BY DOUG DeMAW, W1FB

CONSTRUCTION PROJECTS, TECHNIQUES, AND THEORYs

Getting To Know RF Filters

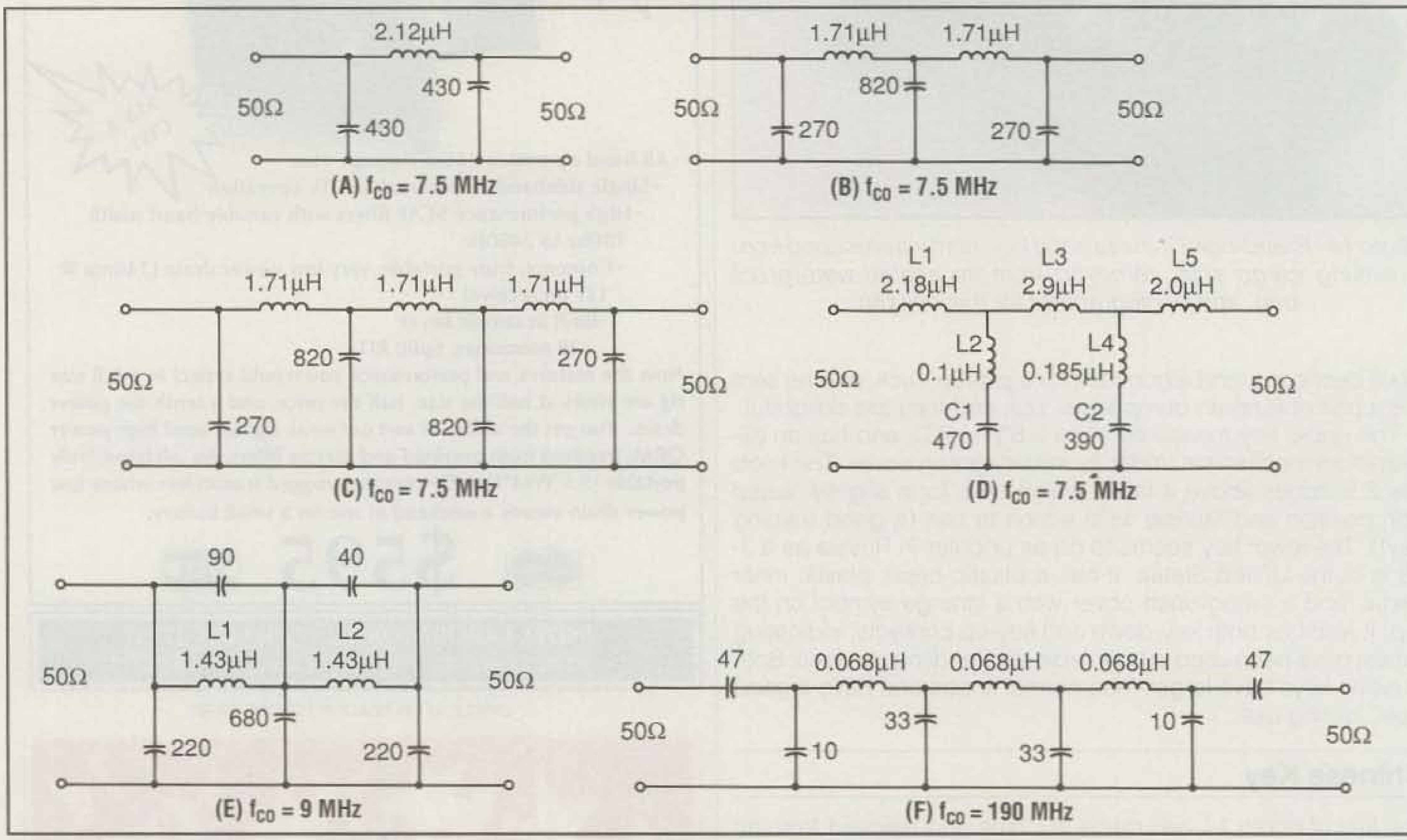

Fig. 1– Various low-pass filter arrangements that are discussed in the text.

Complying with FCC regulations that address the purity of a transmitter output waveform (spurious energy, inclusive of harmonics) should be as important to the builder of homemade gear as is the audible quality of the signal. A good target for the amateur builder is the reduction of spurious energy, referenced to peak output power, by at least 30 dB. Commercial manufacturers are held to such rigid standards in order to sell their products. A caring amateur constructor abides by the same rules.

Unfortunately, many solid-state transmitter designs are published without regard to acceptable attenuation of spurious RF energy. This oversight in design occurs frequently with regard to QRP transmitters. The builder tries to save money and simplify his or her circuit by using a single pi-section output filter, and more often than not there is a serious impedance mismatch between the collector of the PA and the input of the filter. It is not unusual to see, for example, a simple 50 ohm filter connected to a 24 ohm collector. A filter does not function effectively when a mismatch exists, and high SWR reduces the available output power

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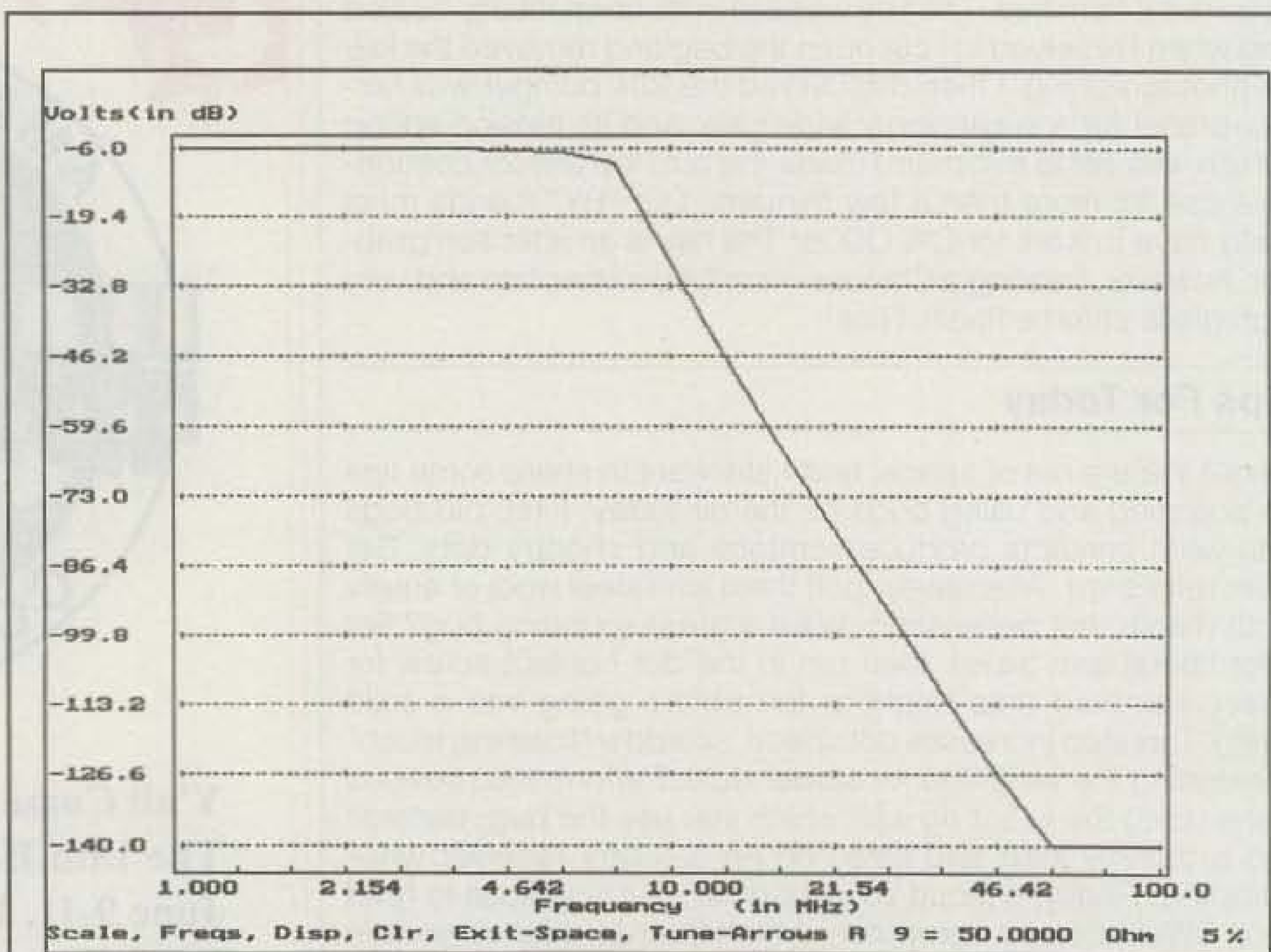

Fig. 2– Computer plot of the fig. 1(C) low-pass filter, based on NOVA software.

because maximum power transfer can only occur when unlike impedances are matched. Other types of harmonic filters are similarly placed in the wrong environment. This article treats the use of effective filters and compares the performance of simple and advanced low-pass networks.

How Many Filter Elements To Use?

The greater the number of filter elements, the better the harmonic attenuation. However, as the number of poles is increased, the insertion loss of the filter rises. In other words, some output power must be traded for increased spurious energy attenuation.

Fig. 1(A) shows a single pi type of low-pass filter designed for use at 40 meters. The second harmonic is down only 13 dB from peak power, per computer analysis with NOVA software.1 The third harmonic is attenuated by 27 dB. Neither figure complies with the FCC regulations. The filter performance worsens as the mismatch between it and the PA collector increases. The mismatch can be resolved easily by using a broadband matching transformer between the PA and the filter (standard design procedure).

Fig. 1(B) shows a 40 meter half-wave type of low-pass filter that is often seen in low-power, solid-state, homebrew transmitters. It also falls short of the mark in attenuating spurious energy. Analysis shows that the second harmonic is down by 22 dB, while the third harmonic is 45.6 dB below peak output power. Using the 13 dB second-harmonic value for the fig. 1(A) filter, we find that for a transmitter output power of 10 watts, the second-harmonic energy is a healthy 0.5 watt, and this can be heard for hundreds of miles. Even a 1/10 watt signal can be heard hundreds of miles away under good conditions if the antenna will accept the harmonic energy.

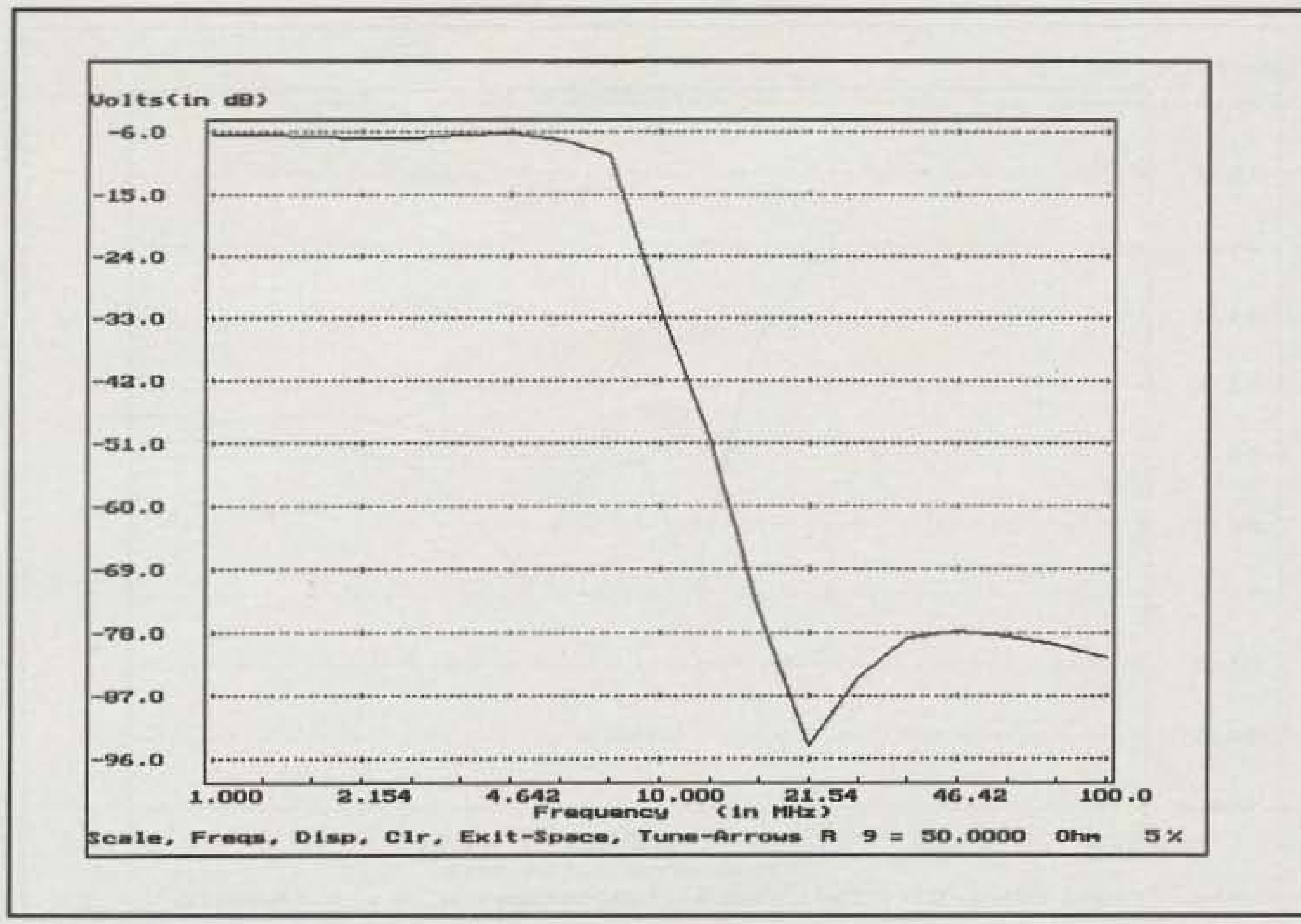

Fig. 3– Filter response for the elliptic filter in fig. 1(D) showing the improved harmonic attenuation compared to no-elliptic filters.

High levels of harmonic energy can cause still another problem: This unwanted energy is not accepted by most antennas and shows up as SWR. This is why some amateurs can't obtain an SWR of 1:1 no matter how carefully they adjust their antennas.

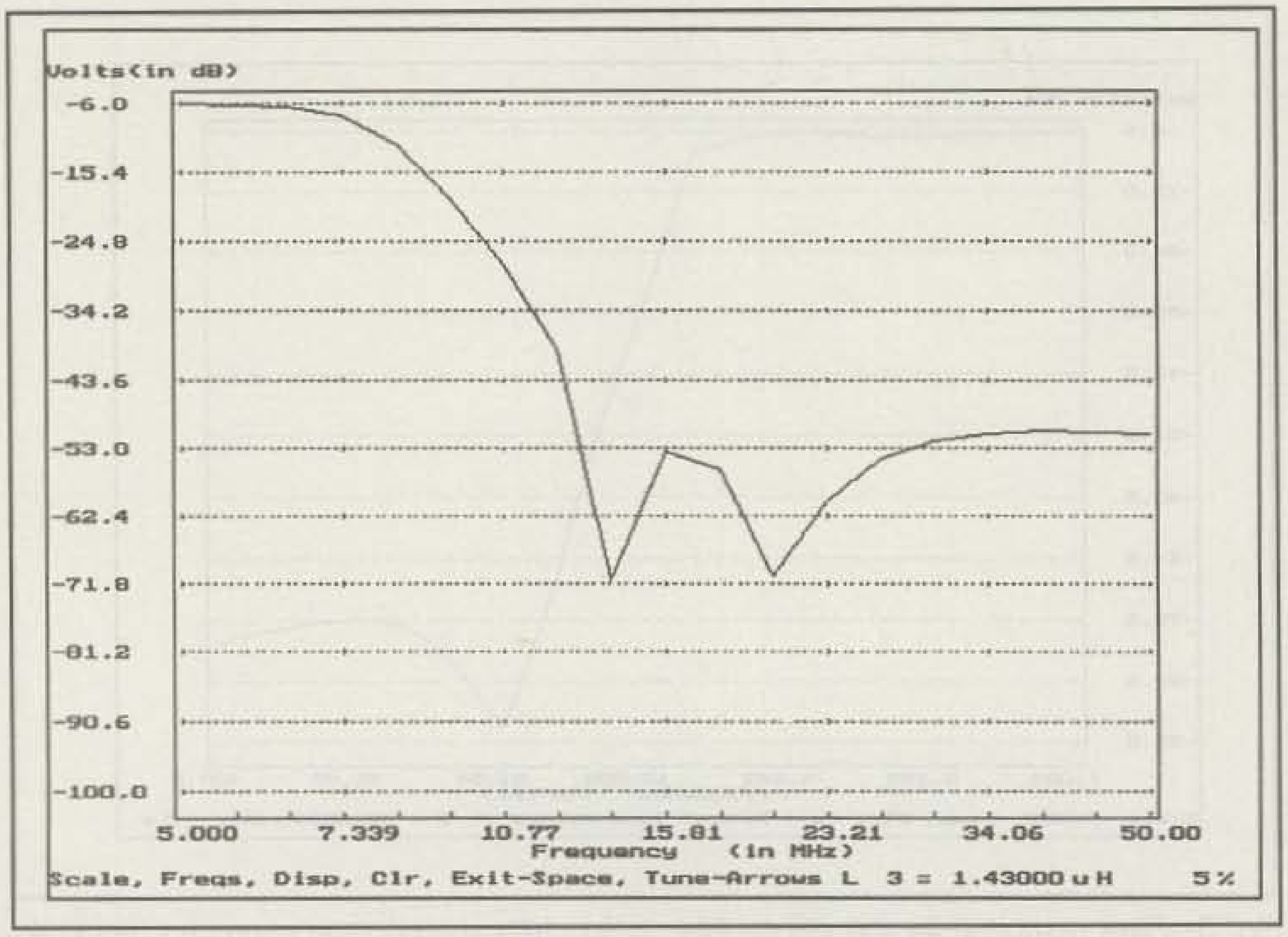

Fig. 4– The response curve for the elliptic filter model in fig. 1(E). The frequency at the bottom scale has been compressed to more clearly define the two notch frequencies.

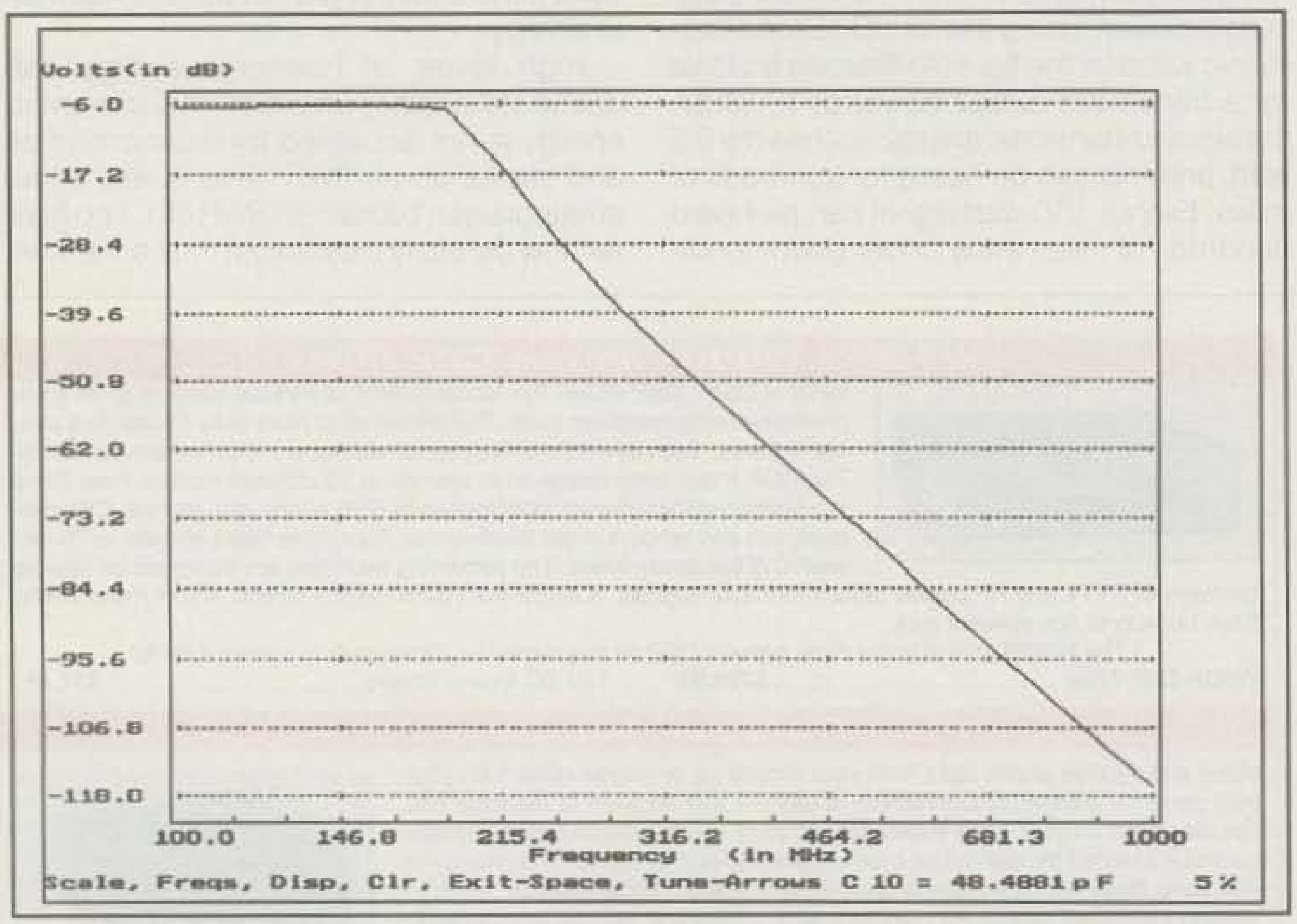

Fig. 5– Computer plot for the 9-element, 2 meter low-pass filter.

The harmonic energy prevents the reflected-power reading from dropping to zero.

A Better Filter

The circuit in fig. 1(C) is my choice for run-of-the-mill transmitter output filters. It is easy to build and not expensive. I designed it for 40 meters with standard-value capacitors. The inductors are wound on Amidon T50-6 toroids (19 turns of No. 22 enamel wire). Polystyrene or dipped silver mica capacitors are best in filters. The T50 cores will accommodate power levels up to 50 watts at low SWR. T68-6 cores (or larger) are recommended for power levels up to 120 watts.

The fig. 1(C) filter attenuates the second harmonic by 32 dB. The third harmonic is down by 37.5 dB. A curve for this Butterworth filter is provided in fig. 2. Filters for other amateur bands can be designed by using the filter tables in *The ARRL Handbook* or with software such as RF CAD or other filter programs.

Elliptic Filters

Fig. 1(D) shows the circuit for an effective elliptic low-pass filter. The series-resonant elements—C1, C2, L2, and L4—are tuned to the second and third harmonics of 7 MHz in this example. Trimmers in parallel with reduced-value fixed capacitors would permit peaking the series elements exactly at the harmonic frequencies, such as 14.2 and 21.3 MHz for 7.1 MHz operation. The trimmers can be tuned for harmonic-signal nulls while observing the S-meter of a receiver.

Harmonic suppression for the fig. 1(D) filter is 51 dB (second) and 88 dB (third), which greatly exceeds the performance of the fig. 1(C) circuit. Fig. 3 shows the response curve for the elliptic filter.

Another method is suitable for obtaining elliptical-filter performance. An example is given in fig. 1(E). The circuit is similar to that of fig. 1(B), except for the two capacitors that have been added across L1 and L2. These capacitors tune the two inductors to the second and third harmonics of the fundamental signal. Again, trimmers across the coils will permit on-the-nose frequency adjustment. Attenuation of the second harmonic is 66 dB, and the third harmonic is down 64 dB. Fig. 4 illustrates where the two notches appear on the response curve.

A 2 Meter Low-Pass Filter

VHF harmonics cause all manner of problems to commercial VHF and UHF services, especially where repeaters are involved. An effective low-pass filter is often helpful when used at the output of a 2 meter transmitter. Fig. 1(F) provides a circuit for a filter that attenuates the second harmonic by 36 dB and the third harmonic by 62 dB. It is designed around standard-value capacitors. L1, L2, and L3 have an ID of 1/4 inch and a length of 1/2 inch. Use 5 turns of No. 18 bus wire for each coil. The two 47 pF capacitors at the filter ports are necessary in order to ensure a 50 ohm bilateral impedance. Best performance will result when each filter section is contained in a separate shield compartment (prevents input-output leakage). The plot for this filter is presented in fig. 5.

Summary Remarks

The purpose of this article is to acquaint the less technical amateur with the workings of harmonic filters and to point out the advantages of using filters that are capable of effectively "laundering" the transmitter output signal.

Those who are interested in the NOVA software may wish to contact the firm listed in footnote 1. NOVA permits designing with transistors, op amps, transformers, and L, C, and R elements. Although the program is designed for use with a dot-matrix printer or a pen plotter, it can be used with a laser printer such as my Panasonic KX-P4410 (or HP laser printers) by envoking WordPerfect for use in combination with NOVA. The resultant laser printout will look like it was processed with a dot-matrix printer.

Footnote

1. RF Engineering, RD 1, Box 587, Chenango Lake Rd., Norwich, NY 13815.

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