The Bodger's Guide to …………..
The alignment of multi-resonator filters without a sweep generator

Introduction

Over half a century ago, Milton Dishal published a paper [1] on a technique for aligning multi-resonator filters. It tunes all sections close to the required frequency with one pass through the filter and does not require a swept source. This tuning method was one of the first things I was taught when I arrived in the now long – defunct Pye Telecom R&D lab as a 21 year old, and it's brilliance and simplicity has stuck with me ever since.

The IEEE library's abstract to Dishal's paper summarises the method beautifully as:

"Very loosely couple a detector to the first resonator of the filter; then, proceeding in consecutive order, tune all odd-numbered resonators for maximum detector output, and all even-numbered resonators for minimum detector output (always making sure that the resonator immediately following the one to be resonated is completely detuned)"

Simples! (With apologies to a well known Internet comparison site)

It seems that this technique is not as well known as I always thought it was. This was brought home to me at Microwave Update in 2009 by the look of surprise on the face of the Rohde and Schwartz representative who was demonstrating a high – end network analyser, when I switched it to CW mode and used the method to align a 24GHz waveguide filter! He had been doing the "set it to sweep and then twiddle all the tuning randomly until the shape is right" method. (Give him his due, a true Bodger's technique!) You just can't get the staff these days……..

Background to Dishal's method

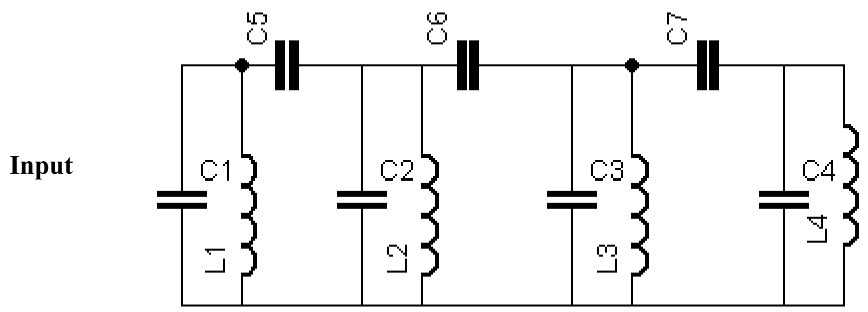

Figure 1 Four branch coupled resonator filter

The method of course applies to any implementation of coupled resonator filters from LF to waveguide, but for simplicity, consider , a four branch, lumped element coupled resonator filter. This is of course the equivalent circuit of the other types of filter. C5, C6 and C7 are coupling between the resonator branches C1/L1 -> C2/L2, C2/L2 ->C3/L3 and C3/L3 ->C4/L4 respectively.

When the filter is correctly aligned, each branch is resonant at the centre frequency (f_0) of the passband. If the second branch is de resonated by shorting it out or otherwise detuning it, L1 and C1 in parallel with C5) are resonated at f_0, it presents a high impedance, and hence a voltage maximum at the input. Now, if this short is removed and the third branch is shorted, L1 and C1 resonate above f_0 and L2 and (C2 in parallel with C6 resonate below f, and the circuit has a low impedance AT f_0 and hence a voltage minimum at the input at f_0.

If the fourth branch is shorted, L3 and C3 in parallel with C7) resonates at f_0 and again presents a high impedance, and hence a voltage maximum at the input

This repeats with subsequent stages in filters with more resonators and alternate high and alternate high and low voltages occur at the input.

Using a circuit simulator like QUCs (2) you can model this process and see the effect, or build a filter and try it!

Dishal alignment in practice

Terminate the filter in the design impedance (50ohms usually). Detune all the resonators (or short out all but the first) and drive the input of the filter with a generator or low power transmitter. Connect a high impedance RF voltmeter or oscilloscope via a very small capacitor connected directly to the input resonator, or use a short wire probe in the cavity.

Tune the first resonator for a voltage maximum at the centre frequency of the filter, then the second resonator for a voltage minimum. Succeeding resonators are tuned for alternating voltage maxima and minima.

Using a Vector Network Analyser or Vector Voltmeter

If you are fortunate enough to own either a vector network analyser, or a vector voltmeter and a suitable return loss bridge, you can make a much more accurate tune up of a filter with a CW source by looking at the phase of the input reflected signal (S11).
If you follow the Dishal setup, i.e, detune all the resonators, but look at the phase of the input reflected power S11. As you tune the first resonator through resonance you will see the phase suddenly start to change as it approaches resonance. Adjust the first resonator so that the phase of S11 goes through exactly 90 degrees from where you started. Then move on to the second resonator and you will see that as you tune it, the phase again starts to rotate. Move it a further 90 degrees from where you left the first resonator. Work your way down the filter, tuning each resonator for a further 90 degrees, and hey presto, once you've adjusted the last resonator for 90 degrees the filter will be perfectly tuned and centred on f_0. All without a swept source, and in a fraction of the time taken for the "tweak and hope" method!
The big advantage of this method over just looking at voltage is that you don't need to connect to the actual resonator, just look at the reflected power, and more importantly it is easier to see an exact 90 degree phase shift than a fairly flat peak in input voltage.

Again, using a circuit simulator like QUCs (2) you can model this process, look at the phase of S11 and see the effect.

References

1. M. Dishal, "Alignment and adjustment of synchronously tuned multiple-resonant-circuit filters,'' *Proc. IRE*, vol. 39, pp. 1448–1455, Nov. 1951.
2. "Quite Universal Circuit Simulator" http://qucs.sourceforge.net/