

# Comblin filter design simplified

Designing microstrip bandpass filters at low frequencies (200 MHz to 1 GHz) provides sufficient rejection on close out-of-band frequencies and also keeps the size of the filter small. But it is normally a difficult proposition to achieve. This problem can be overcome by designing comblin bandpass filters in these frequency ranges.

By Anurag Bhargava

The range of filters that can be used in 200 MHz to 1 GHz band is limited, and this range becomes even narrower if a sharp rejection profile is needed. Filters that can be designed in this frequency range are lumped element filter, SAW filter, helical filter, interdigital filters and comblin filters. The lumped-element filter will not be a good choice if a sharp rejection is needed because of component's 'Q' limitation. Helical filters are the best, as they provide excellent rejection profile in this range but suffer from big size, assembly and tuning problems.

Surface acoustic wave (SAW) filters provides excellent performance. Their only shortcoming is that they are lossy. Interdigital filters also occupy relatively big space and provide moderate rejection profile.

If the moderate rejection profile is needed, then comblin bandpass filters can prove to be a good choice as each resonator is  $\lambda/8$  long and it is directly terminated to ground from one side. And on the other end, sections are grounded using a capacitor. Choosing proper capacitor value can keep the length of the resonator sections relatively small.

## Comblin filter topology

The typical comblin filter schematic in Microstrip form is shown in Figure 1. The resonators in this type of filter consist of quasi transverse electromagnetic (TEM)-mode transmission lines that are short-circuited at one end and have a lumped capacitance  $C_0$  between the other end of each resonator line element and ground.

Coupling between resonators is achieved in this type of filter by way of fringing fields between the resonator lines. If the resonator sections are  $\lambda/8$  long at the primary passband ( $f_0$ ), then the second passband will be centered on  $4f_0$ . If the resonator line elements are made to be less than  $\lambda/8$  at the primary passband, the second passband will be even further removed from the primary passband.

Another property of this filter is that, in theory, the attenuation through the filter will be infinite at the frequency for which the resonator lines are  $\lambda/4$  long. Because of this property, the attenuation above the primary passband will be high and, depending on what electrical length the resonator has at the passband center, the rate of cutoff on the upper sideband can be made unusually steep. (The closer to  $\lambda/4$  long the resonators are at the passband center, the steeper the rate of cutoff will be above passband.)

We see that comblin filters have the following attractive features:

- (a) They are compact.
- (b) They have strong stop-bands, and the stop-bands above the primary passband can be made to be strong.
- (c) If desired, they can be designed to have an unusually steep rate of cutoff on the high side of the passband.

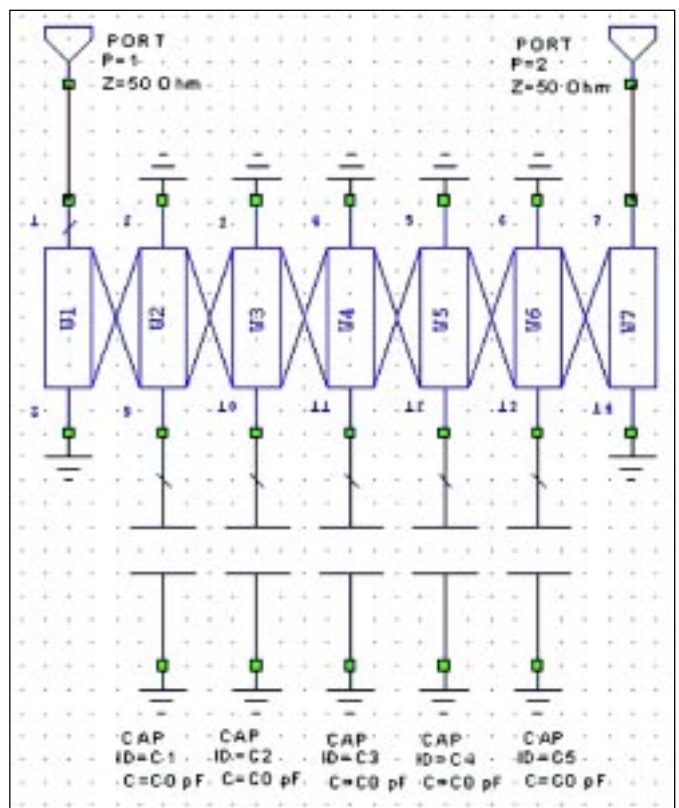


Figure 1. Typical comblin filter.

(d) Adequate coupling can be maintained between resonator elements with sizeable spacings between resonator lines. (This feature means that the proper coupling can be maintained in manufactured filters without unreasonable production tolerance requirements.)

(e) Filters of this type can usually be fabricated without dielectric support materials so that, if desired, dielectric losses can be eliminated.

## Simulation-oriented synthesis of comblin bandpass filter

The aim for the bandpass filter to be designed was a center frequency of 500 MHz. Rejection was sought at 250 MHz and should be better than 40 dB and a minimum of 20 dB at 600 MHz.

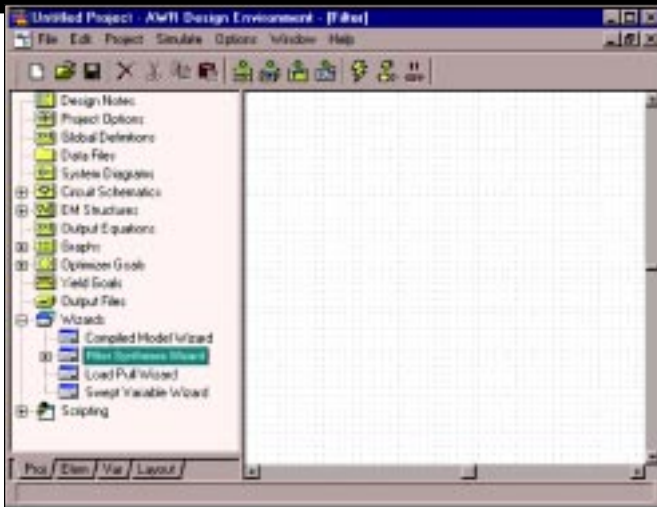


Figure 2. Microwave office window.

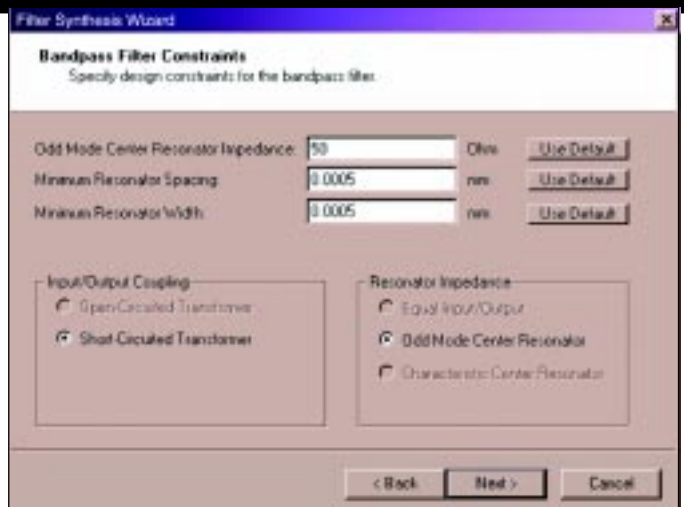


Figure 5. Filter constraint window.

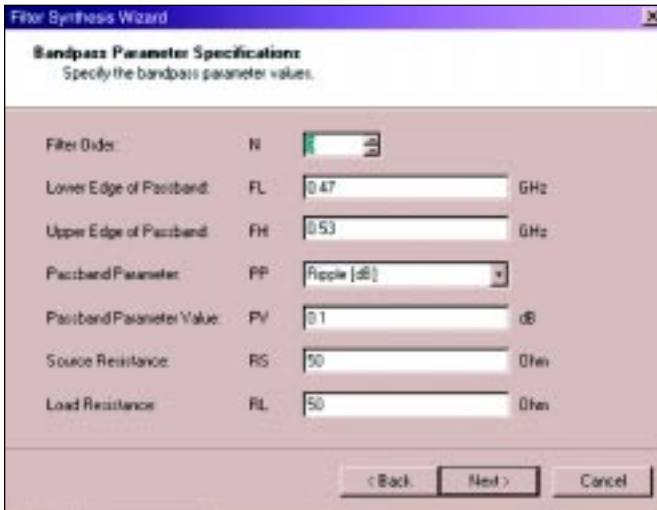


Figure 3. Bandpass parameter specification window.

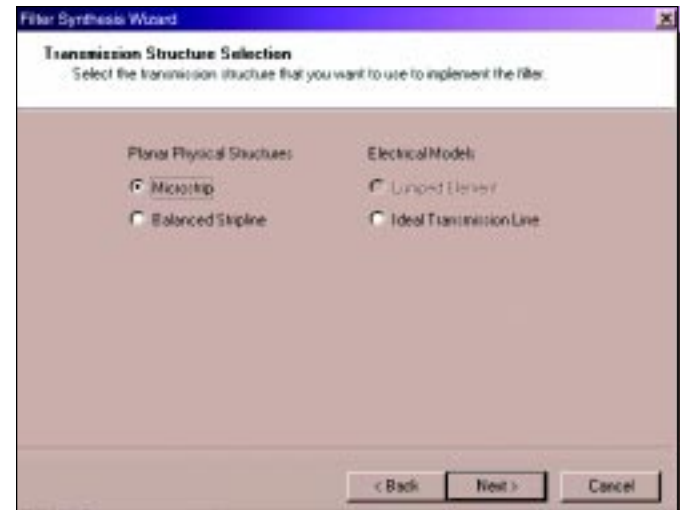


Figure 6. Transmission structure selection.

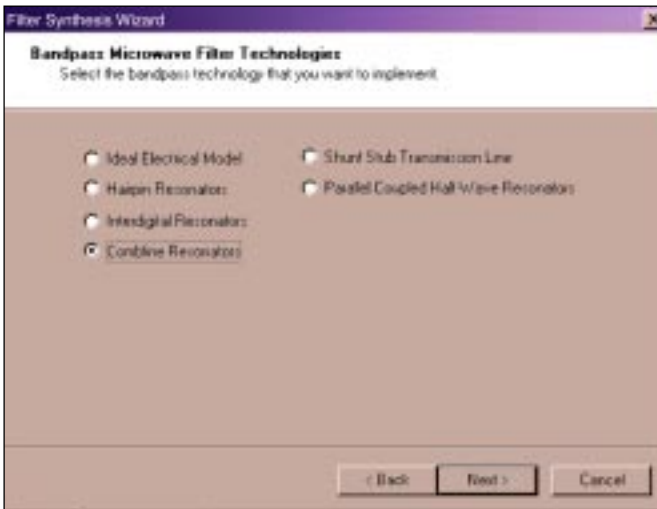


Figure 4. Bandpass filter type selection.

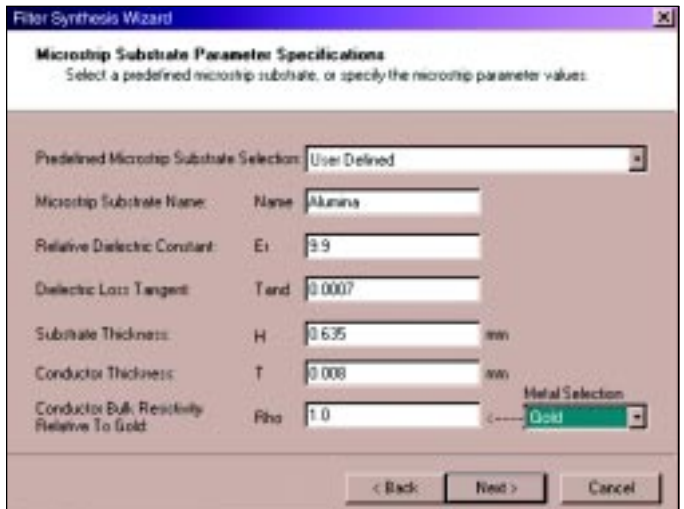


Figure 7. Microstrip substrate parameter specification.

The design for the combline bandpass filter can be initiated by selecting Filter Synthesis Wizard available in Microwave Office 2002 format.

The transmission response can be selected viz., lowpass, bandpass, etc. Additionally, the approximation to be used for synthesizing filter

must be selected viz., Butterworth, Chebyshev, etc.

The specifications sought from the filter should now be entered in the pop-up window as in Figure 3.

For the present requirement, a third-order Chebyshev bandpass filter needs to be designed and passband edges are selected as 470

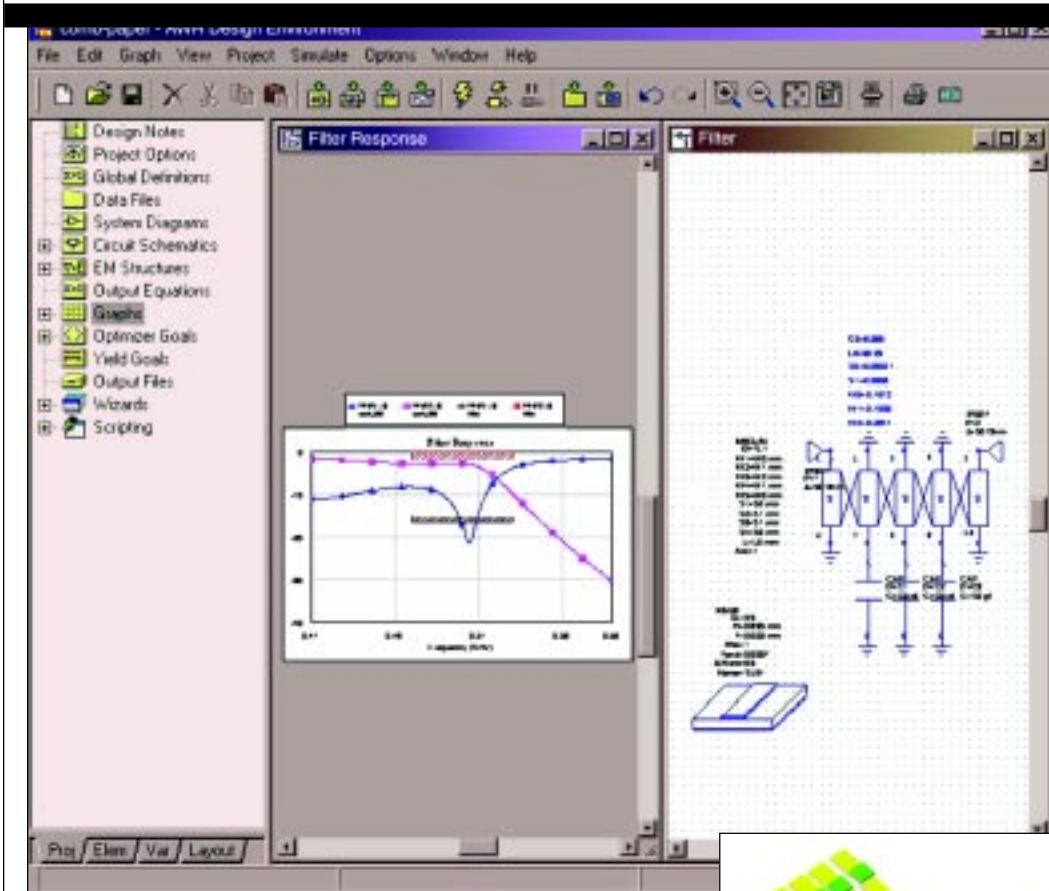


Figure 8. Initial synthesized 500 MHz combline bandpass filter.

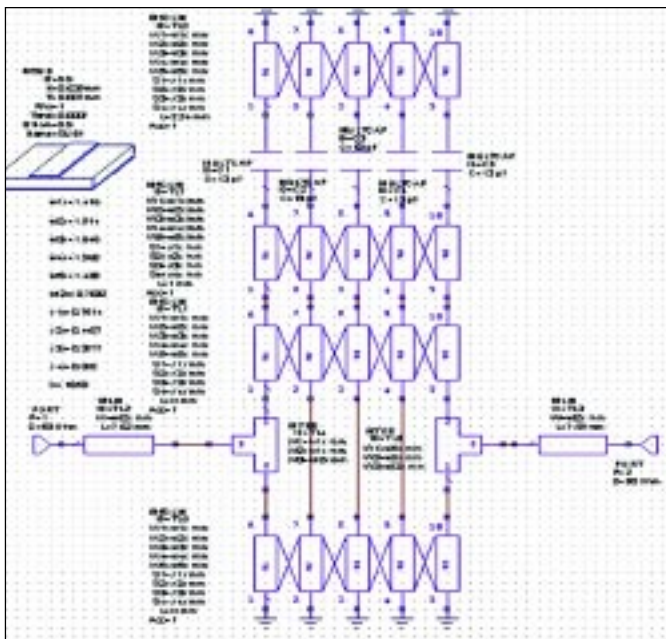


Figure 9. Re-organized combline bandpass filter.

MHz and 530 MHz. The passband parameter is selected as ripple, and 0.1 dB of ripple was entered with source and load resistance kept as 50 ohms.

Now, after entering the synthesis parameters, the bandpass filter technology should be chosen as shown in Figure 4. The options available are ideal electrical model, hairpin, interdigital, combline resonator etc. The type selected here was combline resonator.

Bandpass filter constraints can now be entered as in Figure 5 to set

odd-mode center resonator impedance, minimum resonator spacing, minimum resonator width, etc.

A transmission structure should be selected such as microstrip or balanced stripline as shown in Figure 6.

Finally, microstrip substrate parameters specification should be entered as per user requirement. The substrate parameter window is shown in Figure 7.

After completing all the above-mentioned steps, the initial filter schematic and filter response looks like Figure 8.

The length of the synthesized bandpass filter is achieved as 30.2 mm, excluding capacitor size. One of the primary concerns was to accommodate this filter in a 1x1" substrate, so the filter schematic was manually reorganized to fit in the specified substrate size.

The coupled lines structure was split into two parts and mounting pads for capacitors were included to account for their effect. The length of new coupled line sections was kept as 10.58 mm and capacitor value and spacing of the resonator lines was optimized for the return loss and insertion loss. The re-organized filter can be seen in Figure 9. It can be seen that the new value of the capacitors is now

13 pF against 6.36 pF

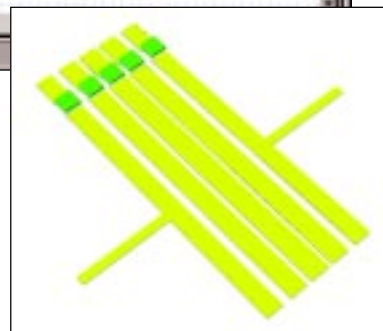


Figure 10. 3-D view of simulated 500 MHz combline bandpass filter.

synthesized earlier. DLI capacitors were chosen for the simulation purposes.

### Simulation vs. measured results

Simulated and measured results for the designed filter are shown in Figure 11 and Figure 12, respectively.

The simulated and measured results are included in the same graph in Figure 13 for the comparison purposes, and they show good agreement between them. RFD

### Acknowledgement

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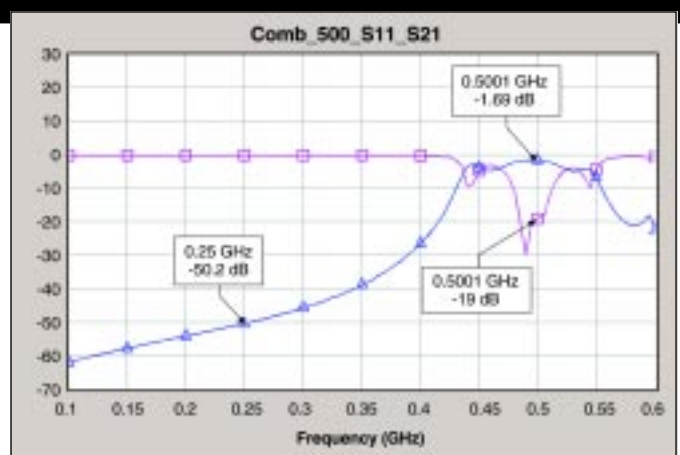


Figure 11. Simulated results for 500 MHz bandpass filter.

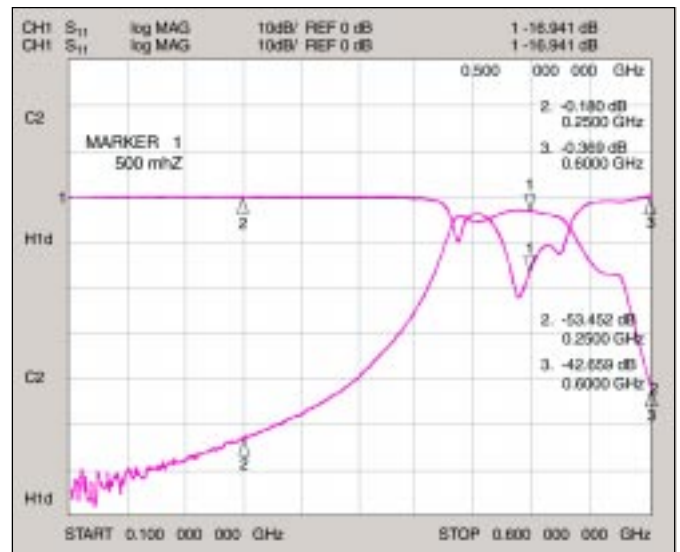


Figure 12. Measured results for 500 MHz bandpass filter.

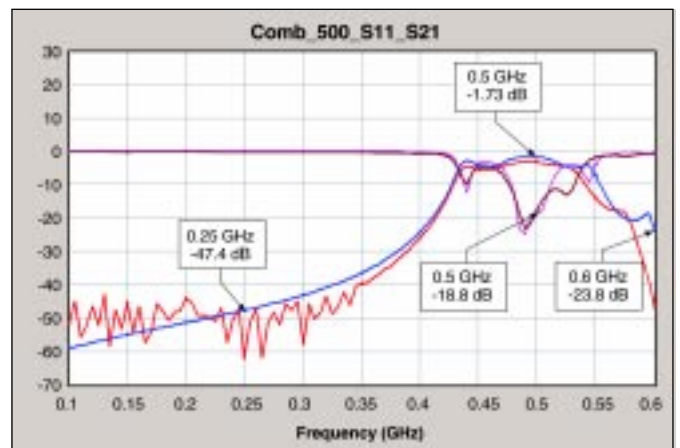


Figure 13. Simulated and measured results for 500 MHz bandpass filter (red curve shows the measured insertion loss of the filter.)

Sci./Engr.-SE for their support, guidance and interest shown in the mentioned circuit design and development.

**References:**

- 1).Matthaei, George. L., "Comblne Bandpass filters of narrow or moderate bandwidth," The Microwave Journal, 1963.
- 2).Cohn, S.B, "Direct Coupled Resonator Filters," Proc. IRE 45, pp 187-189 (February 1957).

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