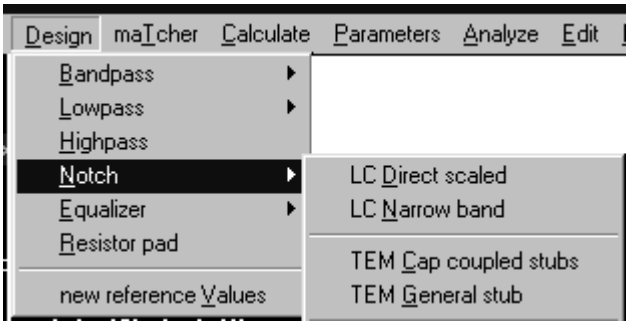
Transmission line notch filters



Cap. coupled stubs

This form of narrow bandwidth notch is described on pages 744 - 749 of Microwave Filters, Impedance-Matching Networks and Coupling Structures By Matthaei, Young and Jones. It is useful for extremely narrow bandwidths and consists of shorted shunt stubs coupled to a series transmission line by small capacitors at 90 degree intervals.

The design example given in the book is duplicated below:

```
File name = CSTOP
Design = Cap. coupled stub notch
order N                      3
passband Ripple (0=Butt. dB) 0.5
Define pass / stop      (dB) 0.5
arithmetic Fo.          MHz. 4000
Bandwidth               MHz. 200
design Zo.                   59.4  <-- The stub impedance
 Source zo.                  50    <-- The series line impedance.
tYpe: 1=sing 2=doub 3=ratio  2
```

The schematic of the design will look like this when drawn by the circuit editor:

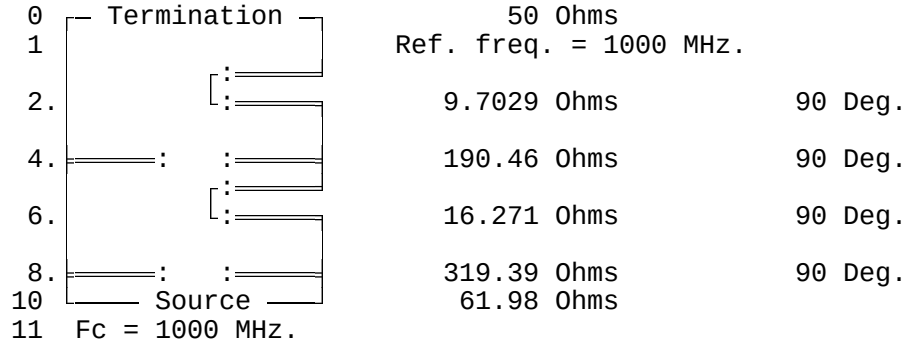
```
 0 ┌─ Termination ─┐          50 Ohms
 1 │               │     Ref. freq. = 4000 MHz.
 2.╞═══:──:═══*─C─┤          59.4 Ohms       74.234 Deg.      0.18911 pFd.
   │               │
 5.╟ + + + + + + + ╢          50 Ohms           90 Deg.
   │               │
 7.╞═══:──:═══*─C─┤          59.4 Ohms        76.96 Deg.      0.15514 pFd.
   │               │
10.╟ + + + + + + + ╢          50 Ohms           90 Deg.
   │               │
12.╞═══:──:═══*─C─┤          59.4 Ohms       74.234 Deg.      0.18911 pFd.
15 └─── Source ───┘          50 Ohms
16  Fc = 4000 MHz.
```

The 3 dB fractional bandwidths for the design are also available from the hard copy option of the Utilities menu.

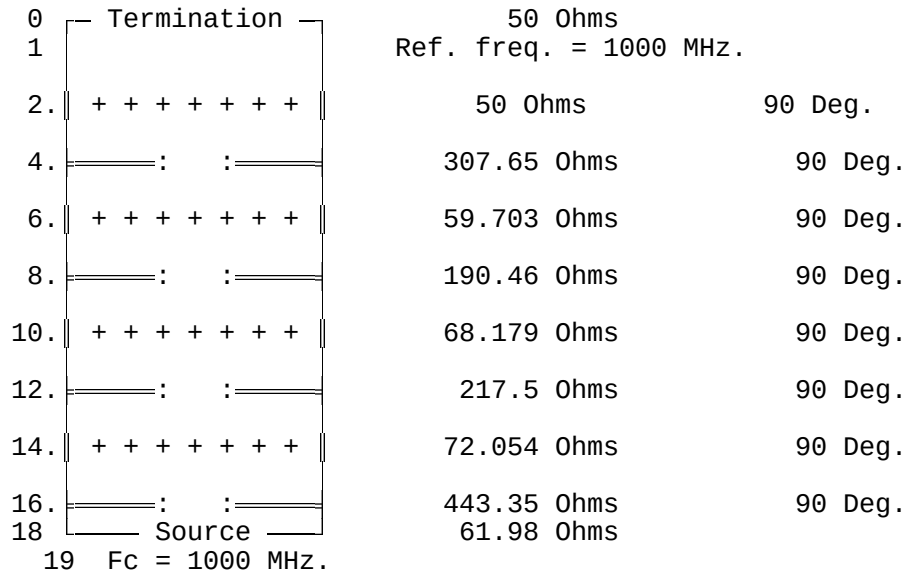
```
3 dB Loading bandwidth
  #      (MHz.)
  1    159.6280
  2    109.6692
  3    159.6280
```

General stub notch

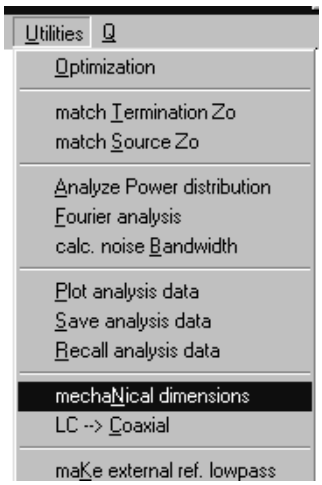
The basic form for the general stub notch type of filter consists of series connected shorted stubs alternating with shunt connected open stubs. This type filter can be quite difficult to construct. The schematic of a 4th order parallel input (confIg: Ser. Par. Kuroda = P) filter would look like this in the circuit editor:



A more practical form is the Kuroda transformed configuration where each stub has been transformed into an open shunt stub isolated from the next by series 1/4 wave lines. The transformation can be done manually using the INsert and KT commands of the circuit editor or automatically by selecting confIg: Ser. Par. Kuroda = K on the parameters menu. The same 4th order filter as above would like this after the transformation:



The Kuroda transformed configuration can be realized in microstrip or stripline at wide bandwidths, or by mutual coupling at narrower bandwidths. Several methods for realizing this type of filter are provided in the mechanical dimensions module available from the Utilities menu.



The mechanical dimensions control menu looks like this:

```
=========> Control <=========
 (T) resonator Type = S
 (G) Ground plane = 0.500
 (D) Dielectric k = 1.000
 (R) Resonator size
 (C) set Cb = *****
 (P) Parameters
 (X) eXit to main menu
 (E) Edit
```

(T) resonator Type = S

The first option on the "Control" menu allows selection of the type of notch filter implementation by bringing up this menu:

```
>  MECHANICAL DIMENSIONS and SPACING  <
=====> Notch resonator configurations <=====
 (M) Microstrip stubs
 (R) Round rod stubs
 (S) Spur-line
 (P) symmetrical Parallel coupled:
      Resonator width = line width.
 (E) Equal line width parallel coupled:
      All line widths equal - adjusted by
      plate cap. (Cb) of last resonator.
```

The first two options do NOT use mutual coupling and are good for very wide notch widths:

(M) Microstrip stubs

Intended for printed circuit type implementations. The line widths are for substrates with a foil thickness of .0015 In.

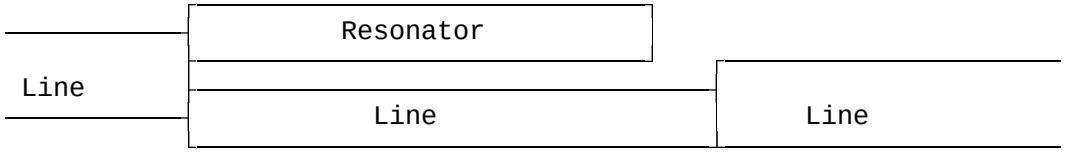
(R) Round rod stubs

This gives the diameters for round rods between parallel ground planes for the necessary Zo of each line and stub.

The next option uses both direct and mutual coupling:

(S) Spur-line

A spur line resonator is physically connected to the line and uses mutual coupling as well. It is useful for wide notch width applications:



The last two options use only mutual coupling giving width and spacing dimensions for rectangular bars placed next to each other in parallel but not actually connected.

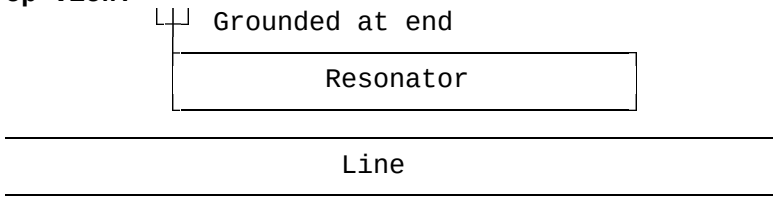
(P) symmetrical Parallel coupled:

In this case the resonator has the same width as the line it is coupled to. This is the default selection.

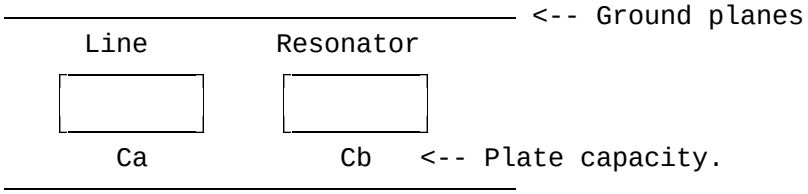
(E) Equal line width parallel coupled:

This option is identical to the parallel coupled configuration except all of the forward lines that each resonator is couple to have
the same width. This width is adjusted by specifying the normalized parallel plate capacity (Cp) of the last resonator. Cb refers to the Cp of line "b" of 2 copuled rods "a" and "b". Values range between 2 and 10 with 4 being the default. This is an iteration and may take a few seconds on a slow computer.

Top view:



End view:



(G) Ground plane = 0.500 - <G>

(D) Dielectric k = 1.000 - <K>

(R) Resonator size

These three menu items control the physical dimensions of the lines and stubs that form the filter.

(C) set Cb = ***

Cb sets the normalized plate capacity (Cp) of the last resonator when using the "Equal line width parallel coupled" configuration.

(P) Parameters

The main parameters menu may be called to make major changes without leaving the spacings module.

(X) eXit to main menu

Exit the spacings module to the main control menu. The <Esc> key will exit to the Utilities menu.

(E) Edit

This allows access to the circuit editor for any purpose needed. It is also an easy way to match the branch numbers and stubs tabulated below the control menu.

Line / stub association convention

When using mutual coupling between forward transmission lines and stubs, it is necessary to be aware of what line each stub is being coupled to by the program. This information is displayed below the control menu window in tabulated form as illustrated below:

```
 LINE <- Coupled to -> STUB
Branch  Zo      Branch  Zo
 2   86.03       4  119.39
 8   70.94      10  169.39
```

Whenever a Kuroda transformed notch is designed, as additional series line is added at the termination end. This is so that every shunt stub will have a series line to couple to. The convention is that each stub couples to the line just before it on the schematic as drawn by the circuit editor.

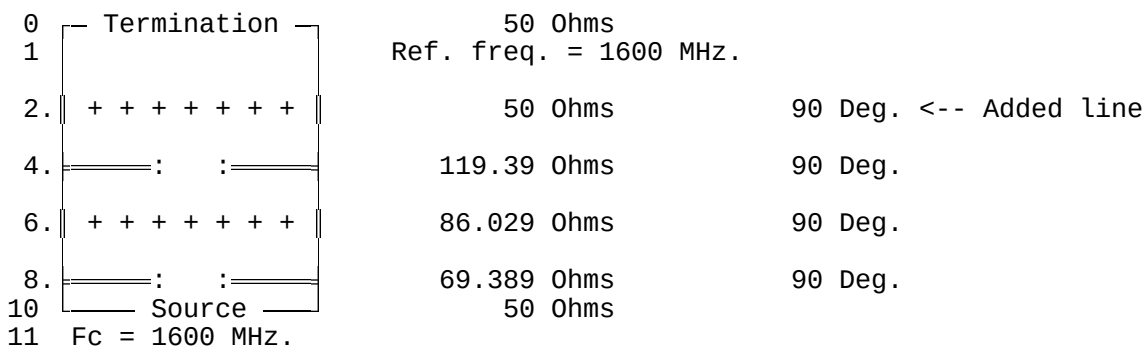
With configurations that do not use mutual coupling, the same listing will be shown like this:

```
LINE ---------------- STUB
Branch  Zo      Branch  Zo
 2   86.03       4  119.39
 8   70.94      10  169.39
```

Reproduced below is a published sample spur line notch filter that should illustrate the line / stub association convention used.

```
File name = SPUR
Design = General TEM Stub notch
order N                      2
passband Ripple (0=Butt. dB) 0
Define pass / stop      (dB) 3.0103
arithmetic Fo.          MHz. 1600
Bandwidth               MHz. 960
design Zo.                   50
confIg: Ser.  Par.  Kuroda   K
tYpe: 1=sing 2=doub 3=ratio  2

   Initial design:
```



After dual, the addition of another forward line and kuroda transforms by using the circuit editor, the design looks like this:

```
 0 ┌─ Termination ─┐           50 Ohms
 1 │               │      Ref. freq. = 1600 MHz.
   │               │
 2.╠═══════:   :═══╣        119.39 Ohms          90 Deg.
   │               │
 4.╟ + + + + + + + ╢         86.029 Ohms          90 Deg.
   │               │
 6.╟ + + + + + + + ╢          29.06 Ohms          90 Deg.
   │               │
 8.╟ + + + + + + + ╢          70.94 Ohms          90 Deg.
   │               │
10.╠═══════:   :═══╣        169.39 Ohms          90 Deg.
12 └──── Source ────┘            50 Ohms
13  Fc = 1600 MHz.
```

The program couples each stub to the forward transmission line just before it (next lower branch number) on the schematic. In the case of this spur-line, an additional line has been inserted requiring the first stub to couple to the line just AFTER it on the schematic. As is, stub 10 couples to line 8, but the stub at branch 2 has no line before it to couple to. To make stub 2 couple to line 4, just reverse the order of the two. Don't expect this to analyze - it's just a way to make the correct stub and line match up!

Use the circuit editor, like this:

```
 0 ┌─ Termination ─┐           50 Ohms
 1 │               │      Ref. freq. = 1600 MHz.
   │               │
 2.╟ + + + + + + + ╢         86.029 Ohms          90 Deg.  <----,
   │               │                                         Reversed order
 4.╠═══════:   :═══╣        119.39 Ohms          90 Deg.  <----'
   │               │
 6.╟ + + + + + + + ╢          29.06 Ohms          90 Deg.
   │               │
 8.╟ + + + + + + + ╢          70.94 Ohms          90 Deg.
   │               │
10.╠═══════:   :═══╣        169.39 Ohms          90 Deg.
12 └──── Source ────┘            50 Ohms
13  Fc = 1600 MHz.
```

The final spacing data looks like this:

```
 >  MECHANICAL DIMENSIONS and SPACING  <
* Spur-line - rectangular bars *
Transmission line bar size = 0.1000 Inches
 Line Width     Gap    Resonator Width
  (Inches)    (Inches)    (Inches)
   0.156       0.202       0.156
   0.209       0.060       0.209
```

```
═══════════> Control <═══════════
 ( ) resonator Type = S
 ( ) Ground plane = 0.500
 ( ) Dielectric k = 1.000
 (*) Resonator size
 ( ) set Cb = *****
 ( ) Parameters
 ( ) eXit to main menu
 ( ) Edit
```

```
LINE <- Coupled to -> STUB
Branch  Zo      Branch  Zo
 2   86.03       4  119.39
 8   70.94      10  169.39
```

```
1/4 Wave = 1.8442 In.  Dielectric k = 1
Recommended resonator length = 1.71566 In.
Ground plane spacing = 0.5 In.
```

==========

For comparison purposes, the actual dimensions from the published filter design are shown below. The dimensions agree within 2%.

Line Width (Inches)	Gap (Inches)	Resonator Width (Inches)
0.153	0.200	0.153
0.212	0.060	0.212