

## Part 2 – Designing Comblin Filters with Free Software

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Comblin filters have more variables than most other filter types, so design software is more complicated. For instance, interdigital filters have resonators that are  $\frac{1}{4}$  wavelength long, and waveguide filters have resonant cavities that are  $\frac{1}{2}$  wavelength long, coupled by posts or irises. The design software must find dimensions for the desired coupling factors, either the resonator spacing, or the post or iris size. But comblin filters have capacitively tuned resonators of any length, as long as it is less than a quarter-wavelength. The coupling is a function of the resonator length and shape as well as spacing; typical shapes are flat striplines, round rods, or rectangular rods. Thus, there are at least two more variables to contend with.

The free software I use to design comblin filters is **Ansoft Designer SV** (Student Version). The software is no longer available, and Ansoft has been acquired by Ansys, but many CDs of the software were given out at various VHF and MUD conferences a few years ago. If you don't have a copy somewhere, another nearby VHFer probably does.

The useful feature of the **Designer** software is a Filter Design Wizard. The Wizard is found by pulling down the **Project** tab and clicking **Insert Filter Design**, as shown in Figure 1.

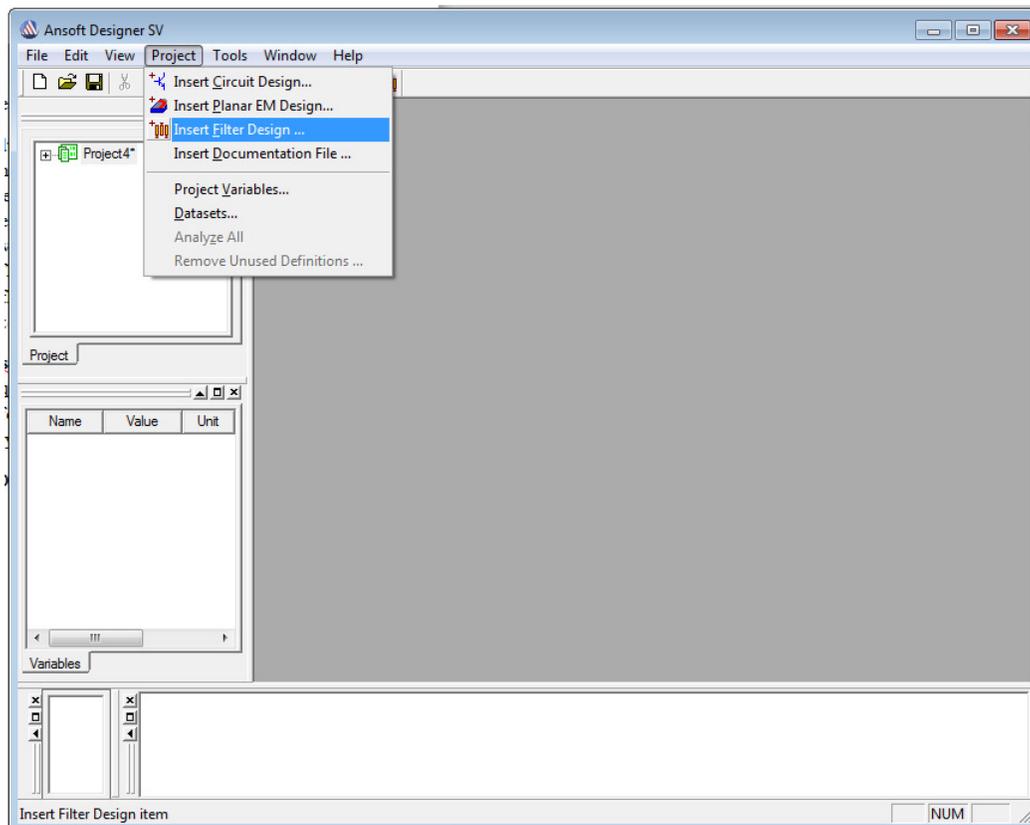
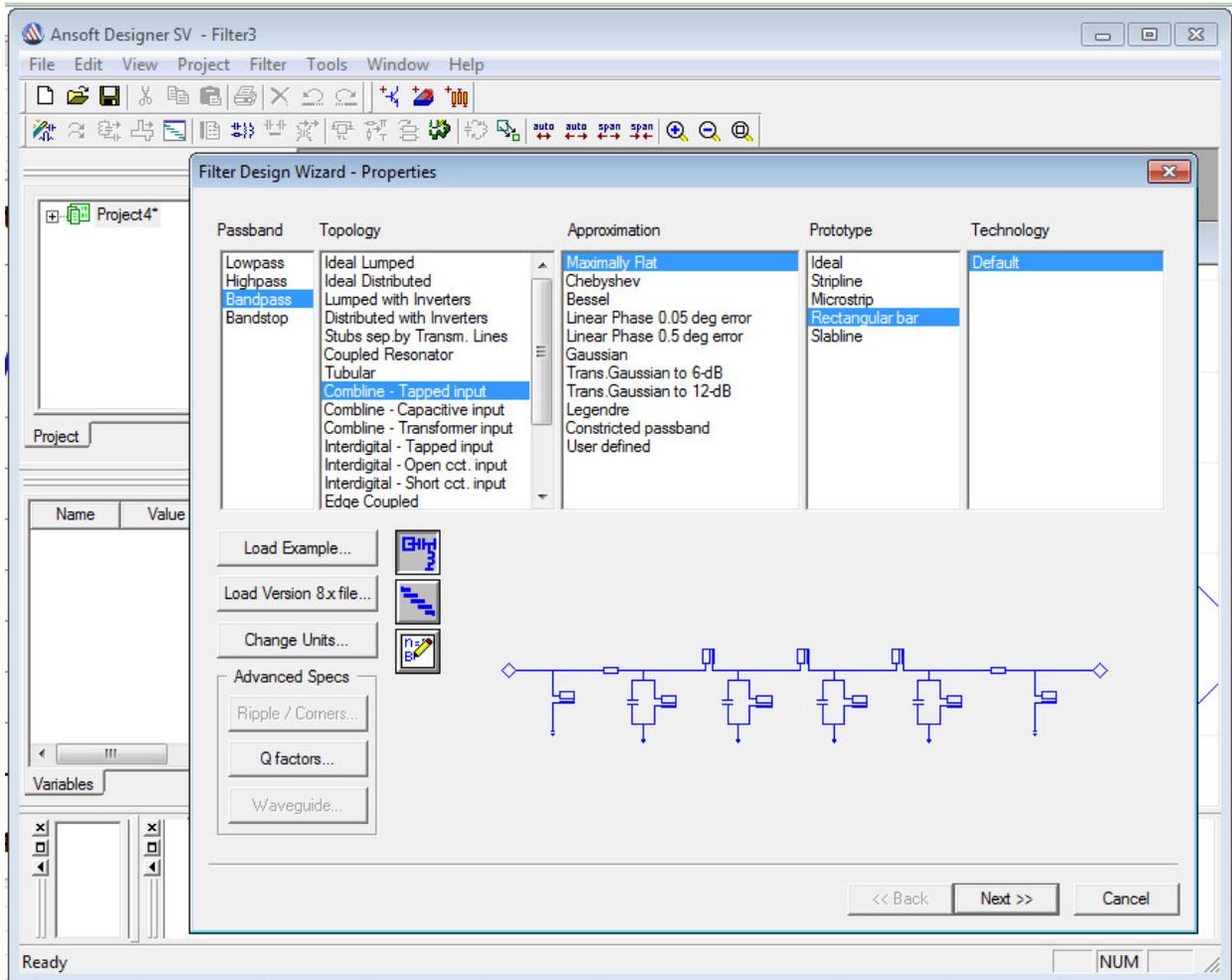


Figure 1 – Starting the Filter Design Wizard in Ansoft Designer SV

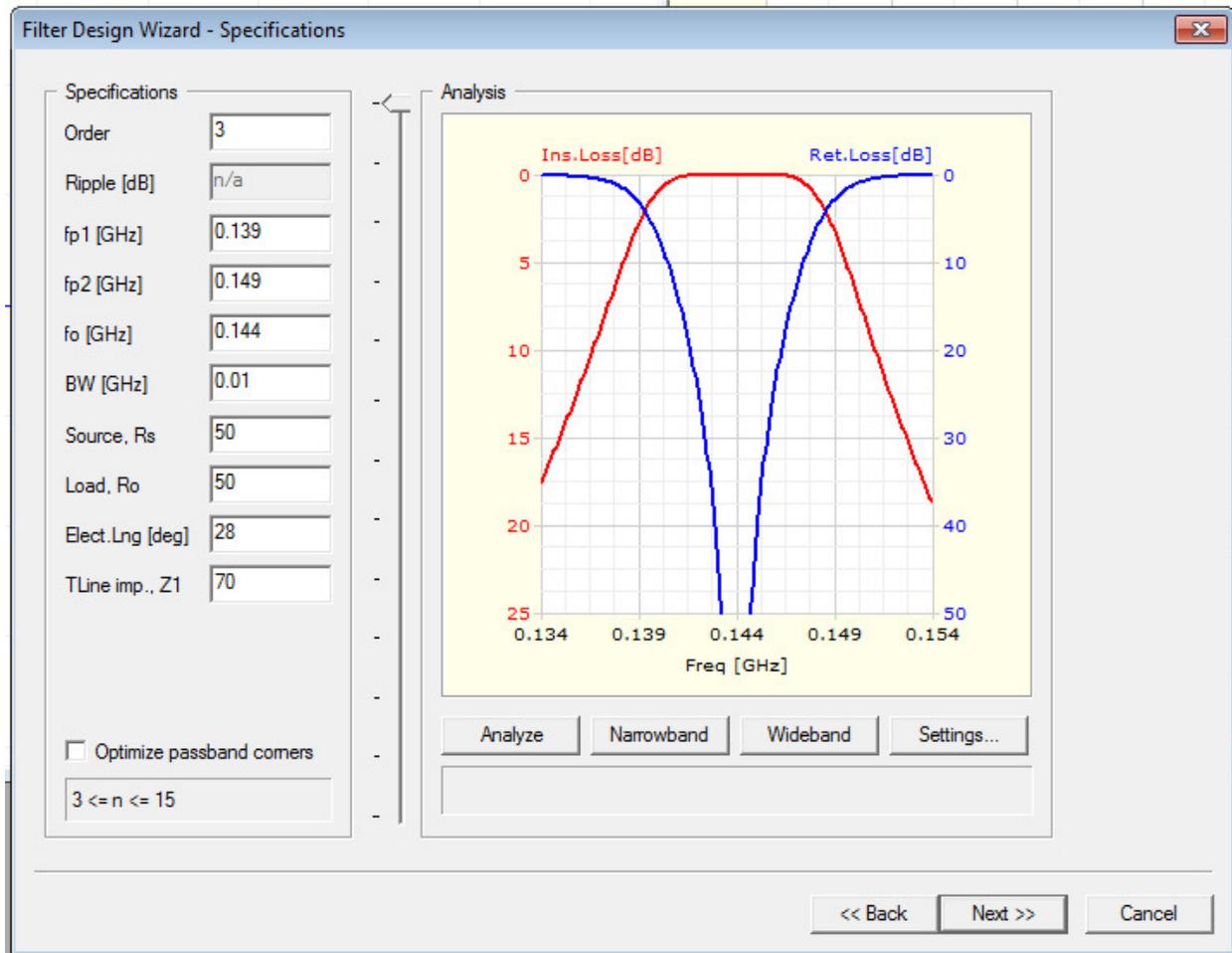
The Filter Design Wizard starts with a **Properties** screen, Figure 2, where we select the filter type, in this case, **Bandpass, Comblne – Tapped input, Maximally Flat, Rectangular bar**. A flat stripline is a very thin rectangular bar – for me, this works better than the **Stripline** choice. You could choose a **Chebyshev** approximation, but for simple ham filters, the dimension are hardly different than **Maximally Flat**.



**Figure 2 – Selection of Properties for a Comblne Filter with Tapped Input**

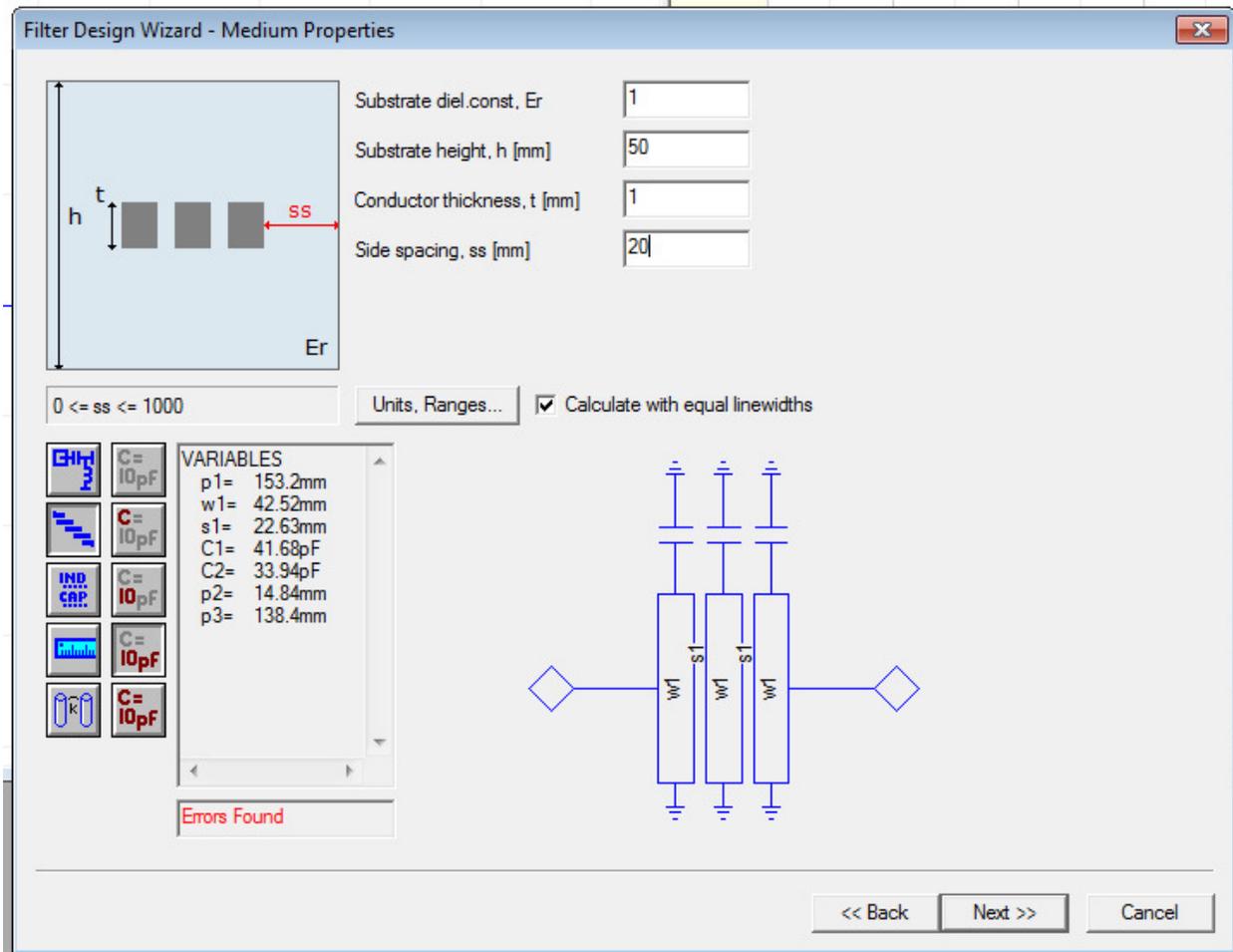
Once these selections are made, click **Next** for the next screen, shown in Figure 3. Here we select our filter specifications: I chose **Order = 3**, for three resonators, a center frequency **fo = 0.144 GHz** for two meters, **BW = 0.01 GHz** for 10 MHz bandwidth. The last two items are starting guesses – the resonator is about 6 inches long in a 7 inch wide box, so **Elect. Lng (deg) = 28**, and **Tline imp. Z1 = 70** ohms, a convenient starting impedance.

The **Analysis** graph on the right side is a performance estimate, with a choice of **Narrowband** or **Wideband** view. The curve will change as specifications are changed.



**Figure 3 - Selection of Specifications for a Comblin Filter with Tapped Input**

After making the specification selections, click **Next** for the next screen, shown in Figure 4. This screen, called **Medium Properties**, gives the physical dimensions. The first step is to fill in the dimensions that we control, at the top. **Substrate diel. Constant,  $\epsilon_r = 1$**  for air. The **Substrate height,  $h$  (mm)** is the height of the box as shown in the sketch on the left – 50 mm in this example. The **Conductor thickness,  $t$  (mm)** is the thickness of the striplines, 1 mm in this example. The **Side spacing,  $ss$  (mm)** is the distance from the edge of the striplines to the side wall of the box. Finally, I check **Calculate with equal linewidths** – the usual filter has a wider center strip, but this just adds a complication when we go to fit the filter in a box.



**Figure 4 – Physical Dimensions of Combine Filter initial guess**

The Filter Design Wizard now displays a set of **VARIABLES**, the dimensions it has calculated:

- **P1** – the length of the center stripline
- **W1** – the width of the striplines
- **S1** – the spacing between the striplines, edge to edge
- **C1** – tuning capacitance needed on the end striplines
- **C2** – tuning capacitance needed on the center stripline
- **P2** – distance from ground to the input tap point – *this is wrong!*
- **P3** – length of end striplines above the tap point

Note the **Errors Found** warning at the bottom; at this point, it doesn't matter since we must change the specifications to fit the filter in the box.

To fit the filter in the box, the width, **W1**, of the three striplines plus the spacings, **S1**, between them plus the side spacings, **ss**, must add up to the length of the box:

$$\text{Box length} = 3 * W1 + 2 * S1 + 2 * ss$$

Click **Back** to return to the **Specifications** screen. The specifications we can change are the **Tline imp. Z1**, which sets the stripline width, **W1**, and the bandwidth, **BW**, which affects the stripline spacing, **S1**. A wider bandwidth requires closer stripline spacing, so we can make small changes in the bandwidth specification to fine-tune the spacing. The side spacings, **ss**, can be whatever is needed to reach a coax connector without too much inductance. Finally, if the stripline length, **P1**, does not match the physical space available, **Elect. Lng (deg)** must be adjusted to change the length.

Figure 5 shows the **Specifications** screen after adjusting the specifications.

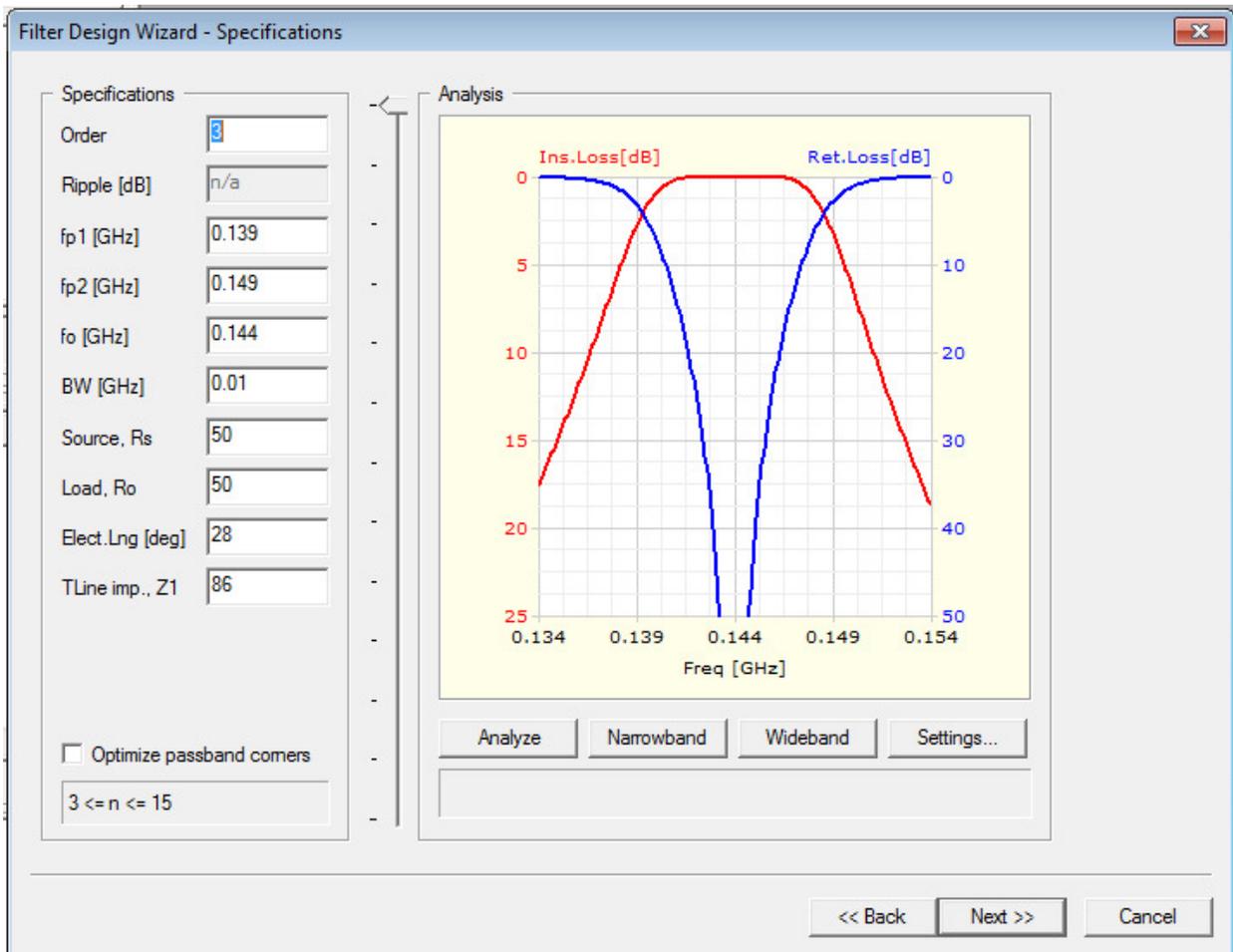
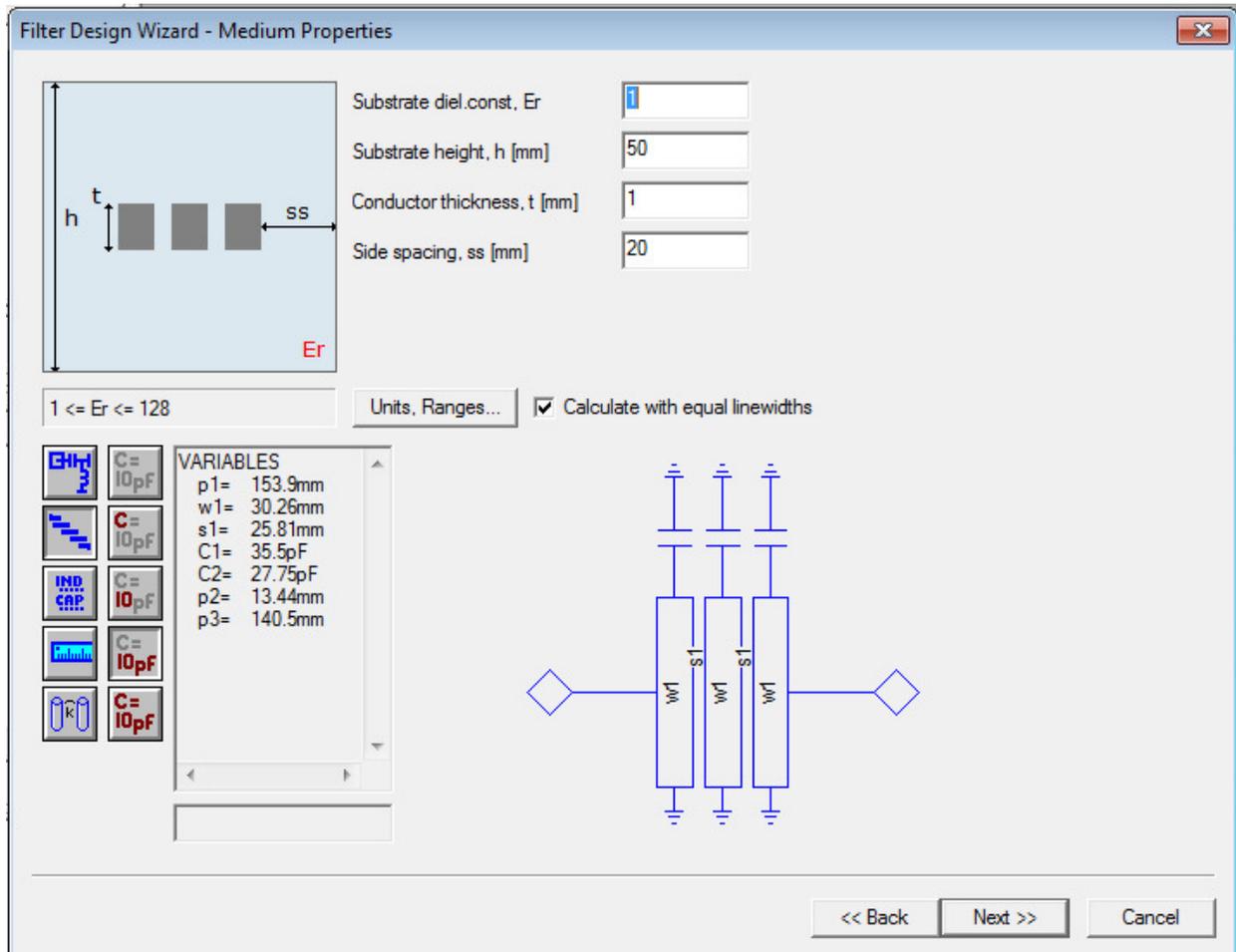


Figure 5 – Adjusted Specifications for Compline Filter

Then we click **Next** for the next screen, Figure 6, to see the results of our changes. Since we increased the **Tline imp. Z1**, the stripline width, **W1**, is narrower. The spacing, **S1**, has also increased slightly. Now we do the arithmetic again, going back and forth between specifications and dimensions until we have results we like. Keeping track of the changes and results will help. Take a screenshot of the final dimensions so you have a record.



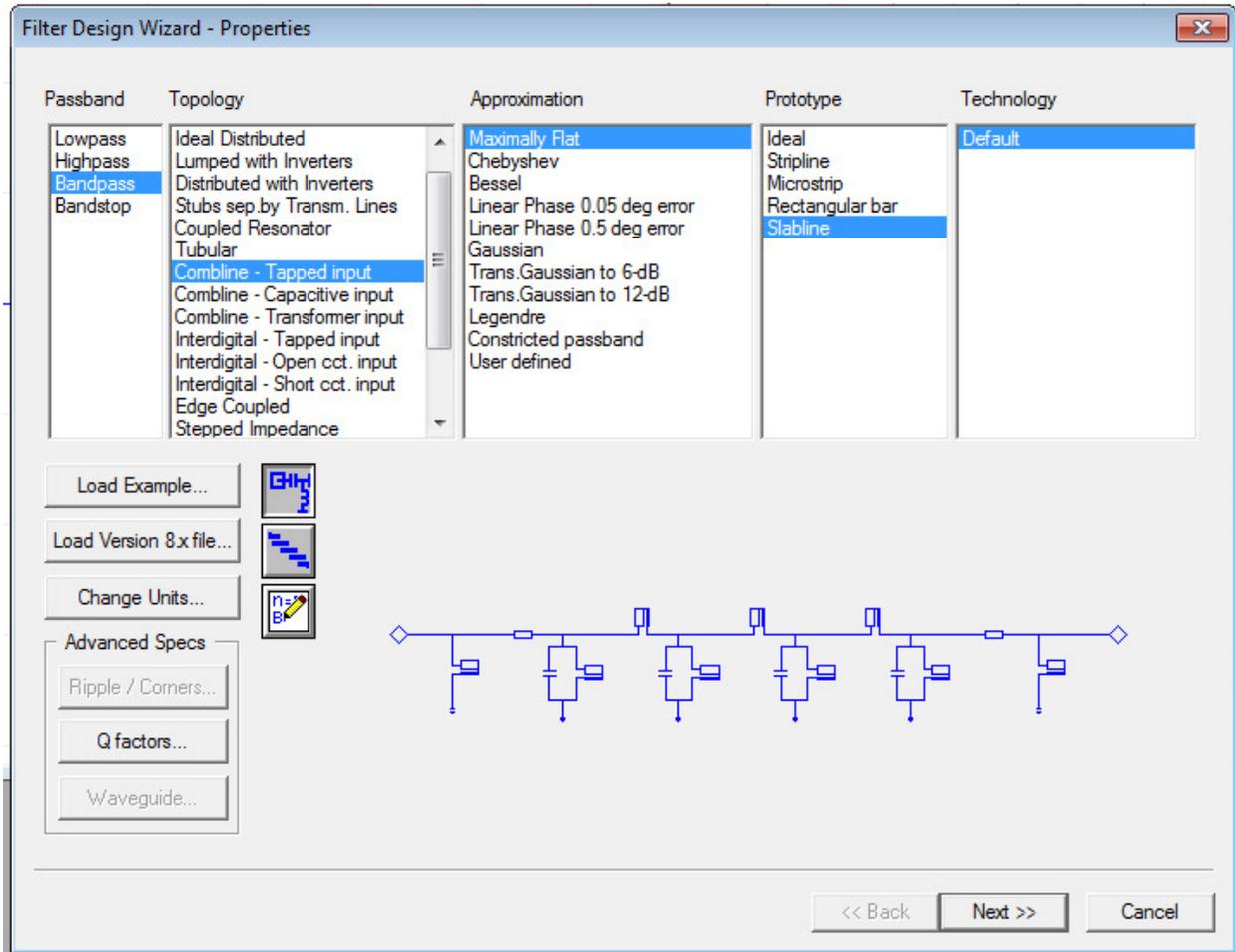
**Figure 6 – Physical Dimensions of Combind Filter after Adjustment**

## Input Tap Point

As was pointed out earlier, the Filter Design Wizard gets the input tap point, **P2**, wrong. However, if we use the **INTFIL** program ([www.w1ghz.org/filter/INTFIL.EXE](http://www.w1ghz.org/filter/INTFIL.EXE)) to calculate the tap point for an interdigital filter with the same center frequency, bandwidth, and Tline impedance, it will be pretty close. Adding a couple of extra holes a few mm apart in the end striplines to allow movement of the tap point might be good for fine adjustments – small holes will not affect performance. All three striplines should have the same overall length, **P1**.

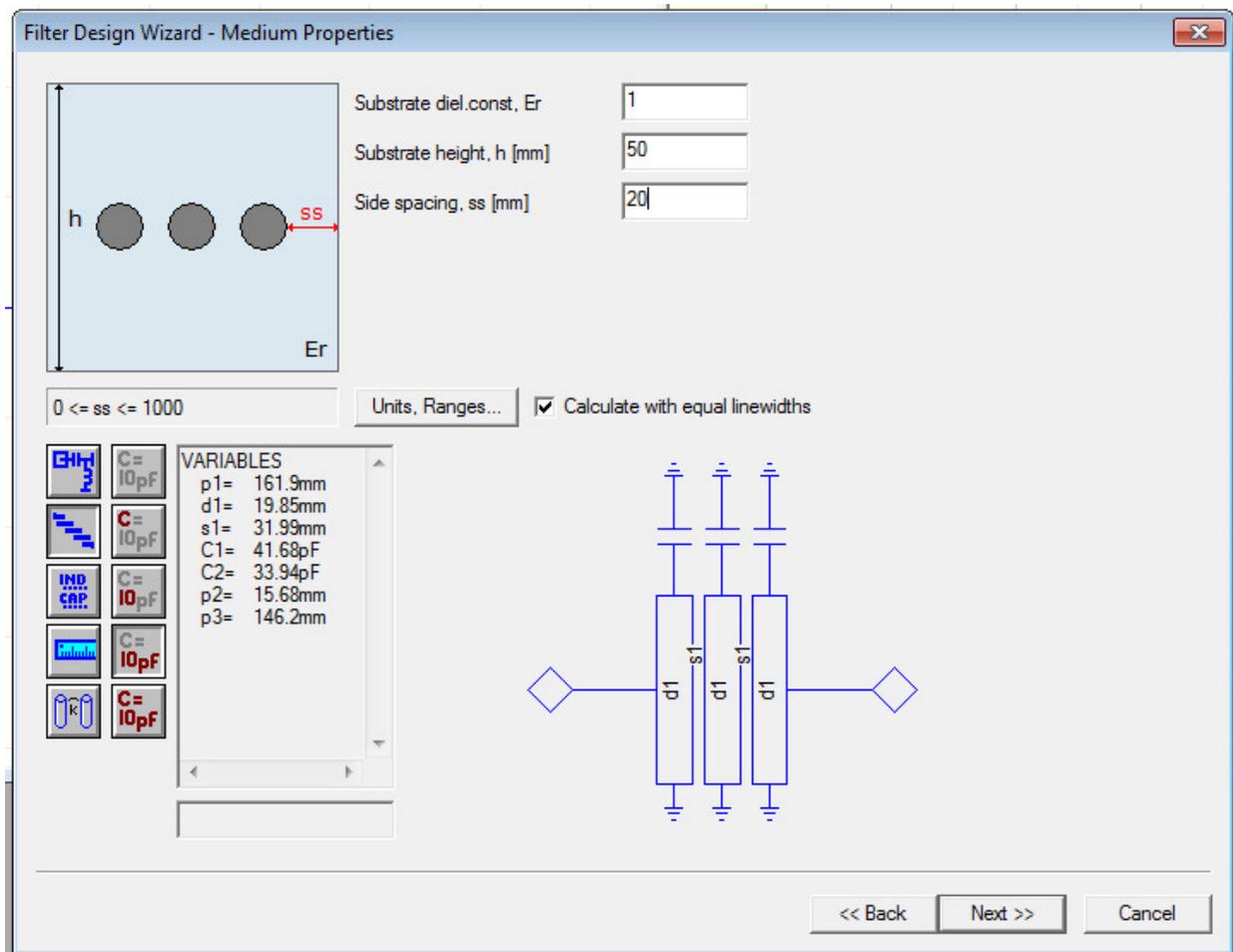
## Other Resonator Shapes

Rectangular or square rods may be used simply by changing the **Conductor thickness, t (mm)**. Round rods are selected by choosing Slabline on the Properties screen, shown in Figure 7.



**Figure 7 - Selection of Properties for a Comblaine Filter using Round Rod Resonators**

This results in a diameter dimension, **d1**, on the **Medium Properties** screen, Figure 8. The spacing, **S1**, is still edge to edge, and the tap point, **P2**, is still wrong. The diameter may be adjusted by changing the **Tline imp. Z1** on the **Specifications** screen.



**Figure 8 – Physical Dimensions for a Combline Filter using Round Rod Resonators**

## Summary

This design procedure may seem a bit convoluted and take a lot of fiddling, but it will result in good, usable filters. The alternative is to pay a lot of money for real filter design software.