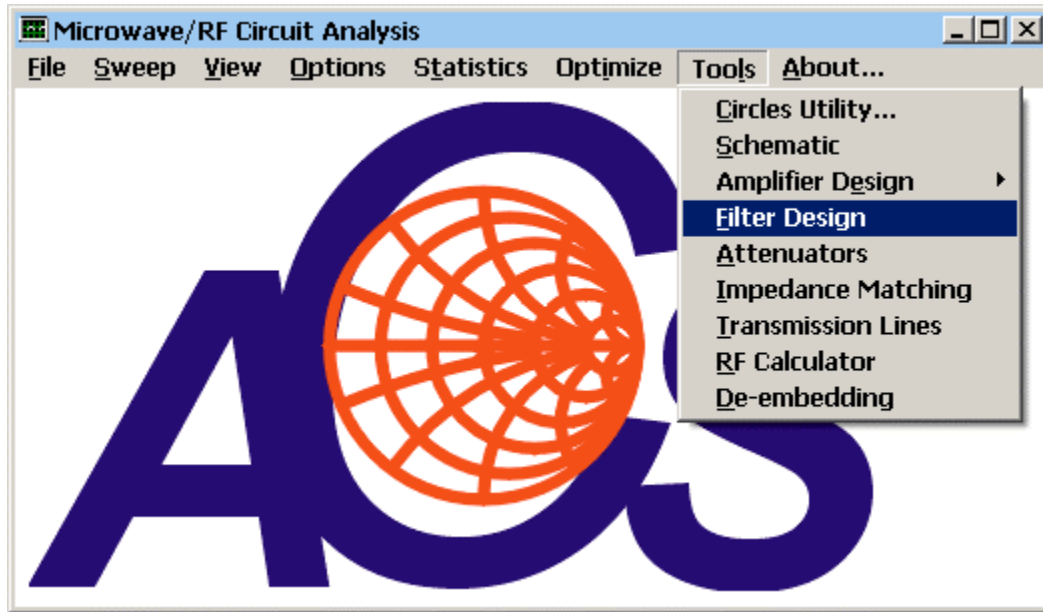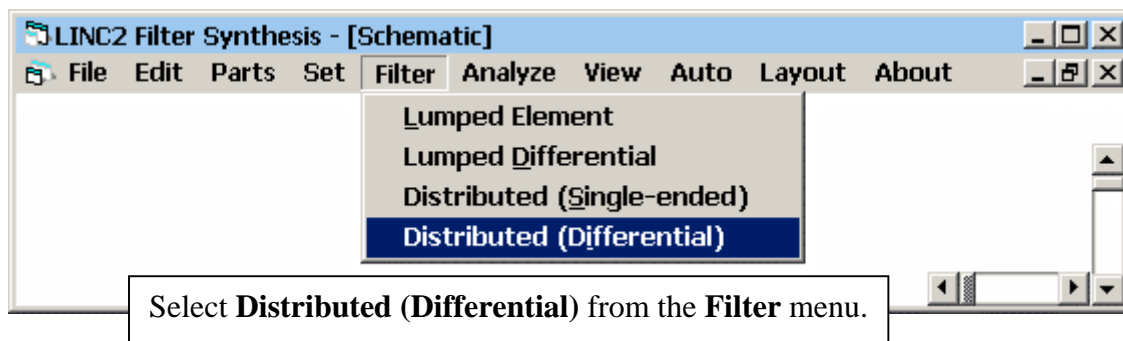# LINC2 FILTER Synthesis

The LINC2 filter synthesis program is started by selecting **Filter Design** from the main LINC2 **Tools** menu as shown above.
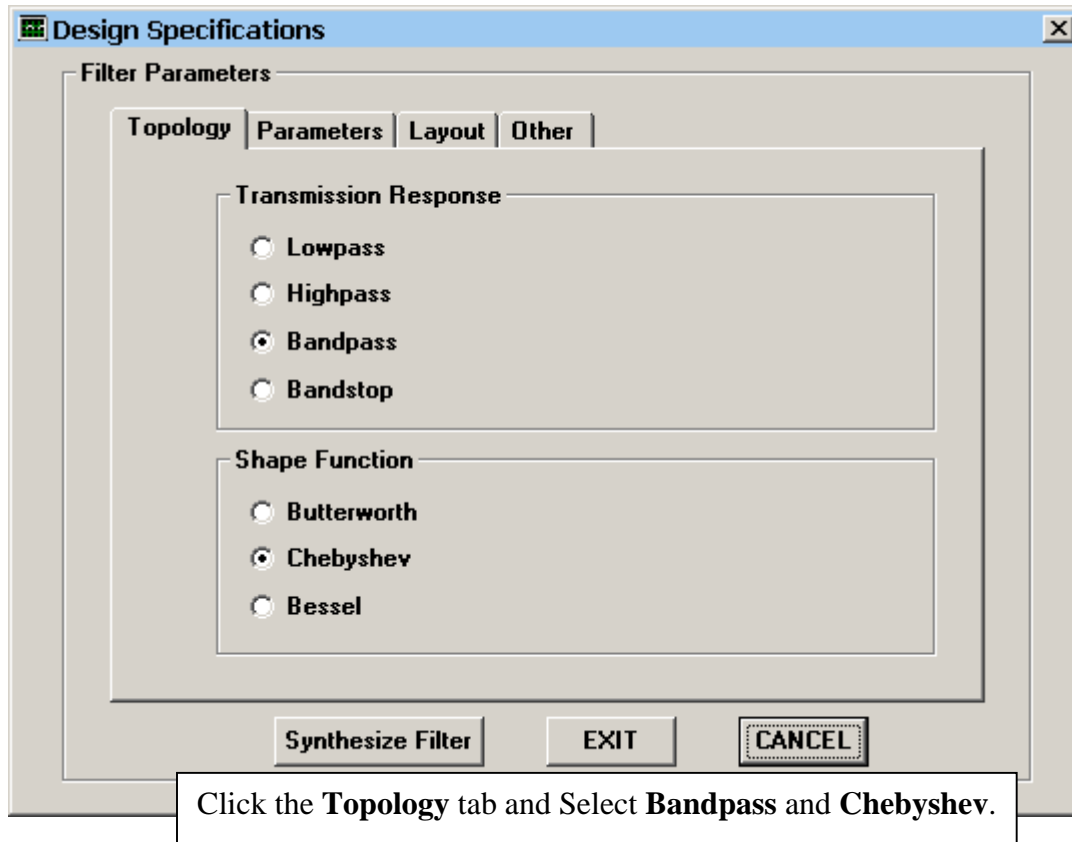
The initial filter synthesis process usually generates an ideal electrical schematic. When the schematic (with ideal elements) is converted to a physical layout, non-ideal attributes are often introduced that alter the desired filter characteristics. EM simulation can help the filter designer understand these changes so they can be compensated for in the original design (such as a shift in the frequency specification).

The following example will demonstrate how a differential 3rd order distributed Chebyshev bandpass filter (with 6.0 – 6.2 GHz passband) can be specified, synthesized, and exported to the Sonnet® EM simulator for analysis in a matter of minutes with only a few menu clicks and keystrokes. The EM analysis will show a slight shift (lower) in frequency and bandwidth (wider) than originally specified. This can be corrected by making the (opposite) adjustment to the design.
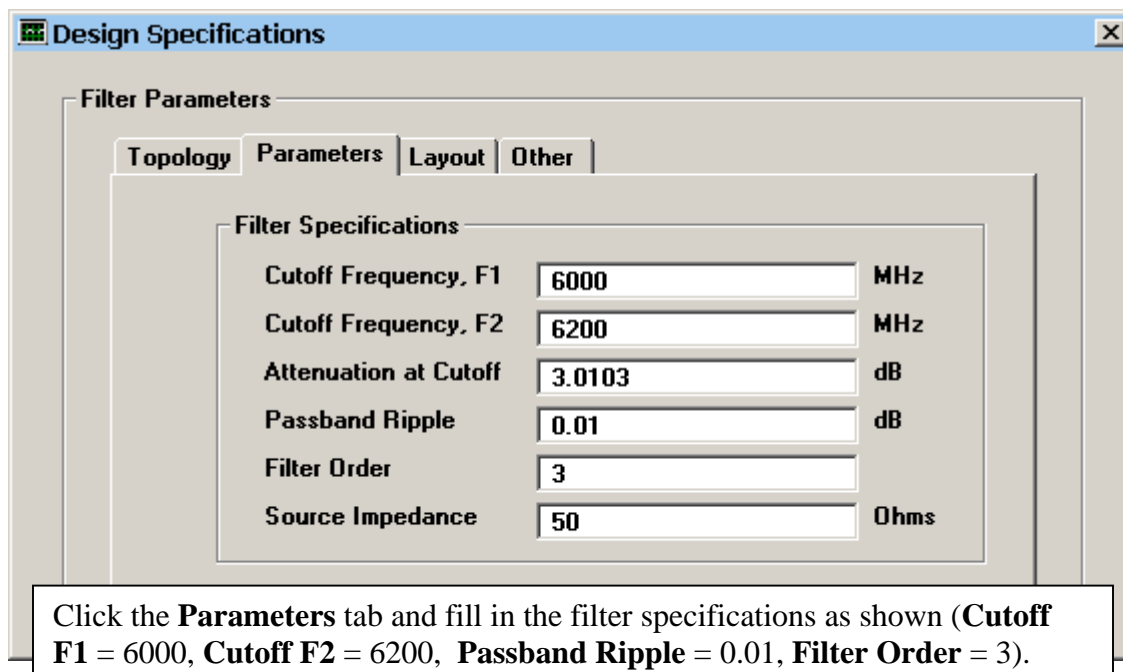
First, select **Distributed (Differential)** from the **Filter** menu:
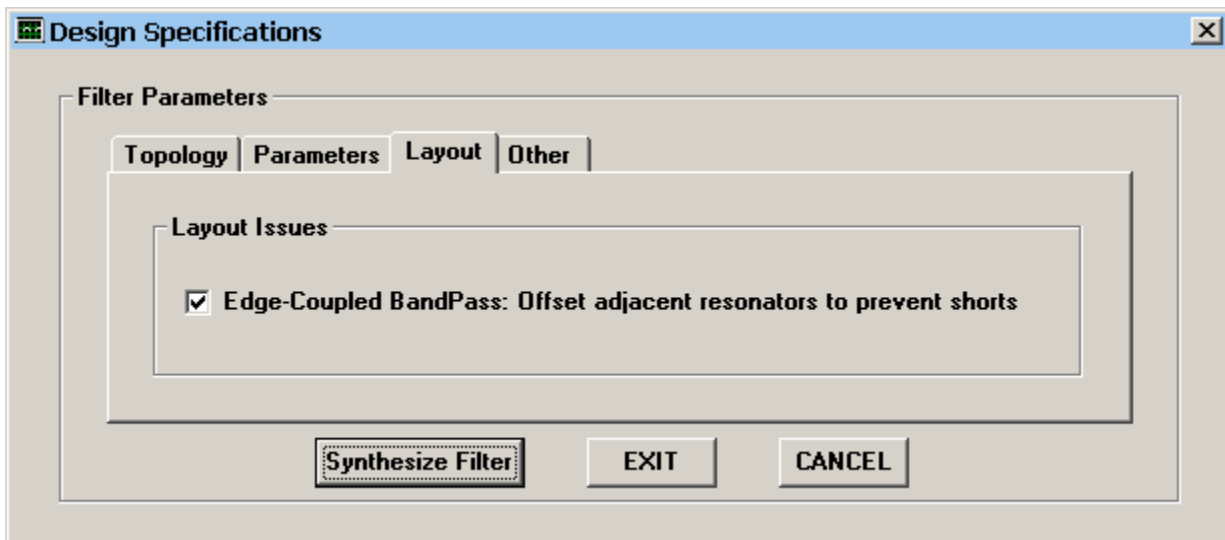

Select **Distributed (Differential)** from the **Filter** menu.

Click **Topology** and Select **Chebyshev Bandpass**.

Design Specifications ☒

Filter Parameters

| Topology | Parameters | Layout | Other |

Transmission Response

○ Lowpass
○ Highpass
◉ Bandpass
○ Bandstop

Shape Function

○ Butterworth
◉ Chebyshev
○ Bessel

[Synthesize Filter]   [EXIT]   [CANCEL]

Click the **Topology** tab and Select **Bandpass** and **Chebyshev**.

Fill in the detailed specifications:

Design Specifications ☒

Filter Parameters

| Topology | Parameters | Layout | Other |

Filter Specifications

Cutoff Frequency, F1	6000	MHz
Cutoff Frequency, F2	6200	MHz
Attenuation at Cutoff	3.0103	dB
Passband Ripple	0.01	dB
Filter Order	3	
Source Impedance	50	Ohms

Click the **Parameters** tab and fill in the filter specifications as shown (**Cutoff F1** = 6000, **Cutoff F2** = 6200, **Passband Ripple** = 0.01, **Filter Order** = 3).

Design Specifications ✕

Filter Parameters

Topology | Parameters | Layout | Other

Layout Issues

☑ Edge-Coupled BandPass: Offset adjacent resonators to prevent shorts

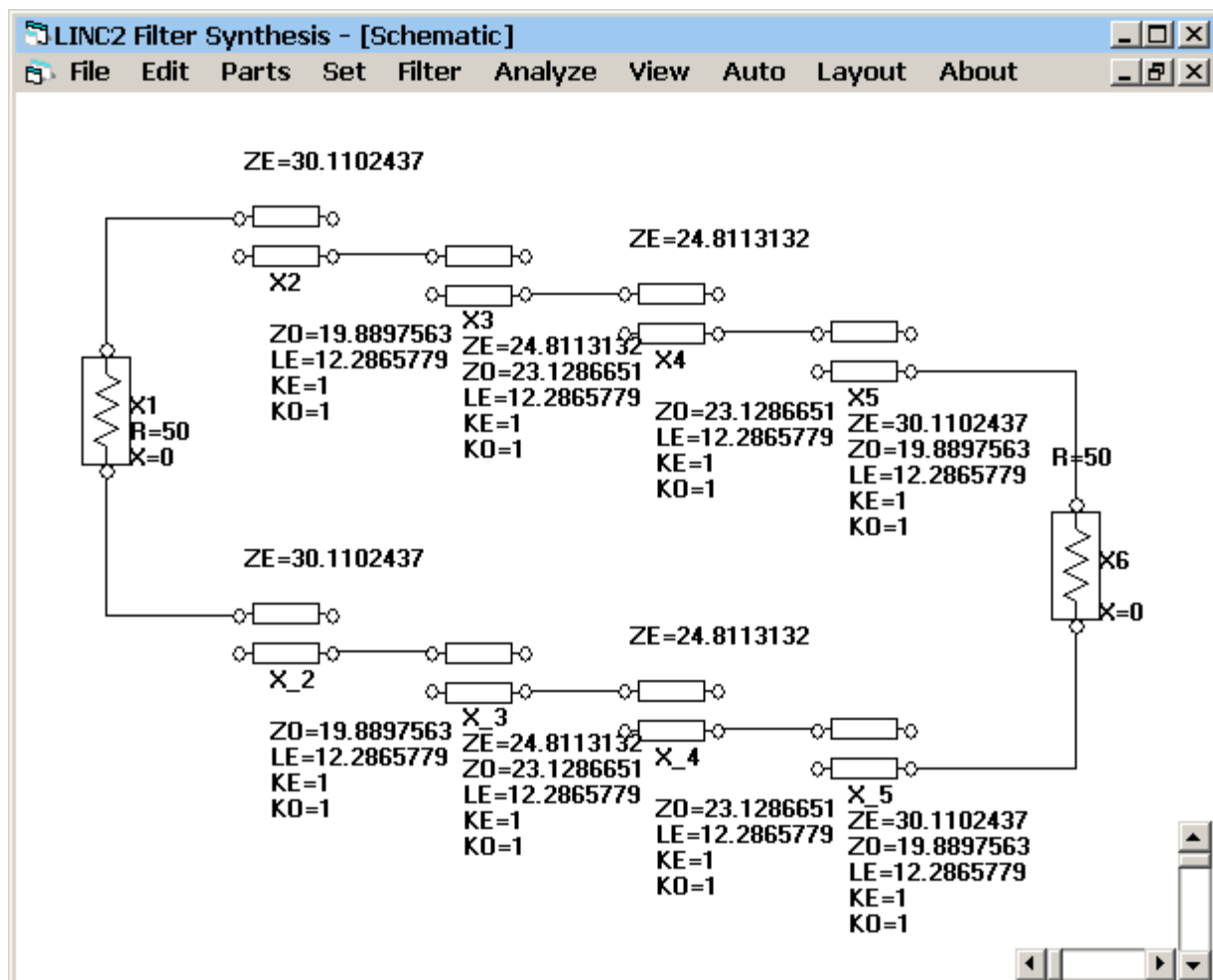Synthesize Filter   EXIT   CANCEL

Click the layout tab to review any layout issues. Make sure that the check box is checked to address the indicated layout issue.

Click the **Synthesize Filter** button and **Exit** to see the filter schematic (below).

LINC2 Filter Synthesis – [Schematic]

File   Edit   Parts   Set   Filter   Analyze   View   Auto   Layout   About

ZE=30.1102437

ZE=24.8113132

X2

X3
ZO=19.8897563 ZE=24.8113132
LE=12.2865779 ZO=23.1286651 X4
KE=1   LE=12.2865779
KO=1   KE=1   ZO=23.1286651 X5
               KO=1   LE=12.2865779 ZE=30.1102437
                               KE=1   ZO=19.8897563 R=50
                               KO=1   LE=12.2865779
                                              KE=1
                                              KO=1

X1
R=50
X=0

ZE=30.1102437

X6
X=0

ZE=24.8113132

X_2

X_3
ZO=19.8897563 ZE=24.8113132
LE=12.2865779 ZO=23.1286651 X_4
KE=1   LE=12.2865779
KO=1   KE=1   ZO=23.1286651 X_5
               KO=1   LE=12.2865779 ZE=30.1102437
                               KE=1   ZO=19.8897563
                               KO=1   LE=12.2865779
                                              KE=1
   KO=1

Click **Auto | Convert T-Lines to…| Stripline** to convert all transmission lines to striplines. Edit the pop-up stripline substrate parameters for **Er = 12.85**, **LT = 0.002** and a **Substrate Height** of **60** (mils) as shown.

Then click **OK** to covert all lines to physical lines (see schematic below).
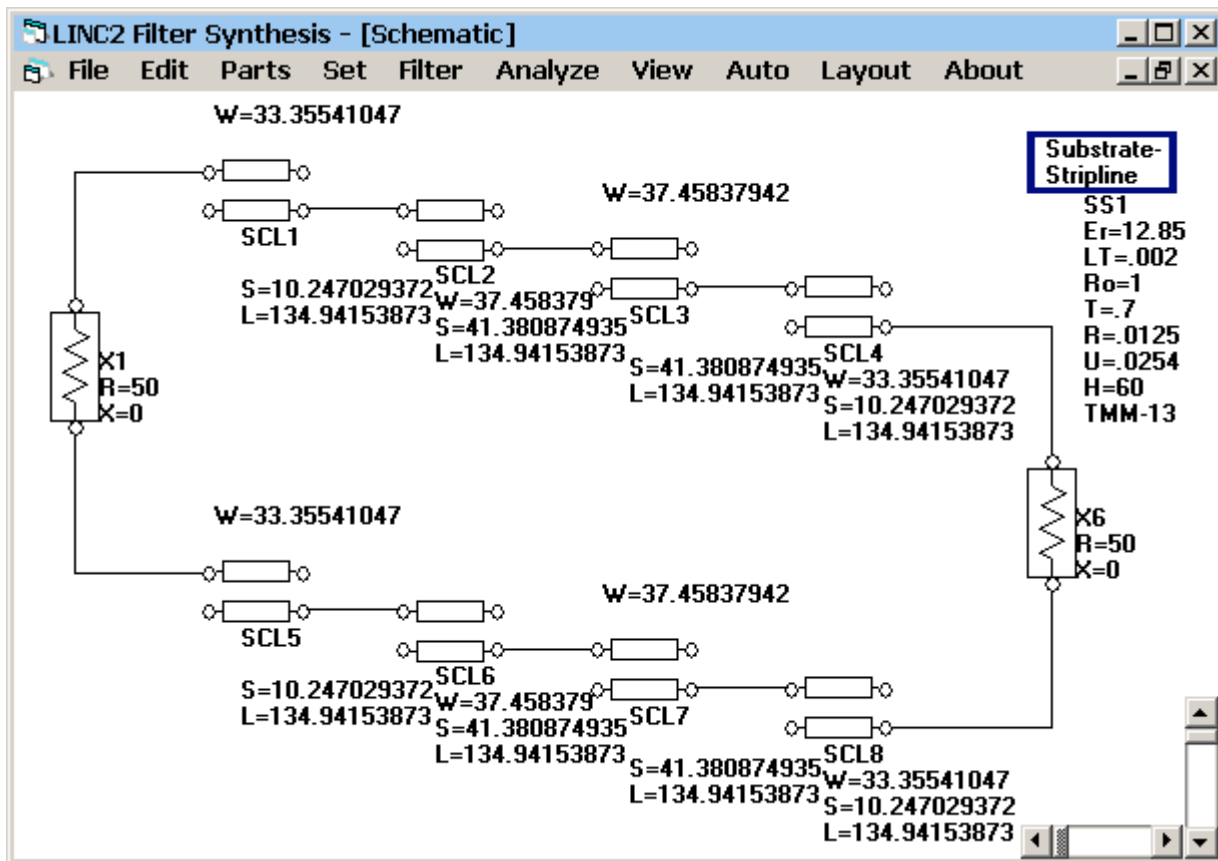
The resulting schematic is converted to all physical T-lines with physical dimensions of length (L), width (W), and gap space (S).

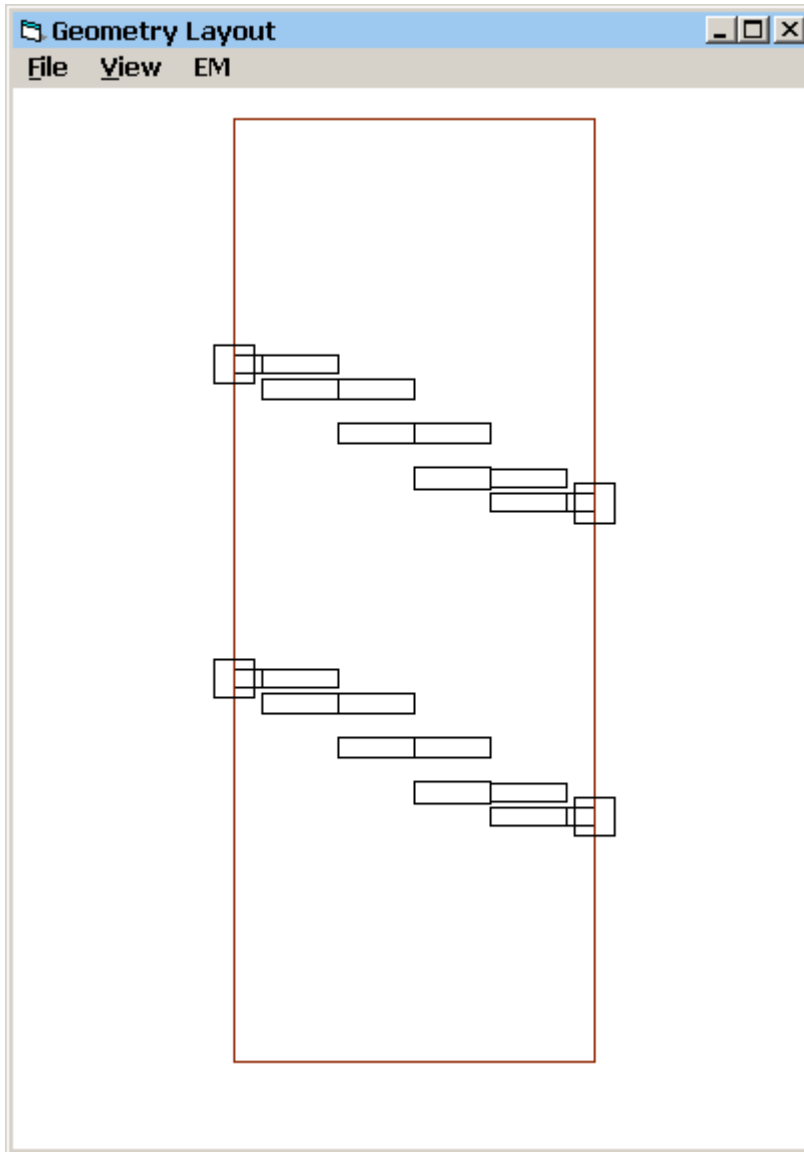Click **Layout** to see the layout geometry (below).
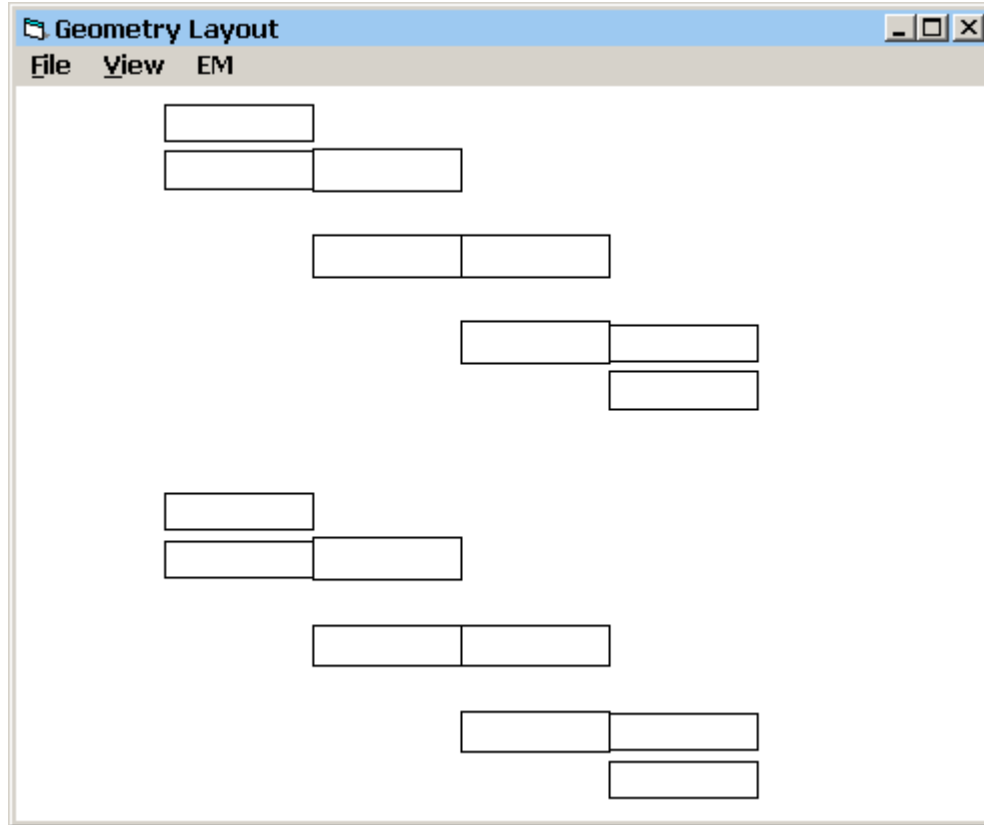
The LINC2 FILTER Geometry Layout

For this example, change the default de-embedding length from 150 mils to 50 mils by selecting **De-embed Length** from the EM menu as shown below. Enter 50 and click OK.
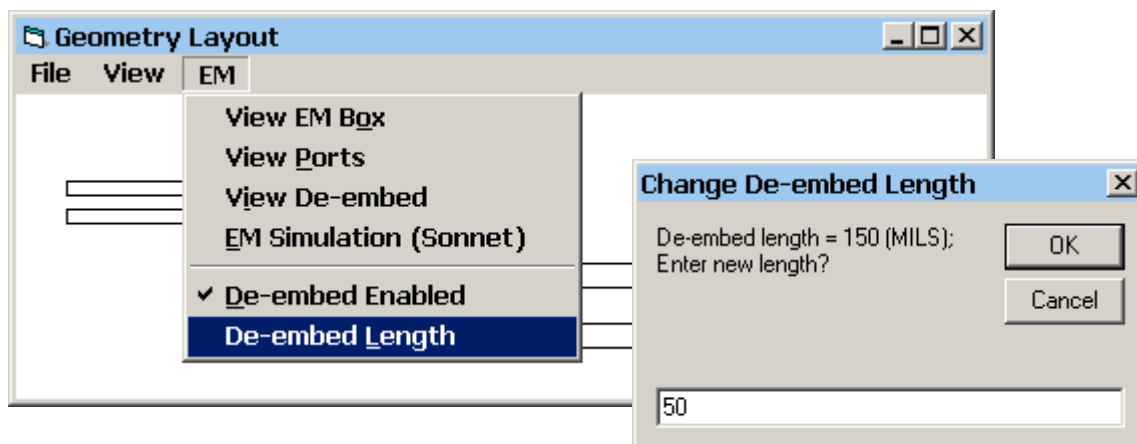
Click **EM | View De-embed** to see the EM simulation box, balanced ports and de-embedding at each port as shown below.

**The LINC2 FILTER Geometry Layout with EM box, ports and de-embedding**

The pair of square boxes drawn at the vertical sides of the EM box represent each port location. These are pairs of differential (or balanced) ports.

The differential port numbers will be correctly exported to the Sonnet ® EM simulator as Port 1/-1 and Port 2/-2.

To run the EM simulation, select **EM Simulation (Sonnet)** from the EM menu.

When EM Simulation (Sonnet) is selected, the file EMTest.SON is created and automatically exported to the Sonnet® xgeom project editor ready for analysis. The EM box, metal and substrate layers and frequency parameters are already loaded. LINC2 automatically calculates the internal cell size and external dimensions of the EM analysis box.

The layout in Sonnet® is shown below. Notice the black arrows pointing inward from each port. These represent 50 mil de-embedding traces (as previous entered from the De-embed Length menu).
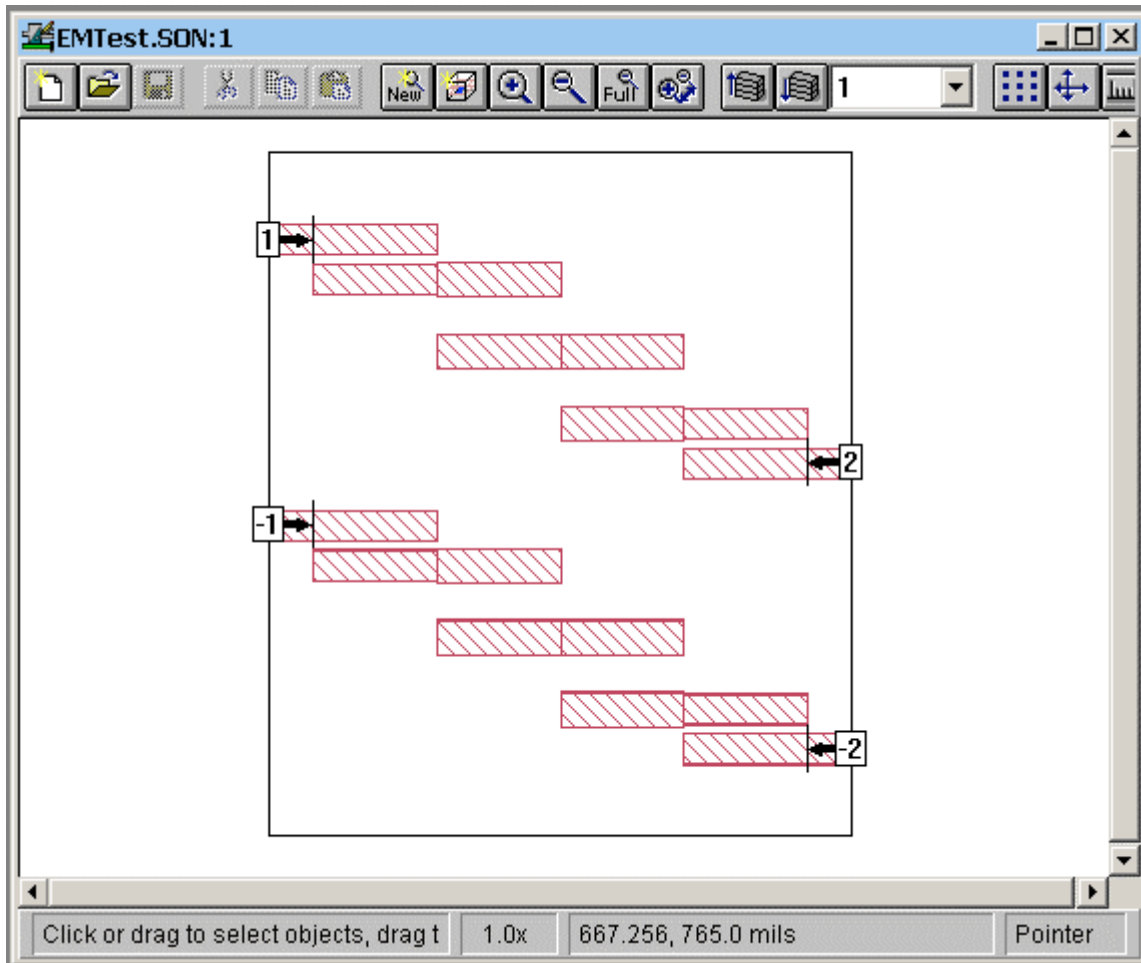
The LINC2 differential bandpass filter design exported to Sonnet xgeom

Select **Analyze** from the Sonnet® project menu to run the simulation. When the simulation is complete, select **Project | View Response | New Graph** to get the response plots shown below.
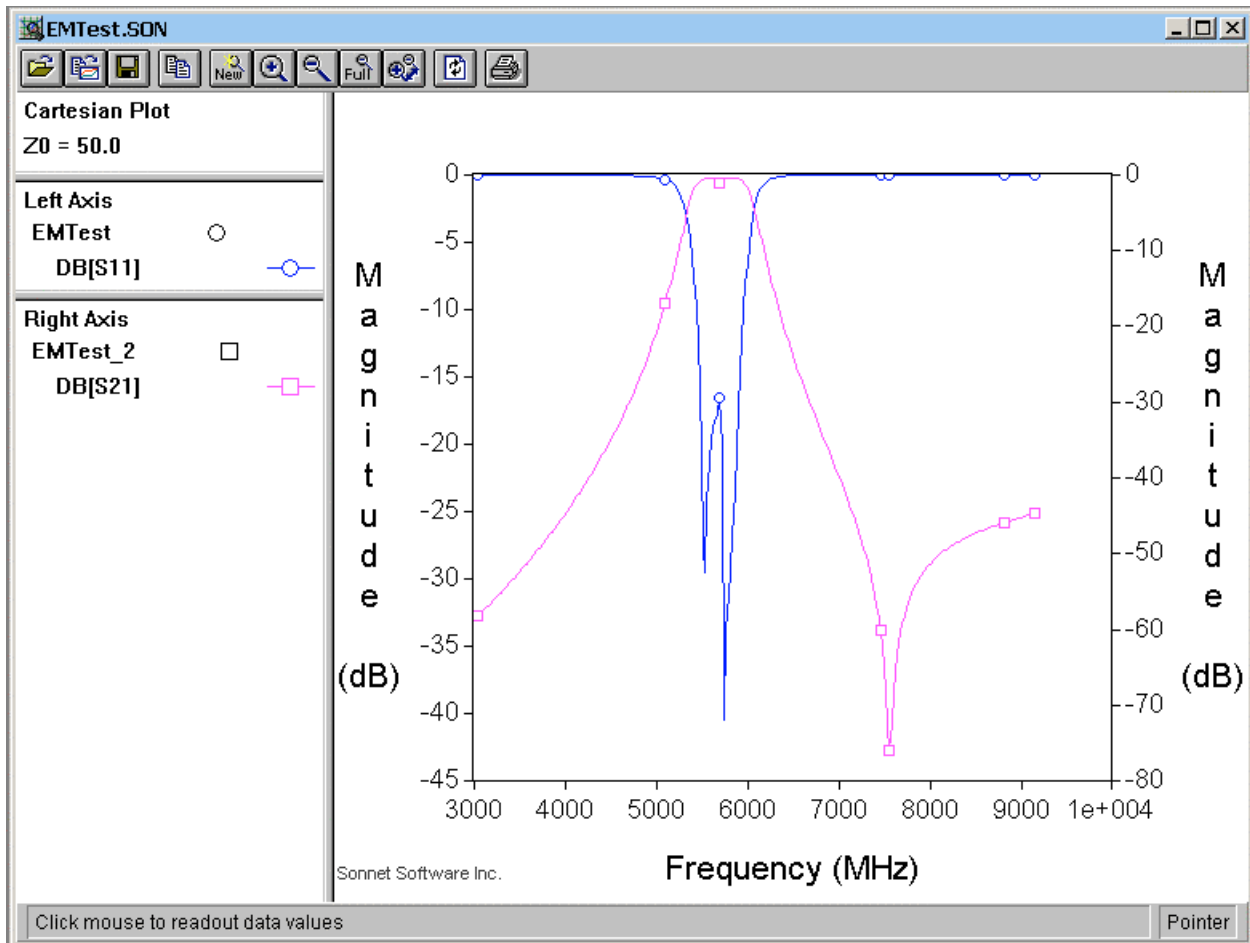
Sonnet EM simulation of the 3rd order differential bandpass filter

The plot of S21 shows that the filter has the correct bandpass response. The pass band extends from abut 5.5 GHz to 6 GHz. From EM analysis we can see that the filter has widened and shifted slightly lower in frequency than the target specification.

Optional:

Click **View | View 3D** from the Sonnet xgeom **View** menu to see the 3-D physical layout (right).
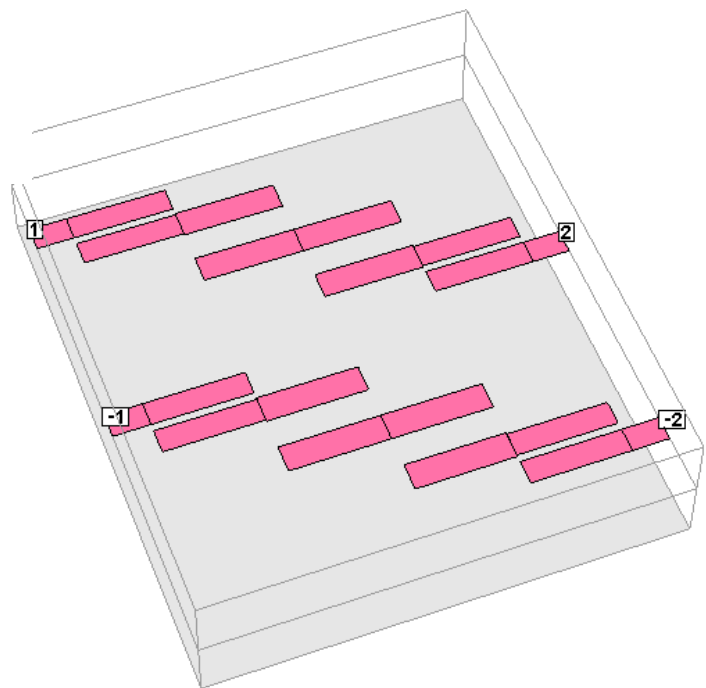
Optional:

It is interesting to compare the EM simulation results with the electrical (circuit theory) simulation results from the ideal synthesized schematic.

Click **Analyze** and **View | Plot** from the LINC2 filter schematic menu bar to see the differential 3rd order distributed Chebyshev bandpass filter's frequency response as synthesized (below, before EM geometry simulation):
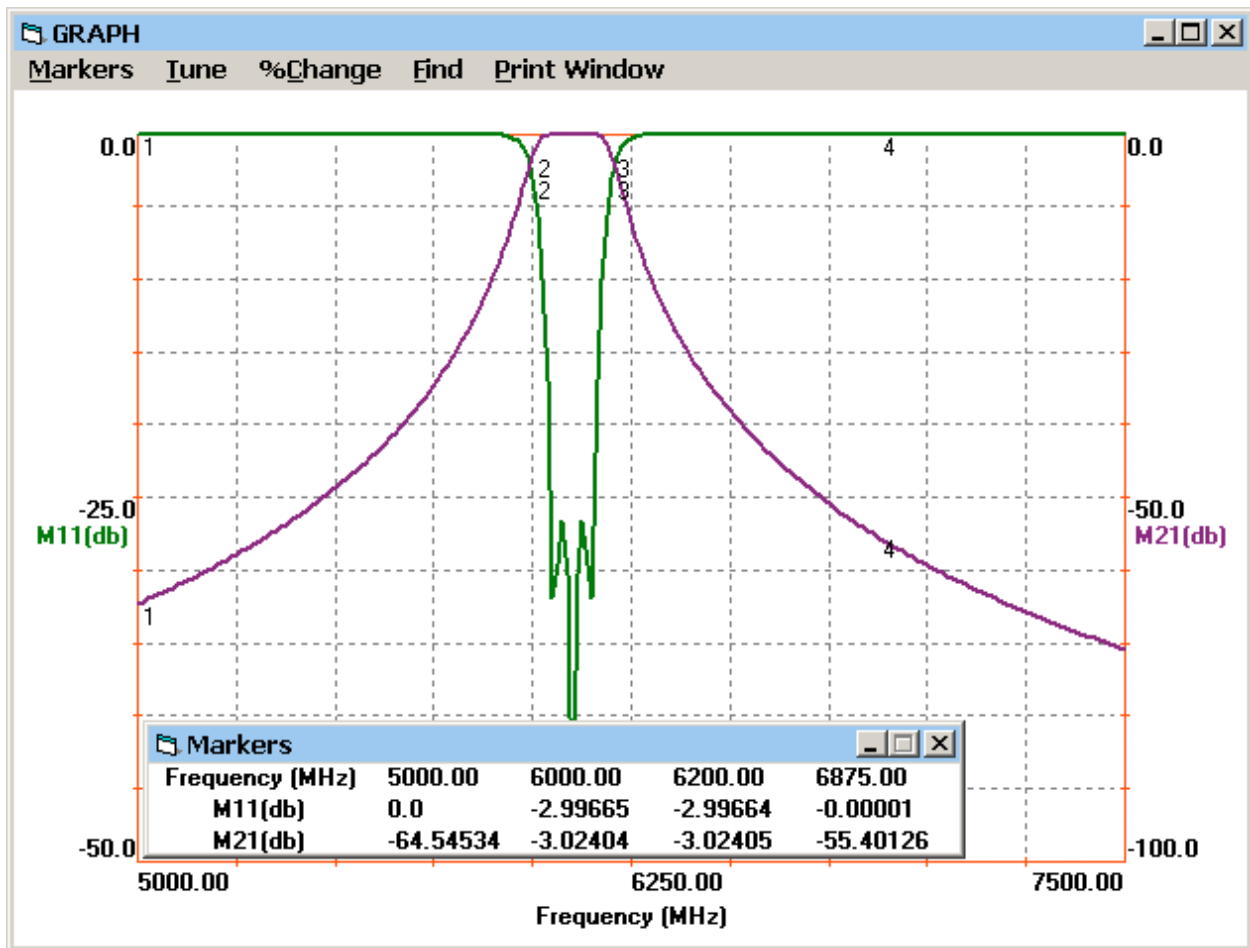
LINC2 synthesized filter response using ideal physical (stripline) coupled line models

The downshift in the frequency response seen in the EM simulation can easily be compensated for by re-running the LINC2 synthesis again with a new frequency specification that is higher by approximately the same amount.

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