Multiplexer evaluation

PCFILT can be used to evaluate multiplexer designs by designing each channel or "port" of the multiplexer separately and joining them together, one at a time for analysis. The final network may have any number of ports so long as the total number of branches does not exceed 150. The network analysis module is capable of analyzing any type of filter that the program can generate in any port position. It can also handle L-C elliptic function filters, equalizers and designs done externally by other software.

When doing an analysis run, the analysis is "looking" into the source end (this is where the junction of all the ports is connected) through the first port shown on the circuit editor schematic drawing. This is referred to as the "forward" port. All of the other ports are terminated internally by dummy loads marked "port term" on the schematic drawing. These will be referred to as "side ports". Side ports show up on analysis as return loss only, just as they would if you were looking into the common port with a real network analyzer. Experience has shown that looking backwards into the termination end of a single port will look the same as looking into the common junction except only that one port will be seen on return loss.

The best procedure for joining ports to a network is to design all of the ports first saving each of them to disk under unique file names. Finally, with the design you want to initially become the forward port in memory, the side ports can be joined to the forward port by using the "Join two designs" option of the main control File option. Remember to change the file name each time. It is only necessary to remember that the network in the file will be joined to the source end of the design in memory.

An alternate procedure is to save the resulting network after each join operation, design the next port and join the saved combination to the newly designed port. This method allows the entire network to be built up without changing the filename, but it does not allow the design parameters to be recorded for each port (in the ".spk" file associated with each unique file name for each port) as with the other method.

The circuit editor can be used to move any side port to the forward position for analysis by using the "Move" or "Rotate" commands. This would be analogous to switching the "A" cable and one of the "dummy terminations" in a real network analyzer set up. This procedure is described in detail in the section on the circuit editor.

Contiguous 2 port comb diplexer

To illustrate the joining procedure, a contiguous diplexer will be designed consisting of two singly terminated 10% bandwidth comb filters joined together by a common resonator. The crossover frequency will be 1 GHz.

First, design the lower frequency channel using the file name CH1. File name = CH1

```
Design = Combline bandpass
Equal resonator zo. (Y or N) Y
order N                      4
passband Ripple (0=Butt. dB) 0.05
Define pass / stop      (dB) 3
arithmetic Fo.         MHz. 950 \     900 - 1000 MHz.
Bandwidth              MHz. 100 /
design Zo.                  75
 Source zo.                 50
confIg: S=SCTL  T=Tapped    T
tYpe: 1=sing 2=doub 3=ratio  1  <-- Singly terminated
electrical Length     (Deg.) 45
```

```
  0 ┌─ Termination ─┐          50 Ohms
  1 │               │      Ref. freq. = 953.646 MHz.
  2.╞════:───:══════╡         77.225 Ohms       17.479 Deg.
    │               │
  4.║ + + + + + + + ║         77.225 Ohms       27.521 Deg.
    │               │
  6 ├────── C ──────┤         2.7152 pFd.
    │        ┌:═════╛
  7.│        └:═════╕         472.75 Ohms           45 Deg.
    │               │
  9.╞════:───:══════╡        92.612 Ohms            45 Deg.
 11 ├────── C ──────┤         2.3551 pFd.
    │        ┌:═════╛
 12.│        └:═════╕         834.33 Ohms           45 Deg.
    │               │
 14.╞════:───:══════╡         87.84 Ohms            45 Deg.
 16 ├────── C ──────┤         2.2924 pFd.
    │        ┌:═════╛
 17.│        └:═════╕         867.25 Ohms           45 Deg.
    │               │
 19 ├────── C ──────┤         2.4027 pFd.
    │               │
 20.║ + + + + + + + ║         77.298 Ohms       34.607 Deg.
    │               │
 22.╞════:───:══════╡         77.298 Ohms       10.393 Deg.
 24 └──── Source ───┘             50 Ohms
 25  Fc = 953.65 MHz.
```

Once the design is done, save it to disk using the "Save design" option of the main control menu. The file name will be changed to CH2 in this example, which is good practice, but is not necessary for a 2 port multiplexer since only 1 side port needs to be saved before the join operation. The "Default" file name could have been used.

Secondly, the high frequency channel is designed using the following specifications. The file name was changed to CH2 and the design was saved to disk simply to record the specifications (CH2.SPK file). The only difference in the specification between the two channels is the center frequency.

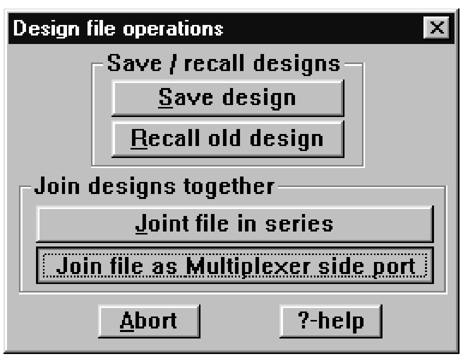
```
 File name = CH2
Design = Combline bandpass
Equal resonator zo. (Y or N) Y
order N                      4
passband Ripple (0=Butt. dB) 0.05
Define pass / stop      (dB) 3
arithmetic Fo.          MHz. 1050 \    1000 - 1100 MHz.
Bandwidth               MHz. 100  /
design Zo.                   75
 Source zo.                  50
confIg: S=SCTL  T=Tapped     T
tYpe: 1=sing 2=doub 3=ratio  1 <-- Singly terminated
electrical Length     (Deg.) 45
```

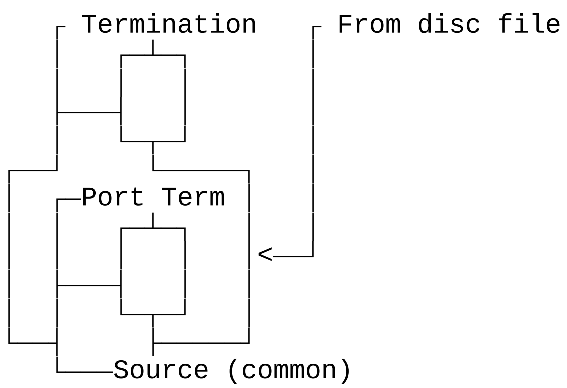
```
  0 ┌─ Termination ─┐          50 Ohms
  1 │               │      Ref. freq. = 1053.3 MHz.
  2.╞════:───:══════╡         77.184 Ohms       16.444 Deg.
    │               │
  4.║ + + + + + + + ║         77.184 Ohms       28.556 Deg.
    │               │
  6 ├────── C ──────┤         2.4002 pFd.
    │        ┌:═════╛
```

```
 7. │          └:═══════╗              528.72 Ohms           45 Deg.
    │                   ║
 9. ╞═════:───:═════════╡               90.94 Ohms           45 Deg.
11  ├─────── C ─────────┤                2.11 pFd.
    │         ┌:════════╝
12. │         └:════════╗              928.92 Ohms           45 Deg.
    │                   ║
14. ╞═════:───:═════════╡              86.608 Ohms           45 Deg.
16  ├─────── C ─────────┤              2.0641 pFd.
    │         ┌:════════╝
17. │         └:════════╗              963.66 Ohms           45 Deg.
    │                   │
19  ├─────── C ─────────┤              2.1548 pFd.
    │                   │
20.║ + + + + + + + ║              77.157 Ohms       35.173 Deg.
    │                   │
22. ╞═════:───:═════════╡              77.157 Ohms       9.8268 Deg.
24  └───── Source ──────┘                  50 Ohms
25  Fc = 1053.3 MHz.
```

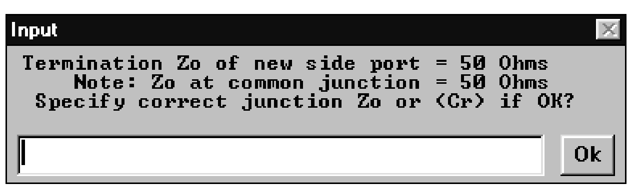
Finally, the filename is changed BACK to CH1 so that the previously saved low frequency port (in the file CH1.DZN) could be joined to the high port that is still in memory.

When the "Join two designs" option is selected, the window shown below will appear. At this point, you can press the [Abort] button to return to the main control menu aborting the join. You can join the CH1 file as a multiplexer port by pressing the [Join file a s Multiplexer side port] button as has been done here. Another option to simply connect the design in the file in series is also provided, but we don't want to do that in this case.





Before the actual joining is done information about the source and termination impedance of the design in the file to be joined is presented. In this case, the side port to be added has a termination Zo of 50 Ohms and a source Zo of the same impedance.



The impedance of the common junction (the new source Zo after the joining) will be set to the source Zo of the design in the file, not the design in memory. In some cases, the source Zo may simulate a voltage source (0 Ohms) or a current source (Infinity Ohms). Another example to follow will explain that situation.

The initial joining of the comb diplexer network is drawn below. Nothing on the drawing says "common", it is always assumed to be the source end unless you insert a forced "`|<—— Common`" branch manually at some other place using the circuit editor "Insert" command. In this example, the junction is two separate tapped resonators (branches 20-22 and branches 44-46) hooked in parallel at the tap. This is incorrect of course. What we actually want is a single common resonator.

```
  0 ┌─ Termination ─┐          50 Ohms
  1 │               │     Ref. freq. = 1053.3 MHz.
  2.╞═════:───:═════╡        77.184 Ohms       16.444 Deg.
    │               │
  4.║ + + + + + + + ║        77.184 Ohms       28.556 Deg.
    │               │
  6 ├────── C ──────┤        2.4002 pFd.
    │        ┌:═════╛
  7.│        └:═════╕        528.72 Ohms           45 Deg.
    │               │
  9.╞═════:───:═════╡         90.94 Ohms           45 Deg.
 11 ├────── C ──────┤          2.11 pFd.
    │        ┌:═════╛
 12.│        └:═════╕        928.92 Ohms           45 Deg.
    │               │
 14.╞═════:───:═════╡        86.608 Ohms           45 Deg.
 16 ├────── C ──────┤        2.0641 pFd.
    │        ┌:═════╛
 17.│        └:═════╕        963.66 Ohms           45 Deg.
    │               │
 19 ├────── C ──────┤        2.1548 pFd.
    │               │
 20.║ + + + + + + + ║        77.157 Ohms       35.173 Deg.
    │               │
 22.╞═════:───:═════╡        77.157 Ohms       9.8268 Deg.
    └───────>       └─── to Source ──> ---------------------------,
 24 ┌── port term ──┐          50 Ohms                              |
 25 │               │     Ref. freq. = 953.646 MHz.                 |
 26.╞═════:───:═════╡        77.225 Ohms       17.479 Deg.          |
    │               │                                               |
 28.║ + + + + + + + ║        77.225 Ohms       27.521 Deg.          |
    │               │                                               |
 30 ├────── C ──────┤        2.7152 pFd.                            |
    │        ┌:═════╛                                               |
 31.│        └:═════╕        472.75 Ohms           45 Deg.          |
    │               │                                               |
 33.╞═════:───:═════╡        92.612 Ohms           45 Deg.          |
 35 ├────── C ──────┤        2.3551 pFd.                            |
    │        ┌:═════╛                                               |
 36.│        └:═════╕        834.33 Ohms           45 Deg.          |
    │               │                                               |
 38.╞═════:───:═════╡         87.84 Ohms           45 Deg.          |
 40 ├────── C ──────┤        2.2924 pFd.                            |
    │        ┌:═════╛                                               |
 41.│        └:═════╕        867.25 Ohms           45 Deg.          |
    │               │                                               |
 43 ├────── C ──────┤        2.4027 pFd.                            |
    │               │                                               |
 44.║ + + + + + + + ║        77.298 Ohms       34.607 Deg.          |
    │               │                                               |
 46.╞═════:───:═════╡        77.298 Ohms       10.393 Deg.          |
```

```
 48 └──── Source ──┘            50 Ohms   <-------------------------'
 49  Fc = 1002.2 MHz.   The source is the "common" connection by default
                     Using the manual "|<── Common" branch
```

In order to correctly complete the multiplexer, a single common resonator coupled to the second resonators of each channel is required. To do this, simply delete the first resonator of first filter and it's tuning capacitor (branches 19 - 22) and insert a "common" just before the first resonator of the second filter using the “Insert” command of the circuit editor (branch 38 below).

```
  0 ┌─ Termination ─┐            50 Ohms
  1 │               │     Ref. freq. = 1053.3 MHz.
  2.╞════:───:══════╡        77.184 Ohms       16.444 Deg.
    │               │
  4.║ + + + + + + + ║        77.184 Ohms       28.556 Deg.
    │               │
  6 ├────── C ──────┤        2.4002 pFd.
    │        ┌:═════╛
  7.│        └:═════╕        528.72 Ohms           45 Deg.
    │               │
  9.╞════:───:══════╡         90.94 Ohms           45 Deg.
 11 ├────── C ──────┤          2.11 pFd.
    │        ┌:═════╛
 12.│        └:═════╕        928.92 Ohms           45 Deg.
    │               │
 14.╞════:───:══════╡        86.608 Ohms           45 Deg.
 16 ├────── C ──────┤        2.0641 pFd.
    │        ┌:═════╛
 17.│        └:═════╕        963.66 Ohms           45 Deg.
    │               │                      The forward port is no longer
    └───────>       └─── to Common A ──>  connected to the source, now it
 19 ┌── port term ──┐            50 Ohms    is connected to "Common A" below.
 20 │               │     Ref. freq. = 953.646 MHz.                       │
 21.╞════:───:══════╡        77.225 Ohms       17.479 Deg.                 │
    │               │                                                    │
 23.║ + + + + + + + ║        77.225 Ohms       27.521 Deg.                 │
    │               │                                                    │
 25 ├────── C ──────┤        2.7152 pFd.                                 │
    │        ┌:═════╛                                                    │
 26.│        └:═════╕        472.75 Ohms           45 Deg.                 │
    │               │                                                    │
 28.╞════:───:══════╡        92.612 Ohms           45 Deg.                 │
 30 ├────── C ──────┤        2.3551 pFd.                                 │
    │        ┌:═════╛                                                    │
 31.│        └:═════╕        834.33 Ohms           45 Deg.                 │
    │               │                                                    │
 33.╞════:───:══════╡         87.84 Ohms           45 Deg.                 │
 35 ├────── C ──────┤        2.2924 pFd.                                 │
    │        ┌:═════╛                                                    │
 36.│        └:═════╕        867.25 Ohms           45 Deg.                 │
    │               │                                                    │
 38 │               │<--- Common A   <-----------------------------'
 39 ├────── C ──────┤        2.4027 pFd.
 40 │               │     Ref. freq. = 1000 MHz. <-- Added reference frequency
    │               │                                for "common" resonator.
 41.║ + + + + + + + ║        77.298 Ohms       34.607 Deg.
    │               │
 43.╞════:───:══════╡        77.298 Ohms       10.393 Deg.
 45 └───── Source ──┘            50 Ohms
```

```
 46  Fc = 1002.2 MHz.
```

One more detail remains. Each transmission line has a specified length associated with it. This length is specified in degrees relative to some frequency. Since the "common" resonator is to be 45 degrees at the crossover frequency (1000 MHz. in this case) an additional reference must be added otherwise it will be assumed to be 45 degrees at the frequency of the last reference in the network before it (branch 20 or 953.646 MHz. in this example). This new reference branch was added at branch 40.

Contiguous 2 port HIGH-LOW diplexer

The first step is to design the lowpass filter to the specifications given below:

```
File name = LP
Design = Lowpass
order N                        4
passband Ripple (0=Butt. dB) 0.05
Define pass / stop      (dB) 3.0103  <-- Half power point.
design Zo.                     50
Cutoff freq. fc.        MHz. 100
Input config:  S-Ser. P-Par. S
tYpe: 1=sing 2=doub 3=ratio  1       <-- Singly terminated.

 0 ┌─ Termination ─┐            50 Ohms
 1 ├────── C ──────┤        19.507 pFd.
   │               │
 2 │               L        112.16 nHy.
   │               │
 3 ├────── C ──────┤        55.402 pFd.
   │               │
 4 │               L           121 nHy.
   │               │
 5 └──── Source ───┘         5e-19 Ohms  <-- Approximate short circuit.
 6  Fc = 100 MHz.
```

Once the design is done, save it to disk using the " Save design" option of the main control menu. The file name was changed to LP in this example.

Secondly, The high pass port is designed using the following specifications. The file name was changed to HP and the design was saved to disk simply to record the specifications (HP.SPK file)

```
File name = HP
Design = Highpass
order N                        4
passband Ripple (0=Butt. dB) 0.05
Define pass / stop      (dB) 3.0103
design Zo.                     50
Cutoff freq. fc.        MHz. 100
Input config:  S-Ser. P-Par. S
tYpe: 1=sing 2=doub 3=ratio  1
```

```
0  ┌─ Termination ─┐           50 Ohms
1  ├────── L ──────┤        129.85 nHy.
   │               │
2  │               C        22.584 pFd.
   │               │
3  ├────── L ──────┤        45.721 nHy.
   │               │
4  │               C        20.934 pFd.
   │               │
5  └──── Source ───┘         5e-19 Ohms
6   Fc = 100 MHz.
```

Finally, the filename was changed BACK to LP so that the previously designed lowpass port (in the file LP.DZN) could be joined to the high pass port that is still in memory.

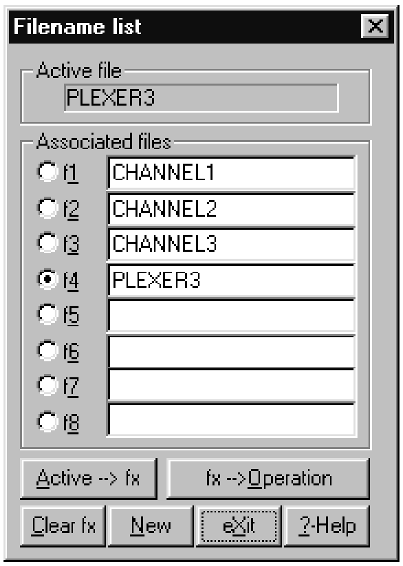
Select the " Join two designs" option of the main control menu and join as a multiplexer.

Unlike the previous example with the comb filters, in this case, the side port to be added has a termination Zo of 50 Ohms and a source Zo that simulates a voltage source (0 Ohms). The impedance of the common junction (the new source Zo after the joining) must be set to 50 Ohms, not to 5e-19 Ohms. No matching is done, the impedance you specify is simply assigned to the "common" or source end. When joining singly terminated designs this way, the impedance here should be the natural design Zo of all the ports. This will normally be the termination Zo of the port being joined in a high or low pass case. In the case of a bandpass port, any termination matching done to the filter will cause some other termination impedance to show. You must still specify the design Zo of all the ports (all of which must be equal).

```
0  ┌─ Termination ─┐           50 Ohms
1  ├────── L ──────┤        129.85 nHy.
   │               │
2  │               C        22.584 pFd.
   │               │
3  ├────── L ──────┤        45.721 nHy.
   │               │
4  │               C        20.934 pFd.
   │               │
   └───────>       └─── to Source ──> --------,
5  ┌── port term ──┐           50 Ohms         |
6  ├────── C ──────┤        19.507 pFd.        |
   │               │                           |
7  │               L        112.16 nHy.        |
   │               │                           |
8  ├────── C ──────┤        55.402 pFd.        |
   │               │                           |
```

```
│               L          121 nHy.        |
│               │                          |  The source is the common
└──── Source ───┘            50 Ohms  <------'   connection by default.
 Fc = 100 MHz.
```

Associated file list



When designing multiplexers, more than a single design file is usually necessary. Each "port" needs to be designed separately and kept in unique files for later joining into a final design that will usually be kept in yet another file. In the examples described earlier, each of file names were keyed in separately. The filename list feature allows all of the design files associated with a large project to be manipulated quickly. Up to 8 unique file names can be included.

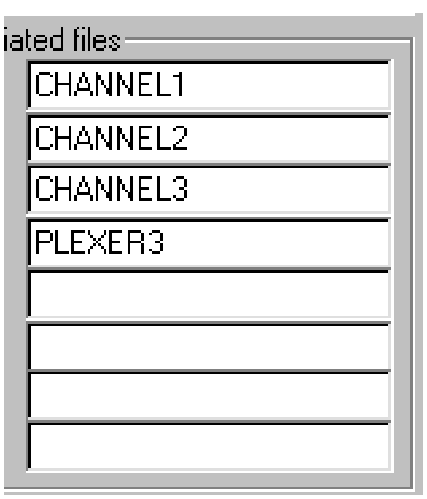
The filename list is simply a list of filenames that can be assigned to the active file name shown on the main window without keying in each name or picking the right one from all the files in your working directory each time. The currently active file name is also displayed. This file name can be quickly stored as any of the 8 edit boxes by pressing a single button.

To display the file list dialog box simply press the keyboard **<B>** hotkey. The feature can also be found on the main menu "File" option. The filename to use is selected by the column of "radio buttons" located to the left of the filenames. Each one can be selected by the keyboard number keys **<1>** to **<8>** or by your mouse. They are marked f1 to f8. Each file name is shown in an edit box where the name can be edited or keyed in manually. The file name selected remains until you change it.

File names are held on the list indefinitely and added to as other files are recalled. Any files that are associated with the recalled files are added to the list. Any file names you type in manually are added and stored also. Individual files or the entire list my be cleared at once.

NOTE: This entire list of file names is saved in the "spk" file when any design file is saved EXCEPT for the "default" filename.

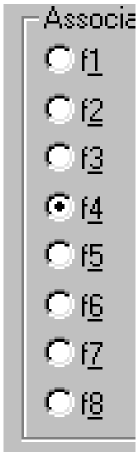
When a file name is selected, the **[fx --> Operation]** button gets the input focus and can be activated by the keyboard **<Space>** bar. This will assign the selected filename to the active filename and bring up the file operations dialog box to allow that file to be saved, recalled or joined to the network in memory.



The procedure to join a previous design stored in the file at f3, for example, into the network in memory as a multiplexer side-port would be : **<B> <3> <Space> <M>.**

The file names

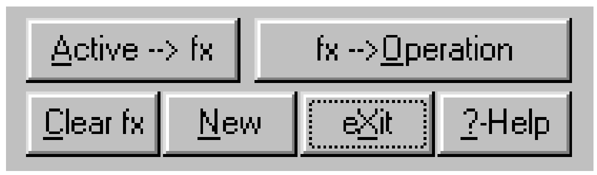
8 file names of designs that are associated with each other such as individual filters that will make up a multiplexer are displayed in 8 edit boxes. These are simply a list of names one of which can be file name of the final multiplexer combination. Each is a small editor in which the names can be changed or keyed in.



Selecting which file

To the left of each file name edit box is a column of "radio buttons". These identify the filename to be used or defined. They can be selected with you mouse or by pressing a keyboard numeric key 1, 2, .. 8. (**NOT** with the keyboard function keys <F1>, <F2> etc.).The selected filename is the little circle with the dot in it. Any time a file name is edited, it becomes the selected file.

Bottom buttons



[Active -> fx]

Copies the current active filename into the edit box selected by the f1 to f8 “radio buttons”.

[fx -> Operation]

Assigns the filename selected (fx) to the active filename and brings up the file operations dialog box.

[Clear fx]

Use this button to clear the filename in the selected edit box. The blank edit window gap will be closed the next time the list is displayed

[New]

Clears all the filenames. If the design in memory is saved after pressing the **[New]** button there will no longer be any associated files recorded in that file.

[eXit]

This will exit from the file name list dialog box without doing anything. Use it leave after simply looking at the list of files.

More about the │<— Common branch

A manually inserted "common" simply moves the junction of all the ports above it (lower branch numbers) away from the source to where ever you insert it allowing other networks to be placed between the junction and the source. It is therefore possible to connect two high/low pass L-C diplexers in series to form a triplexer. In this case, each discrete diplexer will have its own common associated with it. The first will automatically be marked "Common A". The second will be "Common B" or the source. The arrows from all the port inputs will be marked as to which common they are connected to, A, B or the source. This idea is represented below for a contiguous triplexer with transitions at 100 and 200 MHz using L-C highpass and lowpass filters.

```
 0 ┌─ Termination ─┐             50 Ohms   <-- 200 MHz. and up output port.
   │               │
   │      ┌─────────────────────┐
   ├──────┤ 200 Mhz. high pass  │
   │      └─────────────────────┘
   │               │
   └───────>       └─── to Common A ──>
   ┌── port term ──┐             50 Ohms   <-- 100-200 Mhz. output port.
   │               │
   │      ┌─────────────────────┐
   ├──────┤ 200 Mhz. Low pass   │
   │      └─────────────────────┘
   │               │
   │               │<─── Common A
   │               │
   │      ┌─────────────────────┐
   ├──────┤ 100 Mhz. high pass  │
   │      └─────────────────────┘
   │               │
   └───────>       └─── to Common B ──>
   ┌── port term ──┐             50 Ohms   <--- DC-100 MHz. output port.
   │               │
   │      ┌─────────────────────┐
   ├──────┤ 100 Mhz. Low pass   │
   │      └─────────────────────┘
   │               │
   │               │<─── Common B
   └──── Source ───┘             50 Ohms
```

Analyzing for channel-to -channel isolation and reverse response

Multiplexers can be rearranged so that they can be analyzed looking into one of the side-port terminations to determine isolation or reverse response. To illustrate the procedure the two-port 4th order diplexer shown earlier will be used. The first step is to recall the diplexer just as it was joined and saved for analysis looking into its common port.

```
 0  ┌─ Termination ─┐          50 Ohms
 1  ├────── L ──────┤      129.85 nHy.
    │               │
 2  │               C      22.584 pFd.
    │               │
 3  ├────── L ──────┤      45.721 nHy.
    │               │
 4  │               C      20.934 pFd.
    │               │
    └────>          └─── to Source ──>
 5  ┌── port term ──┐          50 Ohms
 6  ├────── C ──────┤      19.507 pFd.
    │               │
 7  │               L      112.16 nHy.
    │               │
 8  ├────── C ──────┤      55.402 pFd.
    │               │
 9  │               L         121 nHy.
    │               │
10  └──── Source ───┘          50 Ohms
11  Fc = 100 MHz.
```

The first step is to remove the side port by deleting branches 5 through 9.

[MISC:] Delete 5,9

```
 0  ┌─ Termination ─┐          50 Ohms
 1  ├────── L ──────┤      129.85 nHy.
    │               │
 2  │               C      22.584 pFd.
    │               │
 3  ├────── L ──────┤      45.721 nHy.
    │               │
 4  │               C      20.934 pFd.
    │               │
 5  └──── Source ───┘          50 Ohms
 6  Fc = 100 MHz.
```

This leaves the forward port intact just as it was before it was joined. It is then reversed source-for-termination.

[MAIN:] Reverse

```
 0  ┌─ Termination ─┐          50 Ohms
    │               │
 1  │               C      20.934 pFd.
    │               │
 2  ├────── L ──────┤      45.721 nHy.
    │               │
 3  │               C      22.584 pFd.
    │               │
```

```
 4 ├────── L ──────┤       129.85 nHy.
 5 └──── Source ───┘           50 Ohms
 6  Fc = 100 MHz.
```

The next step is to join the lowpass port back, but this time in series. The entire multiplexer could also be series joined and the UN-reversed highpass port deleted. The resulting network is shown below.

```
 0 ┌─ Termination ─┐            50 Ohms
   │               │
 1 │               C       20.934 pFd.
   │               │
 2 ├────── L ──────┤       45.721 nHy.
   │               │
 3 │               C       22.584 pFd.
   │               │
 4 ├────── L ──────┤       129.85 nHy.
 5 ├────── C ──────┤       19.507 pFd.
   │               │
 6 │               L       112.16 nHy.
   │               │
 7 ├────── C ──────┤       55.402 pFd.
   │               │
 8 │               L          121 nHy.
   │               │
 9 └──── Source ───┘        5e-19 Ohms
10  Fc = 100 MHz.
```

In this case, the original lowpass file was joined. Note that the simulated voltage source impedance needs to be changed to 50 Ohms.

```
[MISC1:] Change 9
What value (Ohms)? 50
```

As joined, the outputs of the two ports are connected. In order to get the input ends of both ports together the highpass port is simply moved to the source.

```
[MISC2:] Move 1,4
Position them after branch 8
```

```
 0 ┌─ Termination ─┐            50 Ohms
 1 ├────── C ──────┤       19.507 pFd.
   │               │
 2 │               L       112.16 nHy.
   │               │
 3 ├────── C ──────┤       55.402 pFd.
   │               │
 4 │               L          121 nHy.
   │               │
 5 │               C       20.934 pFd.
   │               │
 6 ├────── L ──────┤       45.721 nHy.
   │               │
 7 │               C       22.584 pFd.
   │               │
```

```
 8 ├────── L ──────┤        129.85 nHy.
 9 └───── Source ──┘         50 Ohms
10  Fc = 100 MHz.
```

The network is now set to look into the output of the highpass port. Assume we would like to look into the lowpass port output first. The choice is made simply by reversing the entire network source-for-termination.

[MAIN:] Reverse

```
 0 ┌─ Termination ─┐         50 Ohms
 1 ├────── L ──────┤        129.85 nHy.
   │               │
 2 │               C        22.584 pFd.
   │               │
 3 ├────── L ──────┤        45.721 nHy.
   │               │
 4 │               C        20.934 pFd.
   │               │
 5 │               L           121 nHy.
   │               │
 6 ├────── C ──────┤        55.402 pFd.
   │               │
 7 │               L        112.16 nHy.
   │               │
 8 ├────── C ──────┤        19.507 pFd.
 9 └───── Source ──┘            50 Ohms
10  Fc = 100 MHz.
```

The lowpass is now nearest the source. Analysis will “look into” this end of the network. The next steps will used the circuit editor **Insert** function to add a **port termination** and a **common** branch at the junction. These are options (J) and (L) on the insert menu. The port termination becomes the common junction of the diplexer.

[MISC1:] Insert after 4

```
-> Par stubs and special <-

(J) Part term.
(K)
(L) Common #
```

```
 0 ┌─ Termination ─┐         50 Ohms
 1 ├────── L ──────┤        129.85 nHy.
   │               │
 2 │               C        22.584 pFd.
   │               │
 3 ├────── L ──────┤        45.721 nHy.
   │               │
 4 │               C        20.934 pFd.
   │               │
   └────>          └─── to Common A ──>
 5 ┌── port term ──┐            50 Ohms
 6 │               │<── Common A
   │               │
 7 │               L           121 nHy.
   │               │
 8 ├────── C ──────┤        55.402 pFd.
   │               │
 9 │               L        112.16 nHy.
```

```
   │                │
10 ├────── C ───────┤        19.507 pFd.
11 └──── Source ────┘            50 Ohms
12  Fc = 100 MHz.
```

As the network sits now, analysis will display port to port isolation.

Using the Rotate command moves the common port to the termination.

[MISC2:] Rotate

```
 0 ┌─ Termination ─┐             50 Ohms
   └────>          └─── to Common A ──>
 1 ┌── port term ──┐          50 Ohms
 2 ├────── L ──────┤         129.85 nHy.
   │               │
 3 │               C         22.584 pFd.
   │               │
 4 ├────── L ──────┤         45.721 nHy.
   │               │
 5 │               C         20.934 pFd.
   │               │
 6 │               │<─── Common A
   │               │
 7 │               L            121 nHy.
   │               │
 8 ├────── C ──────┤         55.402 pFd.
   │               │
 9 │               L         112.16 nHy.
   │               │
10 ├────── C ──────┤         19.507 pFd.
11 └──── Source ───┘             50 Ohms
12  Fc = 100 MHz.
```

Analysis will now show the reverse channel response.

To look into the highpass port it is necessary to return to the simple series joined configuration and reverse the network just as we did earlier. **Rotate** again then delete the **port term** and **common**.

Power analysis:

This type of diplexer is often used to combine two signal sources into a common port rather then to divide a single port into two separate frequency ranges. The signal sources can be transmitters which will require the filters to handle high power levels. The power analysis module can be used to determine the voltage and current handling requirements of each part while the network is in this configuration. It is not likely that power would be applied at exactly the crossover frequency (100 MHz in this case) but this is a situation that clearly illustrates how to interpret the results given by the analysis. Below is the results assuming 10 Watts input and infinite Q lossless parts. Note that half the power is sent to the output (3 db forward loss), one quarter is dissipated in the highpass termination and one quarter is reflected (6 dB return loss).

```
Inductor Q=1e+11 Cap. Q=1e+11 Trans. Q=1e+11
   Frequency   Rtn. loss    Atten.       Delay       Phase
    (MHz.)       (dB)       (dB)         (nSec)      (Deg.)
    100.000       6.071       3.010        8.239     214.688

         10.0000 W. ------>| Loss        |------>
          2.4712 W. <------|  2.52898 W. |  4.9998 W.

    ------- Termination --------
   <------  15.811 V.------>  |
             0.316 A.--------X
                              |
 6 ------| 2.529 W. |--X------   <-- The entire highpass port.
                       |              (Common A)
             0.379 A.---
   <------  15.811 V.------>
                               
          ---------------->   <------------------------------------,
          |                                                        |
          |          | 0.000 W. |  <-- Series inductor at branch 7  |
          44.624 V.                                                 |
          ---------------->                                        |
             0.587 A.--------X                                     |
                                                                   |
 8 ------| 0.000 W. |--X------                                     |
                       |                                           |
             1.310 A.---                                Lowpass filter
   <------  37.634 V.------>                                       |
                                                                   |
          ---------------->                                        |
          |                                                        |
          |          | 0.000 W. |                                  |
          55.264 V.                                                 |
          ---------------->                                        |
             0.784 A.--------X                                     |
                                                                   |
10 ------| 0.000 W. |--X------                                     |
                       |                                           |
             0.260 A.---                                           |
   <------  21.177 V.------>  <------------------------------------'
                              |
             0.565 A.--------X
                              |
11 ------- Source (~) --------
```

A Triplexer:

The next example is a contiguous Triplexer consisting of a lowpass, bandpass and highpass. In this case the individual port files no longer exist requiring that the parts be moved using only the one network file. The bandpass port is in the forward position below. This is the port we will be “looking into” with the analysis.

```
  0  ┌─ Termination ─┐        50 Ohms
     │               │
  1  │               L           148 nHy.
     │               │
  2  ├────── C ──────┤        1.7401 pFd.
     │               │
  3  │               C        21.091 pFd.
     │               │
  4  ├────── C ──────┤        28.604 pFd.
  5. ├─── C ── L ────┤        32.958 pFd.         163.9 nHy.  Fx = 68.477 MHz.
     │               │
  7  │               C        55.344 pFd.
     │               │
  8  ├────── C ──────┤        12.438 pFd.
     │             ┌─┴─┐
  9. │             C   L      39.269 pFd.        40.548 nHy.  Fx = 126.13 MHz.
     │             └─┬─┘
 11  ├────── C ──────┤        25.854 pFd.
     │               │
 12  │               C        7.4463 pFd.
     │               │
 13  ├────── C ──────┤        1.3478 pFd.
     │               │
 14  │               L         343.4 nHy.
     │               │
     └────>          └─── to Source ───>
 15  ┌── port term ──┐            50 Ohms
     │               │
 16  │               L        63.632 nHy.
     │               │
 17  ├────── C ──────┤        29.895 pFd.
     │             ┌─┴─┐
 18. │             L   C      62.924 nHy.        48.239 pFd.  Fx = 91.35 MHz.
     │             └─┬─┘
 20  ├────── C ──────┤        54.806 pFd.
     │               │
 21  │               L         158.7 nHy.
     │               │
     └────>          └─── to Source ───>
 22  ┌── port term ──┐            50 Ohms
     │               │
 23  │               C        44.662 pFd.
     │               │
 24  ├────── L ──────┤        51.045 nHy.
     │               │
 25  │               C        26.917 pFd.
     │               │
 26. ├─── L ── C ────┤        115.42 nHy.        20.493 pFd.  Fx = 103.48 MHz.
     │               │
 28  │               C        20.221 pFd.
```

```
   │               │
29 ├─────── L ─────┤       36.945 nHy.
   │               │
30 │               C       17.517 pFd.
   │               │
31 └───── Source ──┘           50 Ohms
32  Fc = 100 MHz.
```

Perform the steps below.

Delete branches 15 to 30.
Reverse the remaining bandpass channel end-for-end.
Series join the entire network.
Delete the UN-reversed bandpass section.
Insert the new side-port (J) and common (L) at the junction.

```
 0  ┌─ Termination ─┐            50 Ohms
    │               │
 1  │               L       63.632 nHy.
    │               │
 2  ├────── C ──────┤       29.895 pFd.
    │             ┌─┴─┐
 3. │             L   C     62.924 nHy.       48.239 pFd.  Fx = 91.35 MHz.
    │             └─┬─┘
 5  ├────── C ──────┤       54.806 pFd.
    │               │
 6  │               L        158.7 nHy.
    │               │
    └────>          └─── to Common A ───>
 7  ┌── port term ──┐            50 Ohms
    │               │
 8  │               C       44.662 pFd.
    │               │
 9  ├────── L ──────┤       51.045 nHy.
    │               │
10  │               C       26.917 pFd.
    │               │
11. ├─── L ── C ────┤       115.42 nHy.       20.493 pFd.  Fx = 103.48 MHz.
    │               │
13  │               C       20.221 pFd.
    │               │
14  ├────── L ──────┤       36.945 nHy.
    │               │
15  │               C       17.517 pFd.
    │               │
    └────>          └─── to Common A ───>
16  ┌── port term ──┐            50 Ohms
17  │               │<─── Common A
    │               │
18  │               L        343.4 nHy.
    │               │
19  ├────── C ──────┤       1.3478 pFd.
    │               │
20  │               C       7.4463 pFd.
    │               │
21  ├────── C ──────┤       25.854 pFd.
    │             ┌─┴─┐
22. │             C   L     39.269 pFd.       40.548 nHy.  Fx = 126.13 MHz.
    │             └─┬─┘
24  ├────── C ──────┤       12.438 pFd.
    │               │
25  │               C       55.344 pFd.
    │               │
26. ├─── C ── L ────┤       32.958 pFd.        163.9 nHy.  Fx = 68.477 MHz.
28  ├────── C ──────┤       28.604 pFd.
    │               │
```

```
29 │                C       21.091 pFd.
   │                │
30 ├────── C ───────┤       1.7401 pFd.
   │                │
31 │                L          148 nHy.
   │                │
32 └───── Source ───┘           50 Ohms
33  Fc = 100 MHz.
```

Use the **Rotate** command to analyze through the bandpass channel to the lowpass channel (as above), next the highpass channel and finally the common port (as below) in turn.

```
 0  ┌─ Termination ─┐              50 Ohms
    └────>          └─── to Common A ───>
 1  ┌── port term ──┐              50 Ohms
    │               │
 2  │               L          63.632 nHy.
    │               │
 3  ├────── C ──────┤          29.895 pFd.
    │             ┌─┴─┐
 4. │             L   C        62.924 nHy.        48.239 pFd.  Fx = 91.35 MHz.
    │             └─┬─┘
 6  ├────── C ──────┤          54.806 pFd.
    │               │
 7  │               L           158.7 nHy.
    │               │
    └────>          └─── to Common A ───>
 8  ┌── port term ──┐              50 Ohms
    │               │
 9  │               C          44.662 pFd.
    │               │
10  ├────── L ──────┤          51.045 nHy.
    │               │
11  │               C          26.917 pFd.
    │               │
12. ├─── L ── C ────┤          115.42 nHy.        20.493 pFd.  Fx = 103.48 MHz.
    │               │
14  │               C          20.221 pFd.
    │               │
15  ├────── L ──────┤          36.945 nHy.
    │               │
16  │               C          17.517 pFd.
    │               │
17  │               │<─── Common A
    │               │
18  │               L           343.4 nHy.
    │               │
19  ├────── C ──────┤          1.3478 pFd.
    │               │
20  │               C          7.4463 pFd.
    │               │
21  ├────── C ──────┤          25.854 pFd.
    │             ┌─┴─┐
22. │             C   L        39.269 pFd.        40.548 nHy.  Fx = 126.13 MHz.
    │             └─┬─┘
24  ├────── C ──────┤          12.438 pFd.
    │               │
25  │               C          55.344 pFd.
    │               │
26. ├─── C ── L ────┤          32.958 pFd.         163.9 nHy.  Fx = 68.477 MHz.
28  ├────── C ──────┤          28.604 pFd.
    │               │
29  │               C          21.091 pFd.
    │               │
30  ├────── C ──────┤          1.7401 pFd.
    │               │
```

```
│                 L          148 nHy.
│                 │
└───── Source ────┘           50 Ohms
 Fc = 100 MHz.
```