Novel designs for elliptic bandstop filters

A new way to design elliptic bandstop filters may lessen frustrations.

By Philip R. Geffe

Designers of RF bandstop filters are often frustrated by the discovery that their numerical design cannot be built as a practical lumped element filter because of extreme element spread.

The design of a 50 Ω bandstop filter centered at 400 MHz, with a bandwidth of 20 MHz, illustrates this point. If an elliptic lowpass prototype having three ladder branches, 0.1 dB passband ripples and a 30 dB stopband is chosen, it is apparent that no choices other than those already made are available (not counting the dual circuit, which offers no improvement). Every calculation is determined in advance, so that only one final design is possible. This design is shown in Figure 1, with the simulated ideal frequency response in Figure 2.

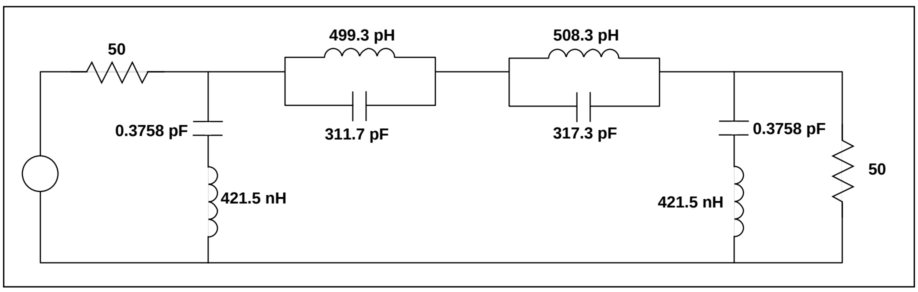


Figure 1. Conventional bandstop filter.

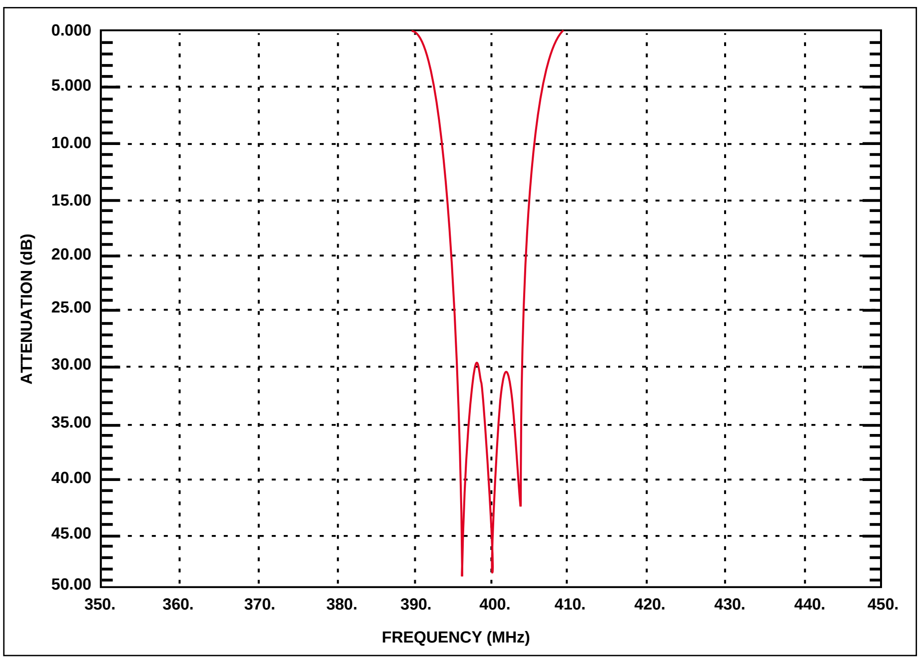
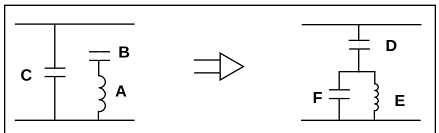


Figure 2. Bandstop filter response.

If this were a bandpass filter, various transformations would be available to make the circuit feasible, but that is not available here. The design is totally inflexible. Note that the element spread for both inductors and capacitors is an appalling figure of 844. At this frequency, inductors that are near 20 nH are desired, but the shunt branches of the filter use inductors that are more than 400 nH, and the series branch coils are less than 1 nH. Any coils built with these values would have a poor Q at 400 MHz.

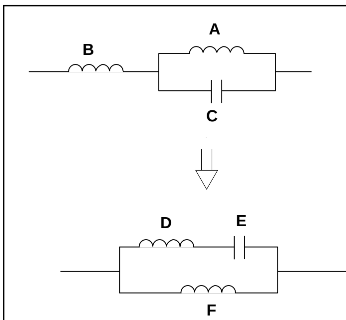
Making transformations possible

Transformations that are desirable—



$$D = B + C \qquad F = C\left(1+\frac{C}{B}\right) \qquad E = \frac{A}{\left(1+\frac{C}{B}\right)^2}$$

Figure 3. Shunt circuit.



$$D = B\left(1+\frac{B}{A}\right) \qquad F = A + B \qquad E = \frac{C}{\left(1+\frac{B}{A}\right)^2}$$

Figure 4. Series circuit.

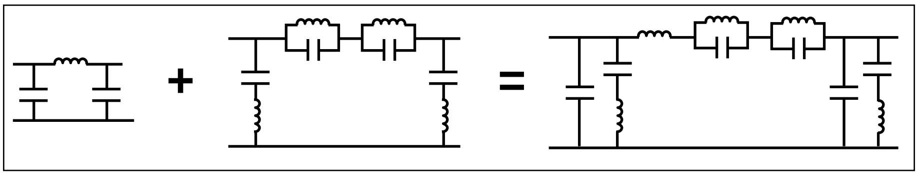


Figure 5. Example of interleaving.

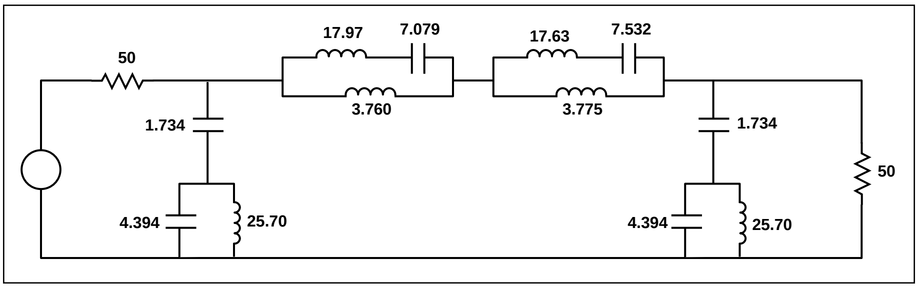


Figure 6. Filter with low inductance spread.

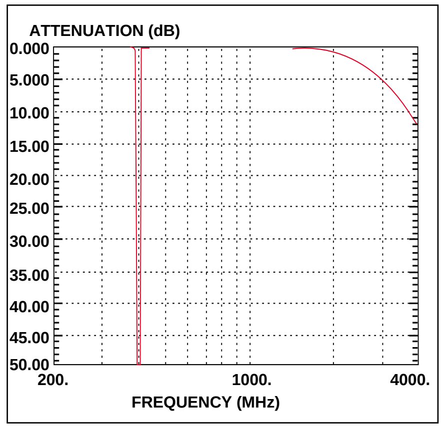


Figure 7. Attenuation of low spread filter.

because they are useful in other circuitry—are the dipole transformations of Figures 3 and 4. Observe that they both require two-terminal networks containing three elements rather than two. This suggests combining the notch circuit with a lowpass or other filter circuit to obtain three-element dipoles. This method is illustrated in Figure 5: a process called "interleaving." This means that two ladders of the same size are interleaved by combining the corresponding shunt branches in parallel, and the series branches in series, as shown in the figure.

This process will serve to embed the notch in the passband of another filter. Now that three-element branches are in the filter, the dipole transformations of Figures 3 and 4 will apply to every branch of the ladder.

Optimizing the element spread

Now let y = inductance spread, and x = bandedge frequency of the lowpass filter. Y is a function of x:

$$y = f(x)$$

To evaluate this function for a given bandedge frequency, x, begin by finding the lowpass element values for the chosen value of x. Because the bandstop element values of Figure 5 are fixed, writing the lowpass element values into the figure completes the design. Now, partition the lowpass series coil of the bandstop filter into two equal parts, and associate each part with one of the series antiresonances. Then perform the dipole transformations of Figures 3 and 4. Finally, calculate the element spread thus obtained (i.e., the function value). If this procedure is performed enough times to plot a smooth curve, it will become apparent that it has a definite minimum. The bandedge frequency that produced this minimum is the optimal value for a practical filter.

Applying this procedure to the previous numerical example gives the design of Figure 6, with its response shown in Figure 7. The inductance spread is reduced from 844 to 6.8, and the capacitance spread is reduced from 844 to 4.3. Although the upper passband is now limited, it appears to be wide enough for many applications. It would, of course, be limited anyway by the parasitics of the circuit, though less so.

Conclusion

One might suspect that partitioning the series coil into two equal parts might not be the best way to proceed. Maybe using multivariable optimization to find the best partitioning for each series coil in the filter would be better. It turns out that a slight improvement can be achieved this way, but the largest improvements obtained were only about 3–4%. The algorithm described previously is more reliable and much simpler.

It is apparent that similar results could be obtained by embedding the notch in the passband of a highpass or bandpass filter. The usefulness of these alternatives would be determined by circumstances.

The numerical minimum obtained for the design of Figure 6 was calculated by using a Golden Section search, not by plotting a graph. RF

About the author

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