

**Bachelor Thesis**

# **Equivalent Circuit Description for SMD-Components**

**By**

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# Contents of the Thesis

- **Introduction to SMD Components**
- **Aim of the Thesis**
- **S-Parameters and Calibration**
- **Equivalent circuit models and measurements for different types of SMD resistors as well as capacitors**
- **Simulations and Results**
- **Conclusion**

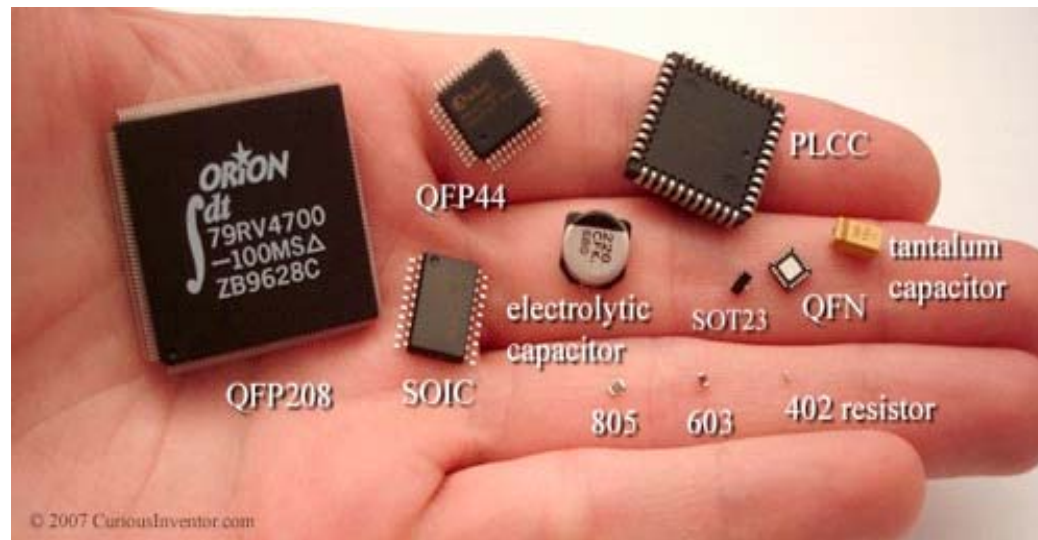
# Introduction to SMD Components

- **Through-Hole Technology**



# Introduction to SMD Components

- Surface Mounted Technology (SMT)



# Introduction to SMD Components

- **Advantages of SMDs**
- **Limitations of SMDs**
- **Why use Surface Mounted Technology**
- **Identifying SMDs**
- **Soldering SMD Components**
- **SMT needs more skills**

# Aim of the Thesis

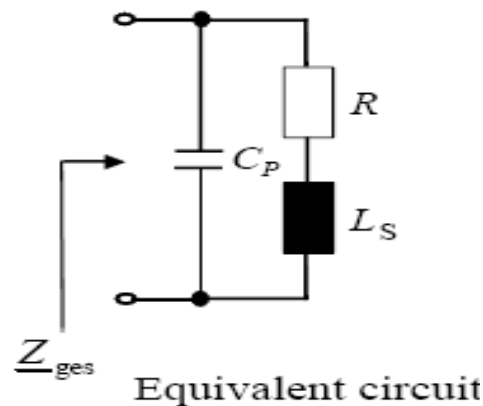
- **To calculate the parasitic elements for:**
  - 0603 type resistors**
  - 0805 type resistors**
  - 0603 type capacitors**
  - 0805 type capacitors**
- **Frequency range from 50 MHz to 10 GHz**

# S-Parameters and Calibration

- What are S-Parameters?
- Why do we need S-Parameters for calculating the Parasitic Elements?
- Calibration
- Important considerations

# Equivalent circuit models and measurements

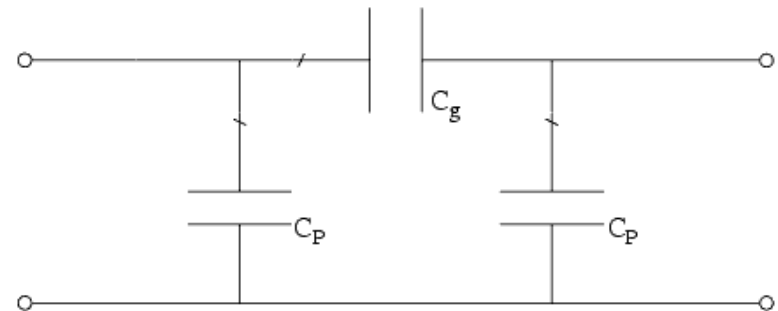
- Introduction to SMD Resistors
- Resistor Model for measuring S-Parameters



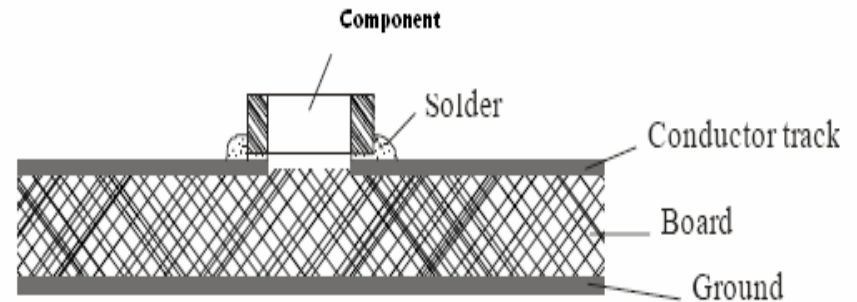


# Equivalent circuit models and measurements

- **Micro-Strip Gap**

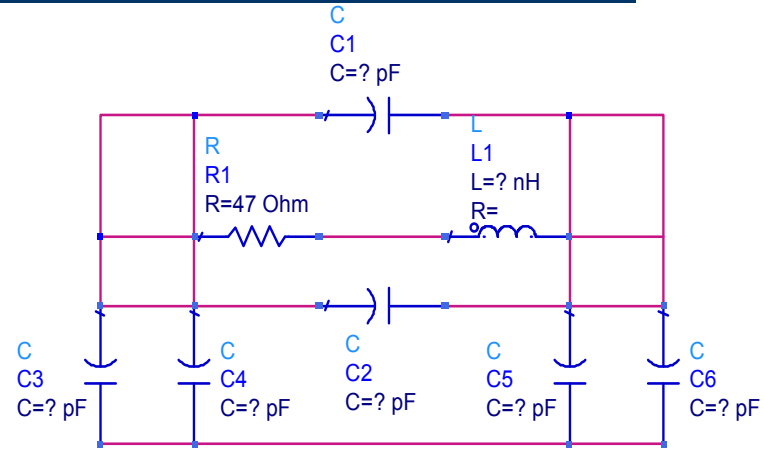


- **Electronic Component on Micro-strip gap**

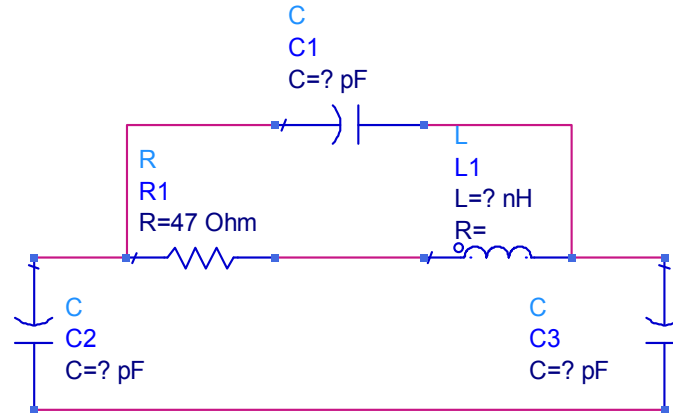


# Equivalent circuit models and measurements

- Equivalent circuit of the Model

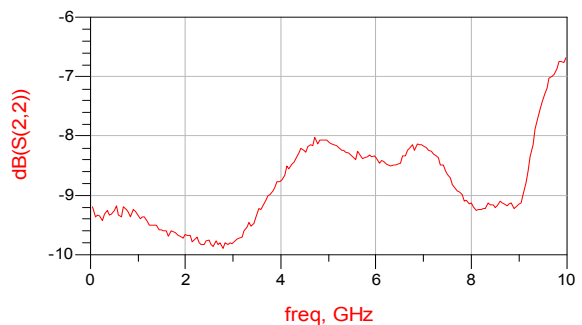
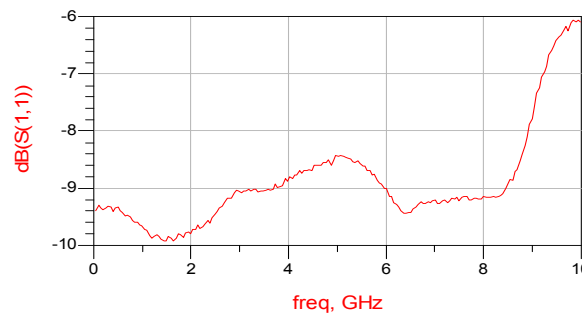


- Simplified circuit of the Model



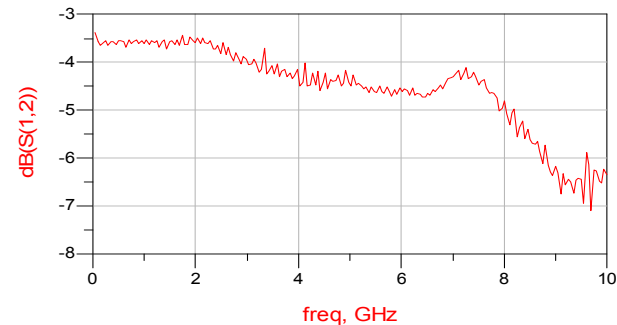
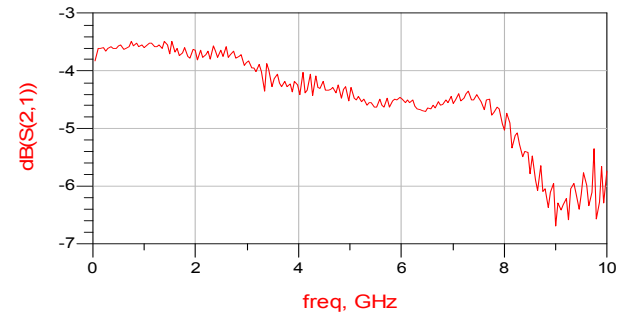
# Equivalent circuit models and measurements

- S-Parameter (S11 & S22) measurements of 0603 type 51 Ohms Resistor



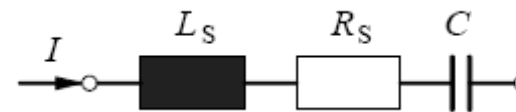
# Equivalent circuit models and measurements

- **S-Parameter (S21 & S12) measurements of 0603 type 51 Ohms Resistor**



# Equivalent circuit models and measurements

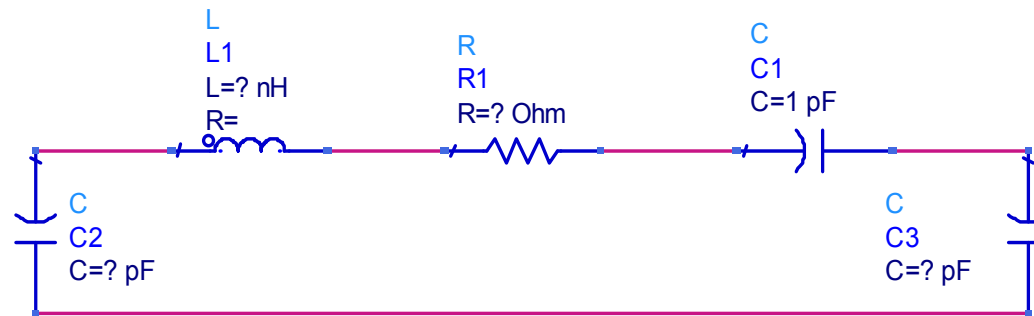
- Introduction to SMD Capacitors
- Capacitor Model for measuring S-Parameters



Equivalent circuit of Capacitor

# Equivalent circuit models and measurements

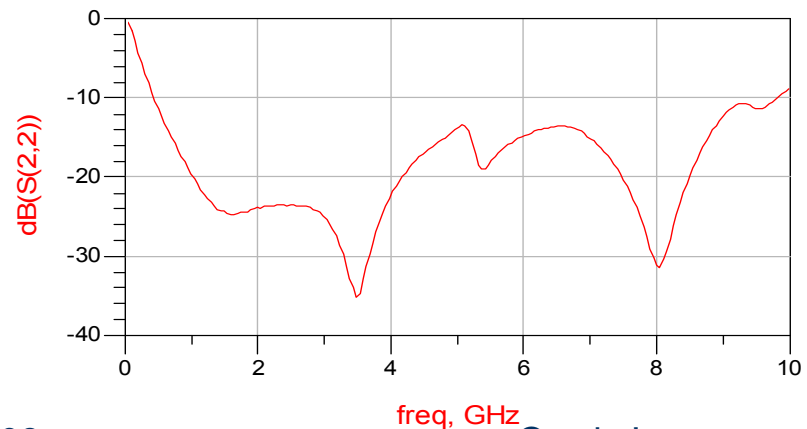
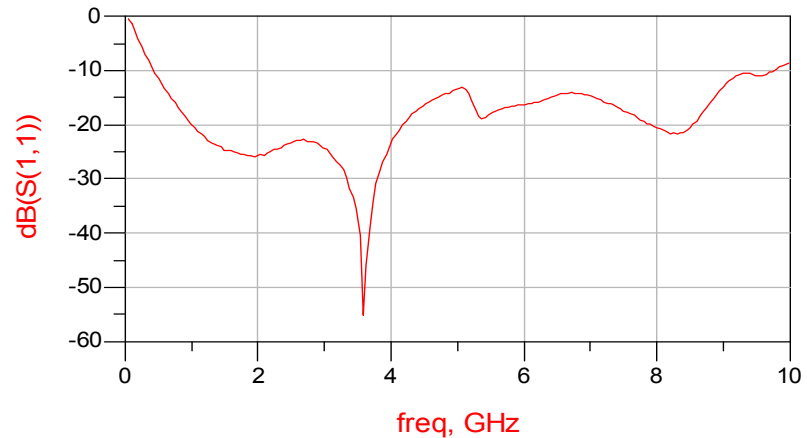
- Simplified circuit of the Model



Simplified circuit of the capacitor model

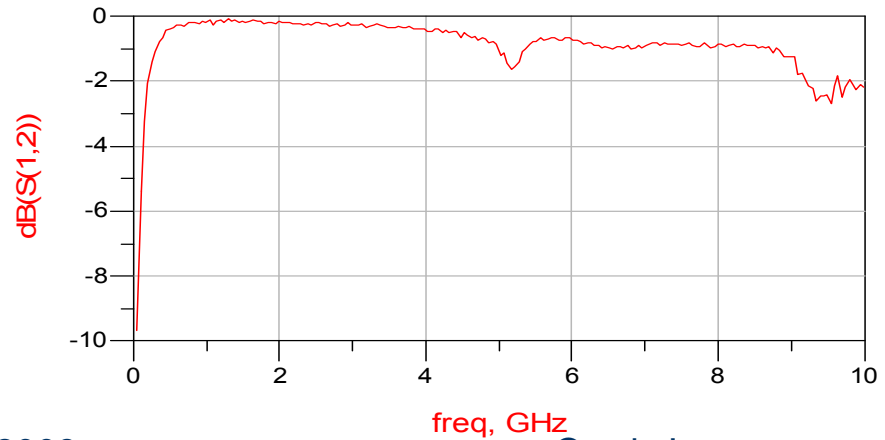
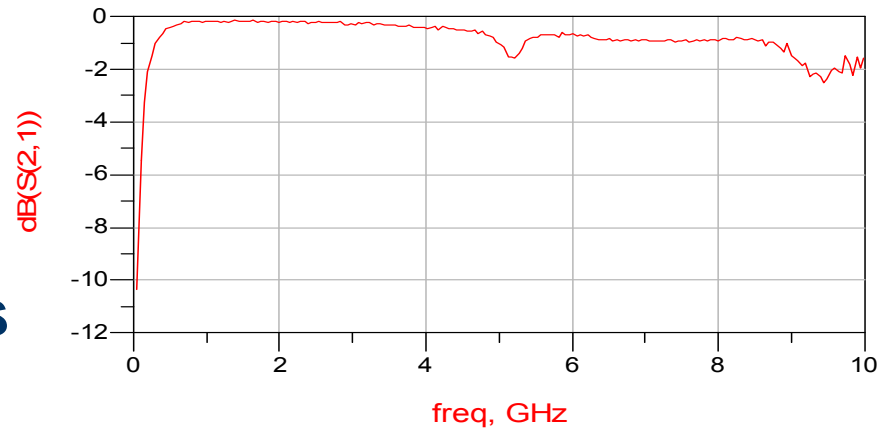
# Equivalent circuit models and measurements

- S-Parameter (S11 & S22) measurements of the 0603 type 10pF capacitor



# Equivalent circuit models and measurements

- S-Parameter (S21 & S12) measurements of the 0603 type 10pF capacitor





# Simulations and Results

- Theory of Optimization
- Error Function (Least Squares Method )
- Explanation of the Set Up

$$EF = \sum_{all\ Goals} W_i \times |simulation_i - goal_i|^2$$

# Simulations and Results

## Set Up

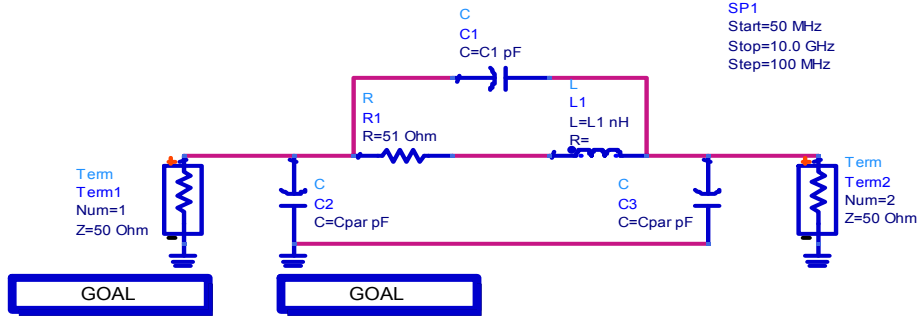
Var Eqn VAR1 L1=0 {o}  
Var Eqn VAR2 C1=0 {o}  
Var Eqn VAR3 Cpar=0 {o}

**S-PARAMETERS**

S\_Param  
 SP1  
 Start=50 MHz  
 Stop=10.0 GHz  
 Step=100 MHz

**OPTIM**

Optim  
 Optim1  
 OptimType=Random  
 ErrorForm=L2  
 MaxIters=300  
 DesiredError=0.0  
 StatusLevel=4  
 FinalAnalysis="SP1"  
 NormalizeGoals=no  
 SetBestValues=yes  
 SaveSols=no  
 SaveGoals=yes  
 SaveOptimVars=yes  
 UpdateDataset=yes  
 SaveNominal=no  
 SaveAllIterations=no  
 UseAllOptVars=yes



**GOAL**

Goal  
 OptimGoal1  
 Expr="dB(S11) - dB(S33)"  
 SimInstanceName="SP1"  
 Min=  
 Max=0  
 Weight=  
 RangeVar[1]="freq"  
 RangeMn[1]=50 MHz  
 RangeMax[1]=6 GHz

**GOAL**

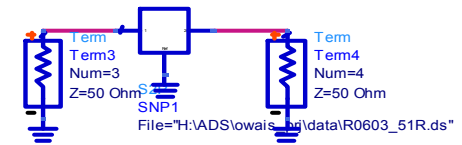
Goal  
 OptimGoal2  
 Expr="dB(S22) - dB(S44)"  
 SimInstanceName="SP1"  
 Min=  
 Max=0  
 Weight=  
 RangeVar[1]="freq"  
 RangeMn[1]=50 MHz  
 RangeMax[1]=6 GHz

**GOAL**

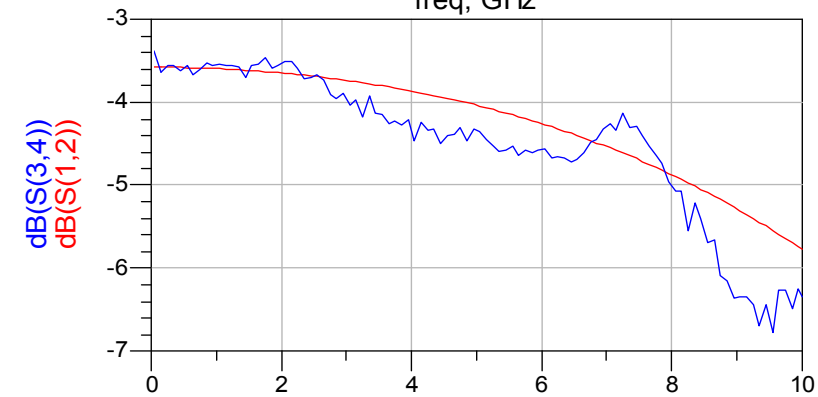
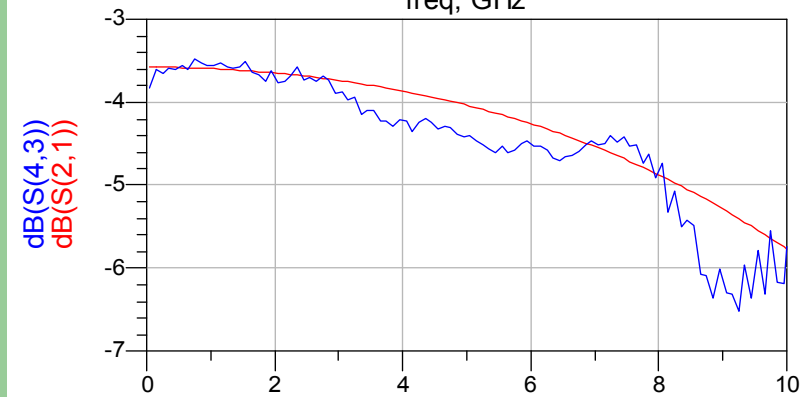
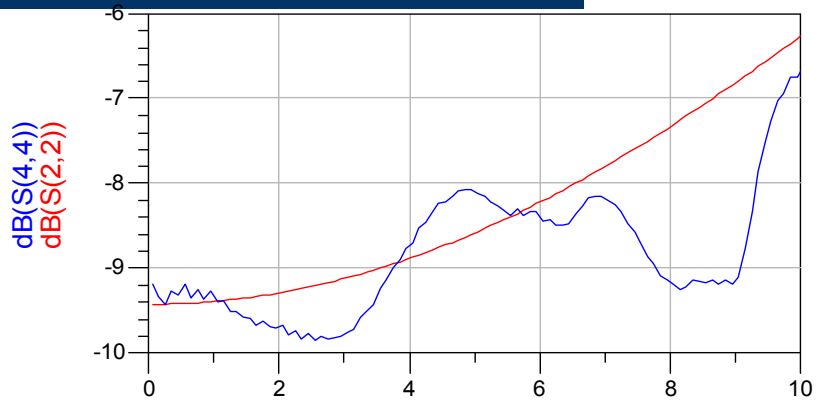
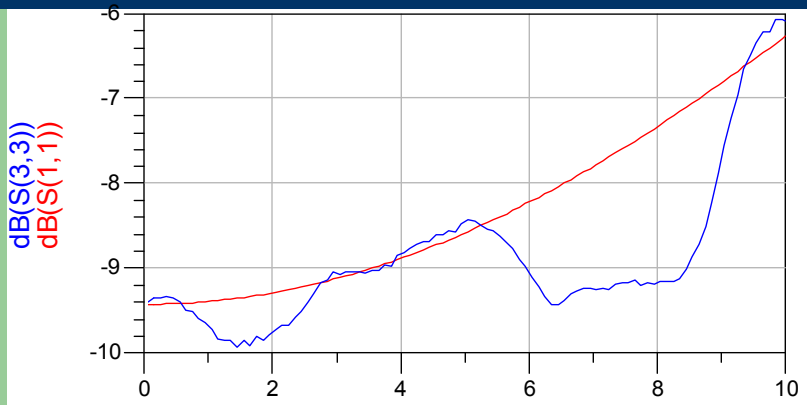
Goal  
 OptimGoal3  
 Expr="dB(S21) - dB(S43)"  
 SimInstanceName="SP1"  
 Min=  
 Max=0  
 Weight=  
 RangeVar[1]="freq"  
 RangeMn[1]=50 MHz  
 RangeMax[1]=6 GHz

**GOAL**

Goal  
 OptimGoal4  
 Expr="dB(S12) - dB(S34)"  
 SimInstanceName="SP1"  
 Min=  
 Max=0  
 Weight=  
 RangeVar[1]="freq"  
 RangeMn[1]=50 MHz  
 RangeMax[1]=6 GHz



# Optimization of 0603 type 51 Ohms Resistor



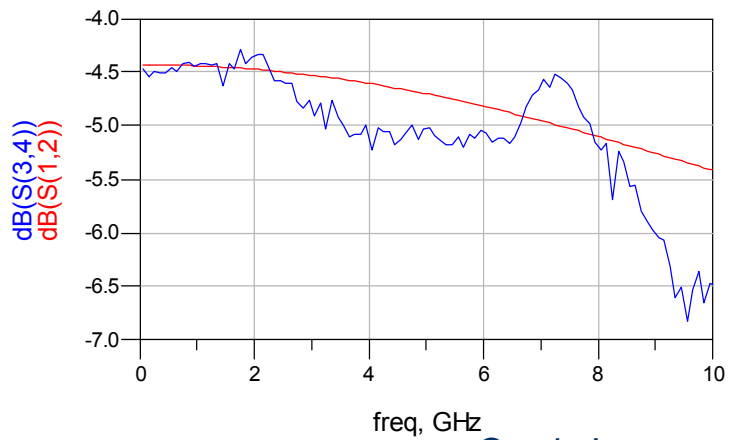
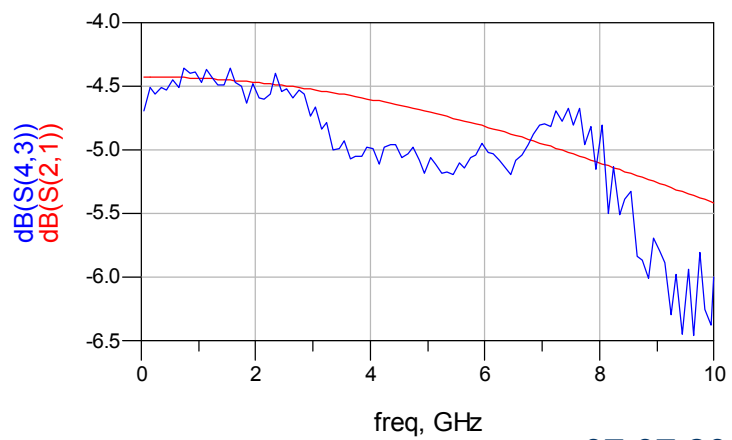
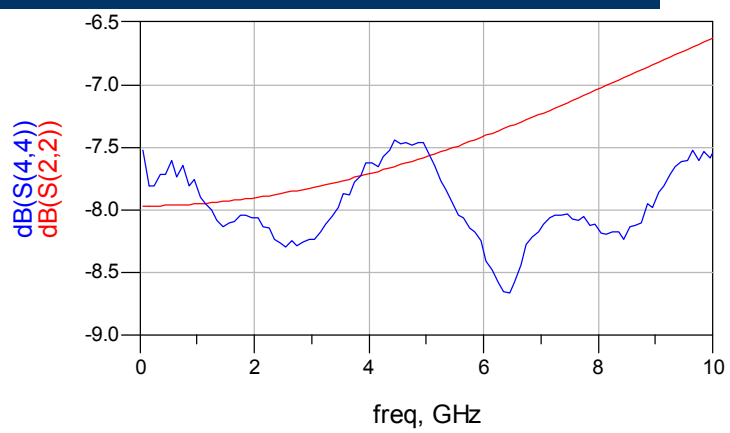
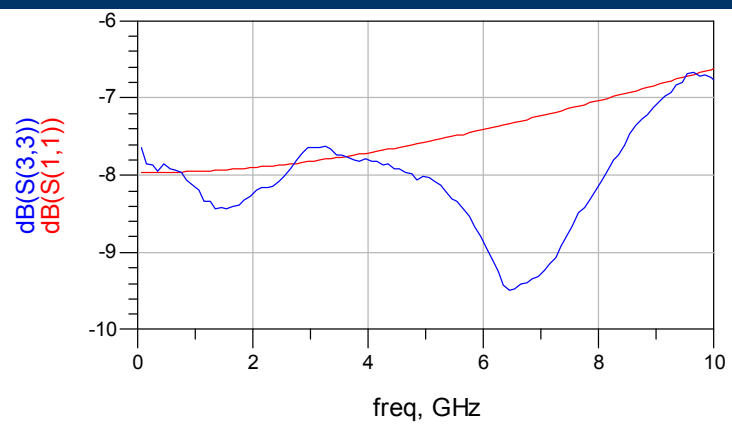
freq, GHz

freq, GHz

# Results for 0603 type 51 Ohms Resistor

	L1 (nH)	C1 (pF)	Cpar (pF)
<b>Initial values</b>	<b>0</b>	<b>0</b>	<b>0</b>
<b>Optimized values</b>	<b>0.776</b>	<b>0.112</b>	<b>0.097</b>
<b>Error function</b>	<b>0.3128</b>		

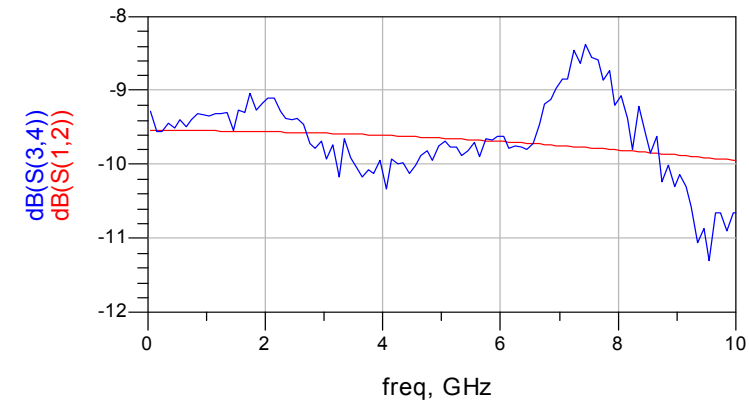
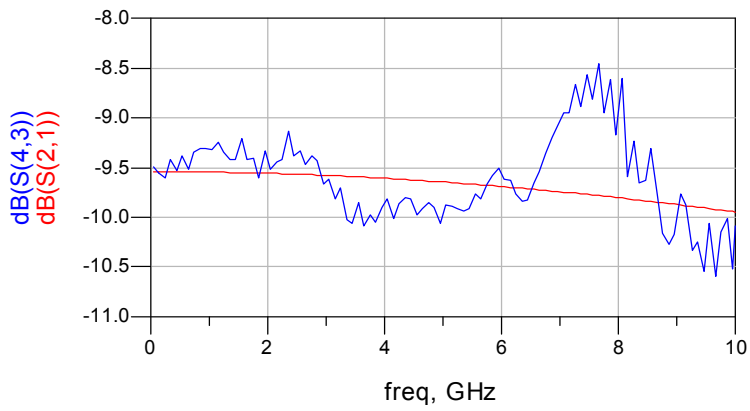
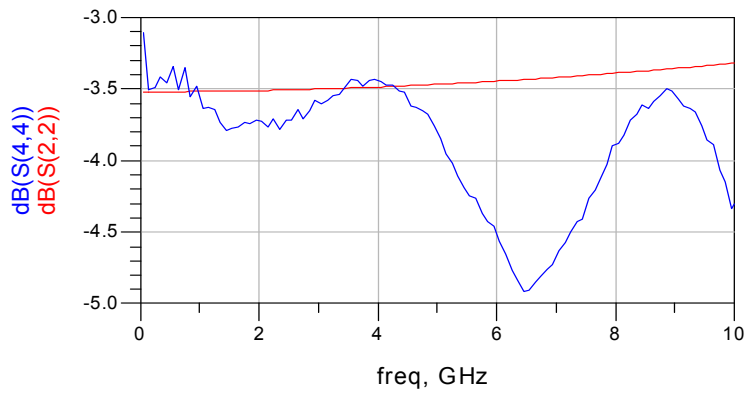
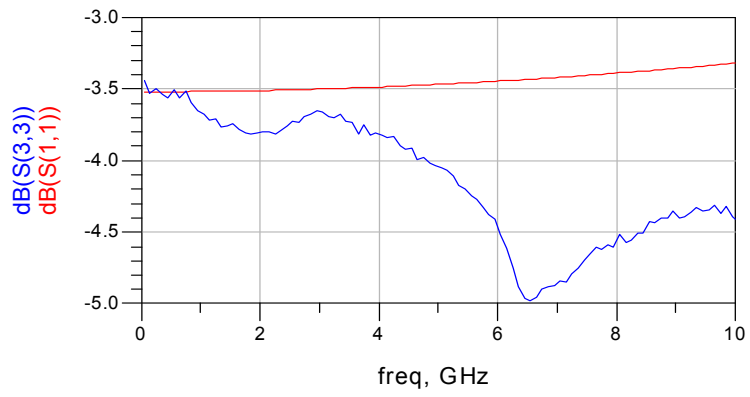
# Optimization of 0603 type 100 Ohms Resistor



# Results for 0603 type 100 Ohms Resistor

	L1 (nH)	C1 (pF)	Cpar (pF)
Initial values	0	0	0
Optimized values	1.03	0.09	0.0023
Error function	0.4587		

# Optimization of 0603 type 200 Ohms Resistor



# Results for 0603 type 200 Ohms Resistor

	L1 (nH)	C1 (pF)	Cpar (pF)
<b>Initial values</b>	<b>0</b>	<b>0</b>	<b>0</b>
<b>Optimized values</b>	<b>0.85</b>	<b>0.022</b>	<b>0.0062</b>
<b>Error function</b>	<b>0.3764</b>		



# Results for 0805 type 47 Ohms Resistor

	L1 (nH)	C1 (pF)	Cpar (pF)
Initial values	0	0	0
Optimized values	0.39	0.072	0.047
Error function	0.3820		

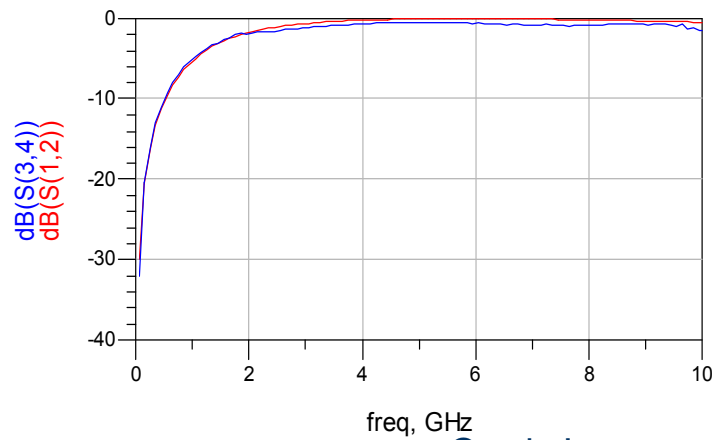
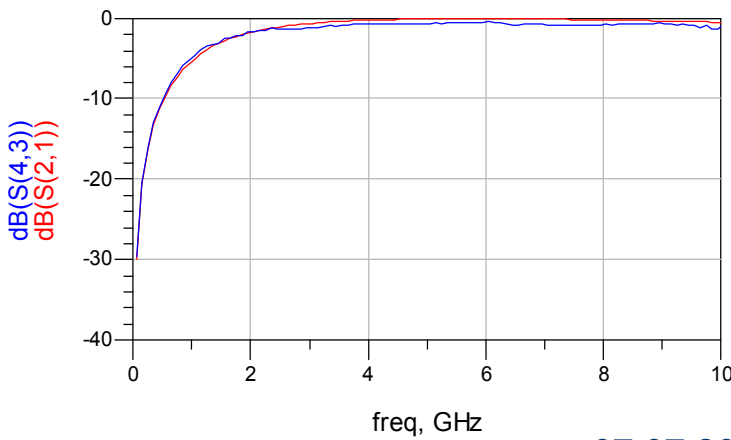
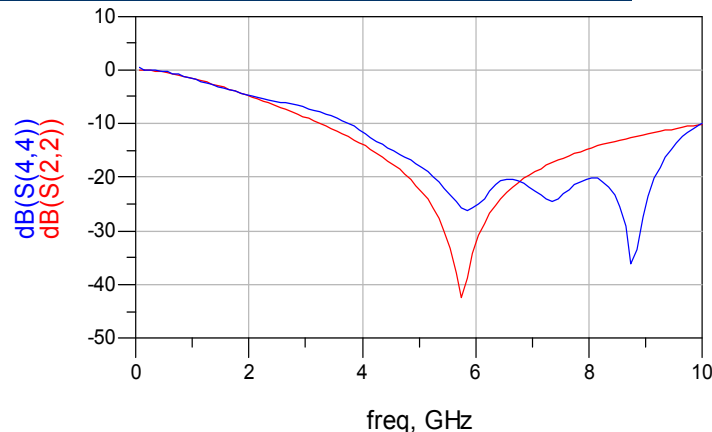
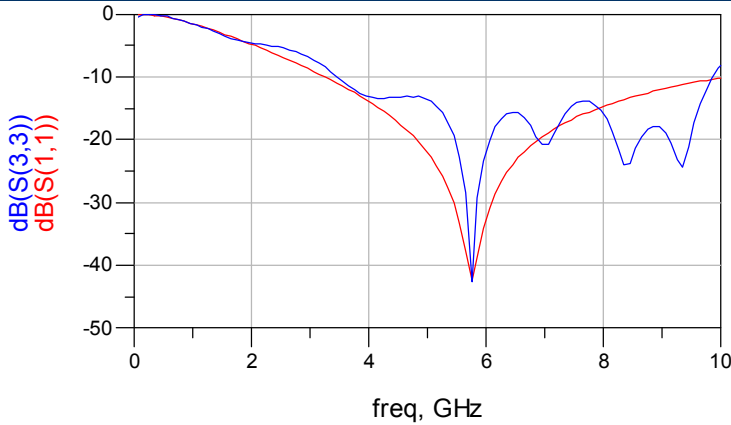
# Results for 0805 type 100 Ohms Resistor

	L1 (nH)	C1 (pF)	Cpar (pF)
<b>Initial values</b>	0	0	0
<b>Optimized values</b>	0.54	0.051	0.0026
<b>Error function</b>	0.4258		

# Results for 0805 type 220 Ohms Resistor

	L1 (nH)	C1 (pF)	Cpar (pF)
<b>Initial values</b>	0	0	0
<b>Optimized values</b>	0.40	0.038	0.0001
<b>Error function</b>	0.3776		

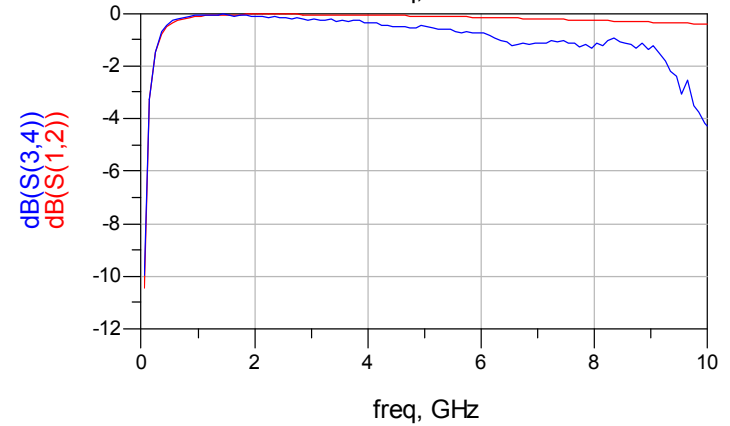
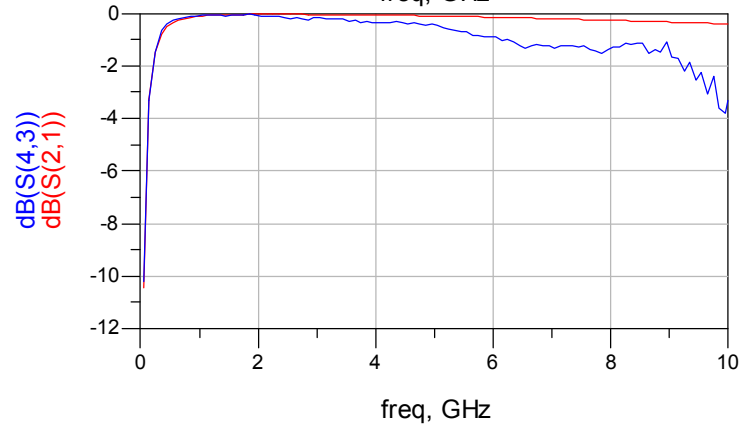
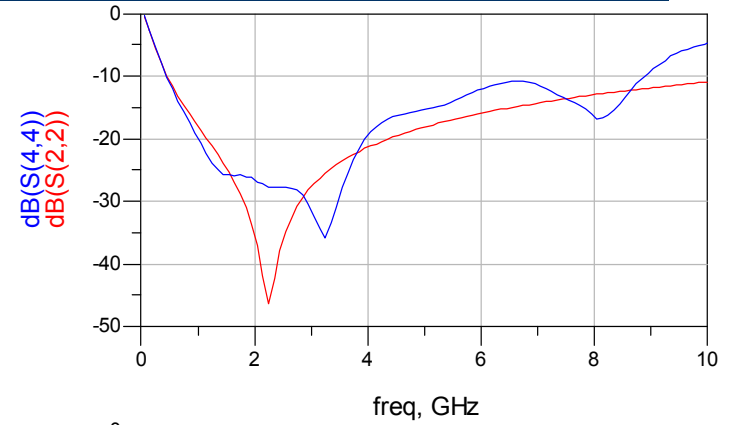
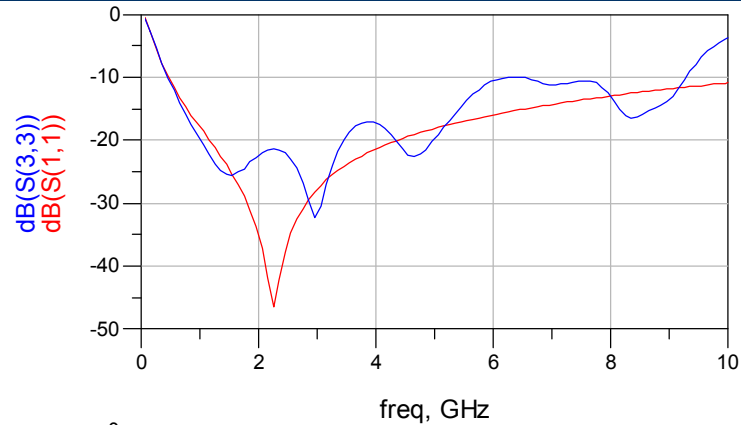
# Optimization of 0805 type 1pF capacitor



# Results for 0805 type 1pF capacitor

	L1 (nH)	R1 (Ohms)	Cpar (pF)
<b>Initial values</b>	0	0	0
<b>Optimized values</b>	1.004	0.753	0.048
<b>Error function</b>	0.3847		

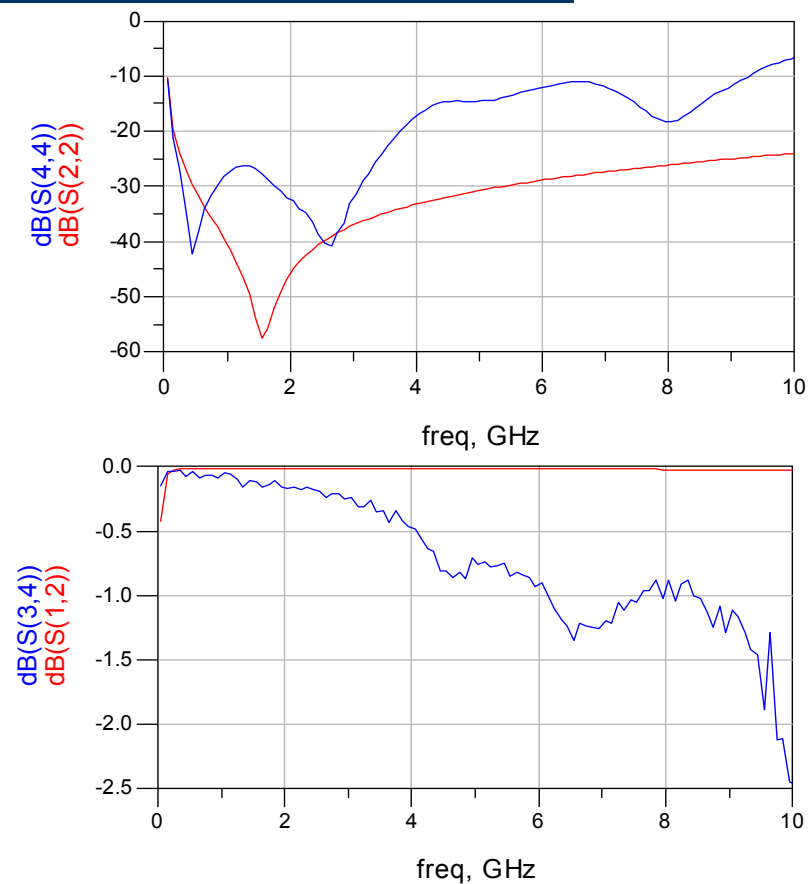
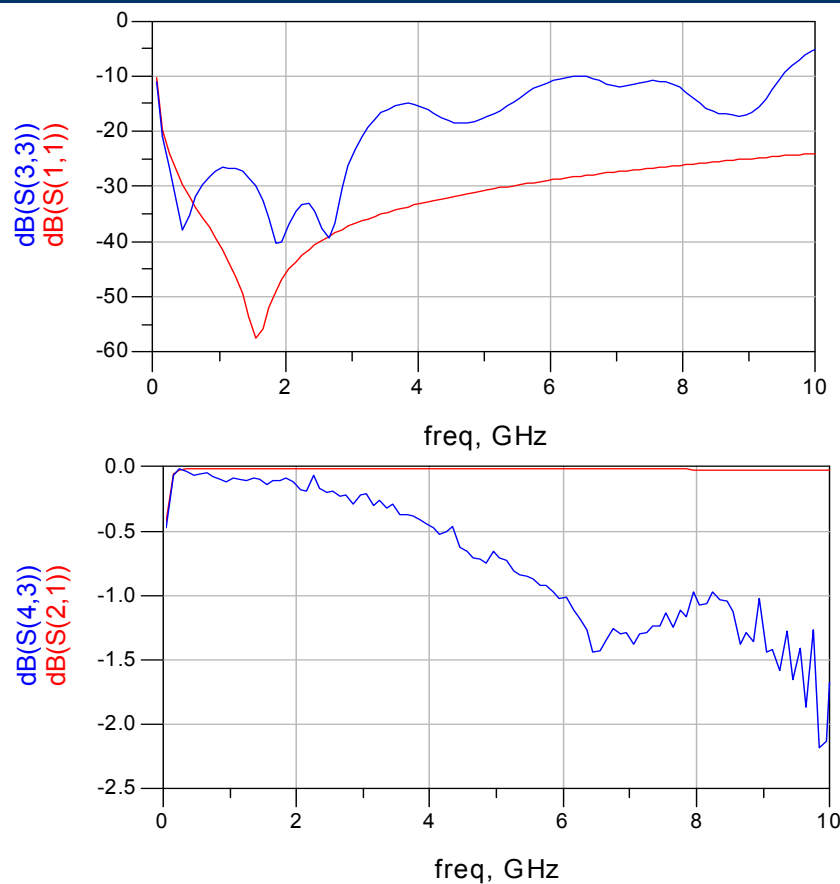
# Optimization of 0805 type 10pF capacitor



# Results for 0805 type 10pF capacitor

	L1 (nH)	R1 (Ohms)	Cpar (pF)
<b>Initial values</b>	<b>0</b>	<b>0</b>	<b>0</b>
<b>Optimized values</b>	<b>0.495</b>	<b>0.404</b>	<b>0.028</b>
<b>Error function</b>	<b>2.9913</b>		

# Optimization of 0805 type 100pF capacitor





# Results for 0805 type 100pF capacitor

	L1 (nH)	R1 (Ohms)	Cpar (pF)
<b>Initial values</b>	0	0	0
<b>Optimized values</b>	0.174	0.127	0.014
<b>Error function</b>	6.898		

# Results for 0603 type 1pF capacitor

	L1 (nH)	R1 (Ohms)	Cpar (pF)
<b>Initial values</b>	<b>0</b>	<b>0</b>	<b>0</b>
<b>Optimized values</b>	<b>0.746</b>	<b>0.684</b>	<b>0.065</b>
<b>Error function</b>	<b>0.4578</b>		

# Results for 0603 type 10pF capacitor

	L1 (nH)	R1 (Ohms)	Cpar (pF)
<b>Initial values</b>	<b>0</b>	<b>0</b>	<b>0</b>
<b>Optimized values</b>	<b>0.384</b>	<b>0.376</b>	<b>0.031</b>
<b>Error function</b>	<b>3.5564</b>		

# Results for 0603 type 100pF capacitor

	L1 (nH)	R1 (Ohms)	Cpar (pF)
<b>Initial values</b>	0	0	0
<b>Optimized values</b>	0.125	0.109	0.014
<b>Error function</b>	5.9851		

**END**

**THANK YOU FOR YOUR ATTENTION!**