

## Lowpass Filter Design

### Introduction and Modeling

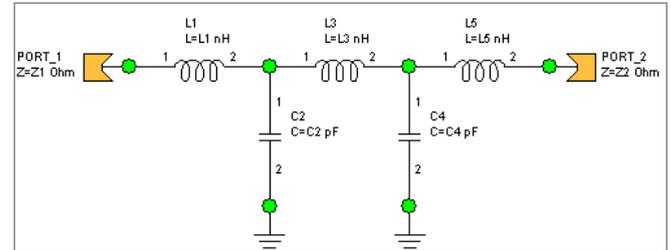
Three models of filter will be designed and analyzed using WIPL-D powerful built in feature Filter Designer (Figure 1). Filter Designer is user-friendly, wizard-like GUI with straightforward two-stage filter. It is intended for automated design of lowpass, highpass, bandpass and bandstop filters of Chebyshev and Butterworth type. Currently supported implementations are microstrip, ideal transmission line and lumped LC ladder.

Specification of microwave filter and design parameters are given in Table 1. Filter type is lowpass and approximation is considered to be Chebyshev.

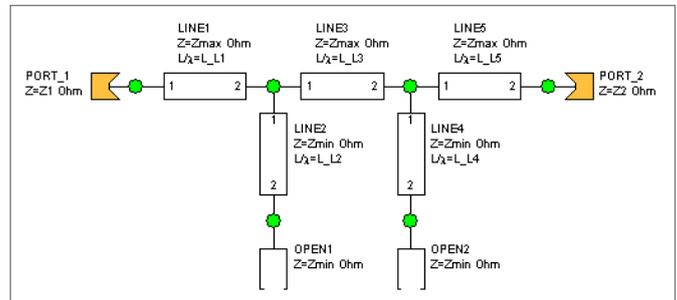
**Table 1. Filter specification (spec) and design parameters**

Spec parameter	Value [Unit]	Design parameter	Value [Unit]
F pass	1 [GHz]	Filter order	5
F stop	1.4 [GHz]	R source	50 [Ohms]
Pass-band attenuation	1 [dB]	R load	50 [Ohms]
Stop-band attenuation	20 [dB]	Ripple	1 [dB]

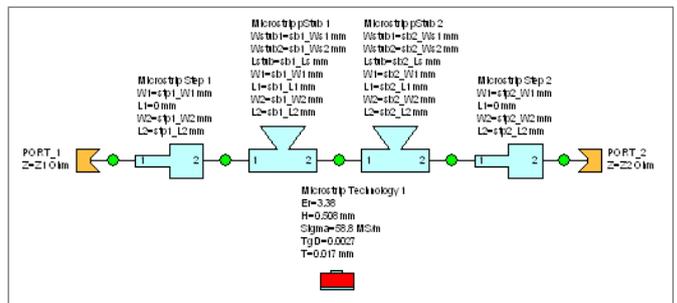
The first model is implemented as LC ladder (Figure 2), while the second is implemented as transmission line (Tx) filter (Figure 3). These are considered to be ideal filters. The third model is implemented as microstrip filter (Figure 4). The three models are simulated in WIPL-D Microwave circuit simulator using closed form equations. The third model is also simulated in WIPL-D 3D EM solver (Figure 5) using full electromagnetic analysis.



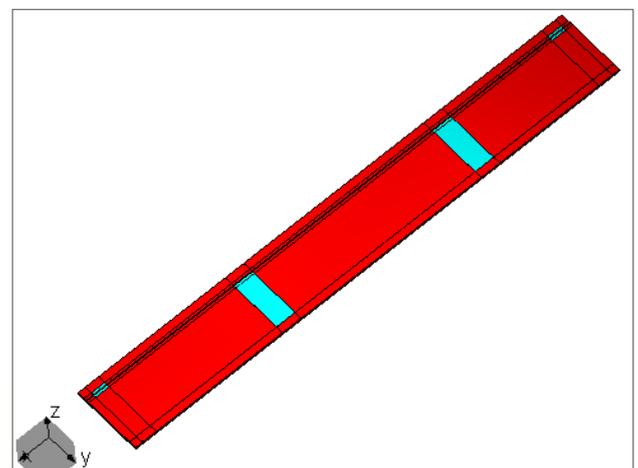
**Figure 2. LC ladder filter. WIPL-D Microwave circuit simulator**



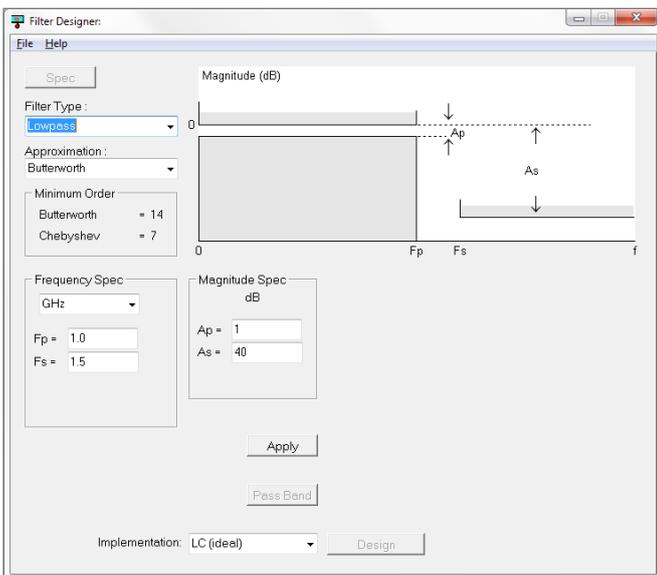
**Figure 3. Transmission line ideal filter (stub type). WIPL-D Microwave circuit simulator**



**Figure 4. Microstrip filter. WIPL-D Microwave circuit simulator**



**Figure 5. Microstrip filter. WIPL-D 3D EM solver**



**Figure 1. WIPL-D Filter Designer**

Our aim is to compare simulation times and s-parameters of analyzed models. We will observe output results starting from 0.014 GHz up to 2.8 GHz.

## WIPL-D Simulation

In WIPL-D software, filters can be designed using powerful built in feature Filter Designer. Filter designer is add-on tool which provides good start for accurate full 3D EM analysis and it is also easy-to-use feature.

We will calculate s parameters for every filter model. Computer used for these calculations is standard desktop PC (or any given laptop), for example Intel® Core™ i7 CPU 7700@ 3.60 GHz.

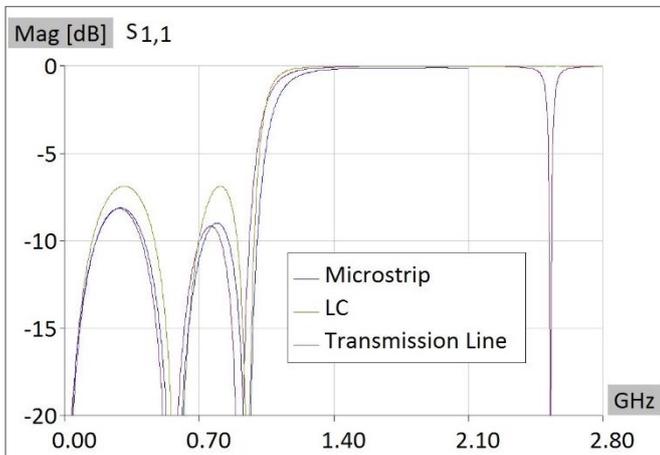
Characteristics of dielectric (microstrip implementation) are given in Table 2.

**Table 2. Dielectric characteristics**

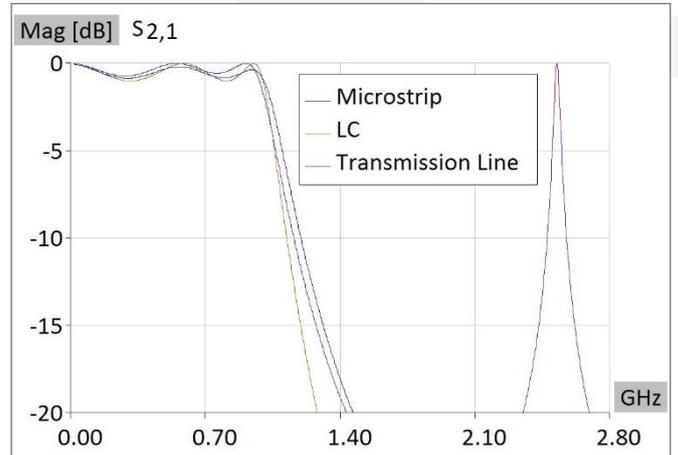
Parameter	Value [Unit]
Er	3.38
H	0.508 [mm]
Sigma	58.8 [MS/m]
TgD	0.0027
T	0.017 [mm]

Operating band of interest is between 0.014 GHz and 2.8 GHz. Due to powerful built-in interpolation, it is sufficient to run the model in 11 frequency points (EM simulation).

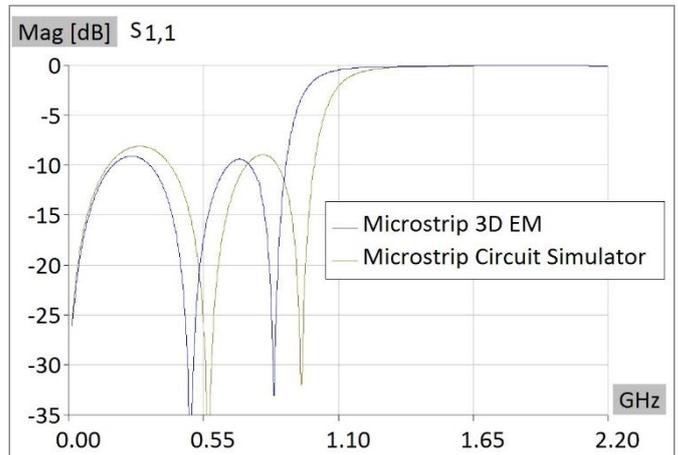
Parameters  $s_{11}$  and  $s_{21}$ , for the LC, microstrip and transmission line models are simulated in WIPL-D Microwave circuit simulator and they are shown in Figures 6-7. Parameters  $s_{11}$  and  $s_{21}$ , for the microstrip model are simulated in WIPL-D Microwave circuit simulator and WIPL-D 3D EM solver and they are shown in Figures 8-9. Number of unknowns and simulation time of analysis are given in Table 3.



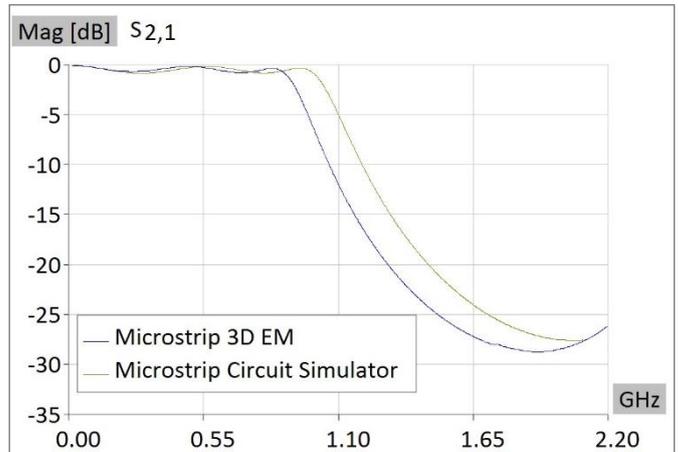
**Figure 6.  $s_{11}$  parameter of LC, Tx and microstrip models in WIPL-D Microwave circuit simulator**



**Figure 7.  $s_{21}$  parameter of LC, Tx and microstrip models in WIPL-D Microwave circuit simulator**



**Figure 8.  $s_{11}$  parameter of microstrip model simulated in WIPL-D Microwave circuit simulator and WIPL-D 3D EM solver**



**Figure 9.  $s_{11}$  parameter of microstrip model simulated in WIPL-D Microwave circuit simulator and WIPL-D 3D EM solver**

**Table 3. Analysis characteristics**

<i>Model</i>	<b>Time @ 0.014-2.8 GHz [sec]</b>
LC	<1
Tx	<1
Microstrip	<1
Micorstrip/ 3D EM	40

## Conclusion

Microwave filters are very important structures. Using WIPL-D Filter Designer we can easily manipulate filters. However, trade-off is present in analysis of microstrip filters. We know that presence of dielectric can cause parasitic changes in filter characteristics and that model calculated using closed form equations must not be considered as accurate model. That is the reason why we use full 3D electromagnetic WIPL-D analysis. Using full analysis, we

get accurate results. The more accurate results we want, the greater disproportion between simulation times using Microwave Pro and 3D EM Simulator is presented (Table 3).

Dielectric is necessary in microstrip filter production because of structure solidity (i.e. metallic conductors are placed on dielectric). Dielectric shifts  $s$  parameters vs. frequency characteristic and inserts losses.

Model simulated using 3D EM simulator has the same dimensions as model simulated in circuit simulator (values of lengths are rounded because real-world production has finite precision). Differences in the results exist, what is expected because closed form equations are less accurate than 3D EM analysis. Less accuracy of circuit model is presented because full 3D EM model involves calculation of EM coupling between discontinuities and elements radiation.