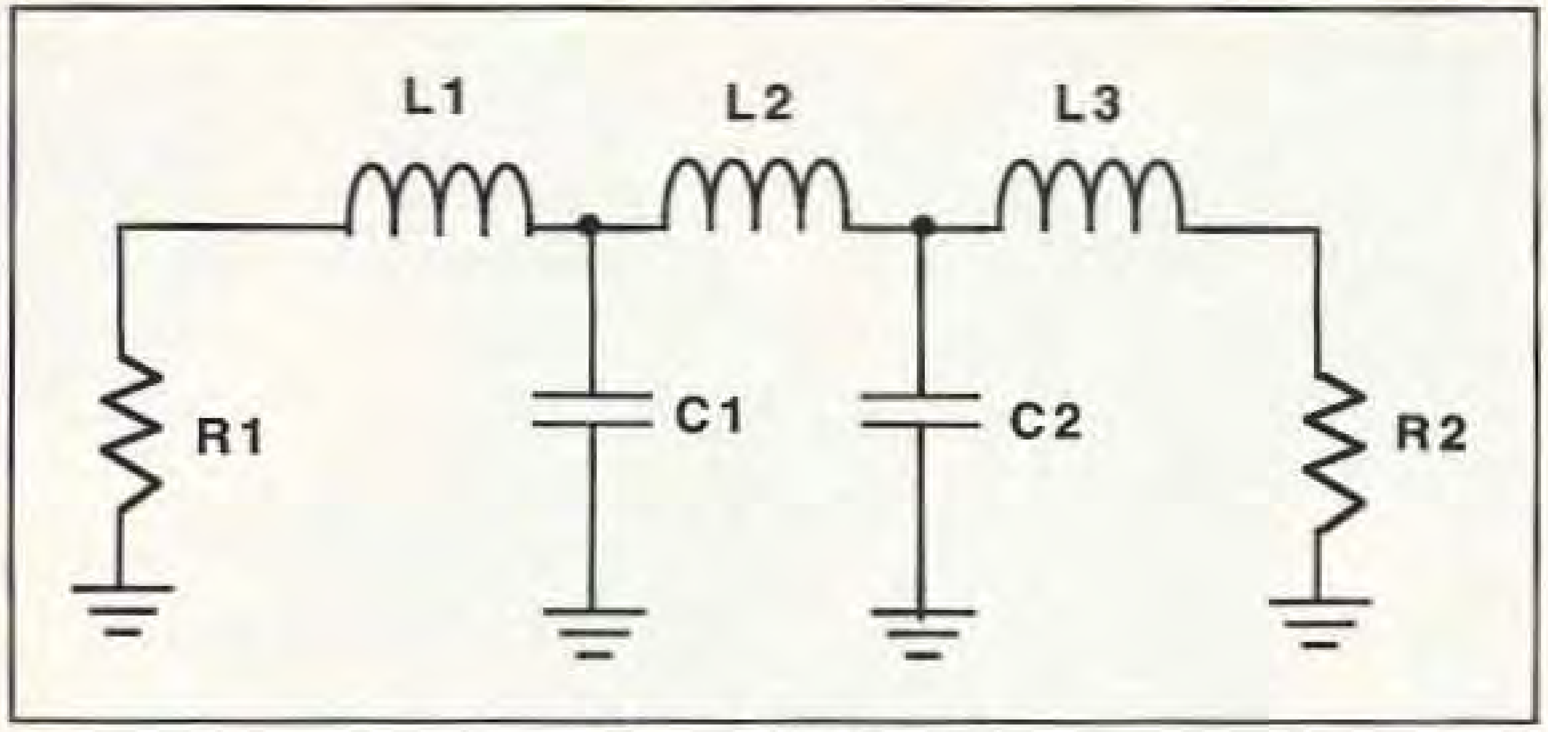

Figure 2. LPF circuit.

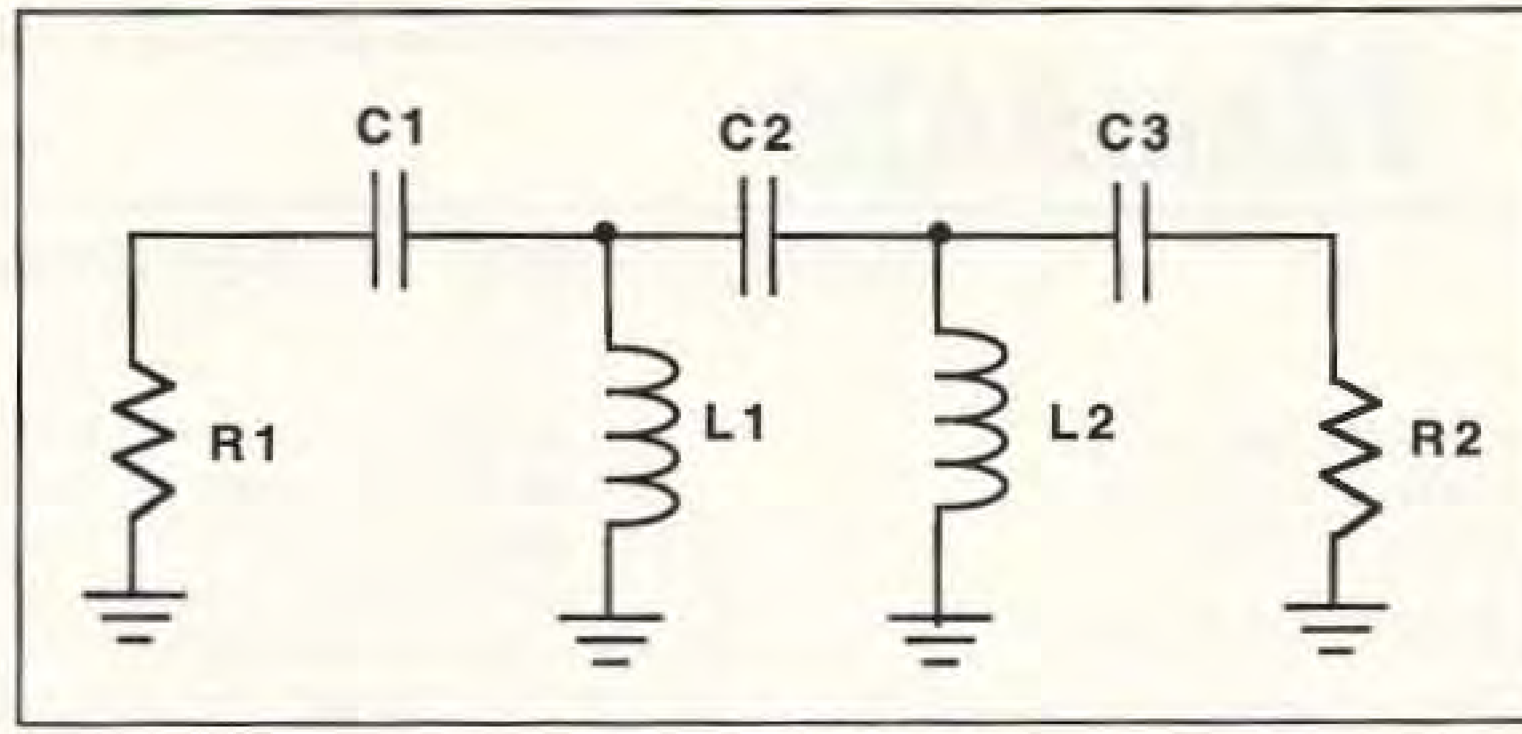

Figure 3. HPF circuit.

erate from 2 to 30 MHz, while the T-50-15 (RED/WHT) have an AL of 135 and operate over 0.1 to 2 MHz. In practice, I found that 3 MHz was not unreasonable for the -15 cores, so I opted to use them. Applying the formula below gave the number of turns:

$$N = \sqrt{L_{\mu H} / A_L}$$

L1, L3: 3.04 µH, 15 turns, T-50-15 (RED/WHT)
L2: 5.24 µH, 20 turns, T-50-15 (RED/WHT)

The capacitors are another matter. Where in blazes do you get a 1454.9 pF capacitor? Well, one solution is to use a 0.0015 µF (1,500 pF) and live with the slight frequency error. I did this and found that the filter had a cutoff frequency only slightly lower than 3,000 kHz, and it was acceptable. Otherwise, it is possible to select standard value capacitors that in some series or parallel combination total 1454.9 pF, or something close to it. For example, 75 pF, 560 pF, and 820 pF add up to 1455 pF, and all are easily available values.

The capacitors used in the filter should be NPO disk ceramic, silvered mica, or polyethelene. I bought several dozen of all types recently from Ocean State Electronics [P.O. Box 1458, 6 Industrial Drive, Westerly RI 02891; phones: 1-800-866-6626 (orders), 401-596-3080 (inside RI), or 401-596-3590 (Fax)]. Ask them for their catalog . . . you'll find a lot of ham building parts that you thought were "history" because other parts distributors no longer carry them.

Another approach is to use a combination of fixed-value and trimmer capacitors in the filter. This is a viable approach if you have a sweep generator and oscilloscope to align the filter, but can be a "bear" if you don't. A procedure for alignment of such filters is given in Hayward and DeMaw's *Solid-State Design for the Radio Amateur* (an ARRL publication).

The filter projects turned out so well that I am convinced it is another case of " . . . the contriving of contrivances is a game for all."

Book Note

One of my publishers has moved, and has also added an "800" number for credit card orders. HighText Publications is owned by Harry Helms and Carol Lewis. Their address is: 125 North Acacia Avenue, Suite 110, Solana Beach CA 92075; phones 619-793-4141 and 4142. Credit card orders are handled by IPG at 1-800-888-4741. They publish my *Receiving Antenna Handbook* and *The Art of Science*, as well as Harry Helms' books *All About Ham Radio* and *Shortwave Listening Guidebook*.

They now claim to be the biggest technical publisher west of Pacific Coast Highway (or, is that the only publisher west of . . . ?), and to have sales greater than the combined profits of IBM and General Motors. Helms, you're dangerous.