Chapter 8

Microwave Filters

SIMULATE A MICROSTRIP LOW PASS FILTER IN ADS

USING DIFFERENT SIMULATION METHODS

Filter specs:

Cut-off frequency = 1.5 GHz (3 dB)

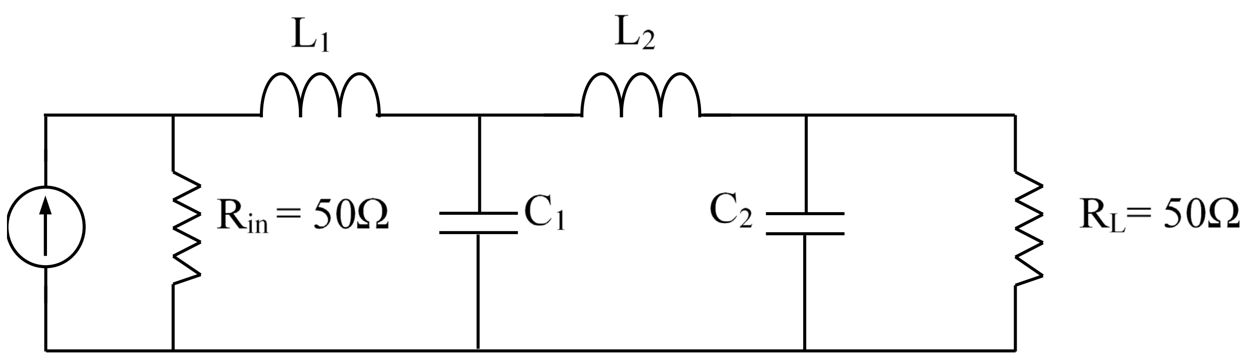
Rejection @ 3 GHz = 30 dB

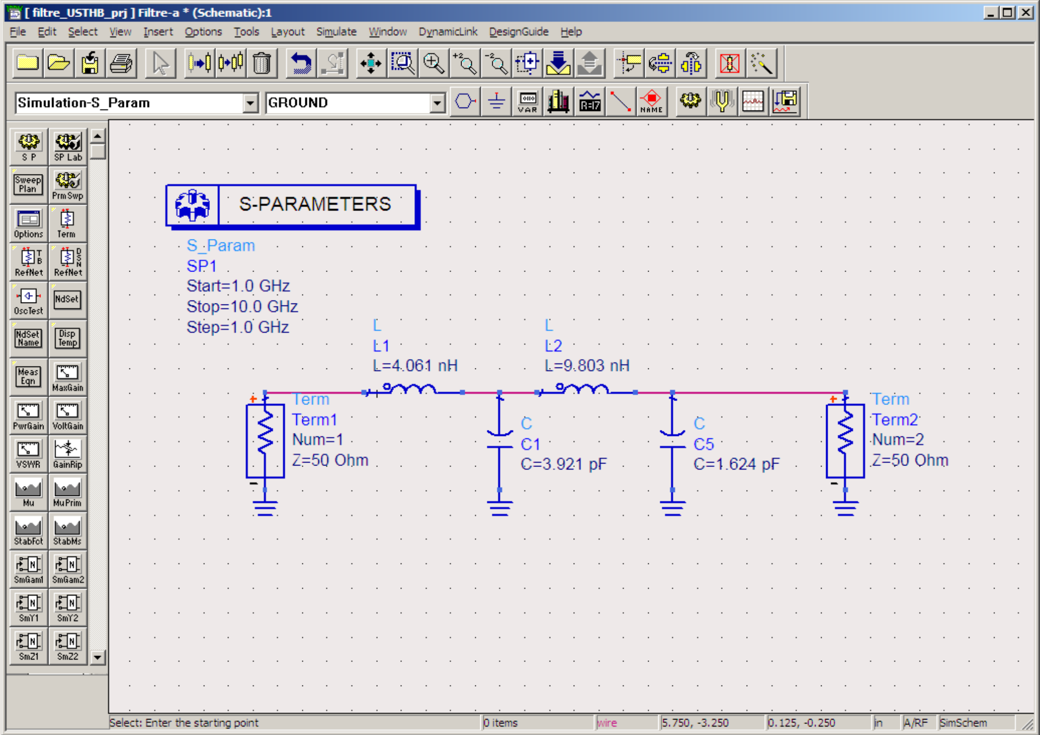
Substrate: FR4, ε_r = 4.2 and h = 1.5 mm, T = 38 µm (fiber-glass)

Step 1 : Find the electric equivalent circuit:

Based on the specifications, we obtain ***n* = 4** with

$L_1 = 4.061$ nH $\quad L_2 = 9.803$ nH $\quad C_1 = 3.921$ pF $\quad C_2 = 1.624$ pF





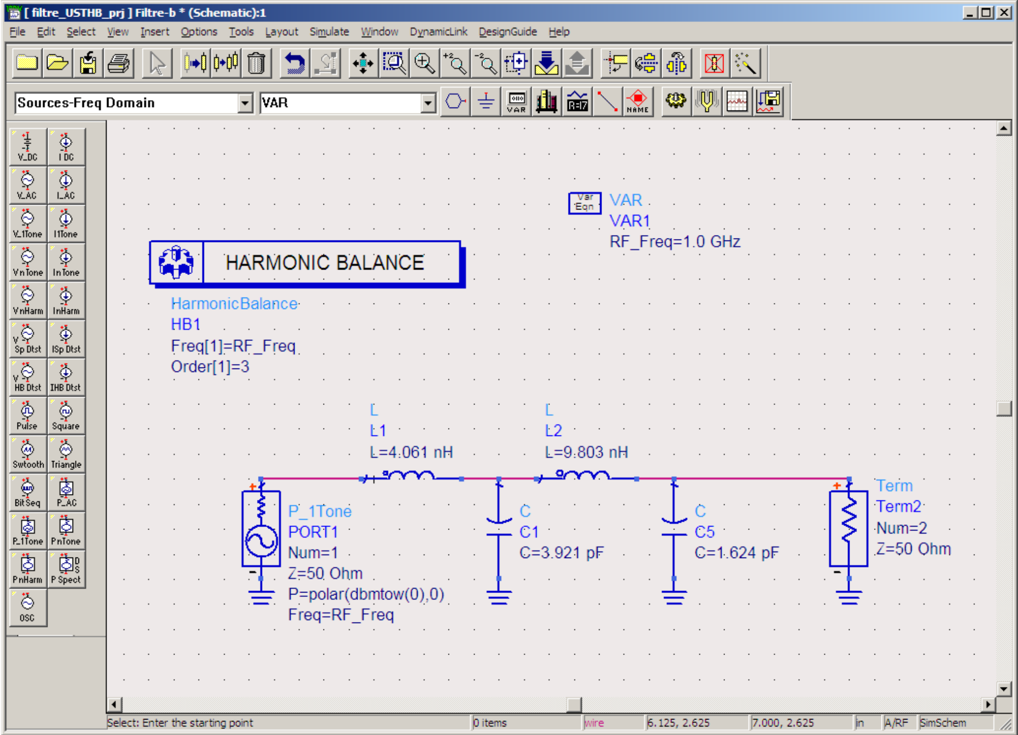
the specs :

Cut-off frequency = 1.5 GHz (3 dB)

Rejection @ 3 GHz = 30 dB

S-Parameters :

The results are close to the specs !



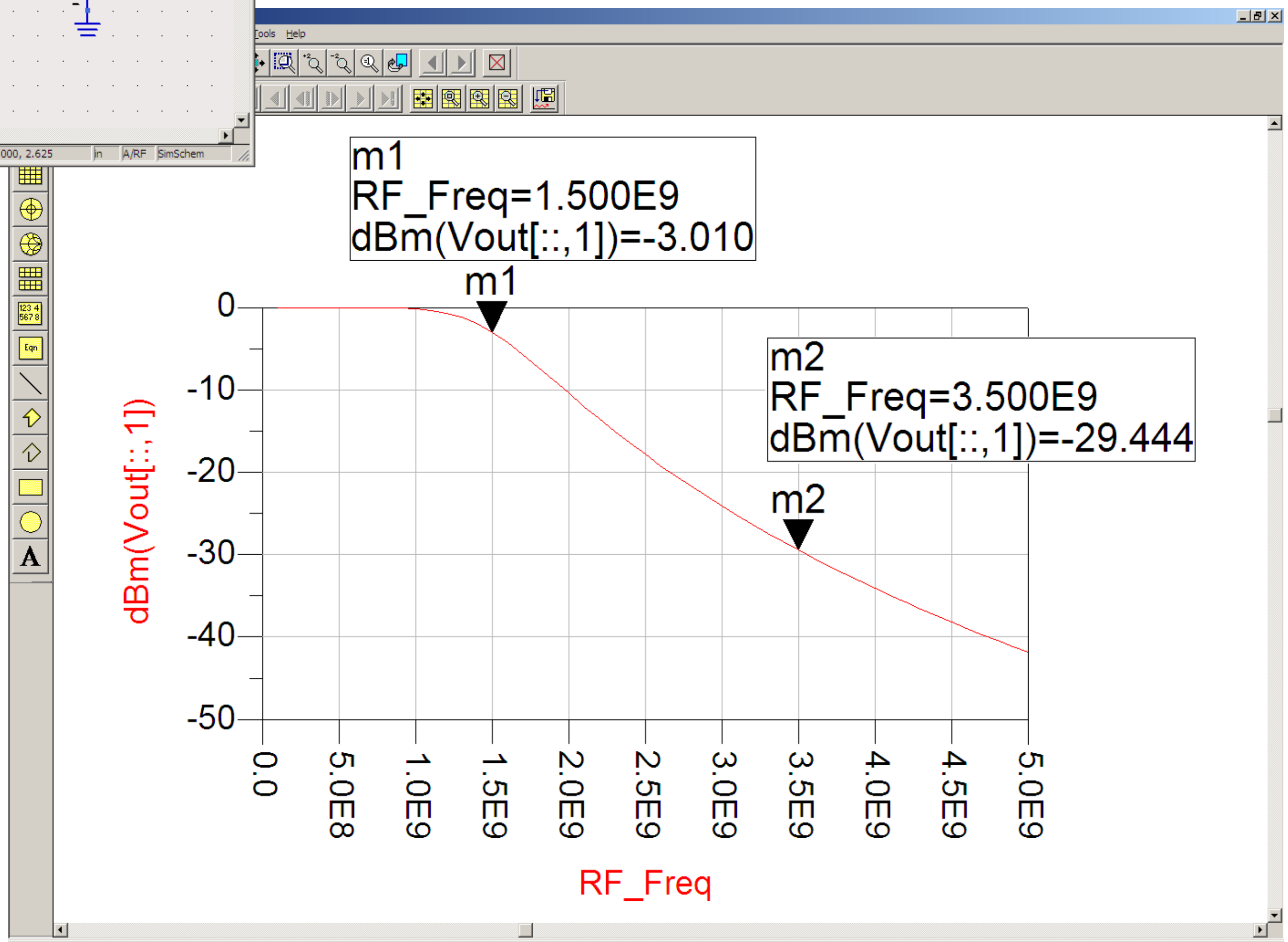
the specs :

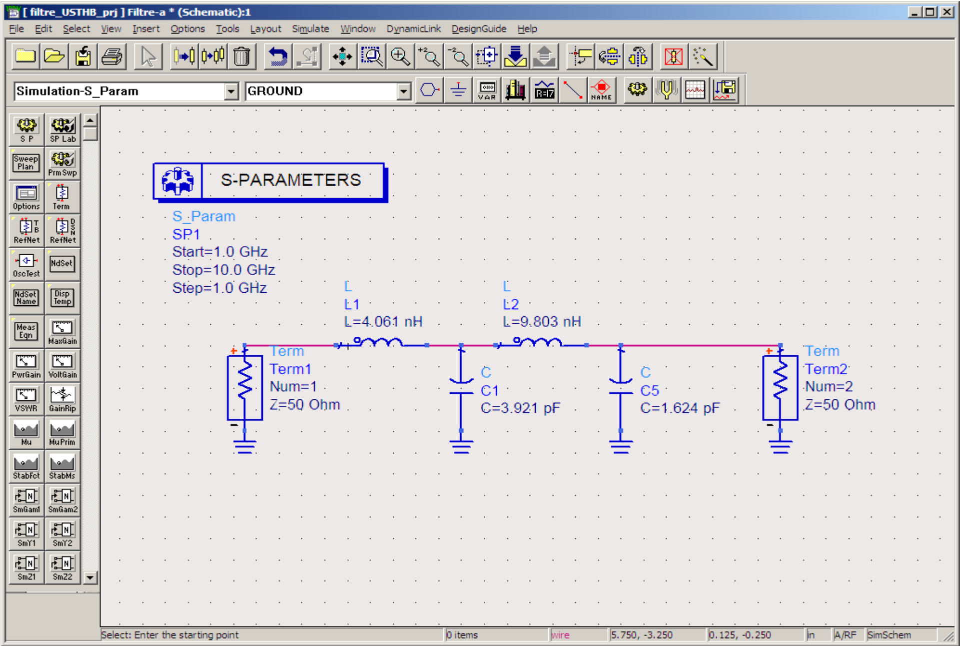
Cut-off frequency = 1.5 GHz (3 dB)

Rejection @ 3 GHz = 30 dB

HB :

The results are close to the specs !





the specs :

Cut-off frequency = 1.5 GHz (3 dB)

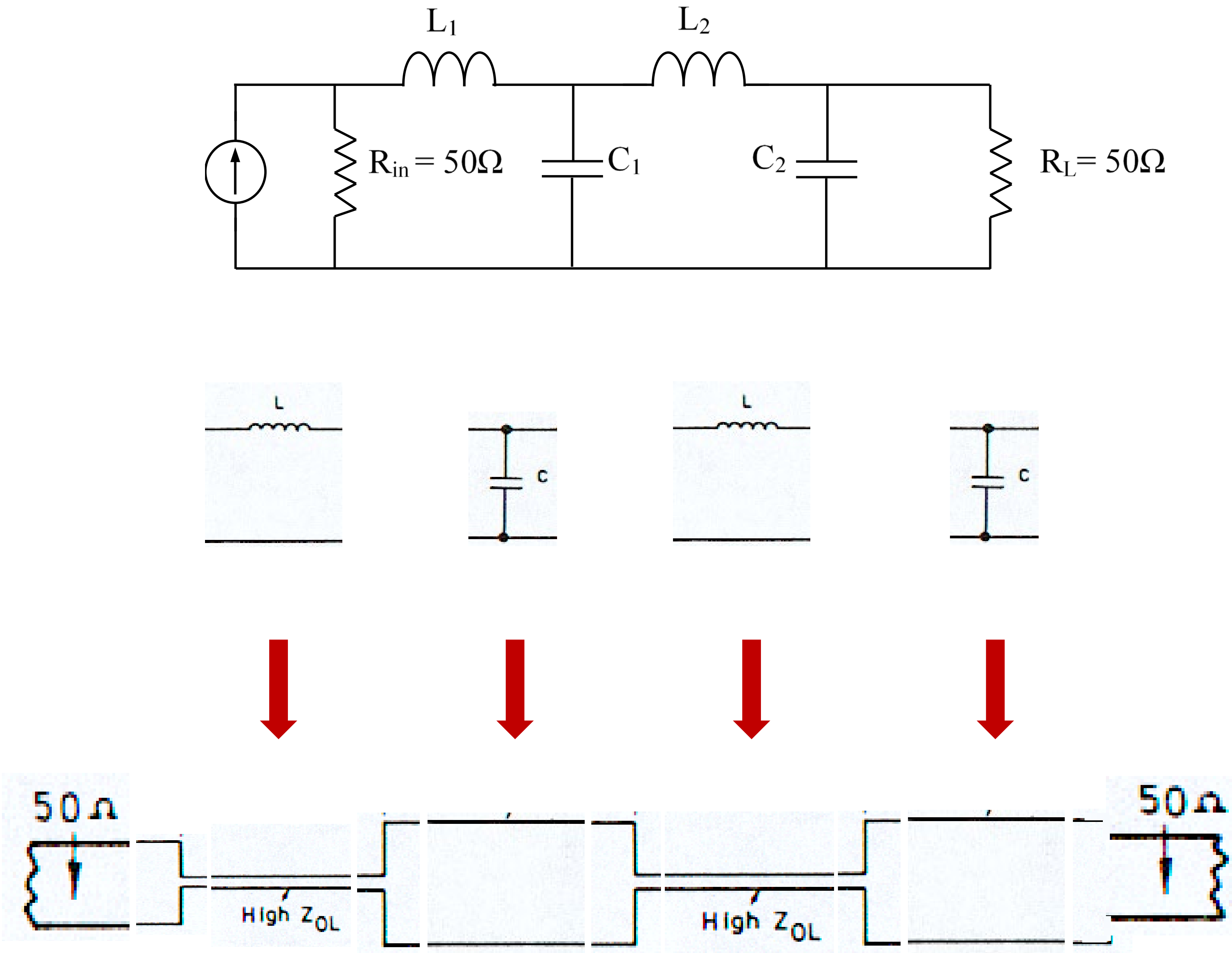
Rejection @ 3 GHz = 30 dB

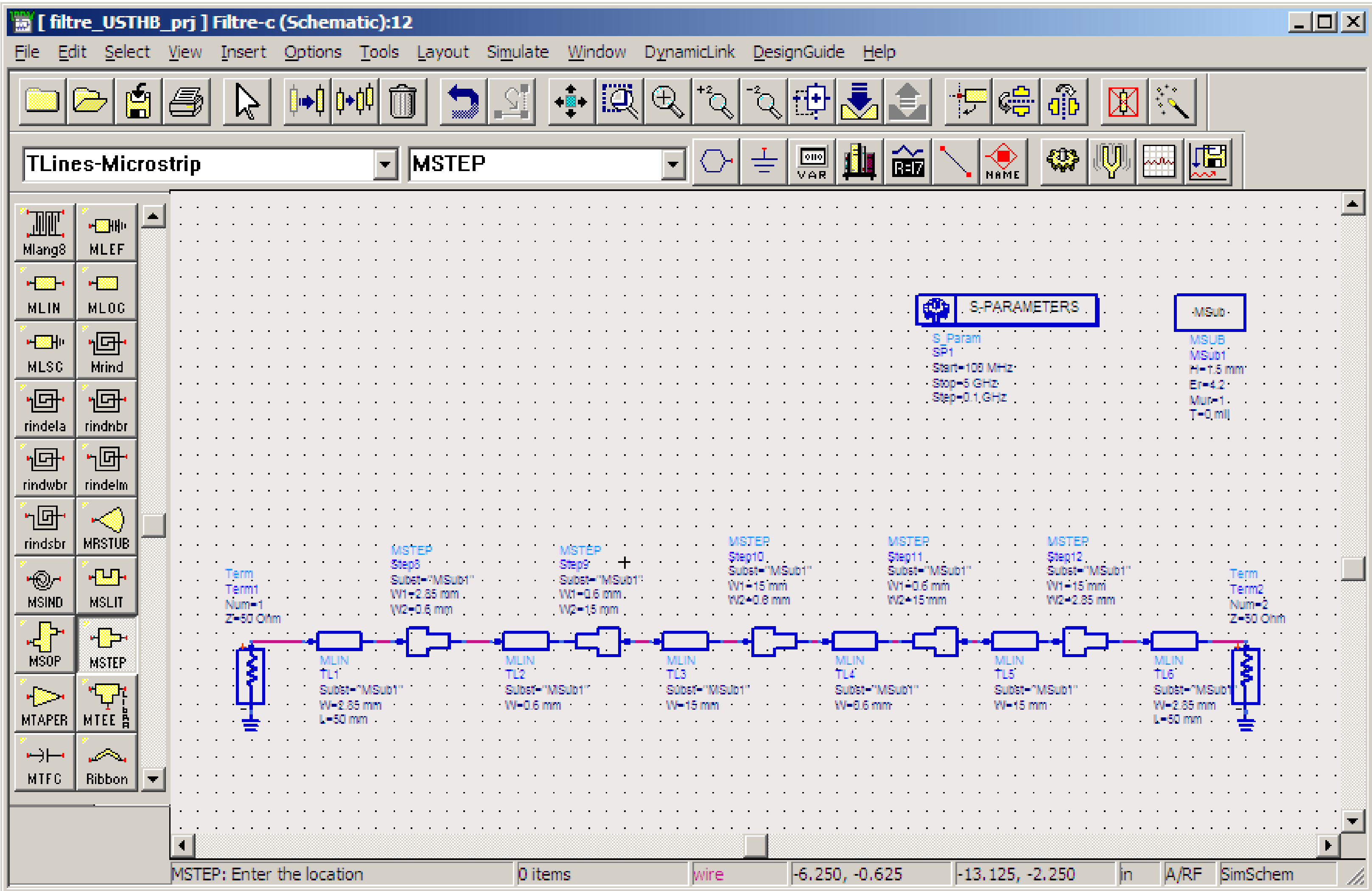
Transform to planar transmission lines

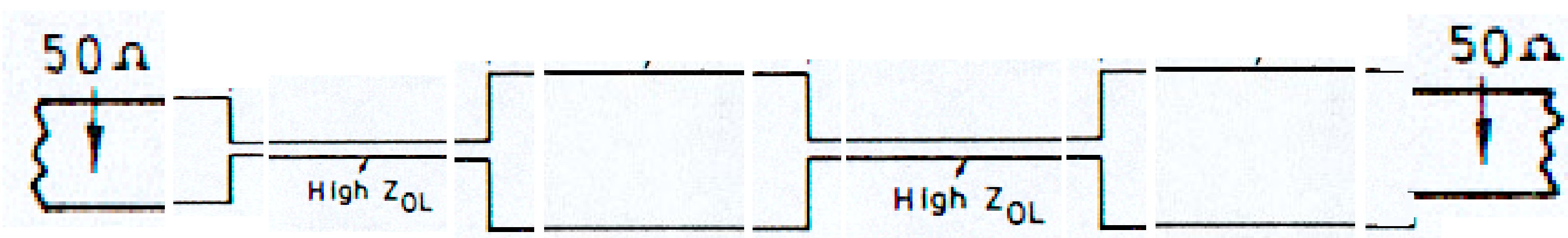
(Microstrip lines)

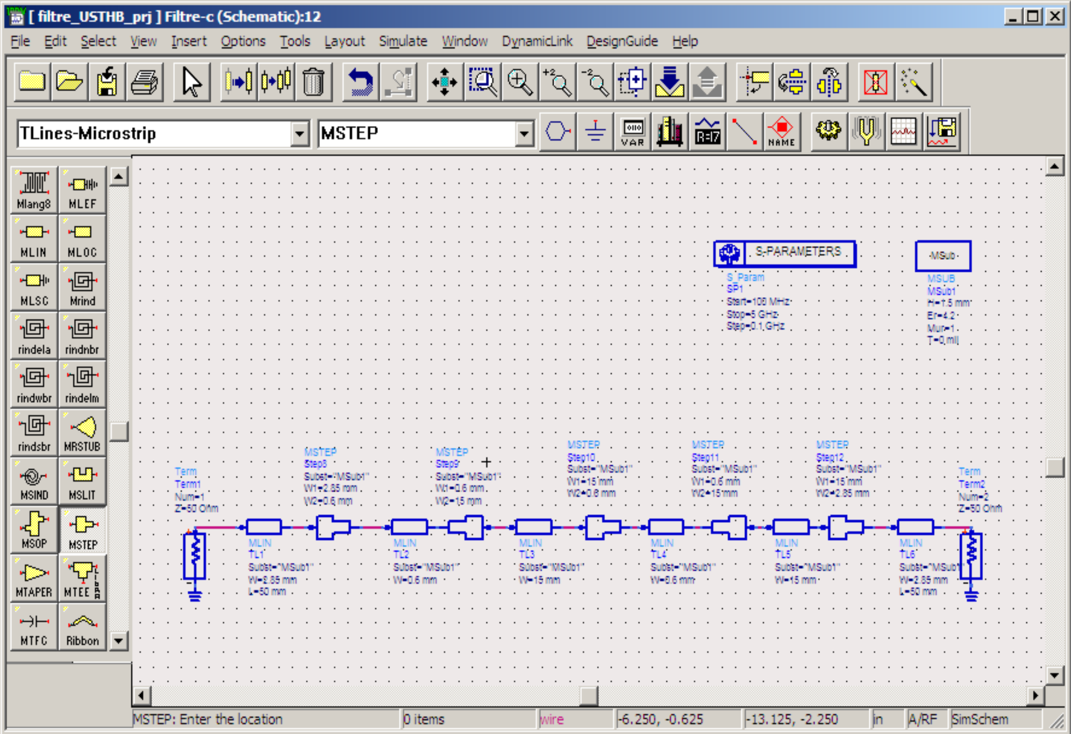
Convert the lumped elements to transmission lines

Capacitive lines	$Z_{0c} = 15\ \Omega$	$w_C = 15$ mm	Effective permittivity = 3.68
Reference	$Z_0 = 50\ \Omega$	$w_o = 2.85$ mm	Effective permittivity = 3.21
Inductive lines	$Z_{0L} = 110\ \Omega$	$w_L = 0.6$ mm	Effective permittivity = 2.83


L1
L2
Rin = 50Ω
C1
C2
RL = 50Ω
L
C
L
C
50 Ω
High Z0L
High Z0L
50 Ω


[filtre_USTHB_prj] Filtre-c (Schematic):12
File Edit Select View Insert Options Tools Layout Simulate Window DynamicLink DesignGuide Help
TLines-Microstrip
MSTEP
Mlang8
MLEF
MLIN
MLOC
MLSC
Mrind
rindela
rindnbr
rindwbr
rindelm
rindsbr
MRSTUB
MSIND
MSLIT
MSOP
MSTEP
MTAPER
MTEE
MTFC
Ribbon
S-PARAMETERS
MSub
Term
Term1
Num=1
Z=50 Ohm
Term
Term2
Num=2
Z=50 Ohm
MSTEP: Enter the location
0 items
wire
-6.250, -0.625
-13.125, -2.250
in
A/RF
SimSchem


50 Ω
High Z_{OL}
High Z_{OL}
50 Ω

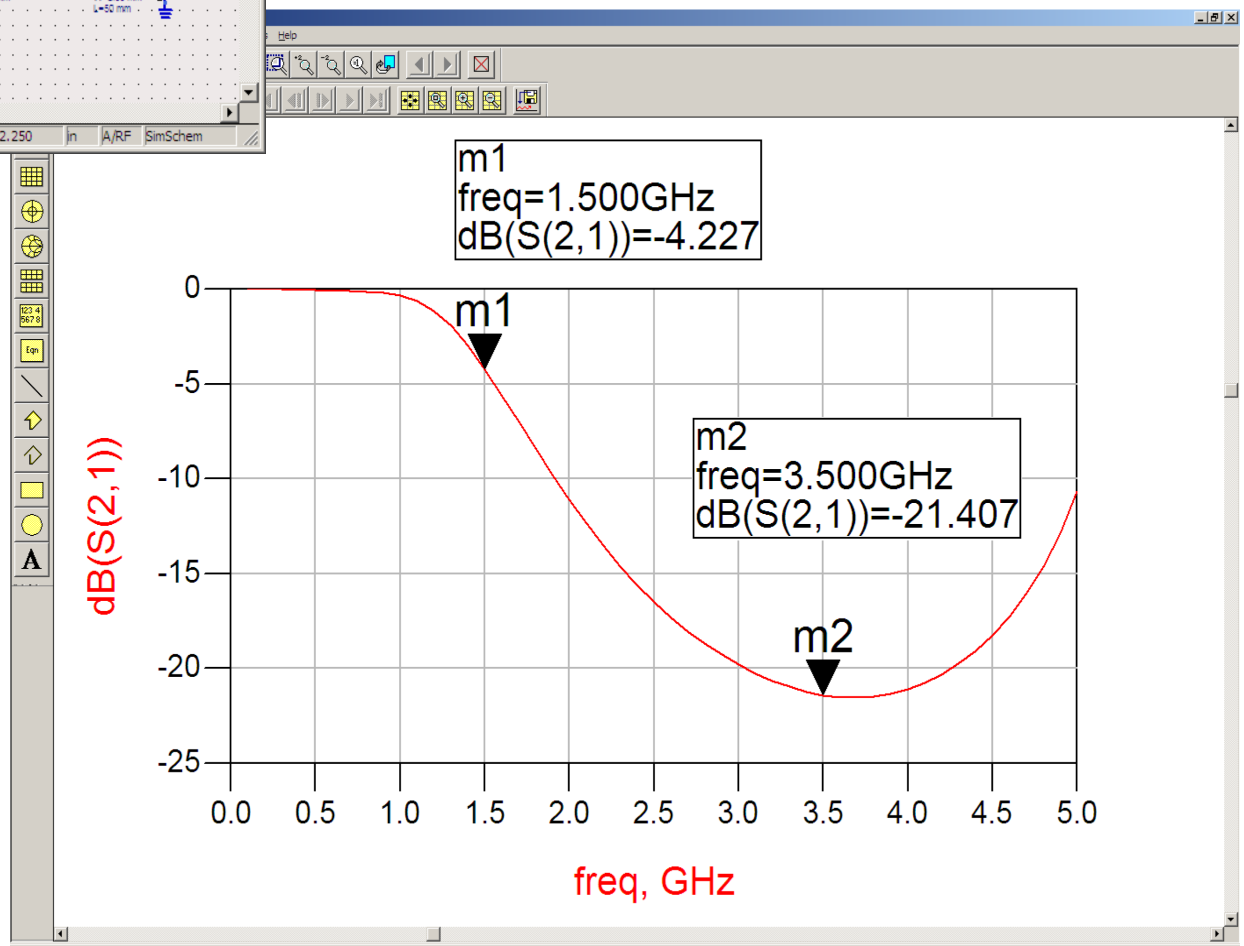


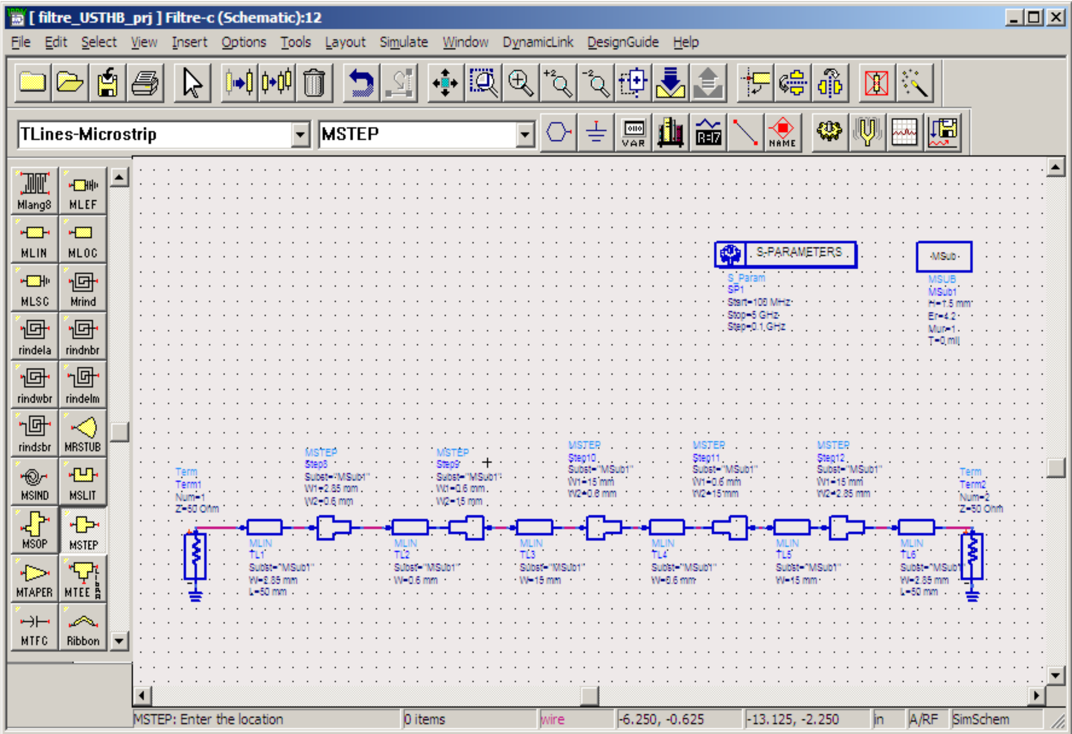
the specs :

Cut-off frequency = 1.5 GHz (3 dB)

Rejection @ 3 GHz = 30 dB

The results show some **discrepancies** vs. the specs





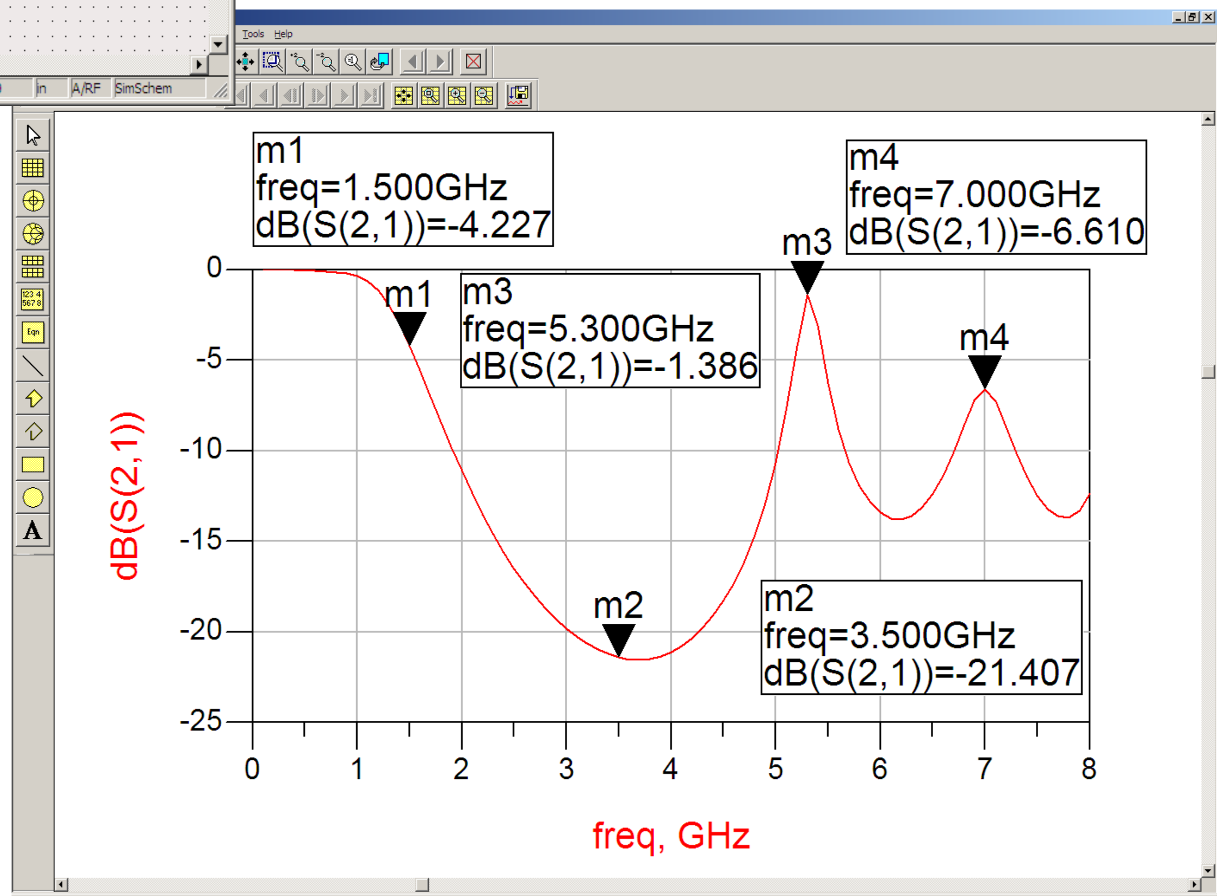
the specs :

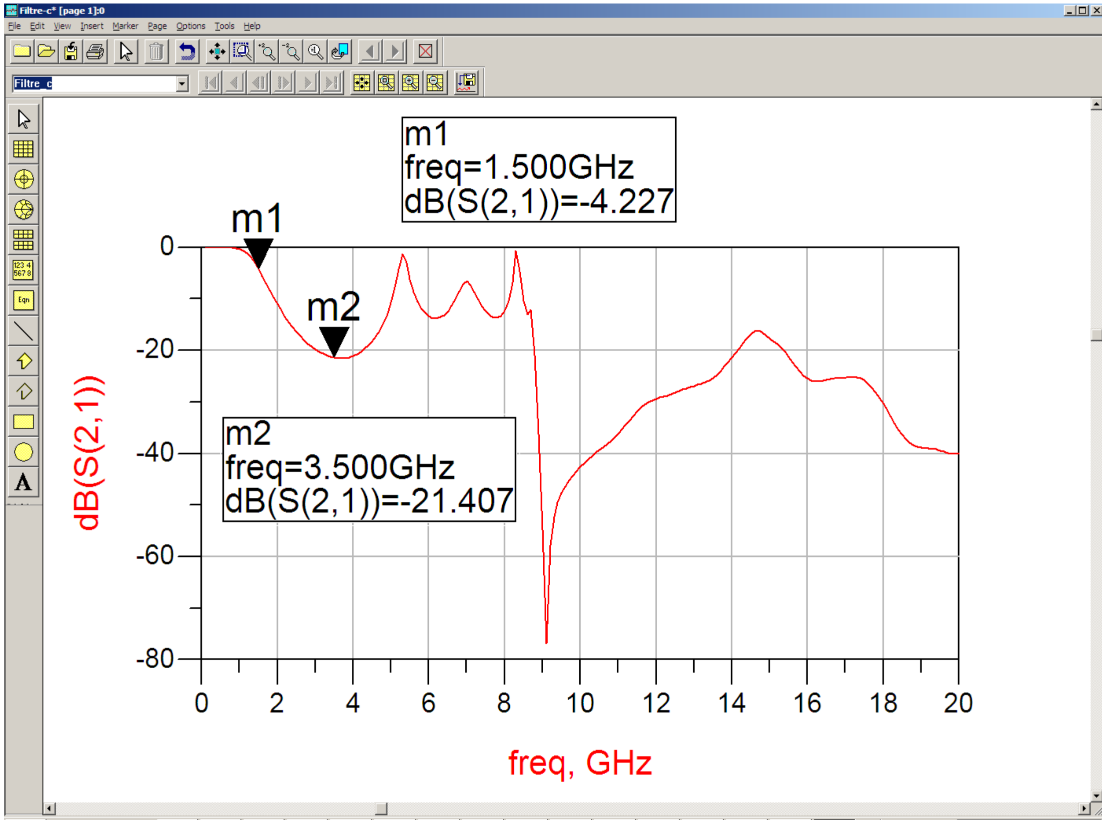
Cut-off frequency = 1.5 GHz (3 dB)

Rejection @ 3 GHz = 30 dB

Re-simulate the filter by increasing the frequency (from 5 GHz to 8 GHz, same step-size: 0.1 GHz).

We see **two** peaks (-1.386 dB and -6.610 dB) at 5.3 GHz and 7 GHz, respectively.

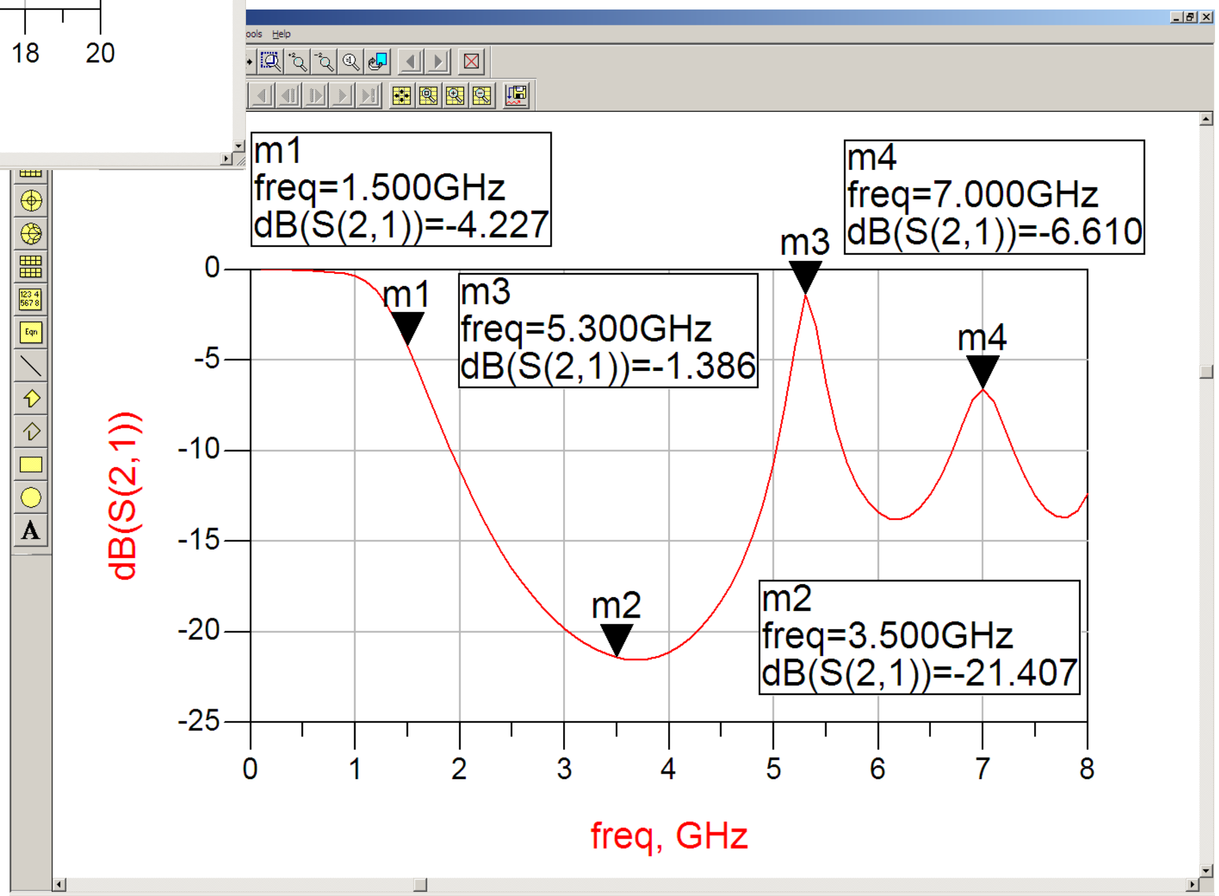




the specs :

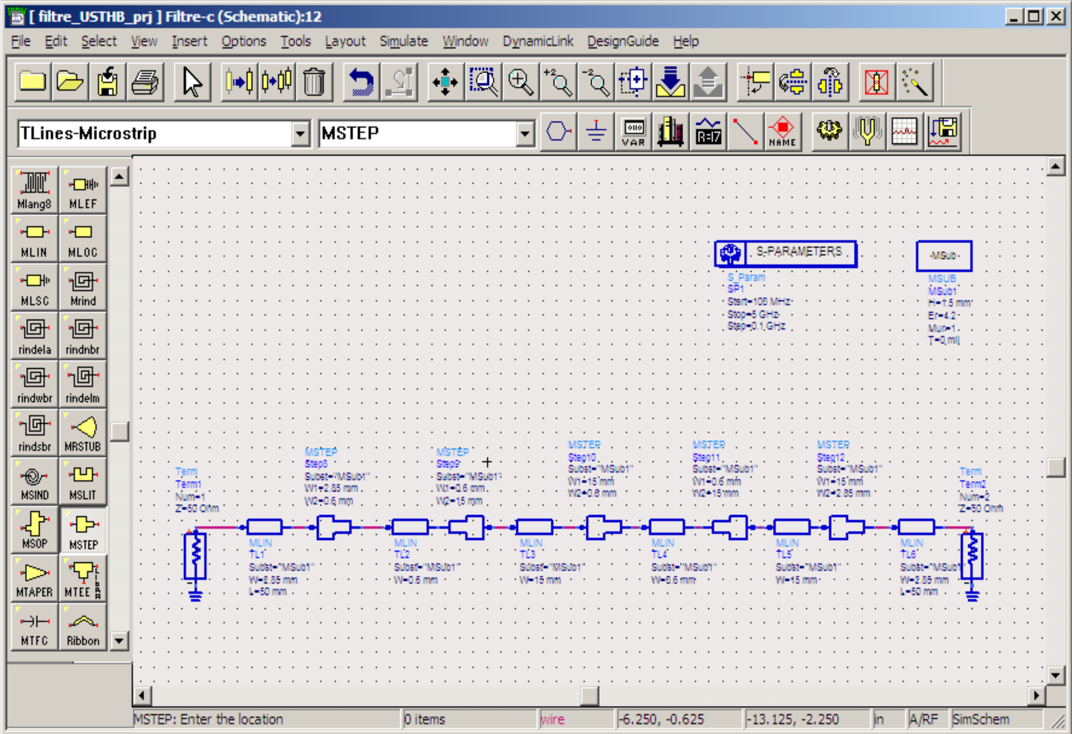
Cut-off frequency = 1.5 GHz (3 dB)

Rejection @ 3 GHz = 30 dB



Re-simulate the filter by increasing the frequency (from 8 GHz to 20 GHz, same step-size: 0.1 GHz).

Conclusion ?



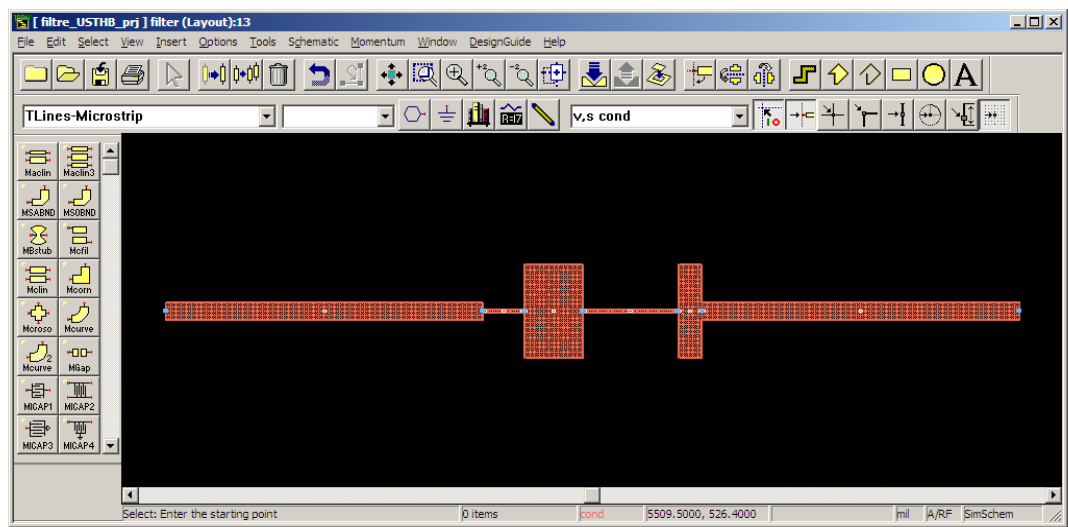
the specs :

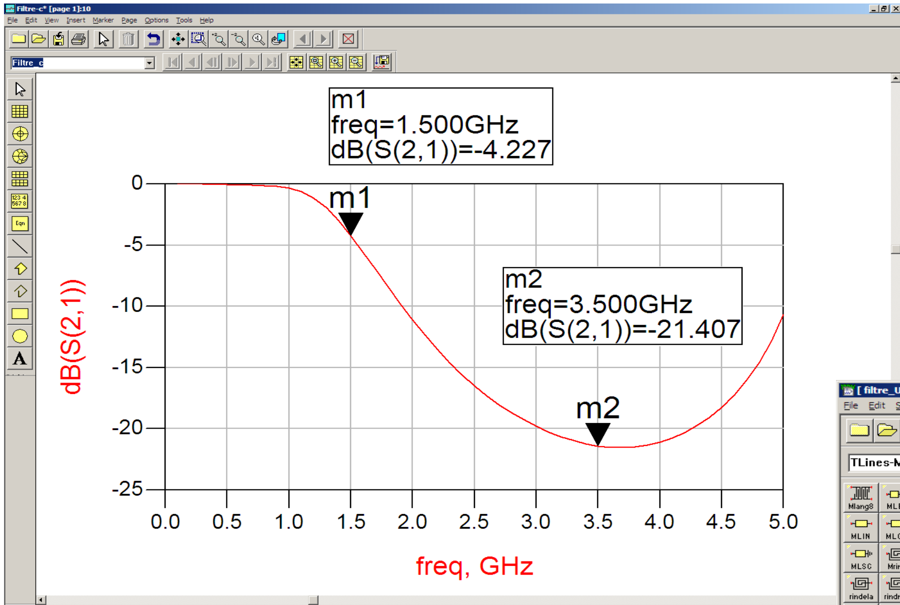
Cut-off frequency = 1.5 GHz (3 dB)

Rejection @ 3 GHz = 30 dB

Simulation with the EM simulator: Momentum

Generate layout: from Schematic to Layout

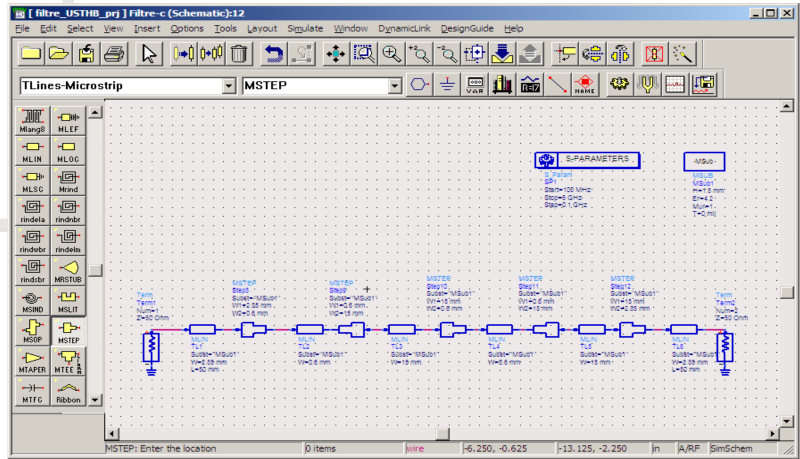


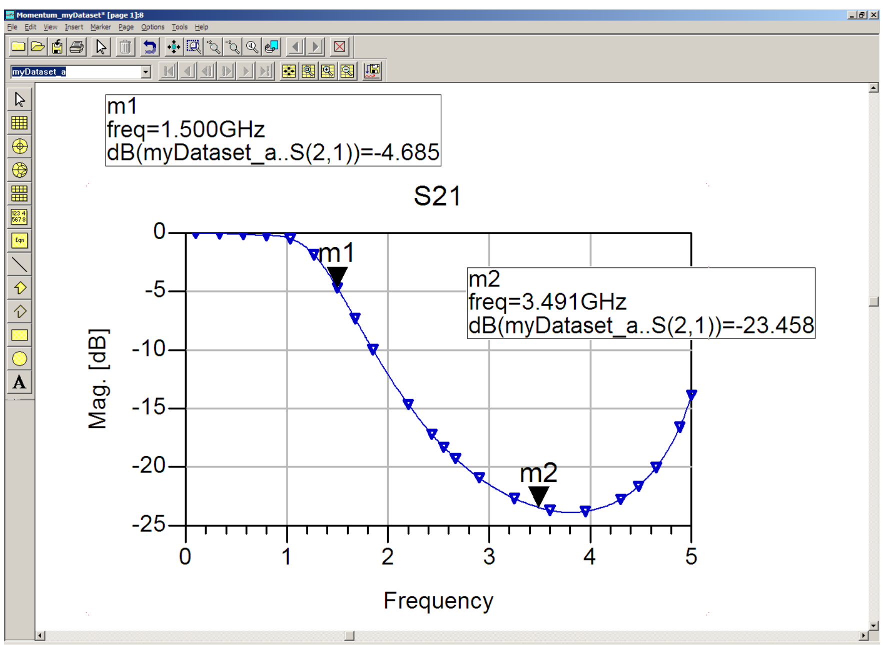


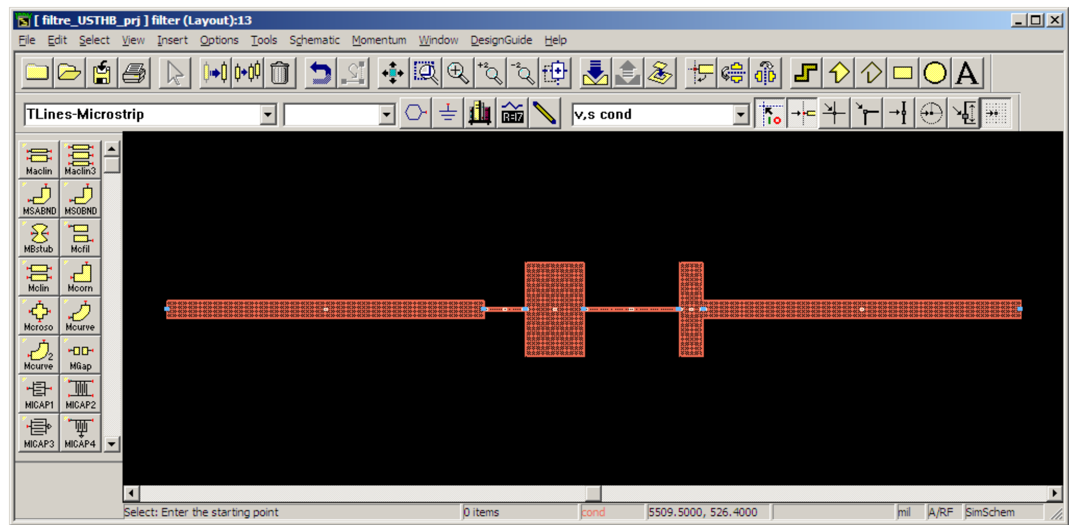
the specs :

Cut-off frequency = 1.5 GHz (3 dB)

Rejection @ 3 GHz = 30 dB







WE SIMULATED A MICROSTRIP LOW PASS FILTER USING

THE **ADS** SOFTWARE AND FOUND SOME STRANGE BEHAVIOURS**.**

ADS-Momentum is a 2 D EM simulator.

WHAT WOULD BE THE PERFORMANCE

IF

SIMULATED WITH ANOTHER SOFTWARE?

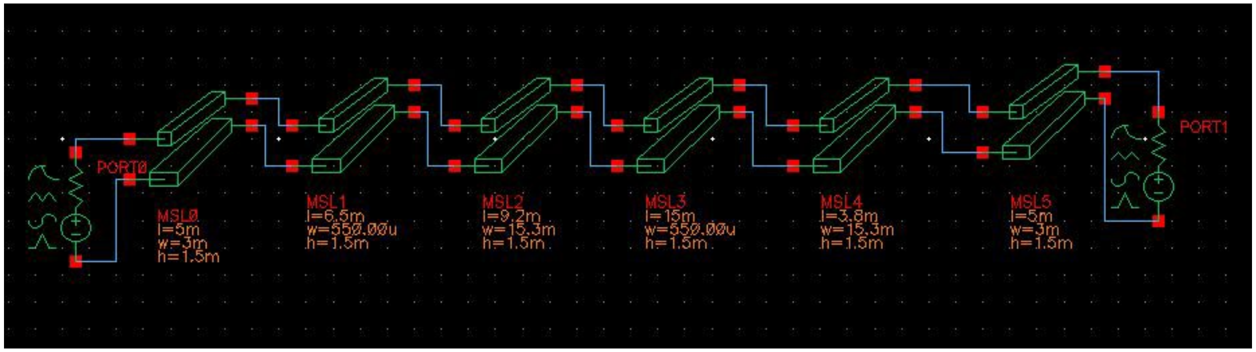
Filter specs:

Cut-off frequency = 1.5 GHz (3 dB)

Rejection @ 3 GHz = 30 dB

Substrate: FR4, ε_r = 4.2 and h = 1.5 mm, T = 38 μm (fiber-glass)

Simulations with Cadence



Note that Cadence uses the model for microstrip line so doesn't need to define meshing.

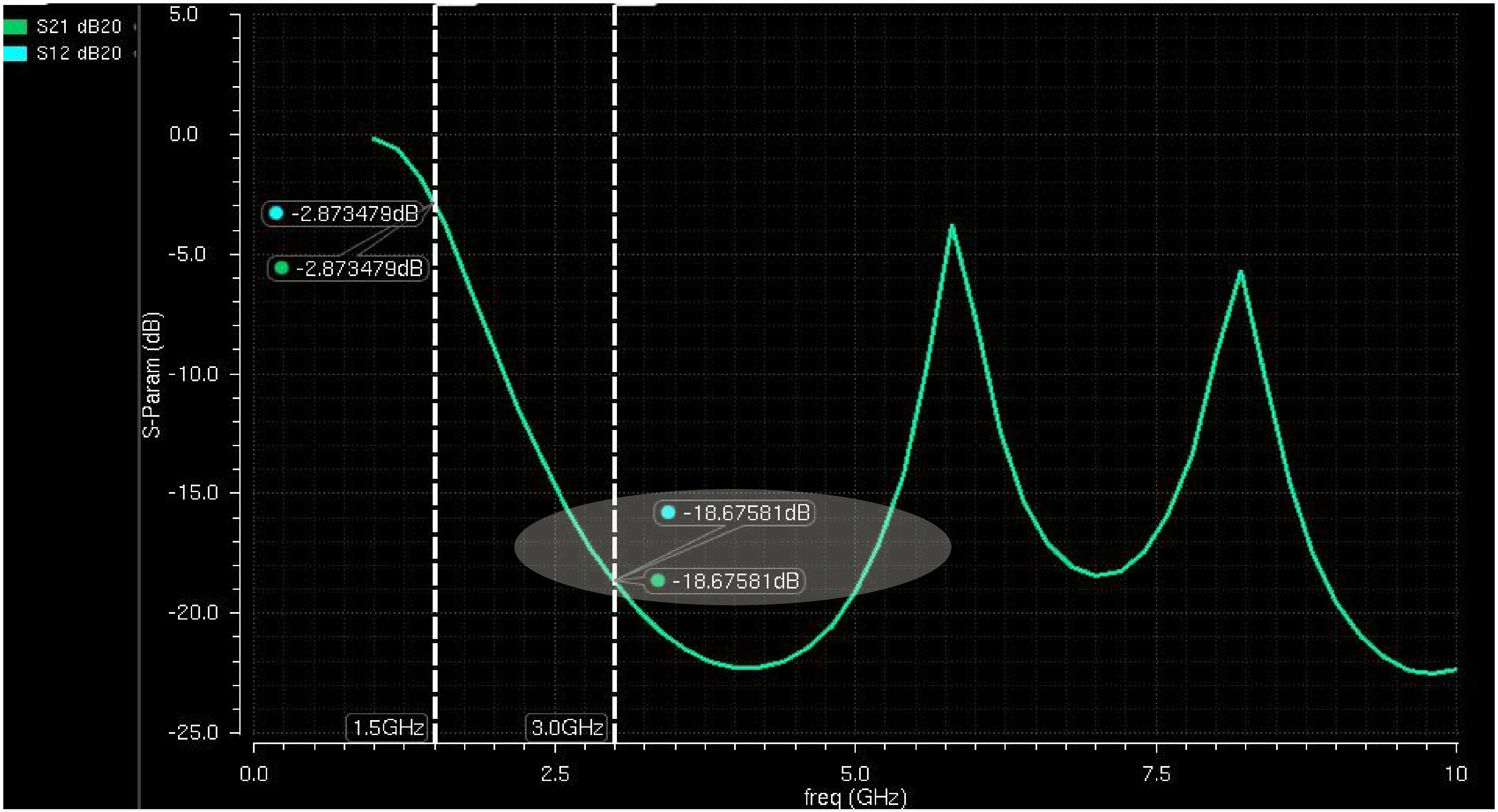
the specs :

Cut-off frequency = 1.5 GHz (3 dB)

Rejection @ 3 GHz = 30 dB

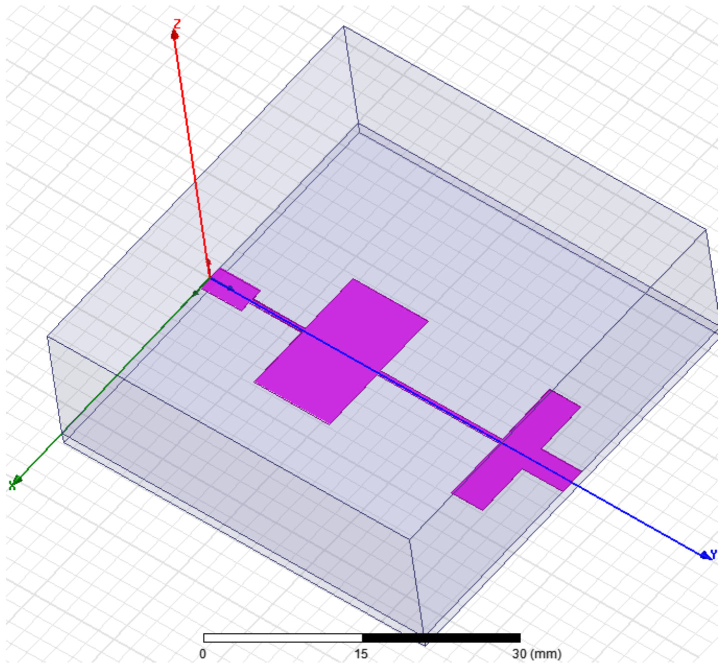
Simulation results by Cadence

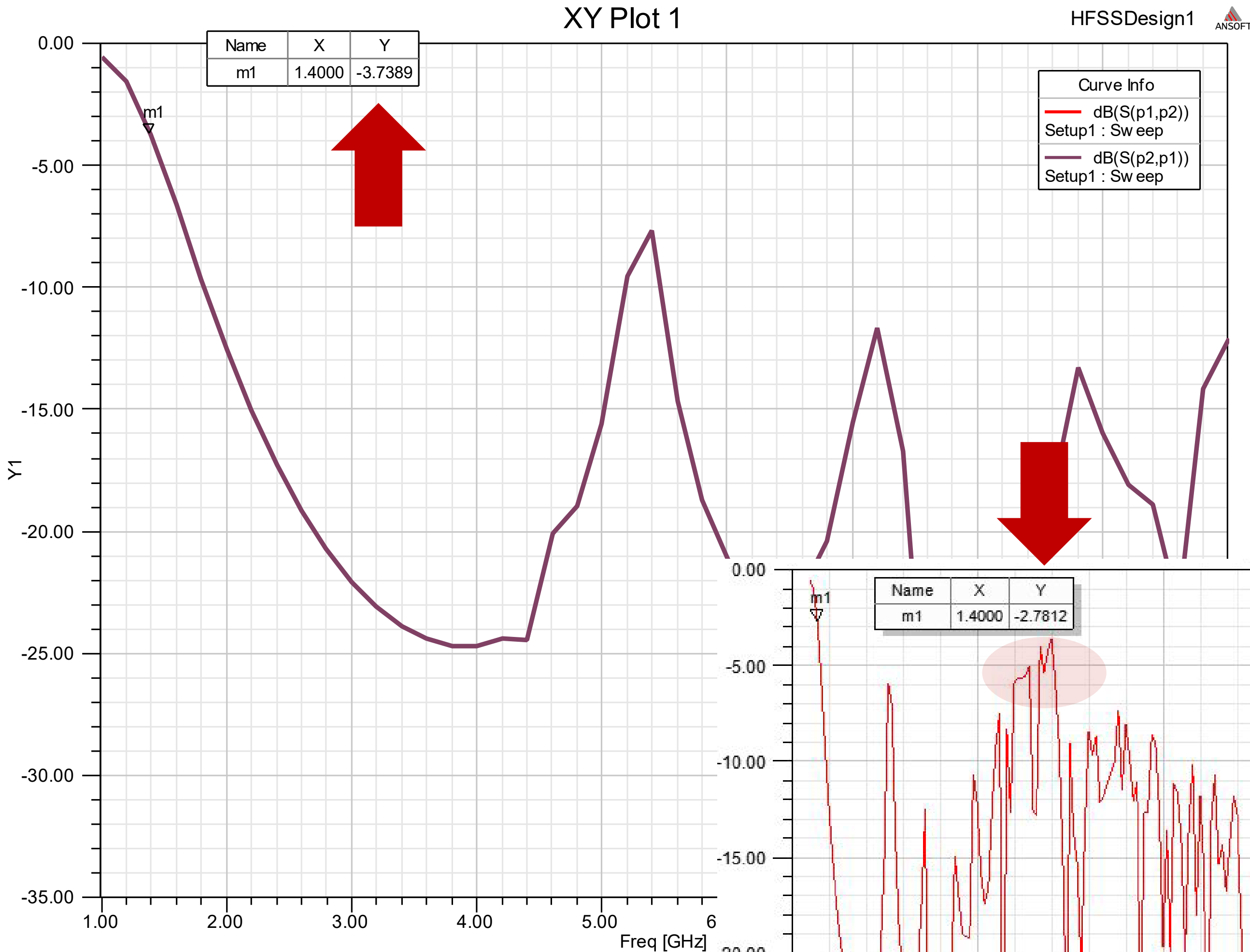
when mesh frequency is 10 GHz



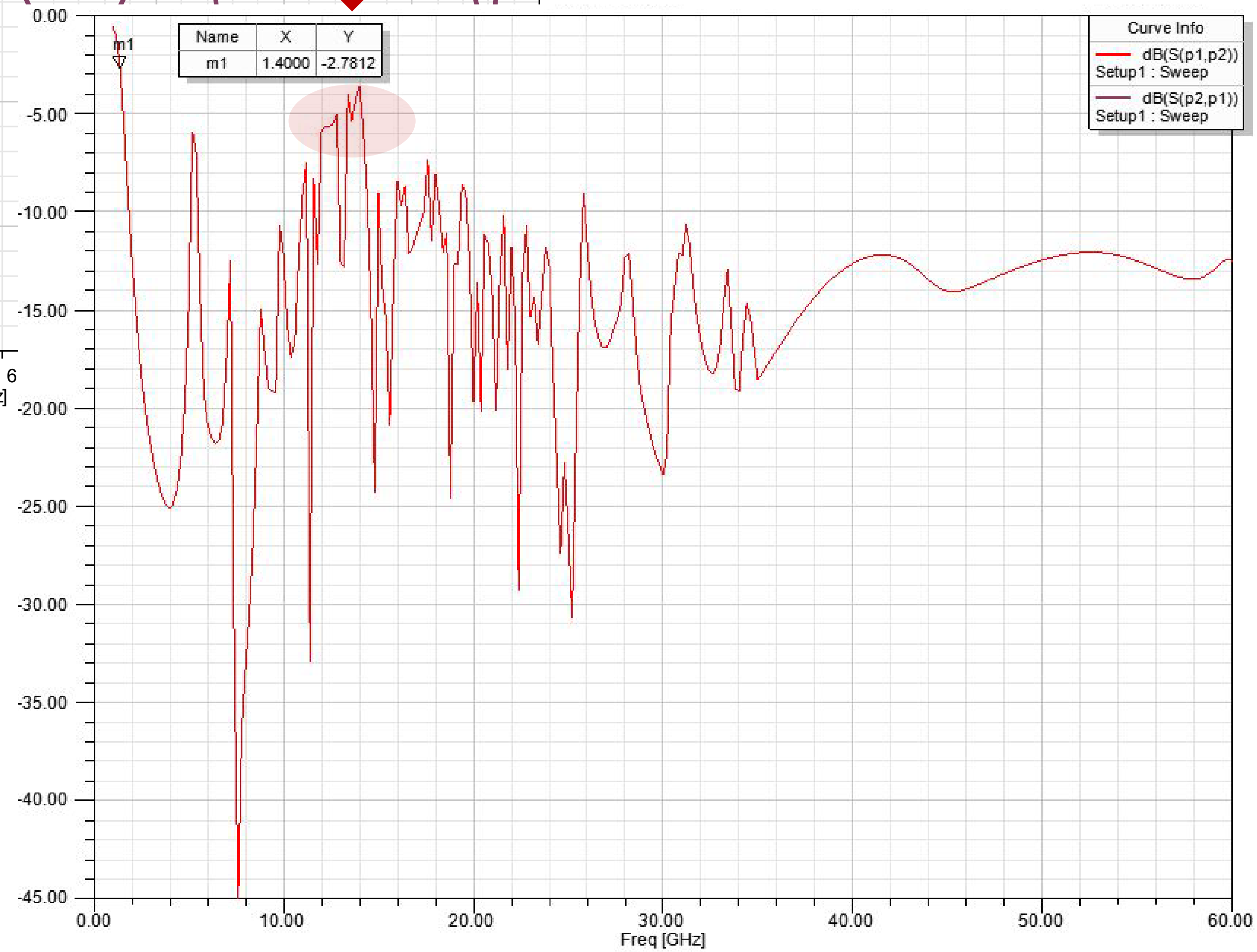
Simulations with HFSS 3D

EM simulator



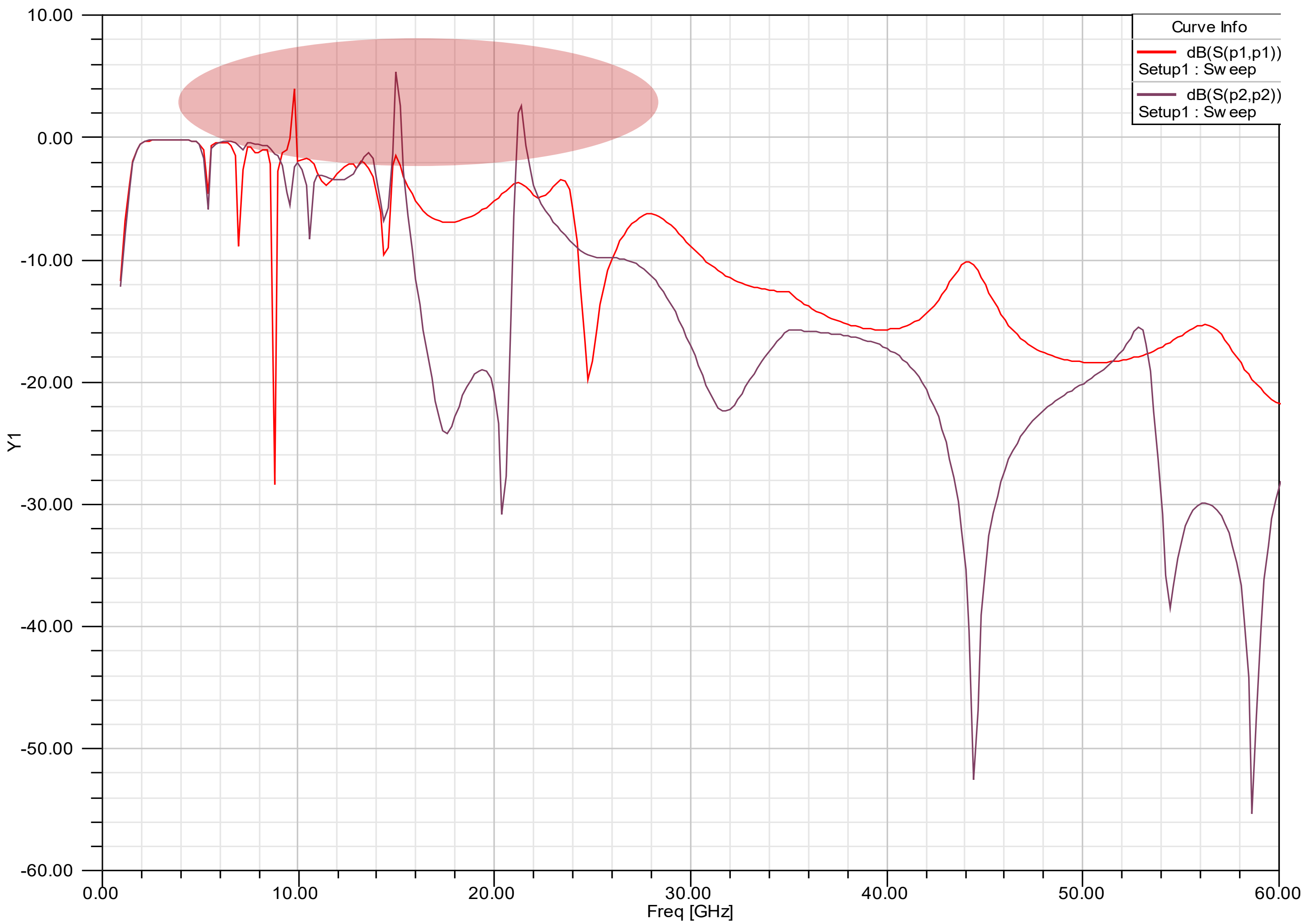


Simulation results by HFSS when mesh frequency is 10 GHz



Simulation results by HFSS when mesh frequency is 60 GHz

Furthermore, when we use the function “adaptive sweep frequency” in HFSS, we got



WE SIMULATED A MICROSTRIP LOW PASS FILTER

USING DIFFERENT SOFTWARE AND STRANGE BEHAVIOURS ARE STILL THERE.

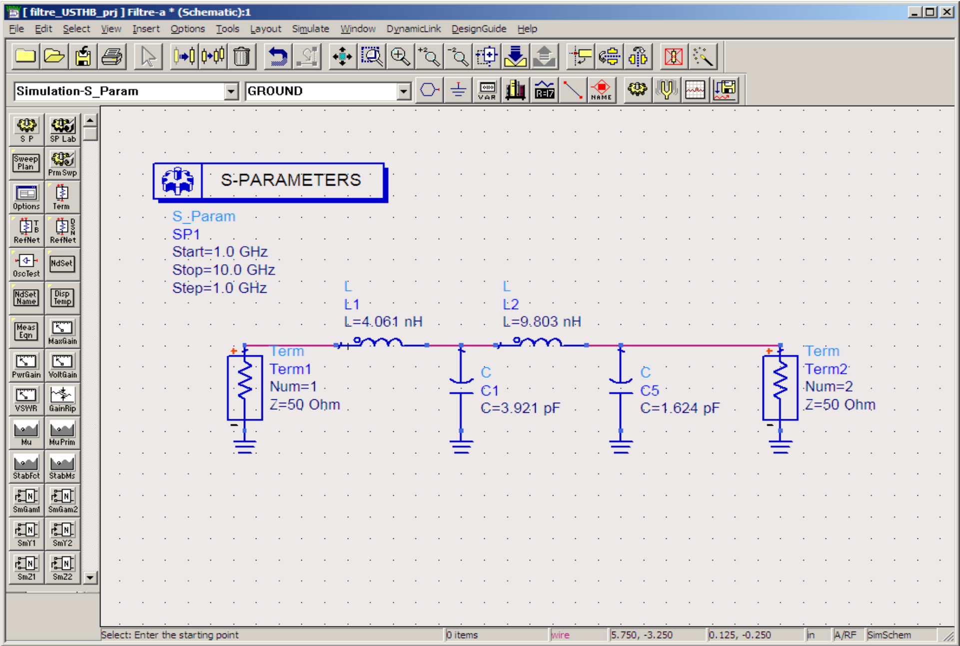
SO WE CANNOT TOTALLY BLAME THE SOFTWARE !

Filter specs:

Cut-off frequency = 1.5 GHz (3 dB)

Rejection @ 3 GHz = 30 dB

Substrate: FR4, ε_r = 4.2 and h = 1.5 mm, T = 38 μm (fiber-glass)



the specs :

Cut-off frequency = 1.5 GHz (3 dB)

Rejection @ 3 GHz = 30 dB

Let us come back to the layout in ADS and check !

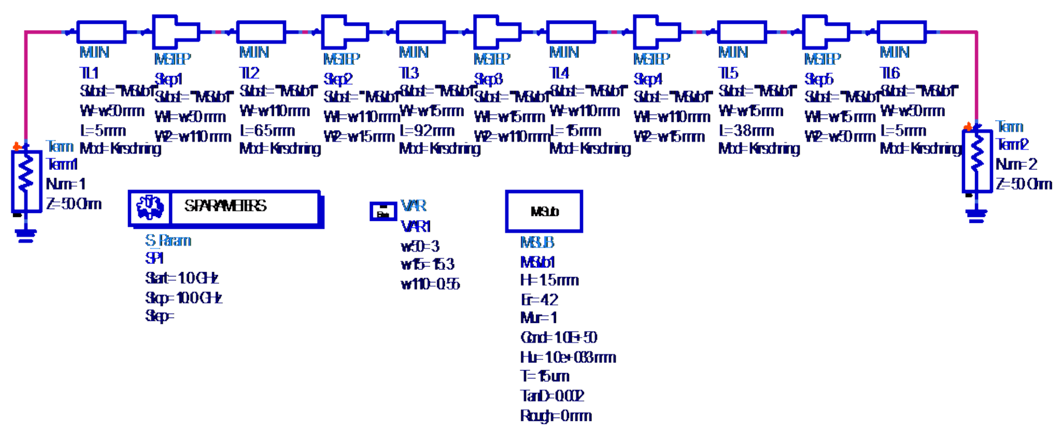
Convert the lumped elements to transmission lines

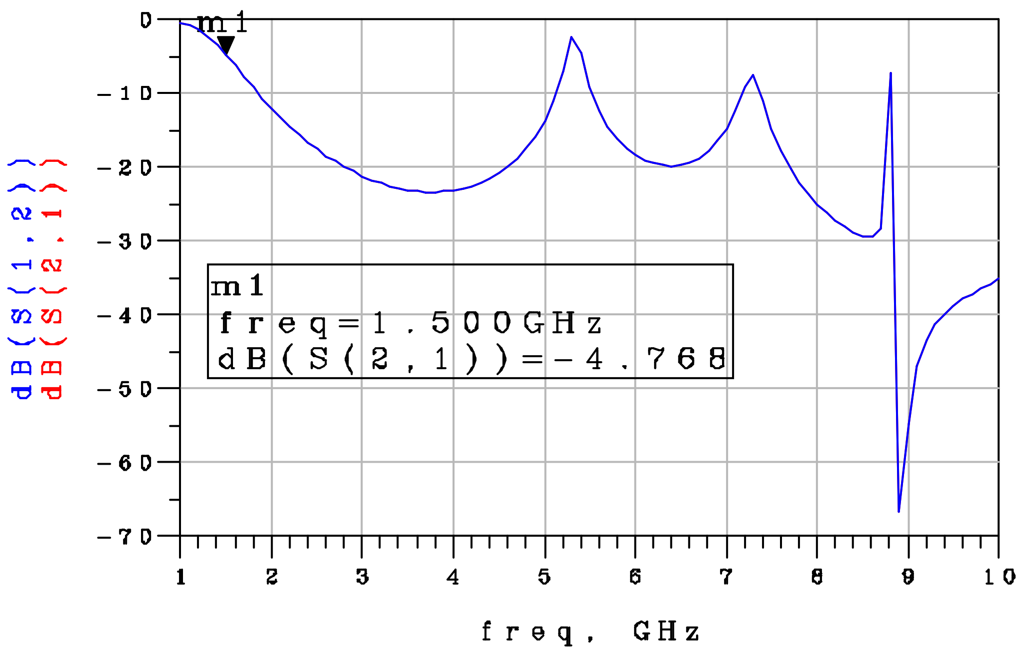
Capacitive lines	$Z_{0c} = 15\ \Omega$	$w_C = 15$ mm	Effective permittivity = 3.68
Reference	$Z_0 = 50\ \Omega$	$w_o = 2.85$ mm	Effective permittivity = 3.21
Inductive lines	$Z_{0L} = 110\ \Omega$	$w_L = 0.6$ mm	Effective permittivity = 2.83

By assuming 15 Ω for capacitive lines and 110 Ω for inductive lines, we had

Freq (GHz)	W_{50} (mm)	W_{15} (mm)	W_{110} (mm)
1	2.96	15.13	0.53
3	2.97	15.26	0.53
10	3.19	16.11	0.58
25	3.98	17.52	1.00
60	4.61	17.88	1.75
100	4.78	17.9	2.09

We chose W_{50}=3mm, W_{15}=15.3mm and W_{110}=0.55mm and got the following schematic:





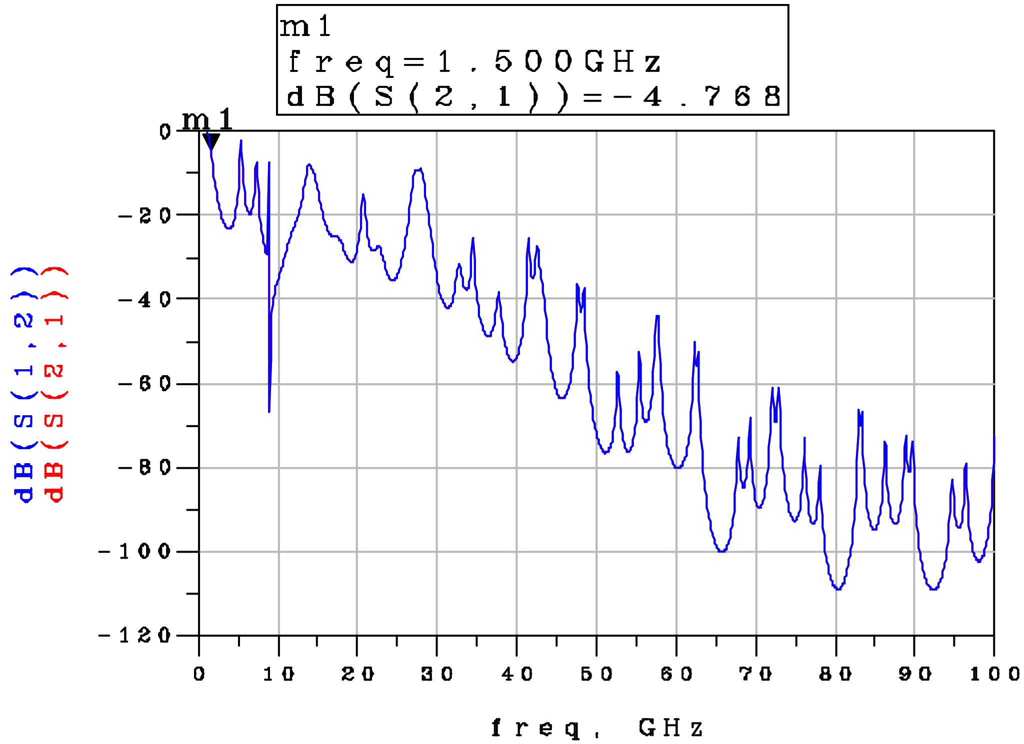
the specs :

Cut-off frequency = 1.5 GHz (3 dB)

Rejection @ 3 GHz = 30 dB

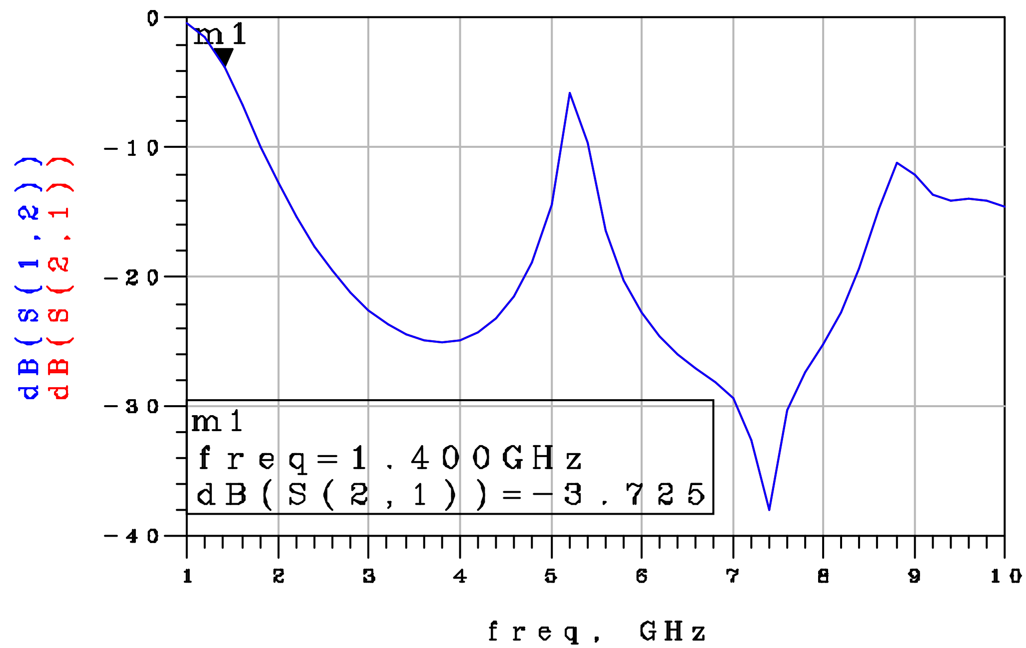
Up to 10 GHz

Fine !

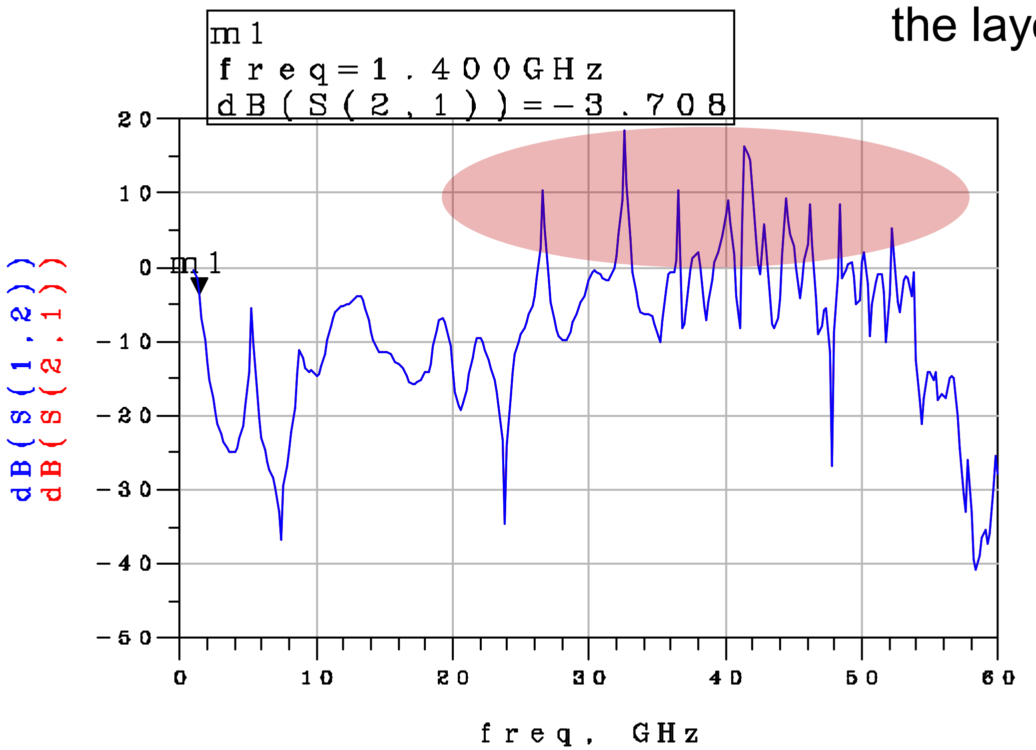


Up to 100 GHz

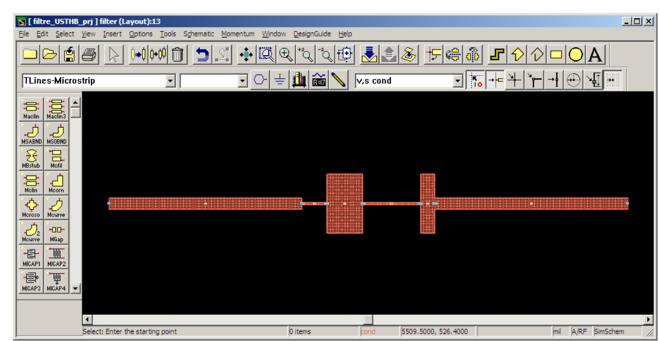
Simulation results by ADS momentum when mesh density is 40 per wavelength and mesh frequency is 10 GHz



Now, let us check the layout:

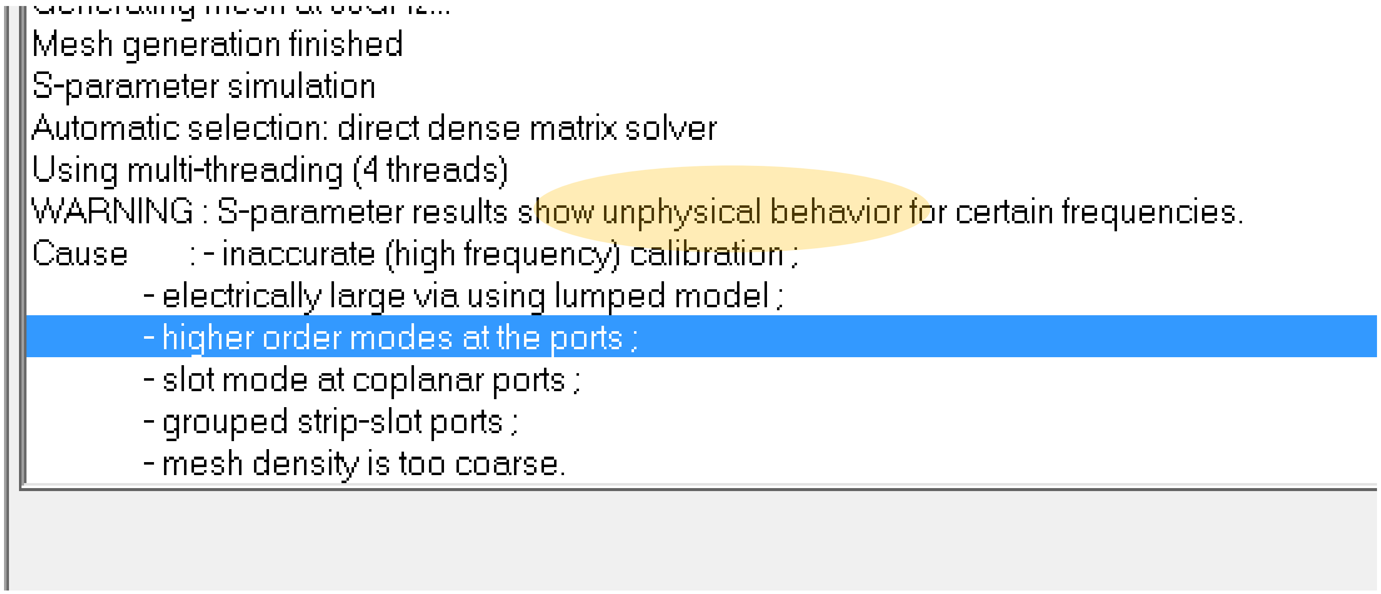


Simulation results by ADS momentum when mesh density is 30 per wavelength (to reduce the simulation time) and mesh frequency is 60 GHz.



Let us check to what is “behind the screen” in ADS.

Although we defined the mesh as fine as possible, the results are wrong at some frequencies. As seen from figure below, ADS itself has predicted the probability of wrong results in some simulations: higher order modes ?



Let us come back to the table :

What is wrong ?

Freq (GHz)	W_{50} (mm)	W_{15} (mm)	W_{110} (mm)
1	2.96	15.13	0.53
3	2.97	15.26	0.53
10	3.19	16.11	0.58
25	3.98	17.52	1.00
60	4.61	17.88	1.75
100	4.78	17.9	2.09

From the theory, the values of W (the width) for a constant impedance should be almost constant (at least for the lowest frequency portion of the electromagnetic spectrum, e.g., in the range 1-10 GHz).

Why ?

QUASI-TEM propagation mode properties as explained in class !!

Let us come back to the table :

What is wrong ?

Freq (GHz)	W_{50} (mm)	W_{15} (mm)	W_{110} (mm)
1	2.96	15.13	0.53
3	2.97	15.26	0.53
10	3.19	16.11	0.58
25	3.98	17.52	1.00
60	4.61	17.88	1.75
100	4.78	17.9	2.09

In fact, the effective permittivity of a microstrip line is usually independent of frequency (at least for the low frequencies portion of the microwave spectrum)

but we noticed here that for the substrate FR4 (**taken by default in ADS**), the effective permittivity and thus, the characteristics impedance is dependent on frequency.

→ dispersive fields are huge, increasing with the frequency.

A too thick substrate acts as a cavity

Therefore, we shouldn't expect realistic responses from microstrip filters at very wide band widths, especially for thick substrates.

Solution ?

Effective permittivity and width for a 50 Ω impedance

Substrate, $\varepsilon_r = 4.2$, h = 1.5 mm

Freq (GHz)	W_{50} (mm)	Eeff
1	2.96	3.21
3	2.97	3.25
10	3.19	3.48
25	3.98	3.88
60	4.61	4.11
100	4.78	4.16

Effective permittivity and width for a 50 Ω impedance

Substrate, $\varepsilon_r = 4.2$, h = 0.38 mm

Freq (GHz)	W_{50} (mm)	Eeff
1	0.75	3.19
3	0.75	3.20
10	0.75	3.24
25	0.77	3.35
60	0.88	3.65
100	1.01	3.88

the too thick substrate acts as a cavity

Therefore, we should reduce the substrate thickness !!

As we know, ADS solves the green functions from the moment method and HFSS solves the Finite Element equations.

If we can define the mesh and ports or even frequency sweep closer to the facts, we can expect the results to be closer to practical situations.

In this case, time domain simulation might be useful.

Thank you !

End of Chapter 8