User Manual for MicroStripOptim

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Date - October 2023

Contents

1 MicroStripOptim for analysis of microstrip filters

`MicroStripOptim` is a GUI for study and optimize the design of microstrip low pass filters. The GUI enables to set the parameters to analyze one specific filter, as well as to analyze the variation of the parameters in the filter response. `MicroStripOptim` can run either in MATLAB or Octave.

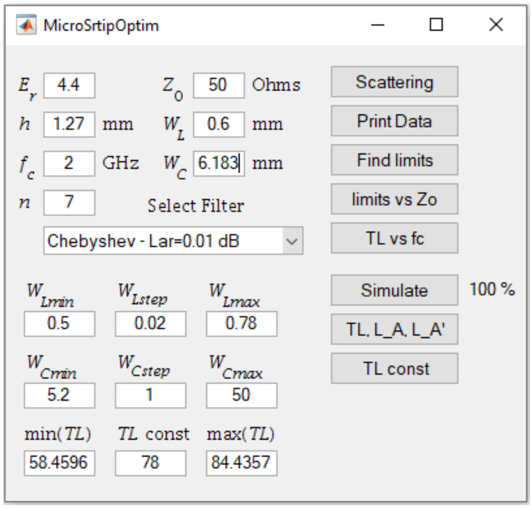


Figure 1: Graphical User Interface for analyzing microstrip low pass filters.

In Figure 1 the `MicroStripOptim` GUI is shown. In the upper left side, there are edit-boxes to configure the properties for obtaining one specific filter. These properties are:

- Dielectric constant, ε_r
- Height of the substrate, h, in mm
- Cutoff frequency, f_c, in GHz
- Filter order, n, from 3 to 9
- Source impedance, Z_0, in Ω
- Width of high impedance line, W_L, in mm
- Width of low impedance line, W_C, in mm

In the middle of the window there is a popup-menu to select the type of filter, with the following options:

- Butterworth - 0.5 dB
- Butterworth - 3 dB

- Butterworth - MAXIMALLY FLAT
- Chebyshev - L_{Ar} = 0.01 dB
- Chebyshev - L_{Ar} = 0.04321 dB
- Chebyshev - L_{Ar} = 0.1 dB

In the lower-left side, there are edit-boxes to set the range of values to conduct sensitivity analysis on the overall filter response. These options will be explained further.

In the right side of the window there are 8 buttons, labeled as: "Scattering", "Print data", "Find limits", "Limits vs Z_0", "TL vs f_c", "Simulate", "TL, L_A, L'_A" and "TL const".

The function of the buttons will be explained in the next section.

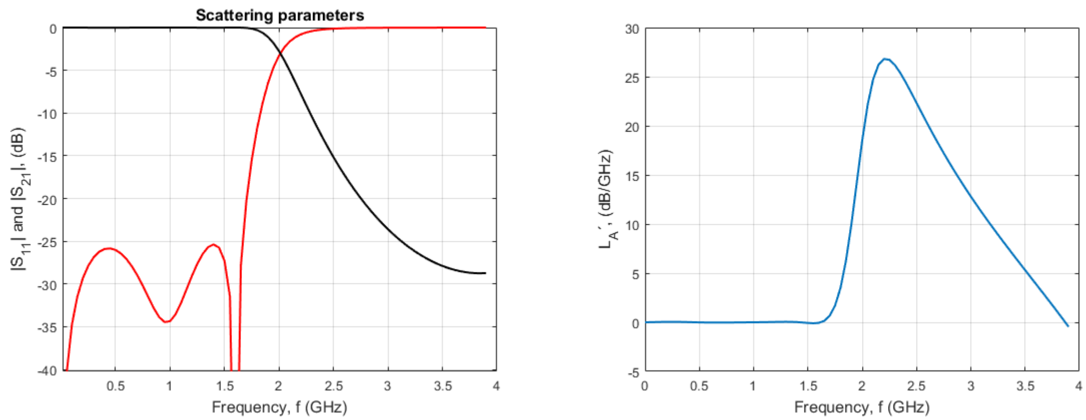
2 Function of the buttons

In this section, we will explain the function of each button embedded in the GUI. In order to illustrate one case of study, the design data inputs shown in Table 1 will be introduced in the edit-boxes in the upper-left side of the GUI.

Table 1: Values introduced to design a filter.

Parameter	Label	Value
Dielectric constant	ε_r	4.4
Height of the substrate (mm)	h	1.27
Cutoff frequency (GHz)	f_c	2
Filter order	n	7
Source impedance (Ω)	Z_0	50
Width of high impedance line (mm)	W_L	0.6
Width of low impedance line (mm)	W_C	6.183
Filter type		Chebyshev - L_{Ar} = 0.01 dB

- **Scattering** takes the data for filter design, values in Table 1, from the edit-boxes of the GUI. Then, it computes the widths and lengths of the filter lines. Afterwards, the program produces the plot of the scattering parameters. The result of this function is shown in two plots. The first plot, see Figure 2(a), corresponds to the scattering parameters $|S_{11}|$ and $|S_{21}|$ of the filter generated using the data of Table 1. The second plot, Figure 2(b), shows the derivative of the attenuation, L'_A, given in dB/GHz.
- **Print Data**. This function takes the data of Table 1, from the edit-boxes in the GUI and retrieves a table with many information about the calculated filter. Figure 3 is an example of the tables retrieved. The table in the left gives information about the filter, like the filter



(a) (b)

Figure 2: Scattering plots. (a) —S_{11}— in red and $|S_{21}|$ in black. (b) Derivative of attenuation, L_A'.

parameters, source impedance, Z_0, limits for W_L and W_C, total length, width of the filter, the maximum attenuation and the derivative of maximum attenuation. The table in the right side of Figure 3 shows the widths and lengths of all the lines of the microstrip, as well as their inductance and capacitance equivalent values.

Filter Data

	Parameter	Value
1	Chebyshev - Lar=0.01 dB	0
2	Filter order, n	7
3	Cutoff frequency, fc (GHz)	2
4	Source impedance, Zo (Ohms)	50.0000
5	Dielectric constant, Eo	4.4000
6	Substrate height, h (mm)	1.2700
7	Limit of max W_L	0.7954
8	Limit of min W_C	5.0727
9	Total length (mm)	78.0005
10	Total width (mm)	8.1830
11	max(L_A'), (dB/GHz)	26.8045
12	max(L_A), (dB)	28.7529

	Length	Val. (mm)	L, C	Val. (H, F)
1	l_Zo	5.1365		0
2	Wo	2.4305		0
3	W_L	0.6000		0
4	W_C	6.1830		0
5	l_L1	5.5585	L_1	3.1712e-09
6	l_C2	9.5331	C_2	2.2161e-12
7	l_L3	13.4357	L_3	6.9555e-09
8	l_C4	10.6730	C_4	2.5992e-12
9	l_L5	13.4357	L_5	6.9555e-09
10	l_C6	9.5331	C_6	2.2161e-12
11	l_L7	5.5585	L_7	3.1712e-09

Figure 3: Data displayed by the program for a requested filter design.

- **Find Limits**. This button runs one algorithm to find the minimum value for W_C and the maximum value for W_L, named as W_{Cmin} and W_{Lmax}, respectively. The first action of this button is to compute W_{Cmin} and W_{Lmax} for the filter type and filter order, n, set in the edit-boxes. Then, the program displays these values in the edit-boxes W_{Lmax} and W_{Cmin} of the GUI. Following to the computation of W_{Lmax} and W_{Cmin} for the selected filter, the software computes the same parameters for all other filter architectures supported in this version of the program. The results are plotted all together, including the width of the source impedance line, W_0, in Figure 4. From this figure it can drawn some conclusions. As a first conclusion, it can be said that, in general, as the order of the filter increases, the limits move away from the value W_0. The only exception is in the limits of W_C for the Butterworth - MAXIMALLY FLAT filter, which has its minimum value in the fifth order. On the other hand, the second conclusion appointed is that the value of W_{Lmax}, in the case of the Butterworth 0.5 dB and 3 dB filters, is very low, making them infeasible, thus, these two filters will be discarded in the next analyzes.

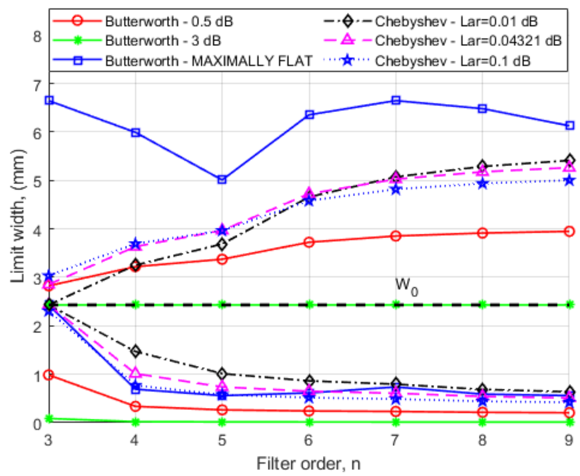
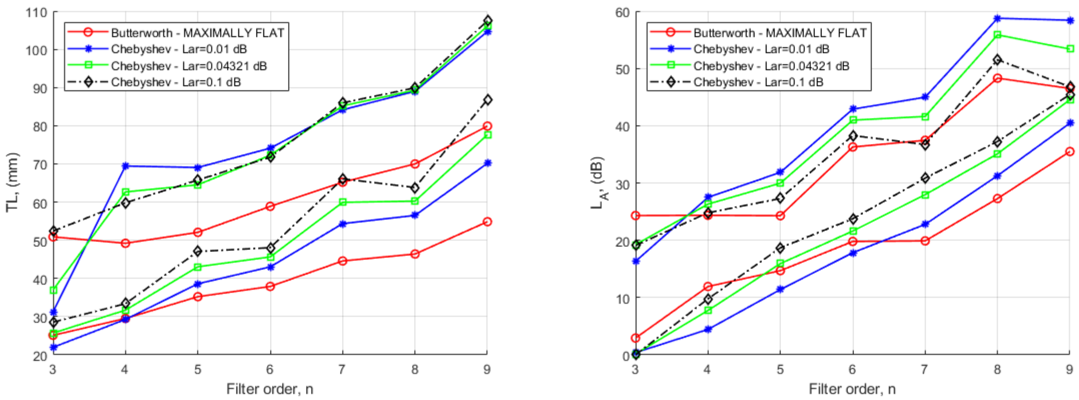


Figure 4: Limit width values for W_C and W_L versus n for different type of filters.

From the limit values for the different filters and orders, further inspection can be made. For example, the total physical length, TL, of the filter varies with the widths of W_C and W_L, observing that the minimum TL for some filter is obtained with W_{Lmin} and W_{Cmax}, whereas the maximum TL is obtained with W_{Lmax} and W_{Cmin}. For each filter, the values W_{Lmax} and W_{Cmin} are computed using the previous analysis, while W_{Lmin} and W_{Cmax} are taken by default as 4 mm and 50 mm, respectively, and are obtained from the edit-boxes in the lower-left side of the GUI. The values for W_{Lmin} and W_{Cmax} were selected considering 4 mm as a feasible thin line for W_L and considering 50 mm as the widest desirable W_C. However, the values for W_{Lmin} and W_{Cmax} can be modified by the user. Figure 5(a) shows the values of TL_{min} and TL_{max} for the feasible filters, *i. e.*, the Butterworth MAXIMALLY FLAT and the three Chebyshev considered. This plot shows that the Butterworth MAXIMALLY FLAT filter yields a lower TL, while the Chebyshev - L_{Ar} = 0.1 dB filter yields greater values of TL.

Other important analysis considering the maximal and minimal values for W_C and W_L is the variation of max(L_A). In this case, the maximum value of max(L_A) is obtained with W_{Lmin}



(a) (b)

Figure 5: (a) Total length versus n for different type of filters. (b) max(L_A) versus n for different type of filters.

and W_{Cmax}, and the minimum value of max(L_A) is obtained with W_{Lmax} and W_{Cmax}. Figure 5(b) shows a plot of the maximum attenuation for different filter types versus the order, n. From this figure it can noticed that the maximum attenuation increases with the order of the filter. By comparing the filters, it can be seen that the Butterworth - MAXIMALLY FLAT filter gives the highest attenuation in the third order response, but gives the least attenuation for higher orders. The filter that reaches the highest attenuation for $n > 3$ is Chebyshev - $L_{Ar} = 0.01$ dB.

- **limits vs** Z_0 performs an analysis of the limits for W_C and W_L, for one filter with the characteristics expressed in the GUI edit-boxes, varying two parameters: the source impedance, Z_0, from 25 Ω to 50 Ω, and the dielectric constant, ε_r from 4 to 12. The plots in Figure 6 show that the limit values for W_C and W_L decrease when Z_0 and/or ε_r increases. It can be seen, from the figure, that at $Z_0 = 50\Omega$, a high value of ε_r could lead to a filter unfeasible since this reduces considerably the limit for W_{Lmax}.

- **TL vs** f_c**'**. The total length of a filter, TL, is greatly affected by the cutoff frequency, f_c. This button carries out this analysis. The function of this button is to take the data from the edit-boxes to select the characteristics of the filter, but, this time, the total length will be obtained for f_c in a rank from 0.5 to 5 GHz. From Figure 7 it can be seen that TL decreases exponentially as f_c increases.

- **Simulate**. This button runs a simulation to obtain data like TL, max(L_A), max(L'_A), by sweeping values of W_C and W_L, where the minimum and maximum values, as well as the step increments, are indicated in the edit-boxes at the bottom of the GUI. These plots are important to analyze the effect of the widths W_C and W_L in the TL or the maximum attenuation

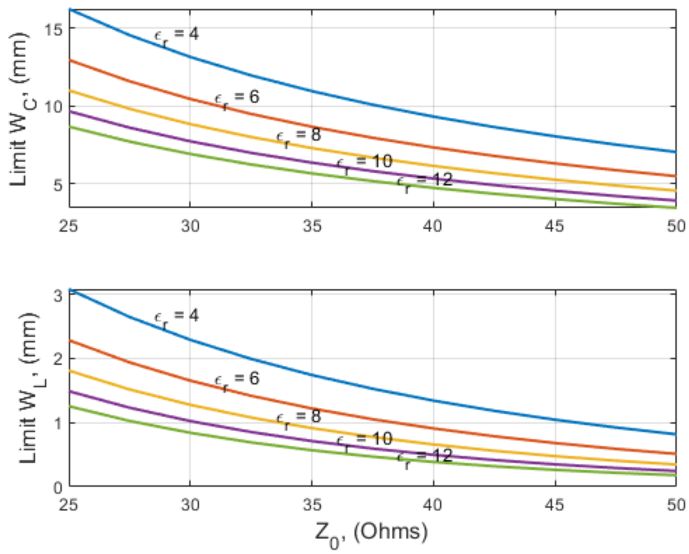


Figure 6: Limit width values for W_C and W_L versus Z_0.

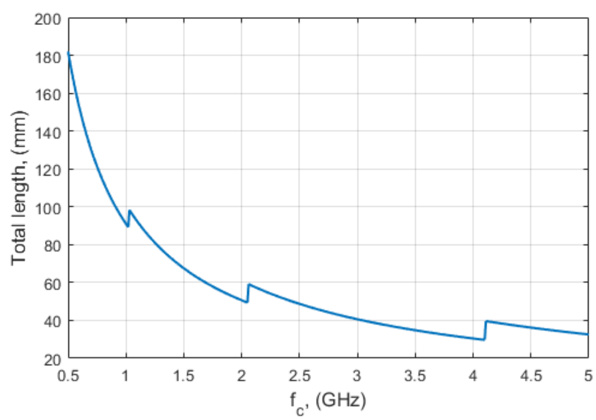
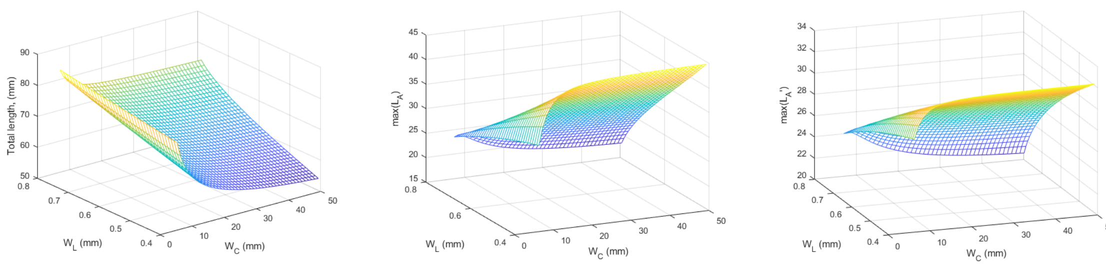


Figure 7: Total length versus f_c.

of the filter. The parameters of the filter are taken from the data on the top of the GUI, but W_C and W_L are swept as mentioned. In this sense, one simulation will give results for one specific filter type and order, while for another type of filter, or order, etc., a new simulation must be run.

- **TL,** L_A**,** L'_A. After one simulation is executed, the next buttons are enabled.. The function of this button is to lay out a 3D-plot, where the first two axes are W_L and W_C, while the third axis, the height of the plot, indicates the variable of TL, $\max(L_A)$ or $\max(L'_A)$, respectively. Figure 8 shows the plot of (a) total length, (b) $\max(L_A)$ and (c) $\max(L'_A)$, for a range of values of W_L and W_C. From Figure 8(a), it can be noticed that TL decreases significantly with lower W_L and higher W_C. On the other hand, from Figures 8(b) and (c), it can be seen that a low value for $\max(L_A)$ and $\max(L'_A)$ occurs with minimum values for W_C, and with medium or higher values of W_C, these two parameters increases with lower values of W_L. From these three plots, one can conclude that for a low value of W_L and a high value of W_C, the length of the filter will be lower, and the parameter $\max(L_A)$ will be higher.



(a) (b) (c)

Figure 8: (a) Total length, (b) $\max(L_A)$ and (c) $\max(L'_A)$, for a range of values of W_L and W_C.

- **TL const**, takes the value from the edit-box “TL const” at the bottom of the GUI, in order to trace a 3D surface of TL versus W_C and W_L, previously obtained with the simulation, then, the above surface is overlapped with another surface corresponding to the constant TL. The points where the surface of constant TL intersects with the TL surface, forms a curve with the values of W_C and W_L that yield a filter of length equal to TL const. Figure 9 shows the surfaces of TL and TL constant, as well as the curve of intersection points between the two surfaces. In this case, TL const is set to 78 mm.

  In addition to the plot of Figure 9, another figure is displayed, where are shown four plots. The first one is a plot of the curve W_C-W_L for constant TL, then the plots of W_C-$\max(L_A)$ and W_L-$\max(L_A)$ in the range of values for W_L or W_C, and finally a 3-D curve with the three parameters, W_C-W_L-$\max(L_A)$, as the axes. Figure 10 shows the plots mentioned in the case of constant $TL = 78$ mm. It can be seen in this figure that the maximum of the curve of $\max(L_A)$ occurs in the point $W_L = 0.6$ mm and $W_C = 6.183$ mm, with $\max(L_A) = 28.7529$ dB.

  The analysis of constant TL curves reveals the existence of a maximum point, representing the optimal configuration that minimizes or maximizes a specific parameter while keeping the filter length constant. The three parameters that can be optimized are the minimal width of the filter, maximal attenuation, and maximal attenuation rate. The GUI also generates a table that provides the optimal values for W_C and W_L in each optimization scenario. Figure 11 displays this table, where the user can choose the desired optimization criterion. For

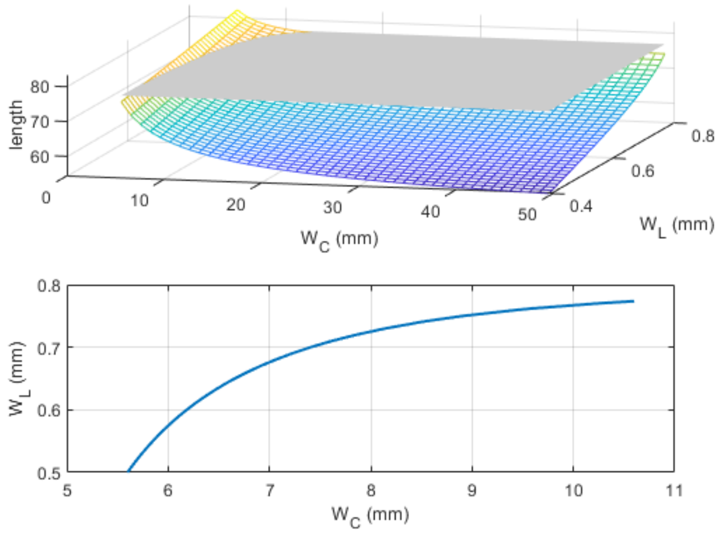


Figure 9: Curve for constant $TL = 78$ mm.

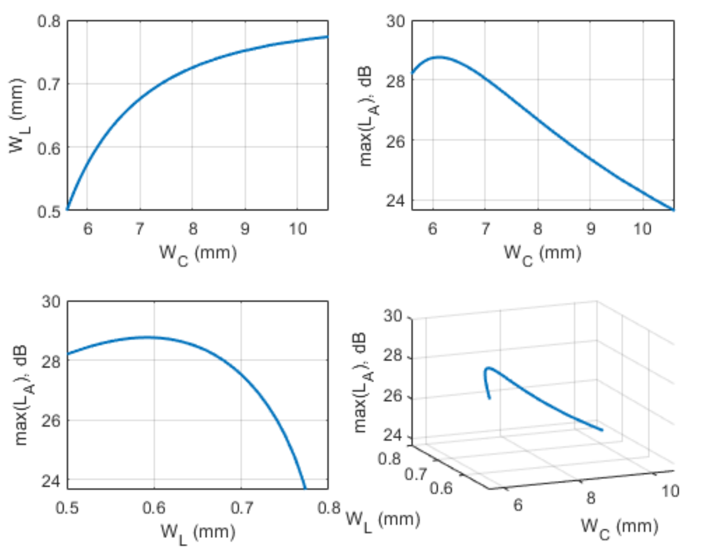


Figure 10: $\max(L_A)$ along the curve for constant $TL = 78$ mm.

instance, when selecting the point of maximum attenuation, the table indicates the values $W_C = 6.183$ mm and $W_L = 0.6$ mm, with $\max(L_A) = 28.7529$ dB.

Optimal Values

	Parameter	Value	W_C	W_L
1	Min(Total Width)	7.5981	5.5981	0.5000
2	Max(L_A)	28.7526	6.1829	0.6000
3	Max(L_A')	26.8675	5.9077	0.5600

Figure 11: Optimal values obtained for constant TL = 78 mm.