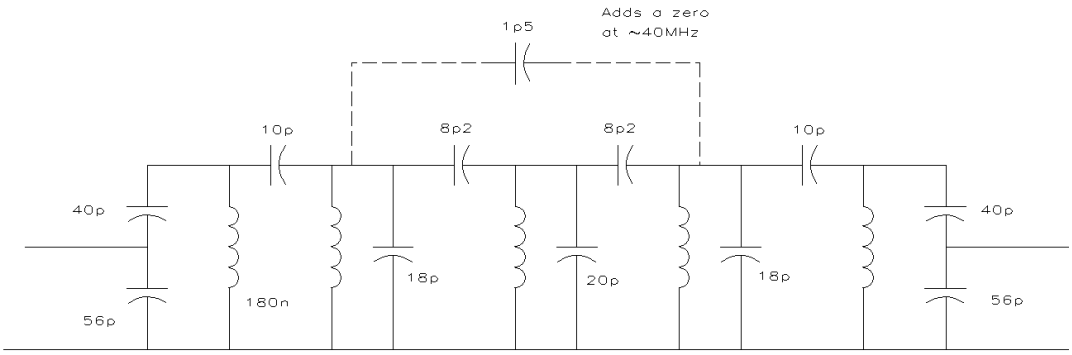
Some Experiments with an L-C bandpass filter.



The circuit diagram shows a bandpass filter covering 50 – 75MHz designed for the second-stage IF filtering of a frequency converter employing an LO of 45MHz to convert to 5 – 30MHz for feeding a wideband digital receiver such as the SDR-IQ and similar. The target stopband was -70dBc at 40MHz, which is the image frequency for a 5MHz final output.

Standard filter design software indicated that a 1dB ripple Chebyshev top-capacitor coupled design would just about meet the requirements and the design shown (without the 1.5pF capacitor with dotted wires) is the synthesized network with matching components added, and capacitors adjusted to the nearest 'friendly' values. All inductors are nominally the same value (193nH, not 180nH as shown on the diagram). The worsened top end frequency rejection of a top-C coupled filter is not a problem, as the majority of the necessary image rejection for this functionality needs to be below the passband.

The simulated response of the circuit is shown below, where the wanted attenuation at 40MHz can be seen to be 65dB, rather than the 70dB desired..

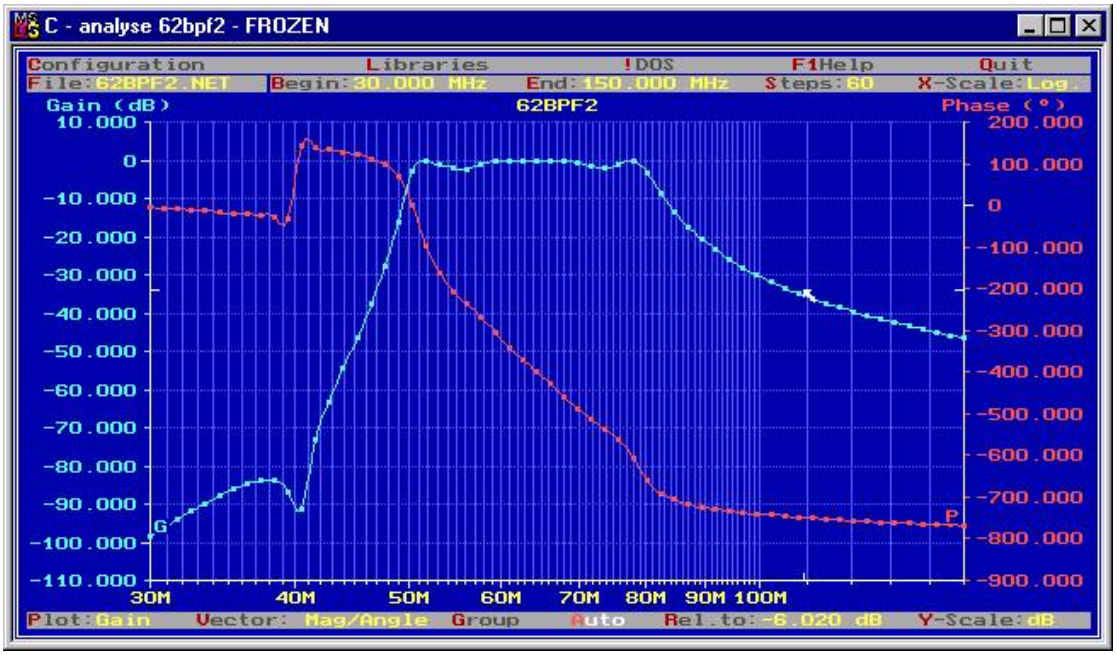
But then, I started wondering:

In any bandpass filter consisting of coupled resonantors, real zeros (sharp nulls) can be added by cross-coupling non-adjacent resonators, and this is often done to improve the cutoff and sharpen the ilter edge response.. Low and high pass elliptic filters generate real zeros for deep nulls in the stopband by adding resonating C or L components to series or shunt elements.

My recollection from a dark past suggested that for bandpass deigns, these zeros always came in pairs, spaced either side of the passband.

So, as an experiment, I added a few pF between stages 2 and 4 to see what happened, and analysed the result. Rather satisfactorily, a value of 1.5pF gave a null pretty close to 40MHz, and the rejection in this region was improved by at least another 10dB – just what was wanted. The ripple was slightly worse, but I can live with that – ultimately software can correct the amplitude response.
The plot of the filter response is shown below.

A very sucessful outcome from just idly playing around with a circuit analysis package!



But where is the other zero that should be there, above the passband? Searching all over the frequency response there is nothing!

I can only assume that since a top-capacitor-coupled bandpass design is not truly symmetrical – as is obvious from the significantly lower stopband rejection above the centre frequency than below it - presumably the symmetrical argument disappears.

But it would be nice to know why there is only the one real zero.
(Incidently, I did try a feedback inductor instead of a capacitor, but all that did is destroy the passband response)

… now to build a prototype.