Nano-Stepping Notch Filter

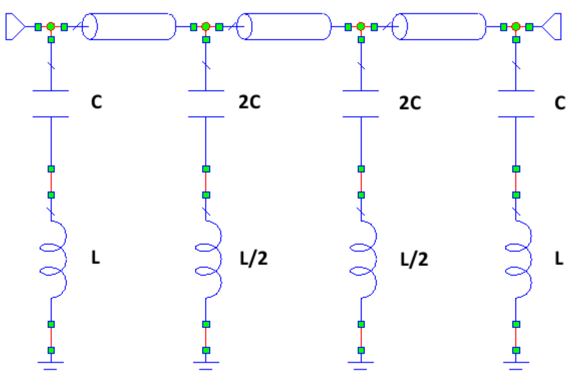
Jim Hagerman
02-01-12

INTRODUCTION

I worked out equations for the von-Newman style high power notch filter. This design is tunable over a fairly wide range, but less than an octave. It is perfect for Eaglet!

CIRCUIT

The optimal solution seems to be a four resonator design. It also works well with three, but the notch becomes more triangular in shape and less suitable for our purposes. The coupling arms are 50 ohm quarter-wave lines.



The values for components are calculated using the following formulas:

$$C = \frac{1}{2 \cdot \pi \cdot f_0 \cdot Q \cdot R}$$

$$L = \frac{Q \cdot R}{2 \cdot \pi \cdot f_0}$$

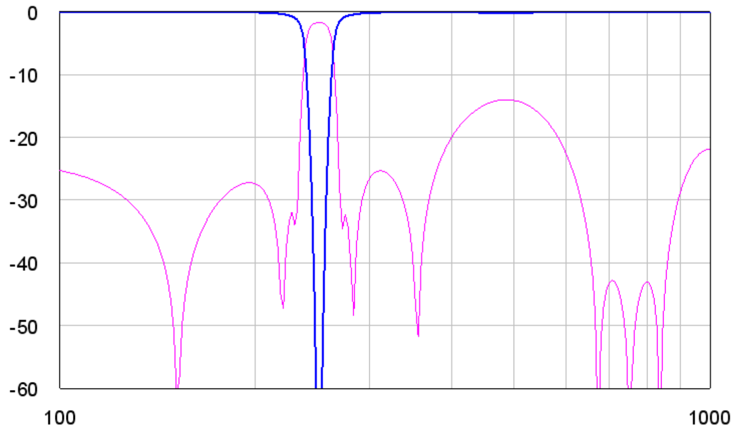
EXAMPLE

For a filter with a notch at 250MHz and a Q of 10 (that's a 10% bandwidth), the component values work out to be:

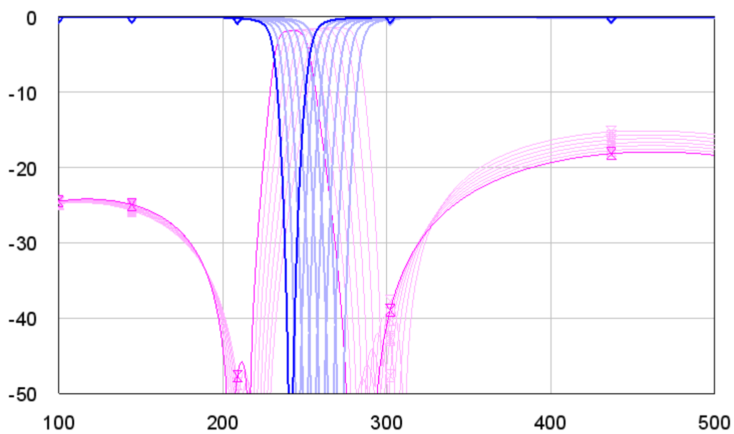
$$C = 1.27pF$$
$$L = 318nH$$

SIMULATIONS

Using the above values and an inductor Q of 100, the notch below was obtained. There are no parasitic notches at high frequencies and the insertion loss remains low out to the inductor SRF.



The tunability is also excellent over a narrow range. This is due to the quarter wave coupling lines. Tuning below was done by incrementing the inductance in 12nH steps (from 270nH to 342nH). It is hard to see, but coverage is continuous at -40dB.



EAGLET

The previous simulation shows the viability of an Eaglet specification. Tuning was adjusted to cover the UHF SATCOM range from 240MHz to 270MHz in 5MHz steps. That is a mere 7 frequencies and is approximated by using 6 PIN diodes to switch in increments of 12nH. The stepped inductor line is a good high power solution, especially in this implementation that keeps the majority of resonant voltage away from the PIN diodes.

Parasitic effects have not been investigated yet, and could prove problematic. The 1.2pF resonator capacitance is relatively small.

Nano-Notch Filter (Part 2)

Jim Hagerman
02-29-12

INTRODUCTION

This is an improvement to the notch filter previously discussed (von-Newman) in that all resonator inductors (tapped lines) are all made equal. Capacitor coupling has been changed to maintain a reasonable polynomial matrix (close to Butterworth).

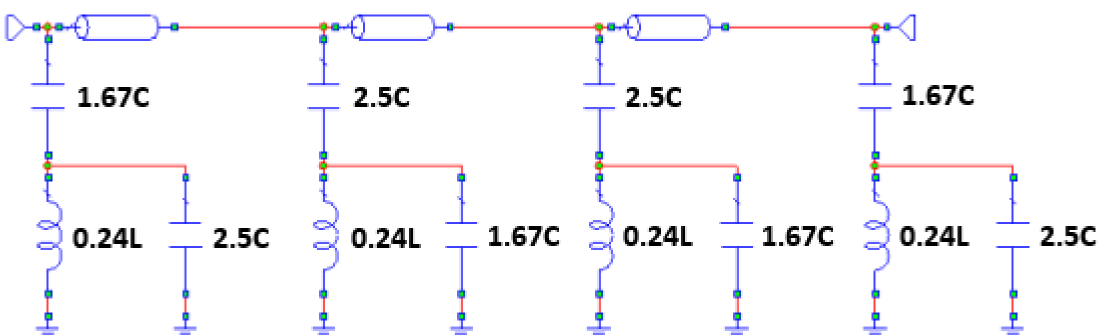
CIRCUIT

The scaling formulas for L and C are typical.

$$C = \frac{1}{2 \cdot \pi \cdot f_0 \cdot Q \cdot R}$$

$$L = \frac{Q \cdot R}{2 \cdot \pi \cdot f_0}$$

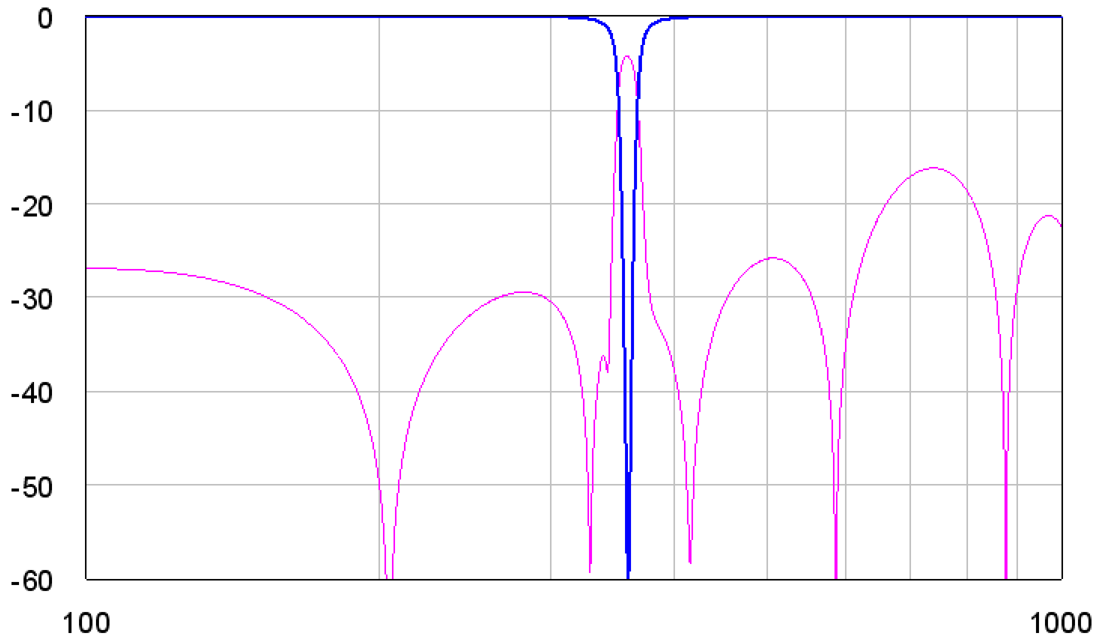
The filter polynomial and coefficients were empirically derived and gives approximate 3dB bandwidth with an inductor Q of 100. It is a good starting point for simulations. The coupling lines are 50 Ohm quarter-wavelength.



Nano-Notch Schematic

SIMULATION

The filter has pretty decent wideband response and a nicely defined shape and tight shoulders. The only real glitch is the S11 hump at 2F. Of course, tapping the line with PIN diodes will cause parasitic notches in the upper band when tuned to anything but the highest frequency.



Typical Wideband Response for a 7% Notch Design

<u>RAVEN</u>

For the 330MHZ to 390MHz band values of C = 1.0pF and L = 70nH give the narrowest practical notch. For better depth, C= 1.2pF may be a more prudent choice.

Nano-Notch Filter (Part 3)

Jim Hagerman
04-06-12

INTRODUCTION

This version of the von-Newman tunable notch filter is flopped, using the inductors as fixed impedance converters and the shunt to ground capacitance as the variable. It seems to work quite well and has the added benefit of being closer to a fixed bandwidth instead of a fixed Q characteristic. I would wager this is close to what the P/Z filter uses.

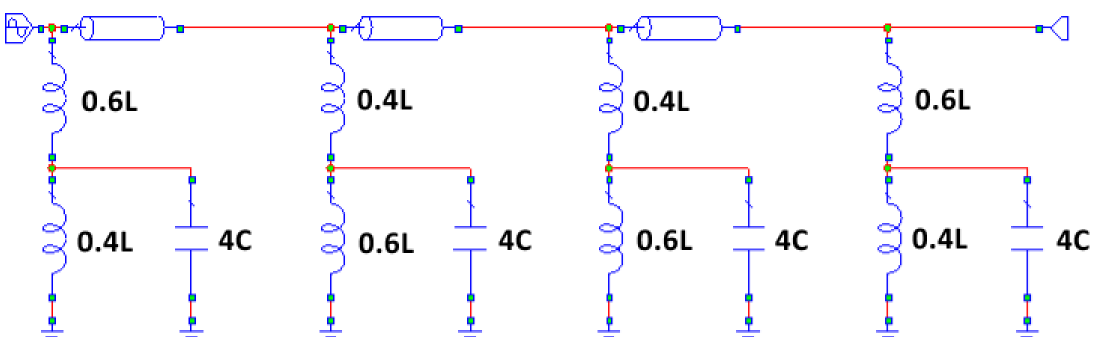
CIRCUIT

The scaling formulas for L and C are the same as before:

$$C = \frac{1}{2 \cdot \pi \cdot f_0 \cdot Q \cdot R}$$

$$L = \frac{Q \cdot R}{2 \cdot \pi \cdot f_0}$$

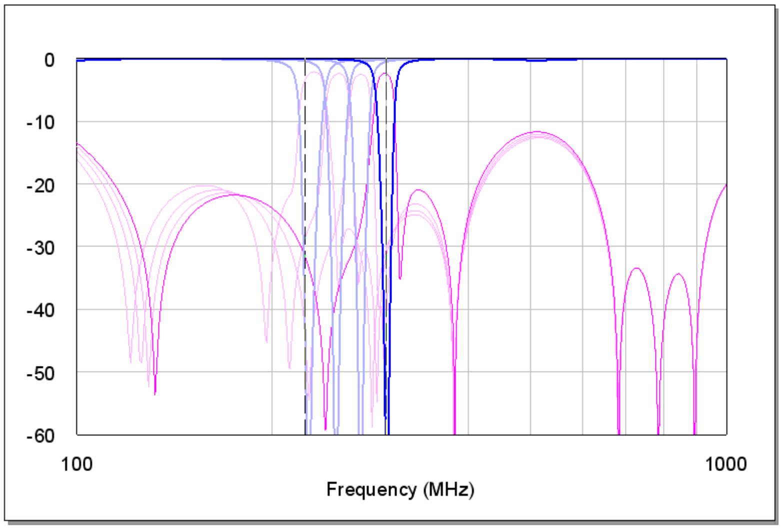
The polynomial of the filter is a pseudo-Chebyshev (0.6, 1.6) and is accomplished by the ratio of inductor impedance converters. This allows the variable capacitors to all be identical, greatly aiding construction and tuning. The four resonator design is a compromise between complexity and cost, while still achieving a decent notch depth. Coupling is via quarter wave lines at F_0.



The circuit tunes well over a decent range and is devoid of the recurring notch effects of the transmission line version. There will, however, likely be parasitic notches is the upper passband due to "off" PIN diodes in a tunable circuit.

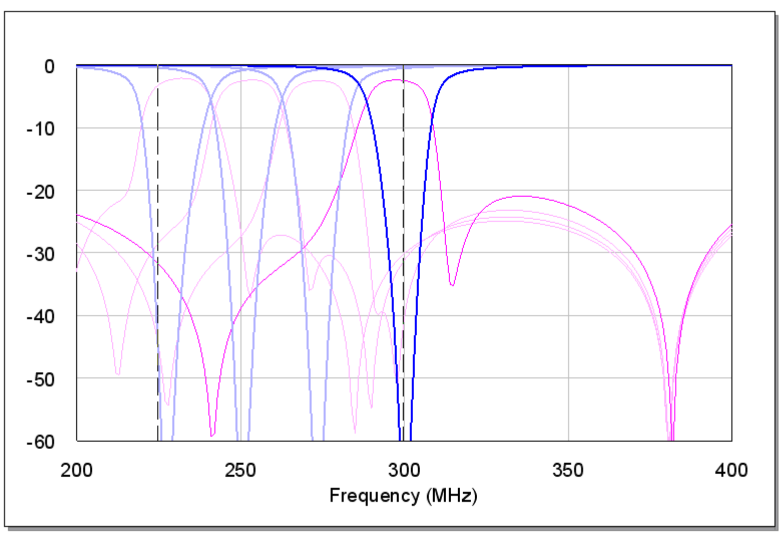
PERFORMANCE

The simulated response looks virtually the same as the previous (Nano-Notch #2) version. The notch is well shaped and the passbands are wide. The upper limit will be set by inductor SRF. The only glitch is a 12dB return loss at about $2F_0$. This example has F_0 at 260MHz, with a range from 225MHz to 300MHz.



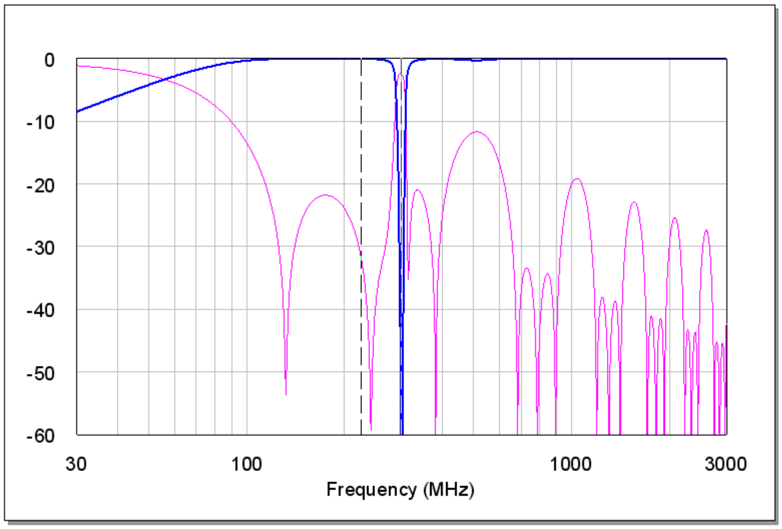
CONSTANT BW

Although the previous version (tuned coils) employed a constant Q characteristic, this circuit (tuned caps) seems to have more of a constant bandwidth. That is perfect for most of our applications!



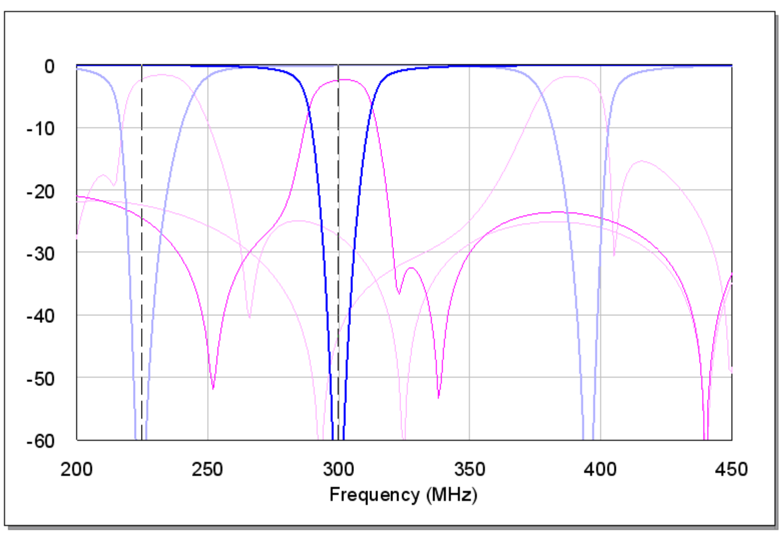
BROADBAND

Taking a look at the wideband performance shows us there is an embedded high pass function limiting the lower frequencies. This is exactly what a P/Z looks like.



WIDER TUNING

The circuit is tunable over a wider range but with the notches becoming misshapen towards the extremes. F_0 was changed to 300MHz for the example below. It may be possible to do the entire RAVEN band with a single filter bank?



CAPACITOR SWITCH

The capacitors can be switched in a binary weighted fashion just as was done for FALCON. Four switches can thus do 16 states. This means a filter would require fewer PIN diodes for a given number of steps. The circuit below shows how to implement a single bit.