

## Make yourself a Diplexer

Do you find you are frustrated by having to change coax connectors when you change bands? Especially if you have to climb the tower in the dark, to swap one coax to another beam, whilst its raining! Here's a simple way to do it automatically, with very low loss, and so you can transmit, listen or scan at will.

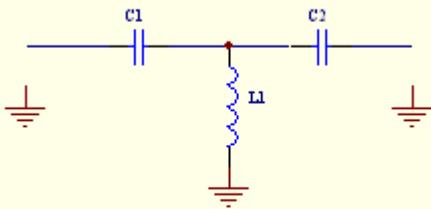
This assumes that you have downloaded the free student version of "Elsie" from Tonne at <http://tonnesoftware.com/elsiedownload.html> ,

You need to have some figure in mind as to the amount of separation needed, if your splitting one rig to two aerial systems, 10 or 15db is enough. If however you want to split one multiband aerial into two rigs, you need more care, but 20db is usually enough. If they are rigs that operate on different bands, that's fine, but if two of the rigs can operate on the same band, you may not have enough separation to prevent some damage when you transmit, and should go back to changing over connectors, use a relay, or a switch, but not this diplexer.

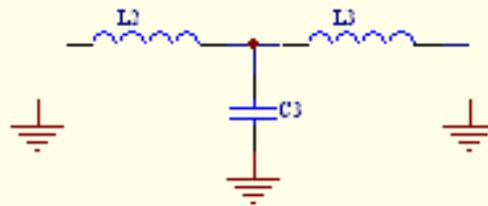
The big advantage with this is the ability to work on two (or more) bands simultaneously! You might have a rig with one output connector, that works on say 2m & 70cm, or 6m & 2m. For the case of beams for 2m & 6m and/or 10m, a diplexer centred at 85Mhz will allow you to connect to both beams at once, and simply change bands on the rig, or scan, as you like. Where did I get the 88Mhz from? Take the geometric mean of the two frequencies you want to separate, the high end of low band & low end of the high band. If you've forgotten your high school maths, then use your calculator to multiply 54 x 144, then take the square root, = 88 Mhz.

By doing this simple calculation, and running "Elsie", you can end up making a small box with 3 coax connectors which allows one connector to be "common" (in this case the rig) a second connector for aerials for 6m and lower frequencies, whereas the third connector is for aerials of two metres and higher frequencies. Be careful to put the upper case M after the frequency values which you enter in Elsie, as mistakes here make for very silly component values! (I've done it).

The whole success of this approach depends on how far apart the two frequencies are, and in the case of 6m/2m, and 2m/70cm, the difference is about 3:1, which makes it easy, as we will see when we run Elsie. A 2:1 frequency ratio works out alright with a 5th order filter. About the closest frequency spacing achievable is 1.3:1, but this requires an order 7 filter, which is so complex that its lossy, and its component values become more critical, so its usefulness is dubious.



High Pass Filter, 3rd order



Low Pass Filter, 3rd order

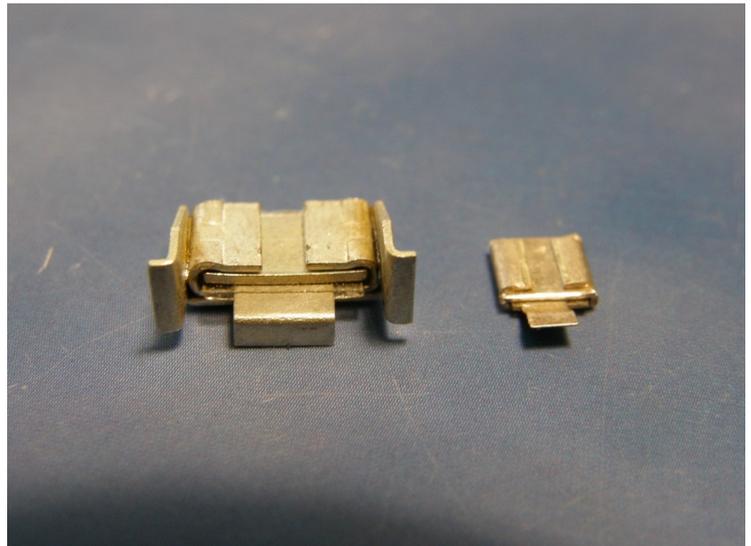
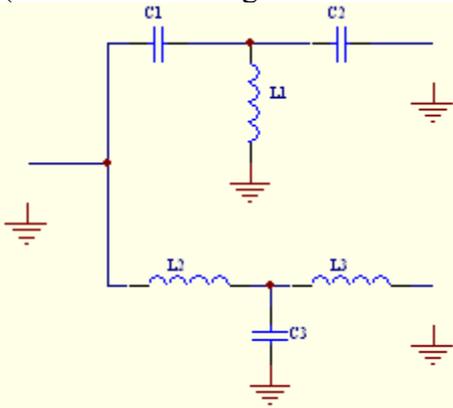
Have a look at Elsie, (latest version at time of writing is 2.39), on the opening page, click on "New Design". Select "Capacitor-input highpass (left side, 9 down), Chebyshev (middle, 2 down), and then the numbers: (right)

Ripple Bandwidth	88M	the cutoff (change over) frequency
Order	3	the complexity of the circuit
Input term	50	the impedance in ohms (can use 75 ohms etc if you wish)
Passband ripple	0.1	a tradeoff between ripple & sharpness of cutoff

At this stage you could select two separate filters, this High pass, then a Low pass, but if you connect these together, they will interfere with each other, so the result is not good.

C1 = 35pF    L1 = 78.8nH    C2 = 35pF

(note: the following circuit shows the low and high pass filters the opposite way round to Elsie's display)



To avoid

this interference, (and to avoid one of the **software bugs** too) click on “Diplexer” (middle of second line), and you should have a circuit, showing the common connection at the left, and to the right upper, the low pass (50Mhz & lower) and below the high pass (144Mhz and above). The bug referred to above (in version 2.32) is that if you come straight to this entry, you can enter the data ok, but after you Plot, the impedance reverts to 1 Ohm, and has to be re-entered each time.

The numbers should be:

Order	3	Crossover freq (Hz)	88M
Passband ripple db	0.1	System Z (ohms)	50

The values are:

low pass	L2 = 136.8nH	C3 = 54.8pF	L3 = 64.8nH
high pass	C1 = 35pF	L1 = 78.8nH	C2 = 35pF

Now click on Plot, and you get 3 curves, note the red Highpass is about -17db down at 50Mhz, the blue Lowpass is about -17db down at 145Mhz, which is probably ok. Note if you change the Passband ripple figure to 0.5db, these figures increase to -20db, my preferred figures, so the values become:

low pass	L2 = 142.2nH	C3 = 56.0pF	L3 = 84.3nH
high pass	C1 = 23pF	L1 = 58.4nH	C2 = 38.8pF

Here you can ask does the SWR get worse? The green curve shows “return loss” in db, and a return loss of 20db means SWR of 1.2:1 (good), and this example shows return loss of > 25db which is an SWR of <1.1 (excellent).

The next question to ask, is how critical are the component values, and what kind of capacitors should you use? Now if your transmitter power is 50 watts in 50 ohms, then the RF voltage is 50, and current is 1 amp, so the use of little NPO ceramic capacitors from the local parts supplier will mean that they will frizzle up quite quickly. They aren't made to pass amps of RF! Even at 10 watts.

You need to find a source of RF power handling capacitors, see picture, rated for 5 to 10 amps (have a safety factor), and Mouser (mouser.com) has them (eg. 5981-MIN02-20J-F) at around \$2 each for 300v rating & 5% accuracy, and higher accuracy, or higher current, for more dollars if necessary. In Australia, order Mouser parts through X-ON in WA, specifying the Mouser part number. Will the 5% be near enough? On the Plot page you can select All 5%, and see if the performance is still ok. With the 5% values selected:

high pass	C1 = 24pF	L1 = 56.0nH	C2 = 39pF
low pass	L2 = 150nH	C3 = 56.0pF	L3 = 82.0nH

In this case the program selects the inductors as 5% values too, which we don't need, as high current RF inductors aren't bought, they're made! (wow! this gets exciting!!).

We need 3 inductors, 58.4nH, 142.2nH, and 84.3nH.

Now exit from the Diplexer routine, and select "Wind L". (second line 3<sup>rd</sup> from the right).

You get the heading "Coil-winding Routine", and Enter arbitrary inductance 142.2n (don't forget the nano-henrys). If you select a diameter, and some turns, you'll get the length. Try:

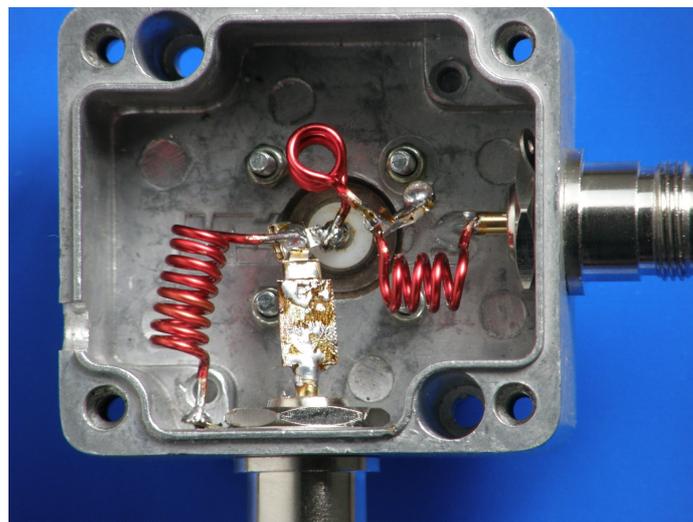
diameter	.65cm	try	.65cm
turns	7		8

click on "Compute"

so coil length	1.2cm (then delete this)	1.6cm
minimum wire gauge	14	13
total wire length		16.4cm

58.4nH	diam 7mm (0.7cm)	4 turns	length 1.0cm	wire length 8.85cm
84.3nH	diam 7mm	4 turns	length 0.6cm	wire length 8.8cm

As the program tells you the total length of wire to wind into your coil, start with this, but allow for about 5mm each end (no more) for soldering into circuit. Use about 16 gauge enamelled copper wire (don't use tinned copper, its more lossy), and you will find that you need a drill to wind on that is a few sizes smaller than the diameter calculated, to end up with the correct number of turns. A little trial & error works well! By choosing 8 turns, then there is room to squeeze or spread the turns to adjust for best SWR if you are that fussy.



Now the circuit makes the assumption that the three inductors (coils) are quite independent, but this might not be so! Coils can link together by sharing their magnetic fields (like a transformer), so they should have their centre lines positioned at 90° to each other. Imagine L2 & L3, they are there to reject the high frequencies, but if they couple together magnetically, then those high frequencies are coupled too, defeating the filter action. When actually making these things, especially for the 70cm band, the lead length of the capacitors should also be as near as you can get to zero mm! Position your coax connectors so as to allow this.

For the 2m & 70cm version, use 148 & 432,  $F_c = 253\text{Mhz}$ , to split between 148 & 432Mhz

This shows up another **program bug** (in version 2.32), in that when you plot, the frequency scale remains 50 to 200Mhz, which gives useless plots for other frequencies. The solution to this is to exit from the Diplexer program, back to the main Elsie program, and select Analysis, then set the Start frequency to say 100M & the Stop frequency to 500M and Transmission bottom (the side scale of the plots) to -40. Then return to the Diplexer.

Order	3	Crossover freq (Hz)	253M
Passband ripple db	0.2	System Z (ohms)	50

The values for this 2m 70cm version are:

high pass	C1 = 8.24pF	L1 = 20.42nH	C2 = 16.0pF
low pass	L2 = 48.0nH	C3 = 19.4pF	L3 = 24.8nH

With the 5% values selected:

high pass	C1 = 8.2pF	L1 = 20nH	C2 = 16pF
low pass	L2 = 47nH	C3 = 20pF	L3 = 24nH

Coils suggested

48.0nH	diam .4cm (4mm)	5 turns	length .6cm (6mm_	wire length 6.3cm
20.42nH	diam .4cm	3 turns	length .5cm	wire length 3.8cm
24.8nH	diam .4cm	4 turns	length .8cm	wire length 5.1cm

If you use a diplexer up your tower, so one low loss coax feeds both 2m & 70cm beams, be aware that if there is some 3<sup>rd</sup> harmonic output from your 2m transmitter, then you will have that harmonic radiated by an efficient 70cm aerial, so your 2m rig will need a good low pass filter, maybe better than it has at present.

Another suggestion would be 40m, 80m, maybe 160m to an ATU, and 20, 15, & 10m to a beam. Splitting frequency would be 10.1Mhz, so the 30m band would still require a changeover of connectors. Its interesting to note that before the arrival of programs to do these calculations, it was so difficult that cut and try was the best, but very tedious way, to achieve a result.

When you're setting up a station, there are many ways to get its operation convenient, this suggests just one way you can suit yourself, and make up one or more boxes very easily, even doing the circuit design yourself!. A change of aerials might mean a change of the diplexer box, about half an hour, once the capacitors have arrived.

Summary:

Use for separating frequencies a long way apart, say 2 or 3 to one ratio.

Select the ripple from .1db for (noise figures below 1db), and put up with lesser separation in dbs up to to .5db for better separation

use high current capacitors and inductors, even at 20 watts.

If outdoors, make it absolutely waterproof, and use type N connectors,

never use UHF or SO239 outdoors, as they let the water into the coax, and give intermittent earth connections.

(they are a 1930's ornament, not a connector!!) use type N or BNC, carefully assembled.

There are a number of variations as to how you can use this type of circuit, for example use two rigs, one length of low loss cable, and two different aerials, and a diplexer at both ends of the coax, still cheaper than two lengths of low loss cable.

As the diplexer is a combination of High & Lowpass filters, you can use a 2m/70cm diplexer, and then add second, say 2m/6m diplexer into the low frequency (2m) port of the first one. This will then give you three different frequency bands combined (perhaps you should call it a triplexer!). Don't go too far with this approach, but tests show that it works ok, long as you don't try half a dozen diplexers connected together!

Peter Ward VK3ZAV since 1955.