Lab 6 Report

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Background

In this week's lab, we go through the process to design the filter and fabricate a band pass filter by copper taper on FR4 substrate. By reading the table to determine the coefficients of filter prototype. Next, using the Richard's Transformation to convert the LC values into short stubs or open stubs. Because the short stubs in series section is hard to be implemented on the circuit board, Kuroda identities can help us to solve this problem to transform the series stubs into shunt open stubs.

Design

Task 1.

a. N5_MaxFlat_LPF_T-Line

By going through the design process from step 1 to step 5.3.

The transformation procedure can help us to know the impedance and length for each line in this design.

The design parameters are shown in the following table.

Design Parameter:		N5 MaxFlat LPF TLine					at 2.5 GHz
Unit:mm		Unit:mm		Unit:mm		Unit:mm	
W_{UE1}	1.76	L_{UE1}	8.635	W_{stub1}	0.084	L_{stub1}	9.095
W_{UE2}	0.539	L_{UE2}	8.897	W_{stub2}	3.963	L_{stub2}	8.351
W_{UE3}	0.539	L_{UE3}	8.897	W_{stub3}	8.4	L_{stub3}	8.04
W_{UE4}	1.76	L_{UE4}	8.635	W_{stub4}	3.963	L_{stub4}	8.351
W_0	3.118			W_{stub5}	0.084	L_{stub5}	9.095

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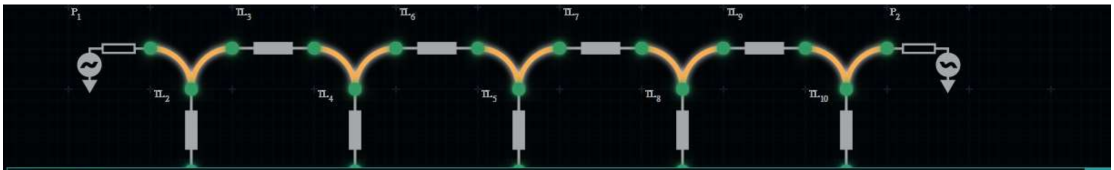
Then, enter this information into the “N5_MaxFlat_LPF_T-Line.zov” and HFSS.



CURRENT NETLIST

Component	Real Impedance	Imag Impedance	Length	Physical Length	Capacitance	Inductance	Beta	Alpha	Gain
TL7	112 none		124.98 m	8.91 m				0 f	
TL8	43 none		124.95 m	8.37 m				0 f	
TL9	69 none		124.98 m	8.65 m				0 f	
TL10	181 none		125.09 m	9.10 m				0 f	
OC5									
OC1									
OC2									
TL2	181 none		125.09 m	9.10 m				0 f	
TL3	69 none		124.98 m	8.65 m				0 f	
TL4	43 none		124.95 m	8.37 m				0 f	
TL5	25 none		124.92 m	8.09 m				0 f	

b. N5_MaxFlat_LPF_LC.zov

From step 2, we determine the LC coefficient of the filter prototype.

Next, doing impedance scaling to map this performance to our design frequency.

The process is shown below.

$$\omega_{3dB} = 2\pi \cdot f_c = 2\pi \cdot 2.5 \cdot 10^9 = 15.708 \cdot 10^9$$

$$L_r = {}^{50}/_{\omega_{3dB}} = 3.183\,nH$$

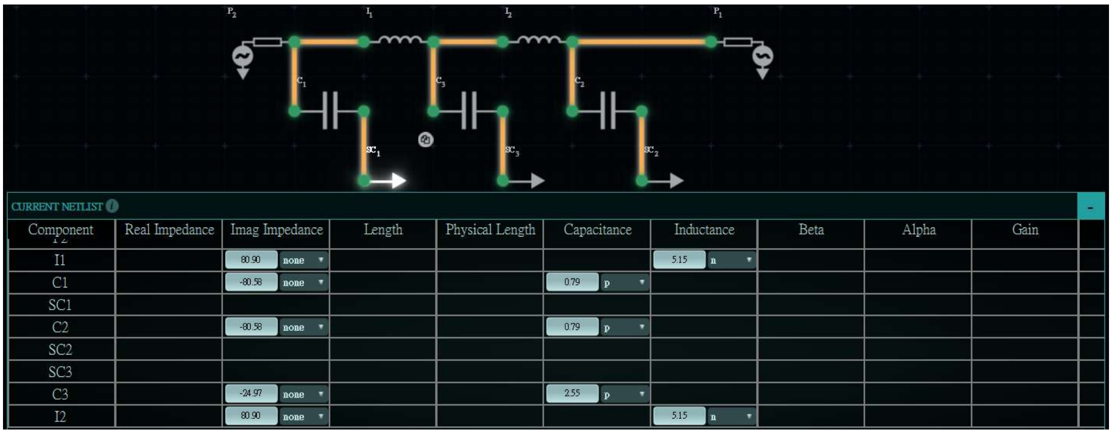
$$C_r = \frac{1}{50 \cdot \omega_{3dB}} = 1.273\,pF$$

from Table: $C_1 = C_5 = 0.618$ $\qquad C_1 = C_5 \Rightarrow 0.7867\,pF$

$L_2 = L_4 = 1.61803 \qquad \Rightarrow L_2 = L_4 \Rightarrow 5.15\,nH$

$C_3 = 2. \qquad C_3 \Rightarrow 2.546\,pF$

Then, enter those information into the “N5_MaxFlat_LPF_LC.zov”

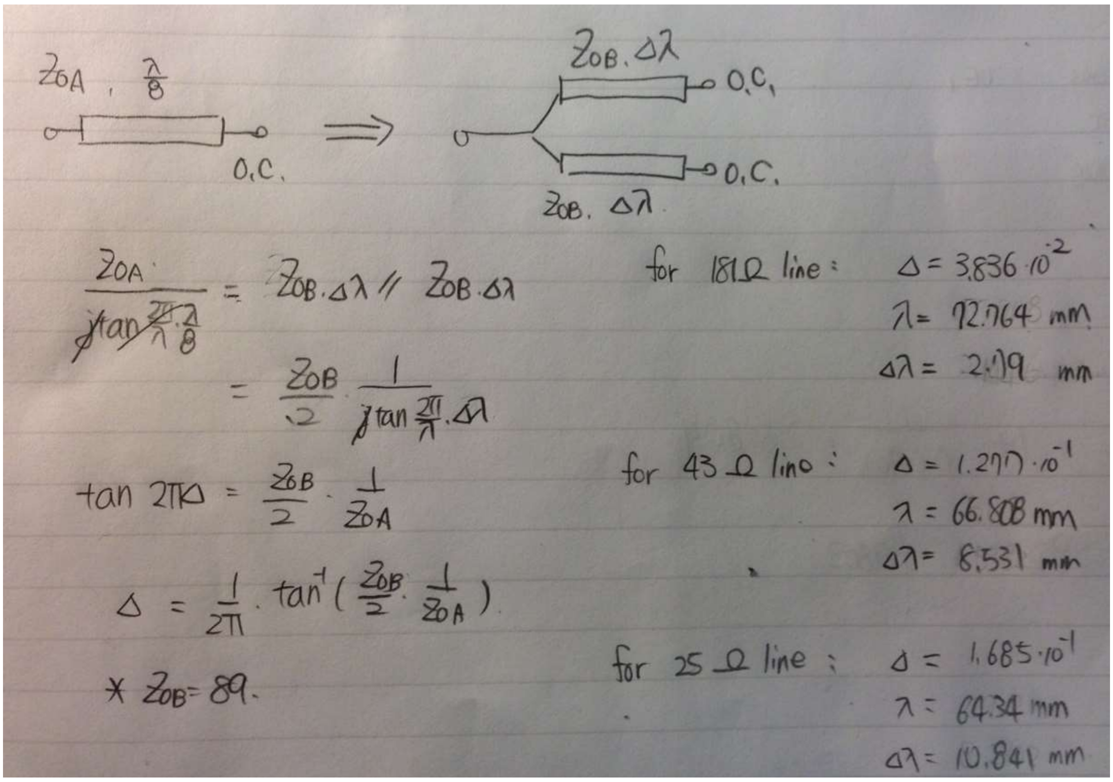


Component	Real Impedance	Imag Impedance	Length	Physical Length	Capacitance	Inductance	Beta	Alpha	Gain
l1		80.90 none				5.15 n			
C1		-80.58 none			0.79 p				
SC1									
C2		-80.58 none			0.79 p				
SC2									
SC3									
C3		-24.97 none			2.55 p				
l2		80.90 none				5.15 n			

c. N5_MaxFlat_LPF_T-Line_Tapped_Stubs

From step 5.3, we get impedance and length information for each line.

By doing the following calculation, we can make this design be a symmetric one and reduce the area on the board.



The design parameters are shown in the following table.

Design Parameter:		N5 MaxFlat LPF Tline TappedStubs				at 2.5 GHz	
Unit:mm		Unit:mm		Unit:mm		Unit:mm	
W_{UE1}	1.76	L_{UE1}	8.635	W_{stub1}	1	L_{stub1}	2.79
W_{UE2}	0.539	L_{UE2}	8.897	W_{stub2}	1	L_{stub2}	8.531
W_{UE3}	0.539	L_{UE3}	8.897	W_{stub3}	1	L_{stub3}	10.841
W_{UE4}	1.76	L_{UE4}	8.635	W_{stub4}	1	L_{stub4}	8.531
W_0	3.118			W_{stub5}	1	L_{stub5}	2.79

Task 2.

By going through the design process from step 1 to step 5.3.

The transformation can help us to know the impedance and length for each line in this design.

The design parameters are shown in the following table.

Design Parameter:		N5_HalfdB_EqRip_BSF_T-Line				at 3 GHz	
Unit:mm		Unit:mm		Unit:mm		Unit:mm	
W_0	3.116	L_{UE1}	12.94	W_{stub1}	1.478	L_{stub1}	14.45
				W_{stub2}	0.666	L_{stub2}	14.75
				W_{stub3}	3.116	L_{stub3}	14.03
				W_{stub4}	0.666	L_{stub4}	14.75
				W_{stub5}	1.478	L_{stub5}	14.45

Procedure

Following the step-by-step description of the activities from “PreLab 6 TAMU ECEN 452 Spring 2016 (Prof. Huff).pdf”

Results and Discussion

Task 1

Max Flat LBF

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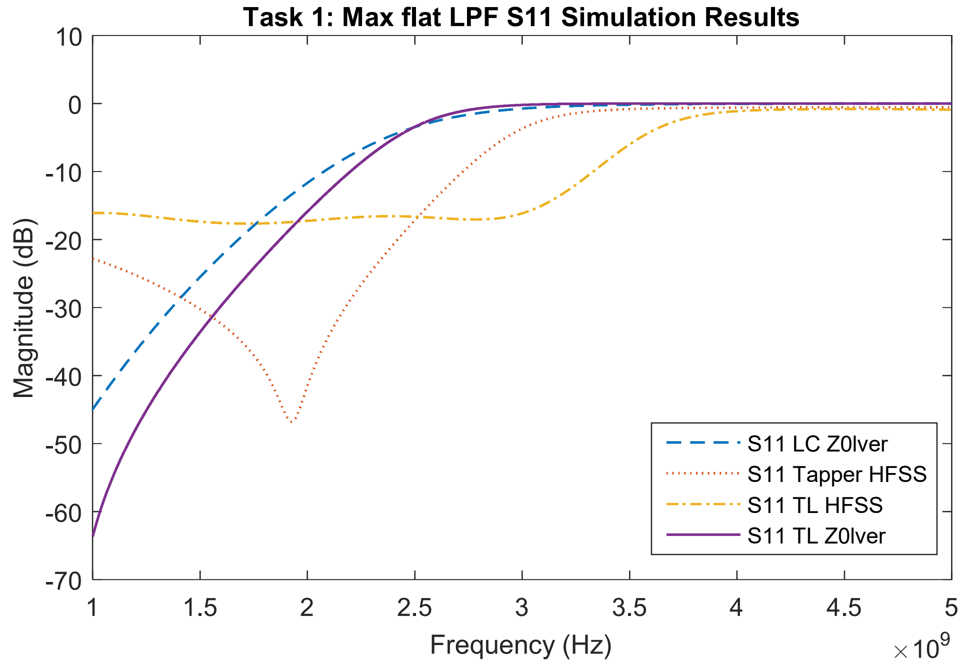
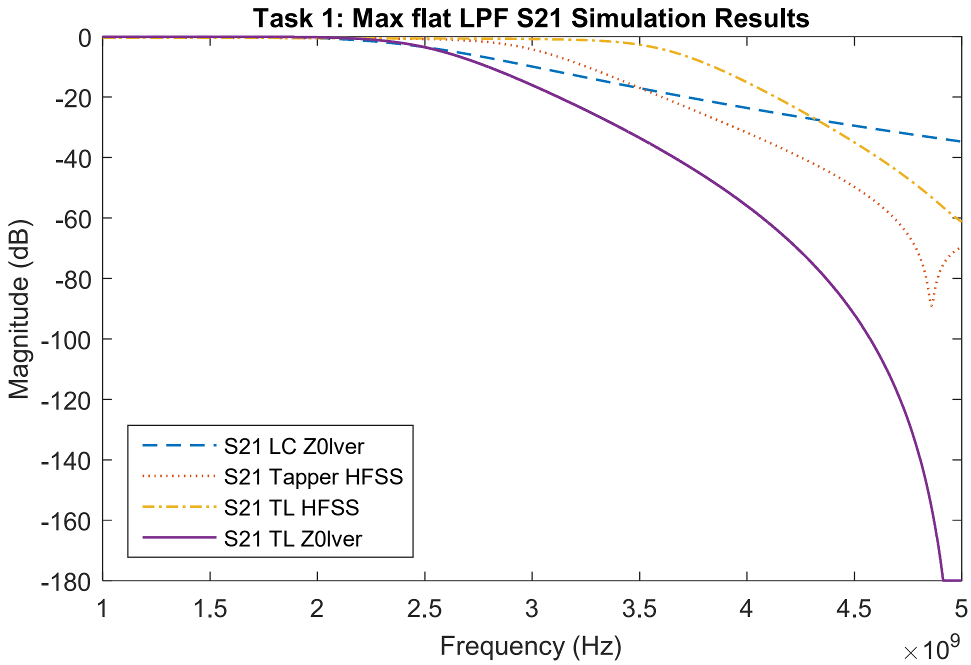
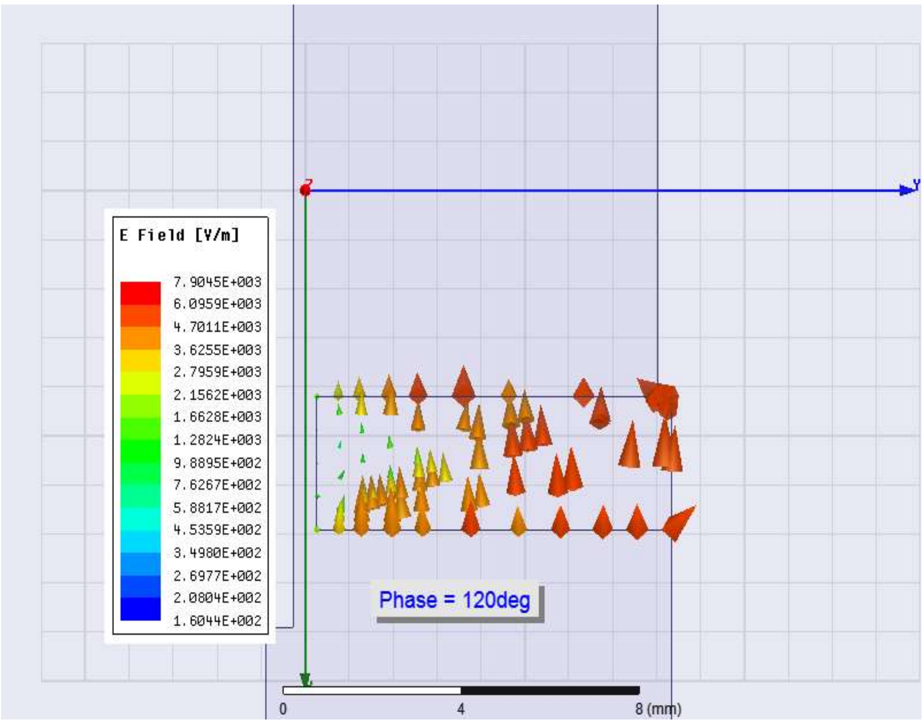




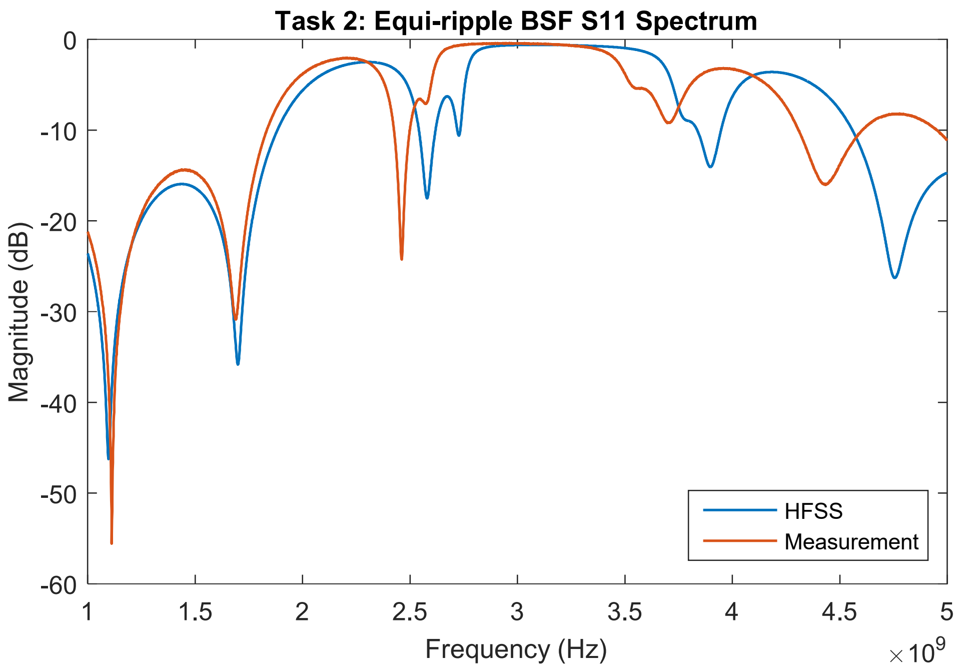
From the simulation result, the data from Tapper HFSS is close to the Z0lver results, from TL model and LC model. The result from this three design are closer to our design goal. But, TL HFSS simulation results are not. The reason is the distance between 43 ohm and 25 ohm impedance stubs, just 2.715 mm, is too close. The energy in this frequency can easily “jump” to the other side. Making the capacitance value formed by the open stubs are different with our prior calculation. And need some tuning work to improve the performance.



By seeing the HFSS simulation result, the E field coupling between these two stubs is very strong.

Task 2

Equi-ripple band-stop filter



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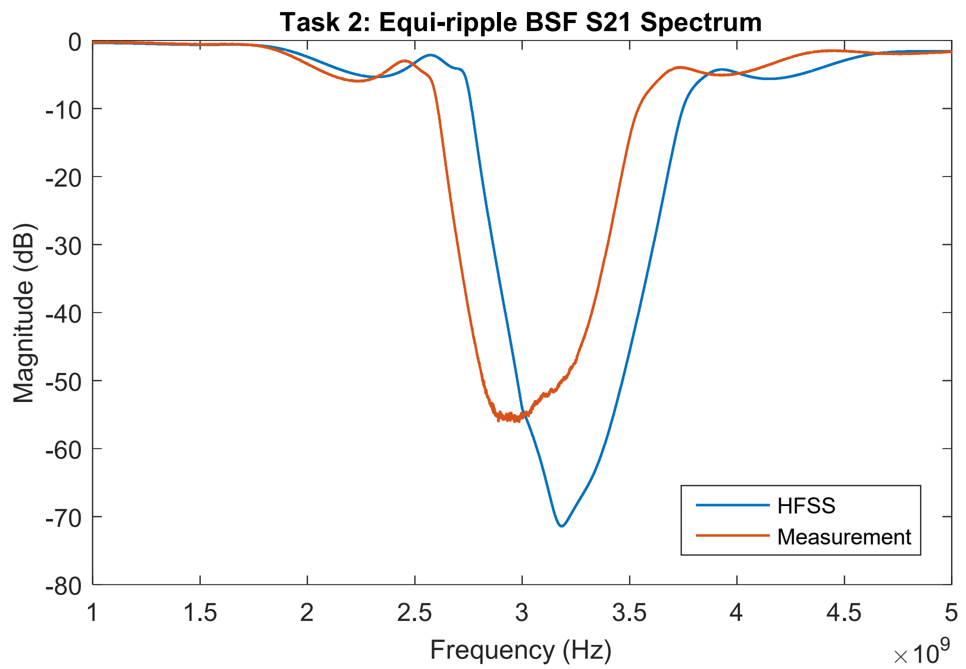

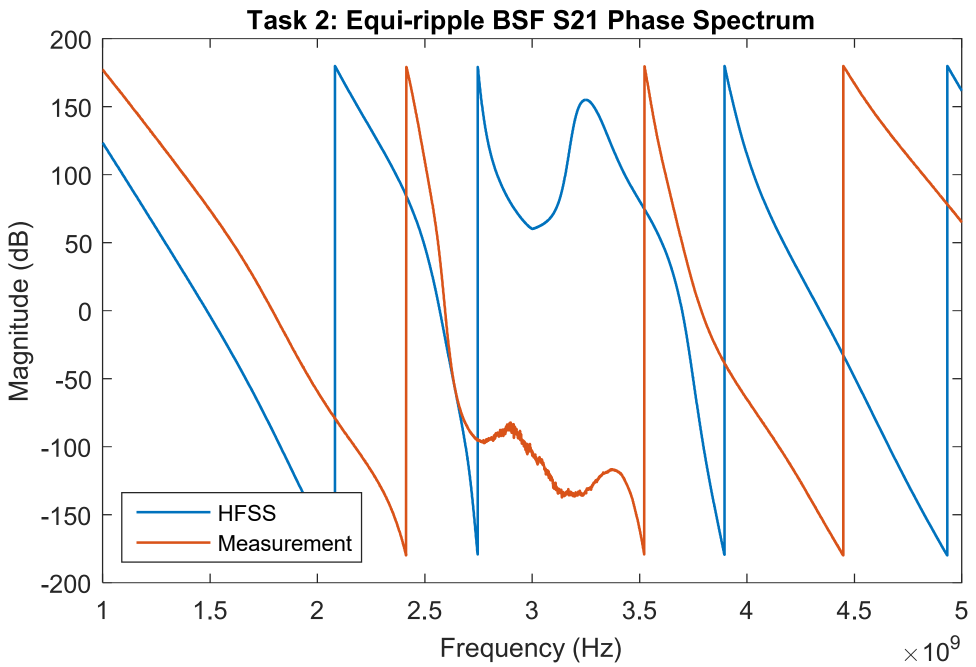

The S parameter results from measurement are similar to the HFSS simulation results before 2.5 GHz. The difference between the data above 2.5 GHz is more obvious. The reason is some fabrication error is “larger” to high frequency wavelength. The loss tangent for FR4 is not 0.01 at high frequency as well.

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Conclusion

- After going through the filter design procedure step by step, the calculations for Richard's Transformation and Kuroda's identities are not a problem.

- Z0lver is a good software to simulate the analytical solution to verify the full-wave simulation results.

- The distance between elements is very important and must to be designed carefully in high frequency.

Reflection

Unit Element ue3 1.00000	Series SC z1' 0.38194	Unit Element ue1' 0.61803	Series SC z2 1.61803	Shunt OC z3 0.50000	Series SC z4 1.61803	Unit Element ue2' 0.61803	Series SC z5' 0.38194	Unit Element ue4 1.00000
N3=1+ue3/z1' N3=3.6182		N5=1+Ue1'/z2 N5=1.38197			N6=1+Ue2'/z4 N6=1.38197		N4=1+Ue4'/z5' N4=3.6182	
Shunt OC z1'' ue3*N3	Unit Element ue3' z1'*N3	Shunt OC z2' ue1'*N5	Unit Element ue1'' z2*N5	Shunt OC z3 0.50000	Unit Element ue2'' z4*N5	Shunt OC z4' ue2'*N6	Unit Element ue4' z5'*N3	Shunt OC z5'' ue4*N4
Shunt OC z1'' 3.6182	Unit Element ue3' 1.3808	Shunt OC z2' 0.85410	Unit Element ue1'' 2.23607	Shunt OC z3 0.50000	Unit Element ue2'' 2.23607	Shunt OC z4' 0.85410	Unit Element ue4' 1.38196	Shunt OC z5'' 3.6182
Shunt OC 181 0.125λ	Unit Element 69 0.125λ	Shunt OC 43 0.125λ	Unit Element 112 0.125λ	Shunt OC 25 0.125λ	Unit Element 112 0.125λ	Shunt OC 43 0.125λ	Unit Element 69 0.125λ	Shunt OC 181 0.125λ

The number in yellow rectangular need some corrections.