

# Advanced VCO Design using Ansoft Designer

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Ansoft Japan

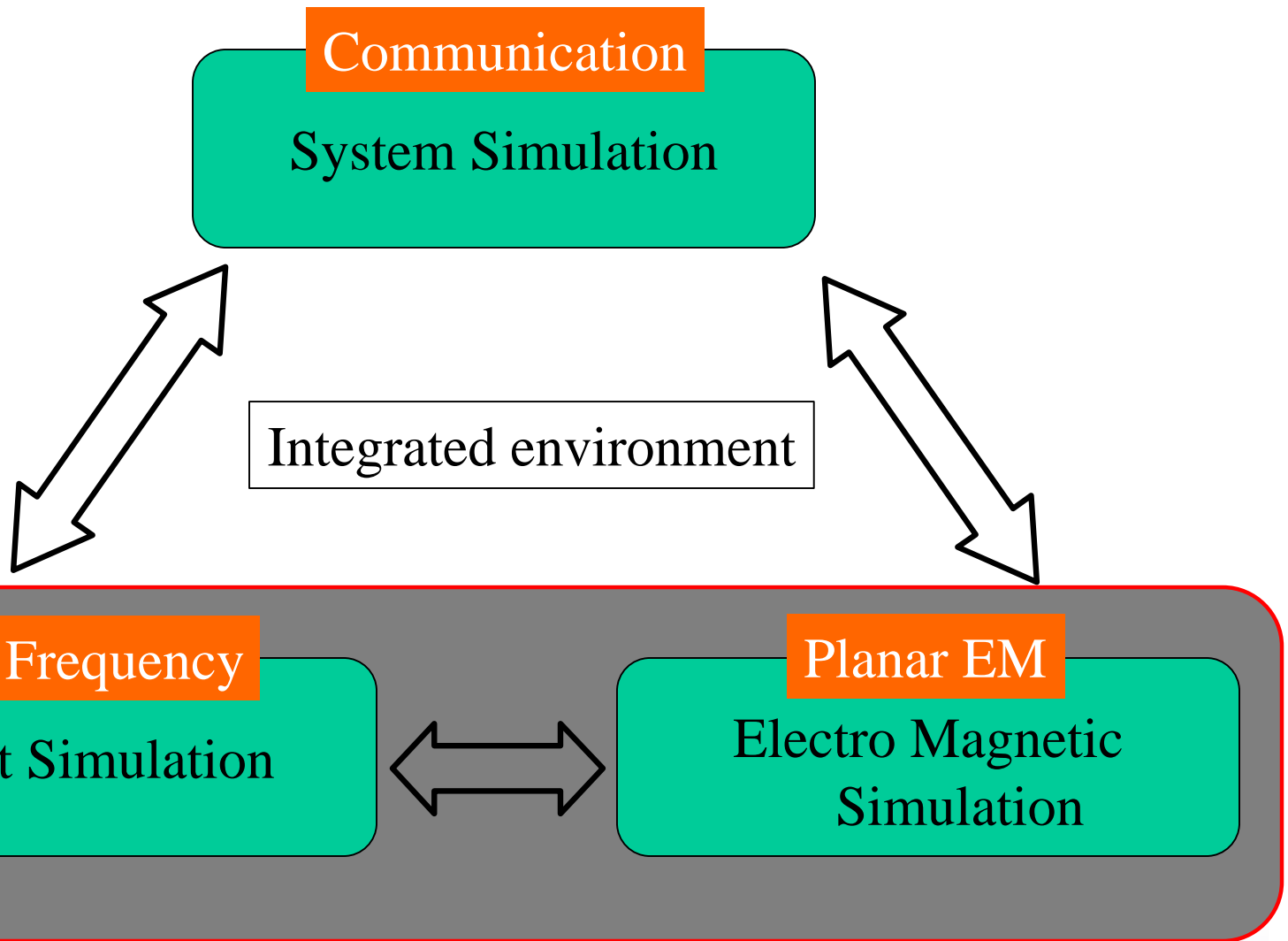


# Agenda

- ▶ About Ansoft Designer
- ▶ VCO specification
- ▶ Device library making
- ▶ Resonant Circuit design
- ▶ Oscillator Circuit design
- ▶ Buffer amp design
- ▶ Total analysis
- ▶ Conclusion



# About Ansoft Designer

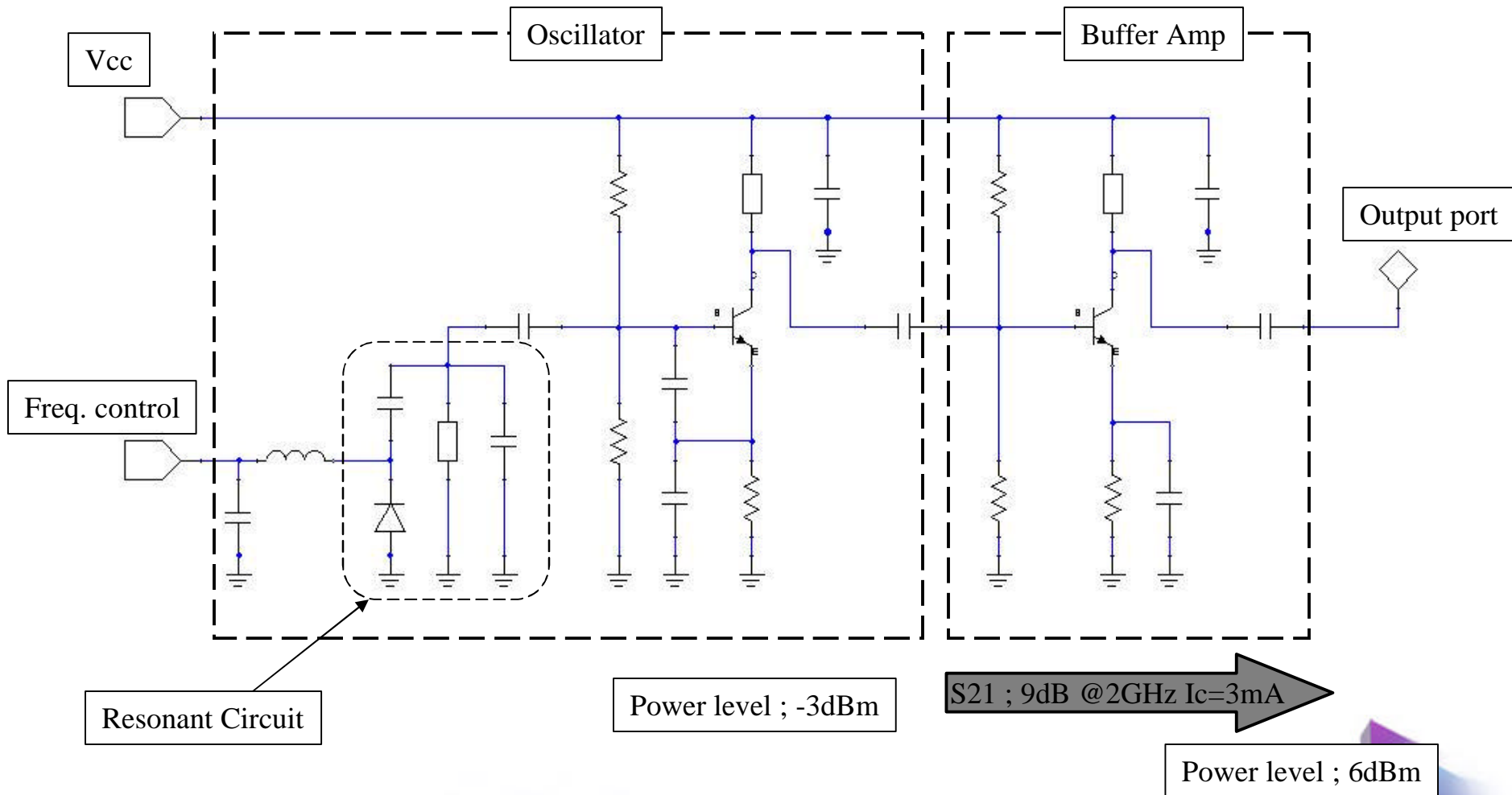


# VCO specifications

- ▶ We intend to design VCO for mobile communications.
  - ▶ Oscillation frequency      1800MHz +/- 30MHz
  - ▶ Output power                more than 4dBm
  - ▶ Supply voltage                3V
  - ▶ Current consumption        8mA

# VCO circuit

- Circuit topology and power estimation



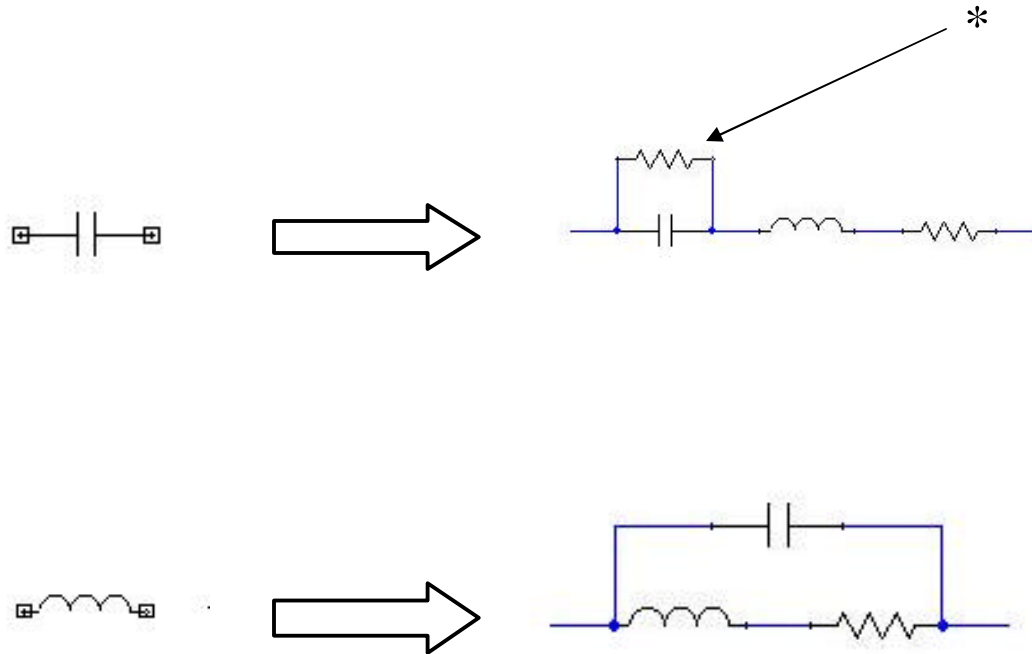
# VCO Circuit

- ▶ Parts to use

- ▶ Transistor            2SC5668(NE667M03) OSC  
                              2SC5435(NE685M03) Buffer
- ▶ Varicap                JDV2S13S
- ▶ Condenser            GRP15, GRP18 series
- ▶ Coil                    LQW18 series
- ▶ Substrate             TMM-4 t=0.8mm double sided

# Device library making

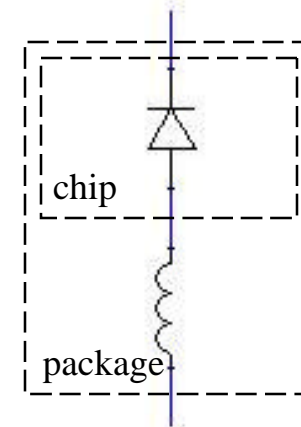
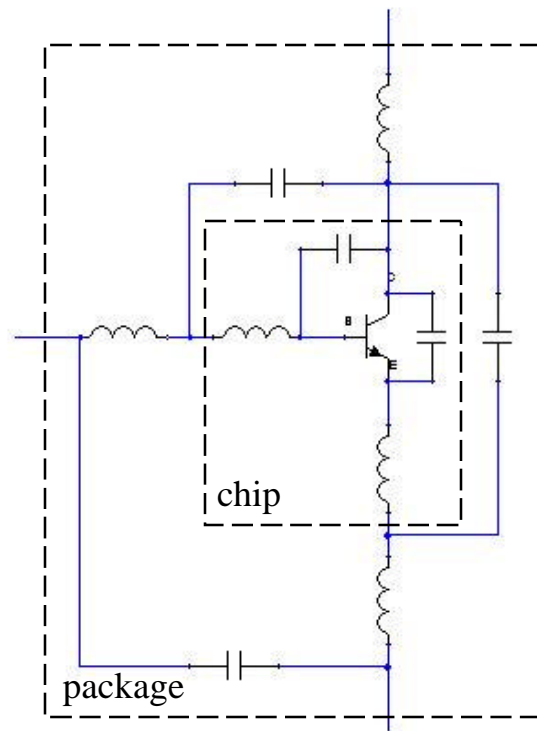
- Equivalent circuit for condenser and coil



- \* Parallel resistor added for improve DC current convergence in Harmonic balance analysis

# Device library making

- Equivalent circuit for packaged transistor and diode





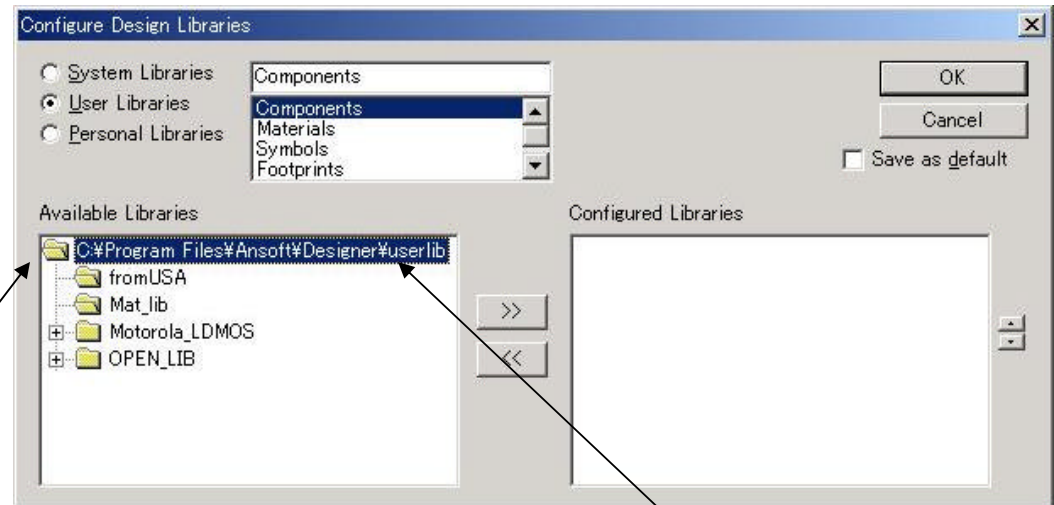
# Device library making

- Write net list and importing library to user-library

```
Transistors.lib - ANSYS
ファイル(F) 編集(E) 形式(O) ヘルプ(H)
.subckt 2sc5010FT 8 7 9
BJTGPS:1 1 2 3 3 MOD = 2sc5010
CAP:2 2 5 C = 40.0e-15F
CAP:3 2 6 C = 120.0e-15F
CAP:4 8 9 C = 5.0e-15F
CAP:5 1 2 C = 180e-15F
CAP:6 2 3 C = 180e-15F
IND:7 5 8 L = 1.25e-9H
IND:8 2 7 L = 0.79e-9H
IND:9 6 8 L = 1.20e-9H
IND:10 1 5 L = 0.004e-9H
IND:11 3 6 L = 0.004e-9H
.ends

.MODEL 2sc5010 BJTGPS (
+PTYPE=NPN
+AREA 1
+IS 186e-18
+BF 250
+NF 1.0
+VA 45.0
+TKF 0.238
+ER 19.9
+NR 0.99
+VB 1.64
+TKR 4.7e-3
+ISE 1.24e-18
+NE 1.12
+ISC 1.28e-18
+NC 1.13
+FB 5.5
+TRB 1.44e-3
+FBM 2.0
+FE 0.9
+FC 5.0
+XTB 0
+EG 1.11
+XTI 3.0
+CJE 368e-15
)
```

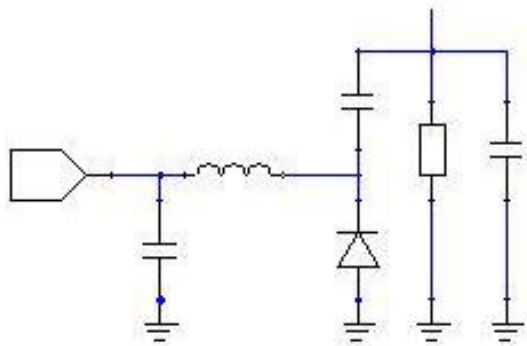
Write net list and copy to user-library



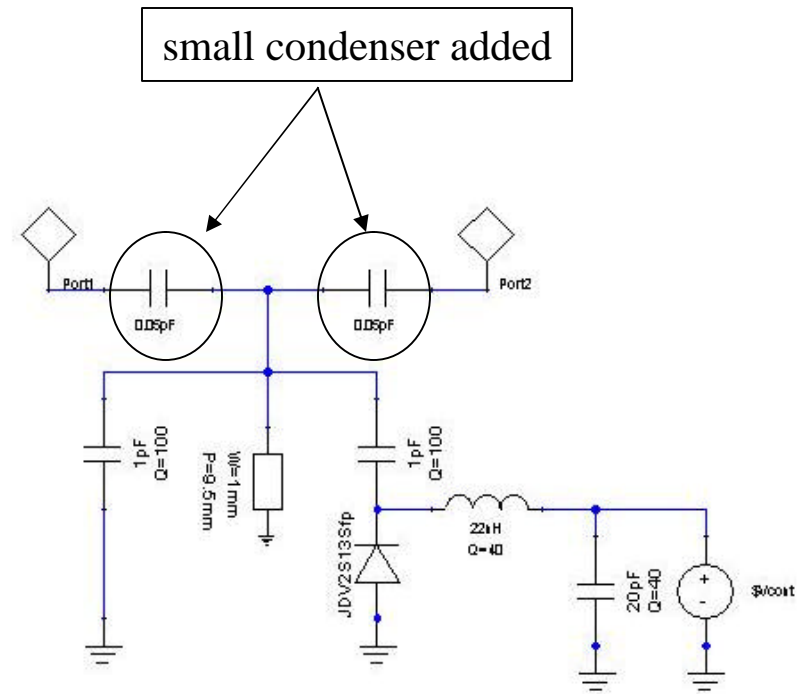
```
Murata_cap_1005.lib - ANSYS
ファイル(F) 編集(E) 形式(O) ヘルプ(H)
*
.subckt MR_0r5pF 1 4
CAP:1 1 2 c=0.56pF
RES:2 1 2 r=10E+9
RES:3 2 3 r=0.781
IND:4 3 4 l=570pH
.ends
*
.subckt MR_0r75pF 1 4
CAP:1 1 2 c=0.71pF
RES:2 1 2 r=10E+9
RES:3 2 3 r=0.887
IND:4 3 4 l=740pH
.ends
*
.subckt MR_1r0pF 1 4
CAP:1 1 2 c=1.12pF
RES:2 1 2 r=10E+9
```

# Resonant Circuit

- Microstrip resonator

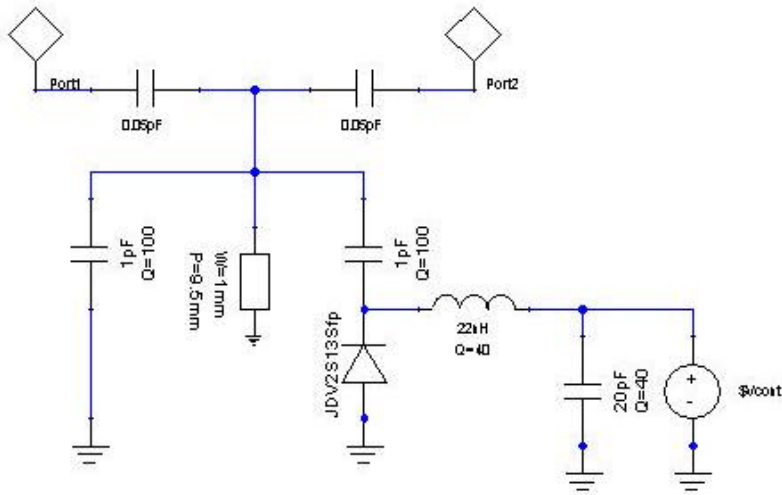


Practical resonant circuit



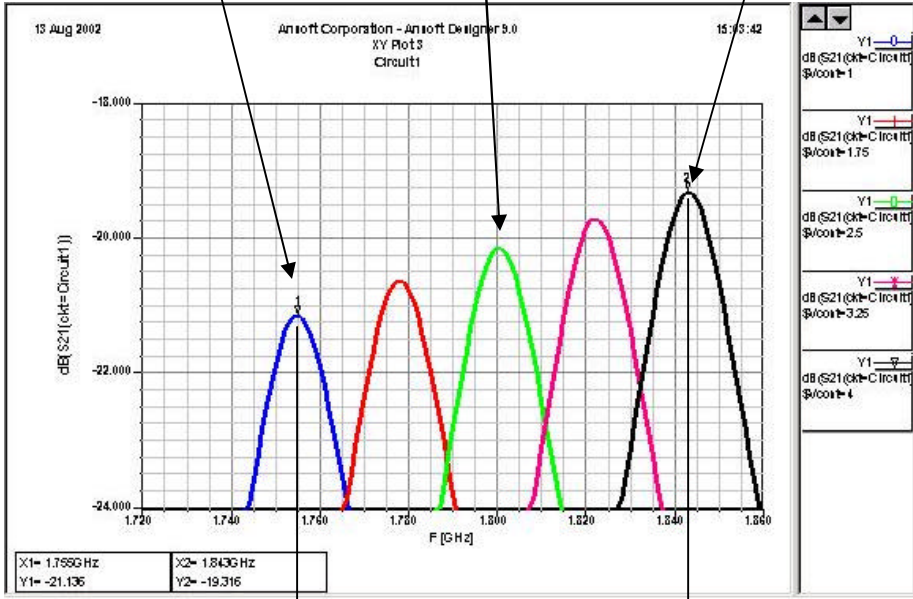
Evaluate resonant circuit

# Evaluate resonator circuit response



Evaluate resonant circuit

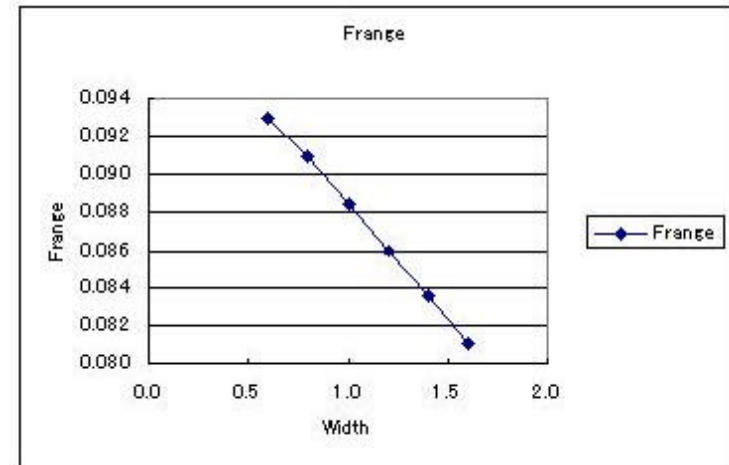
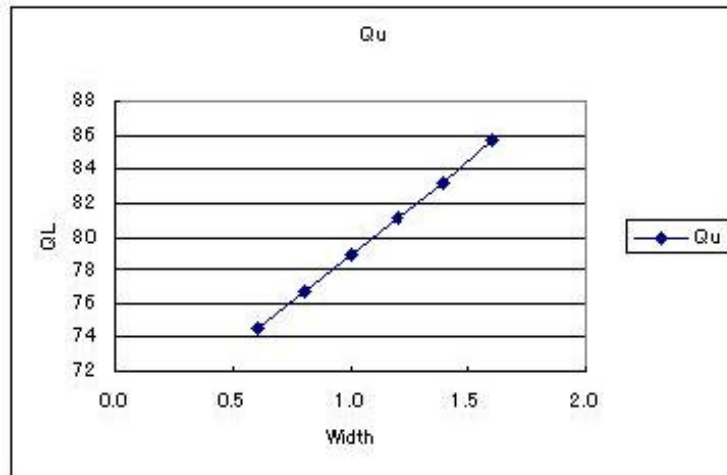
1V    tuning voltage = 2.5V    4V



Frequency range

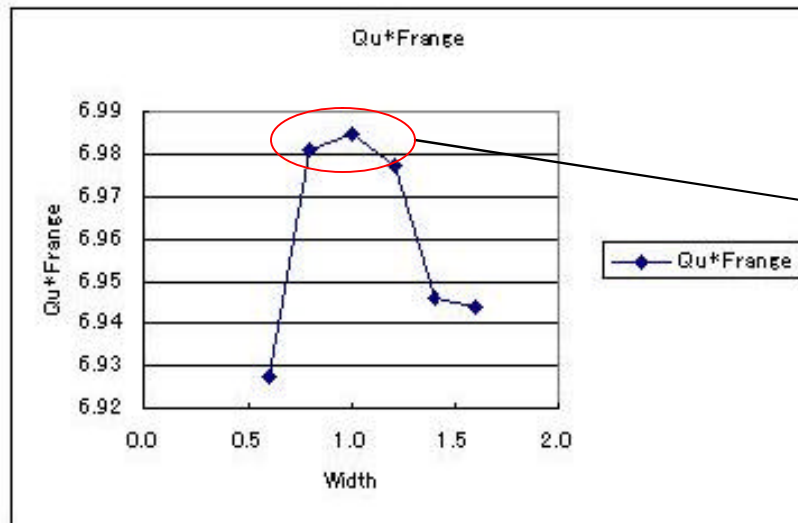
# Relation between unloaded Q (Qu) and Frequency range

- Qu and Frequency range change according to microstrip width.
- As Qu increase, frequency range is decrease.



# Determine microstrip width

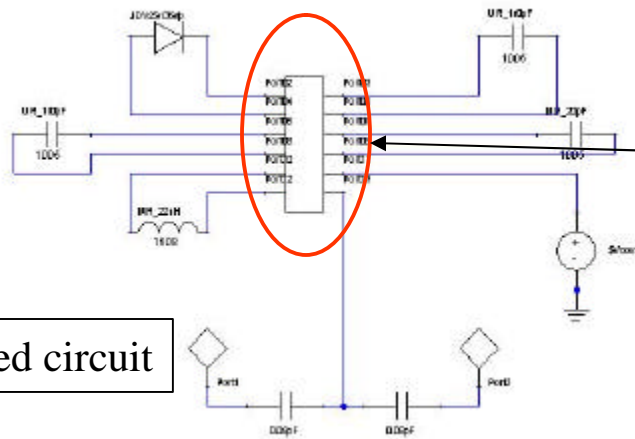
- “Qu\*Frequency range” is introduced as a indicator to evaluate resonant circuit performance



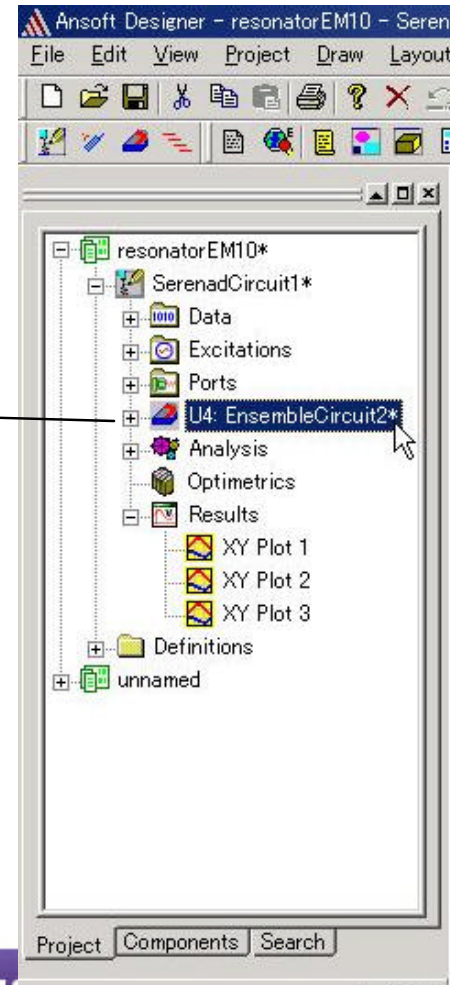
It shows 1.0mm is best

# Insert physical layout

- It can make layout by inserting EnsembleCircuit.

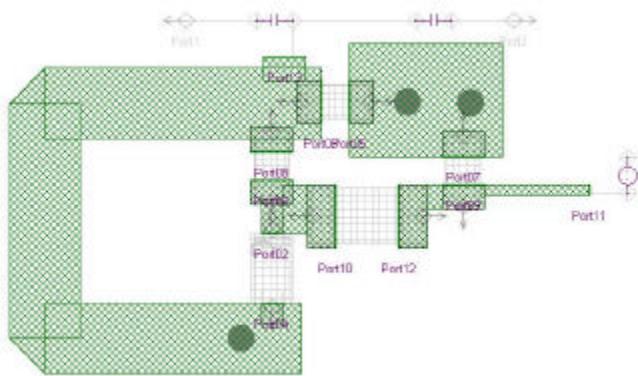


Revised circuit

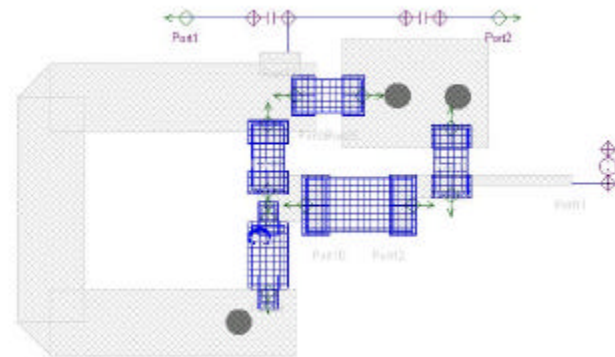


# Simulation with physical layout

- Make microstrip layout and simulate resonant circuit under co-simulation

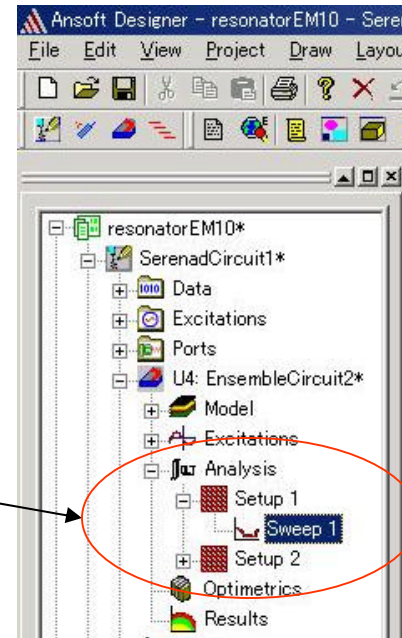
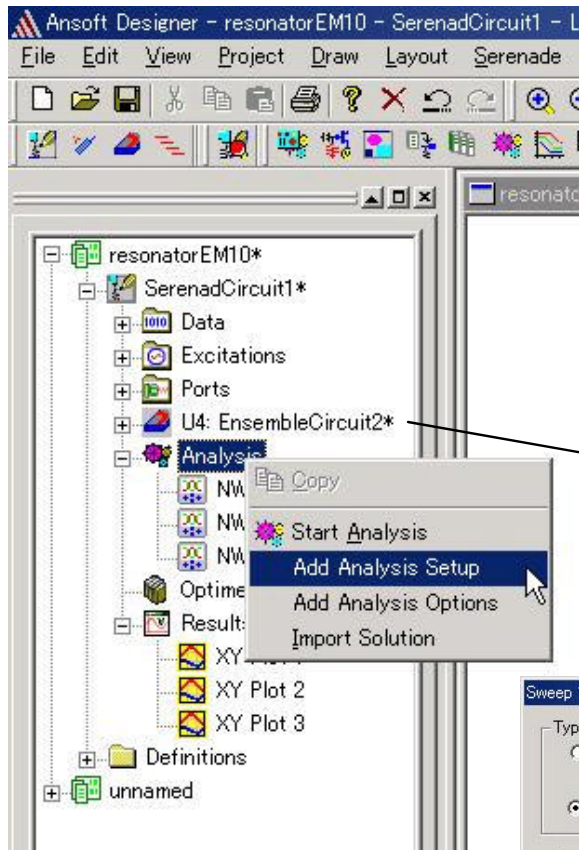


Pattern layout

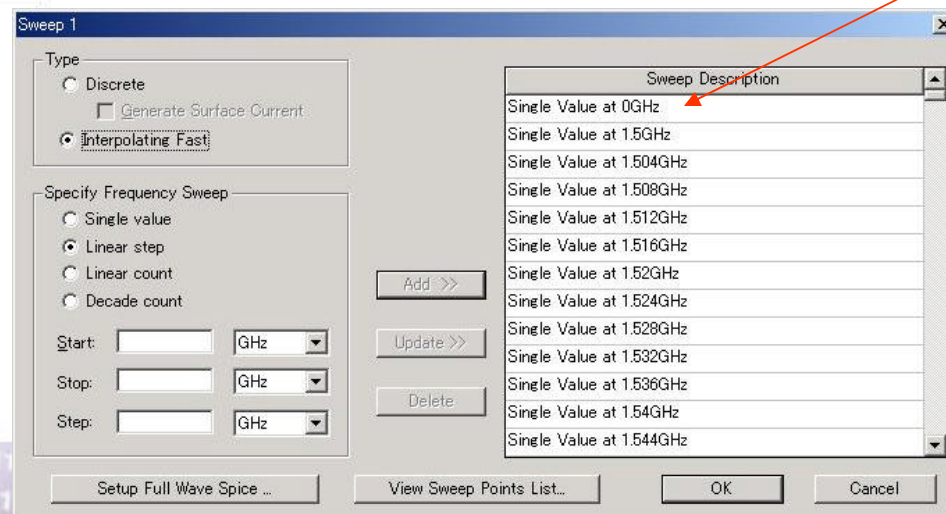


Parts layout

# Simulator setting

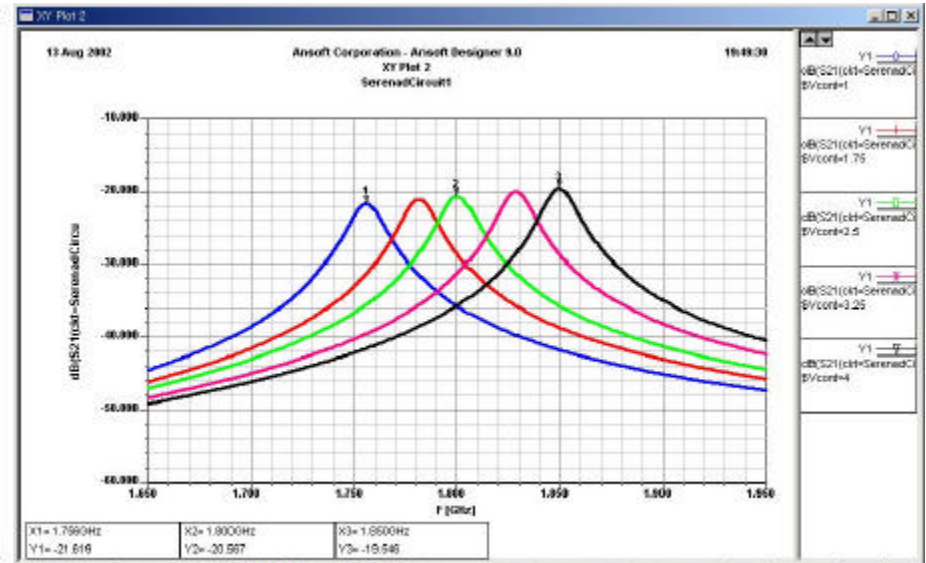
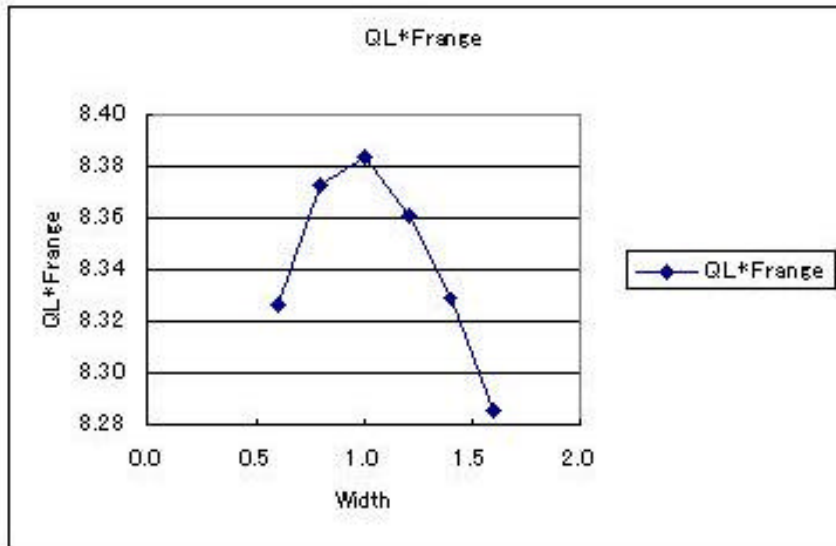


Include 0Hz

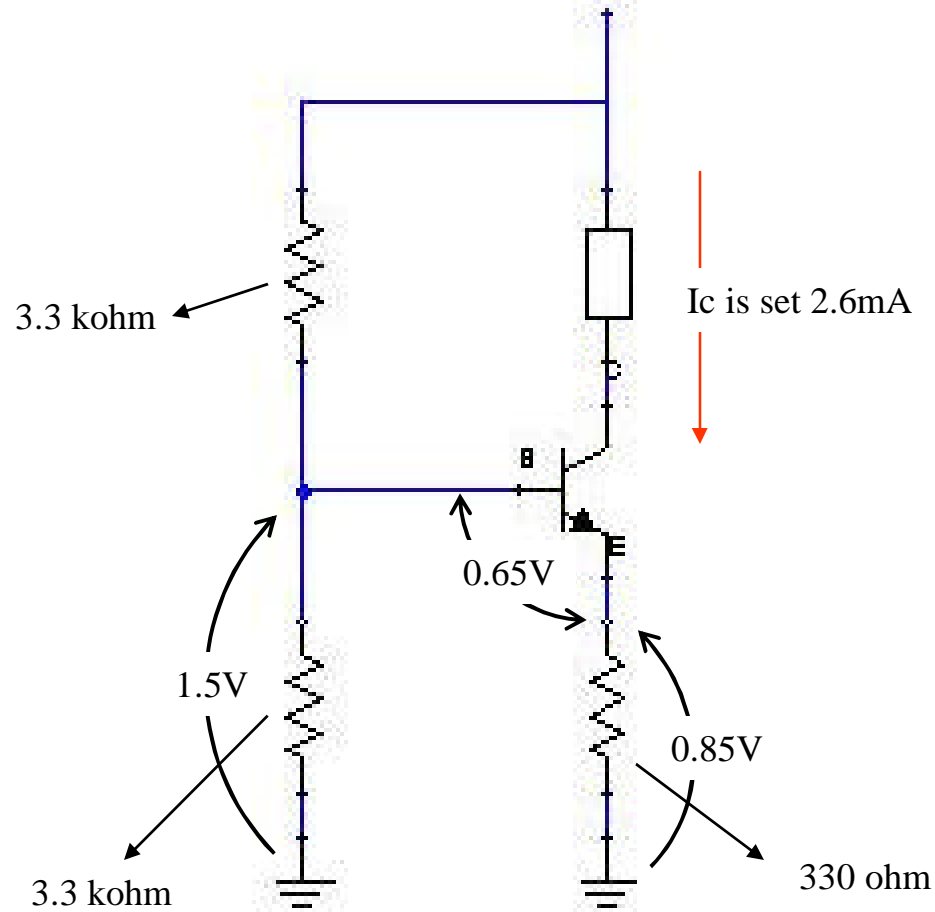




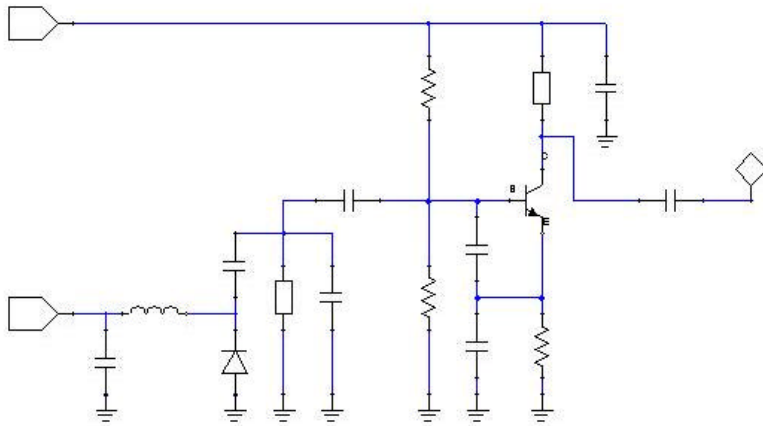
# Resonant circuit simulation result



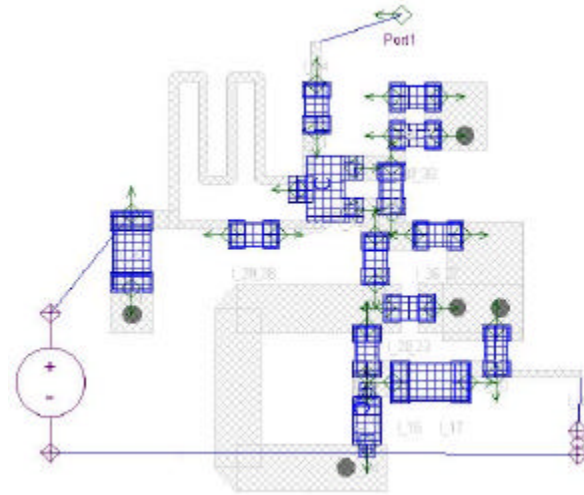
# DC bias calculation



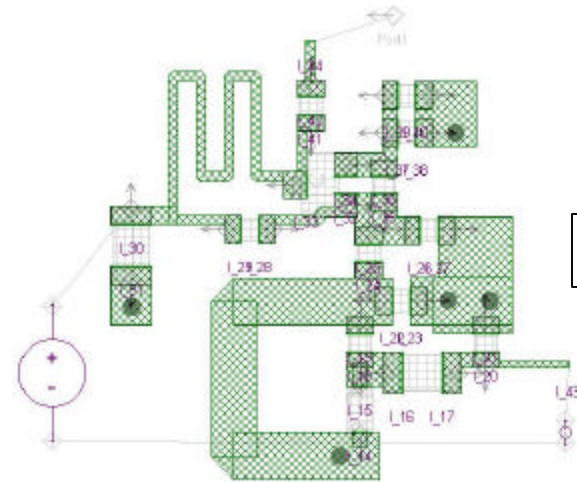
# Oscillator circuit



Oscillator circuit



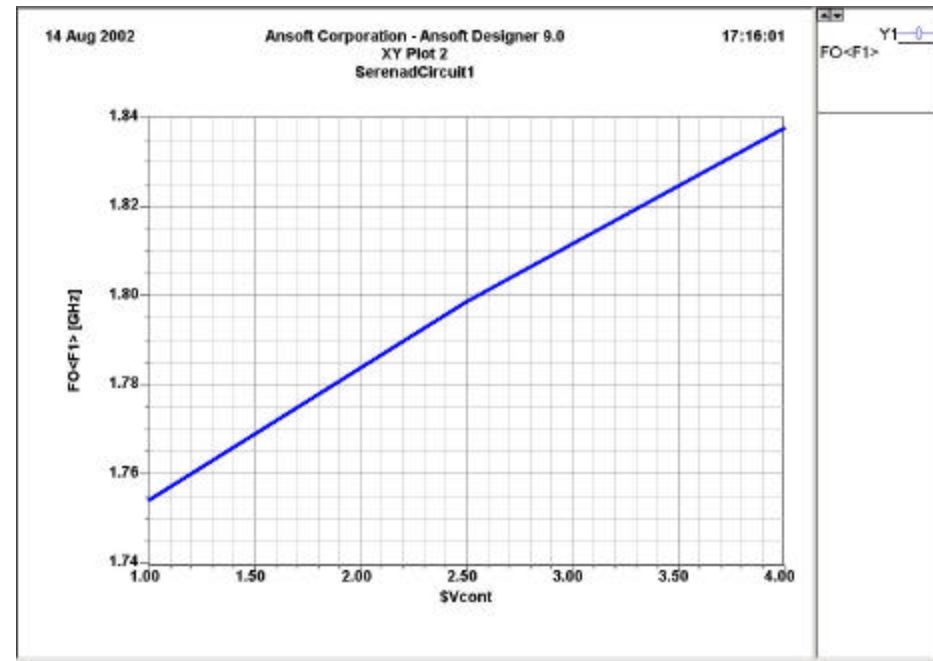
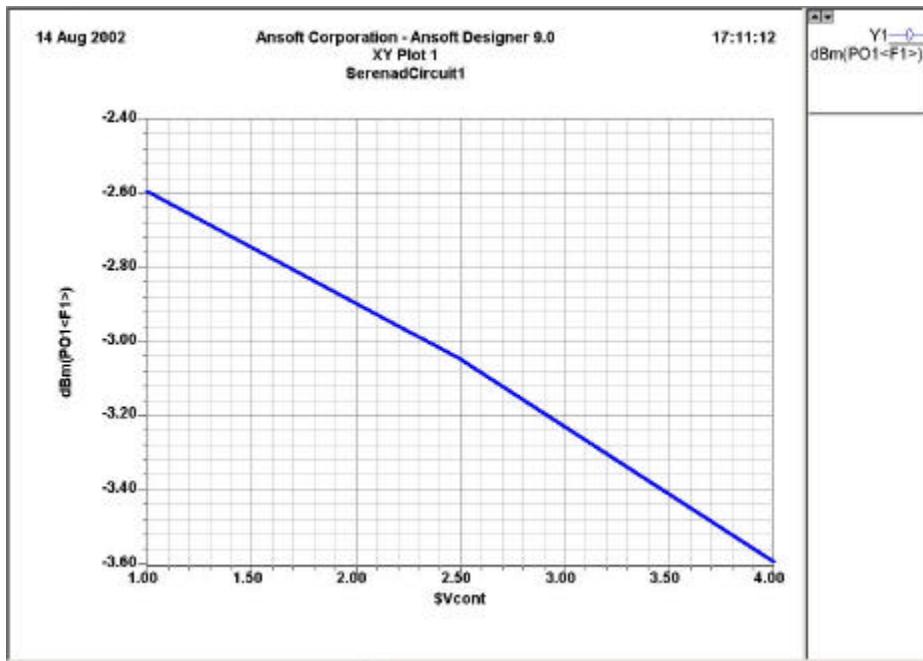
Parts layout



Pattern layout

# Simulation result

- After adjust resonant circuit

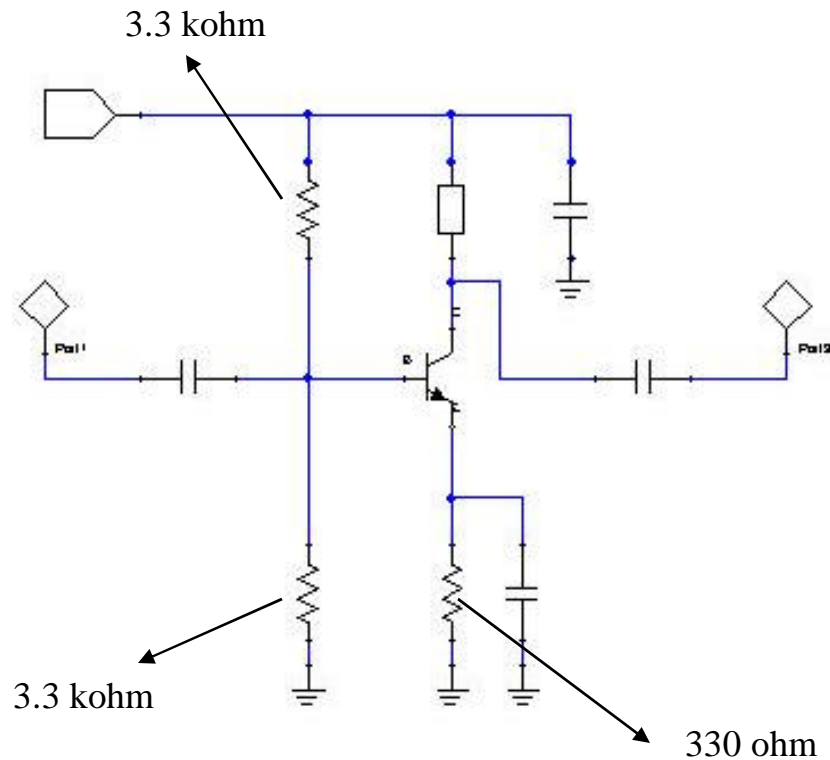


Output Level

Oscillation frequency

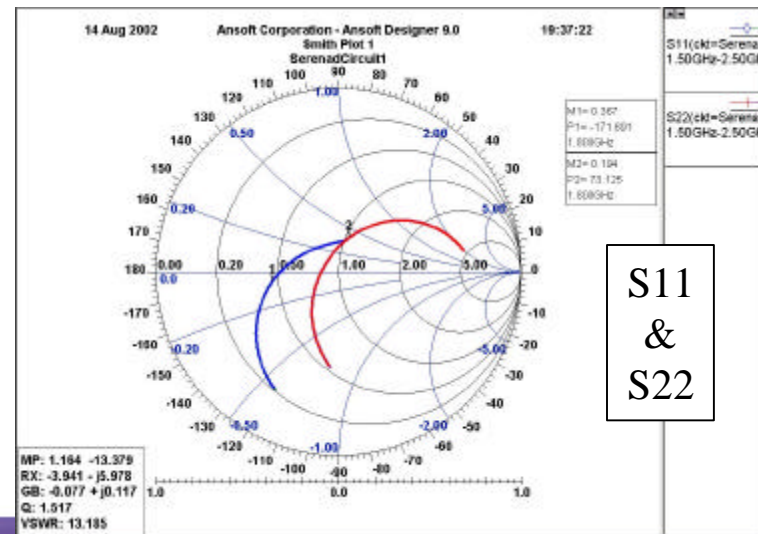
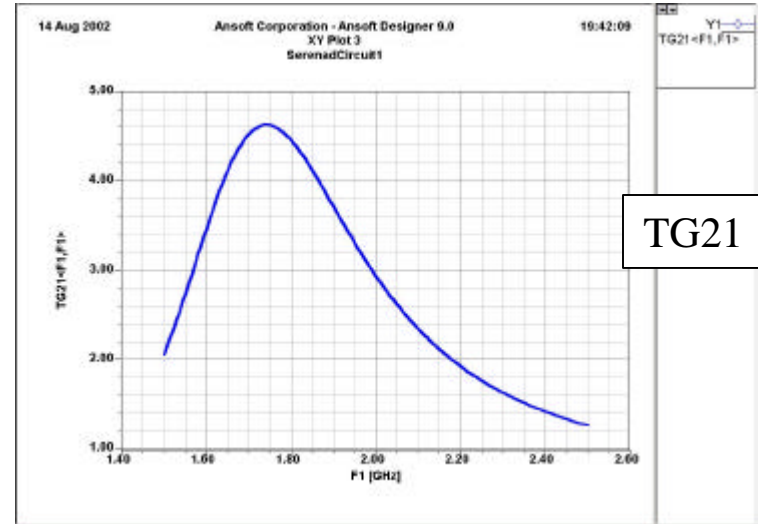
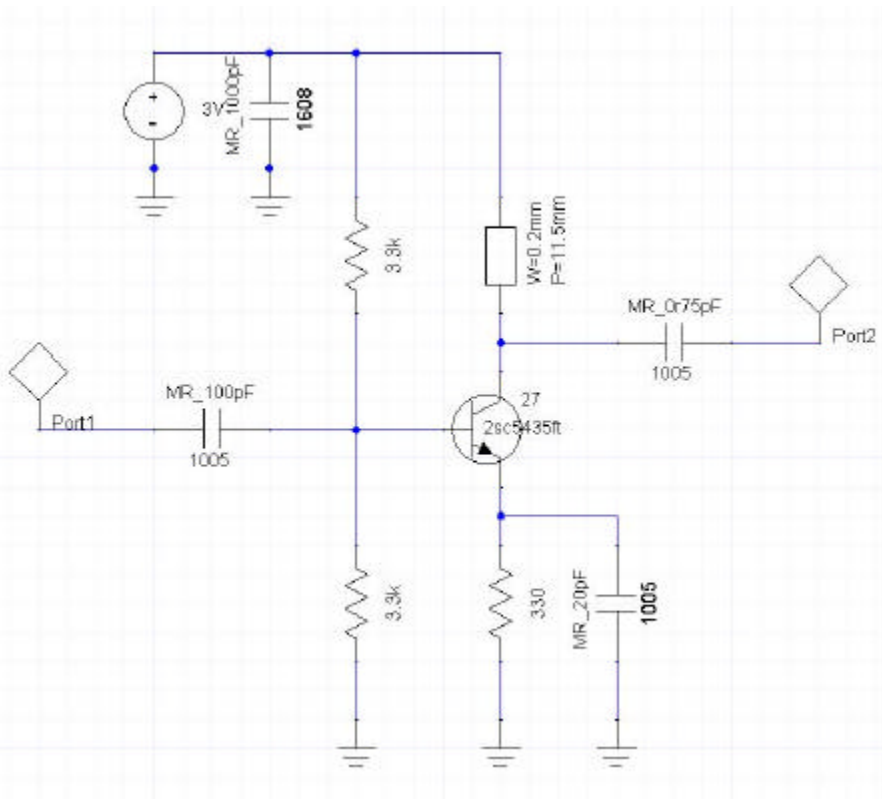
# Buffer amp design

- DC bias

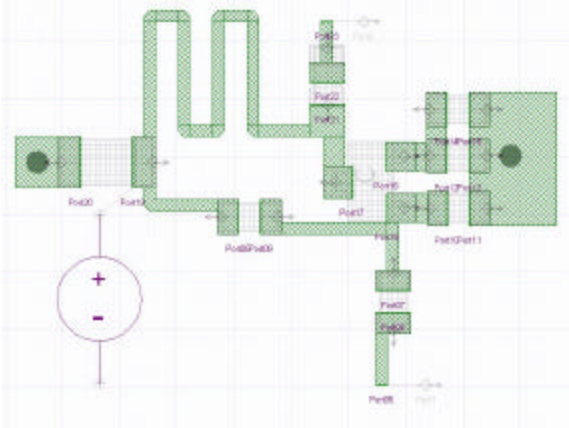


# Impedance matching

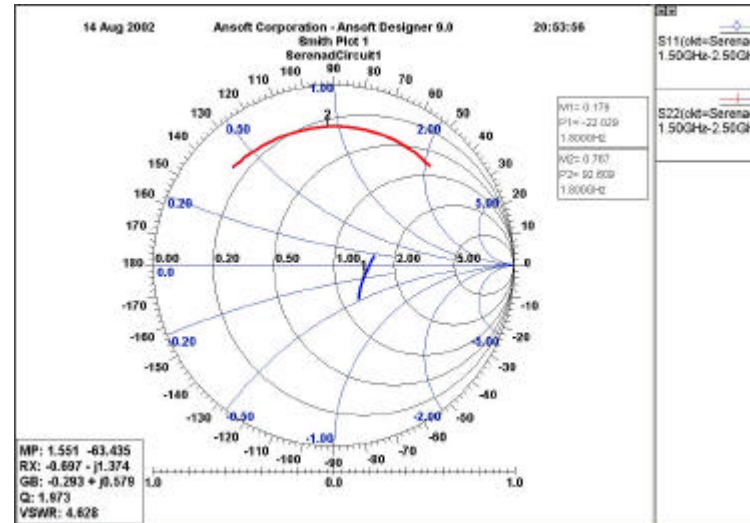
## Adjusted circuit



# Simulation result with physical layout



Pattern layout

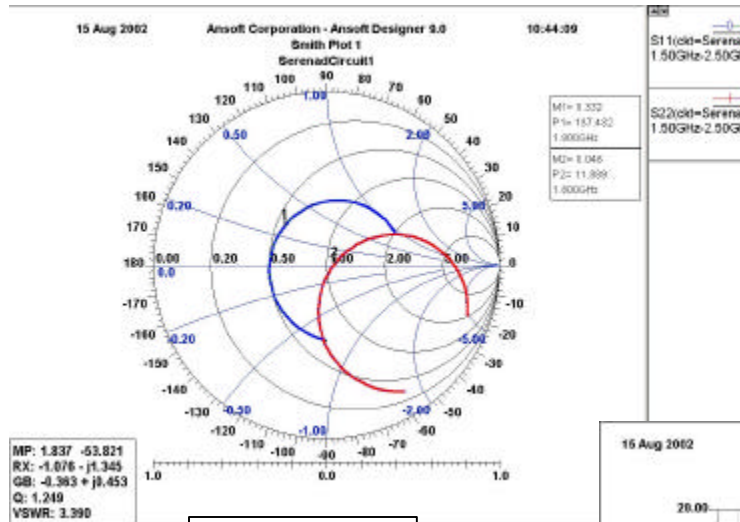


S11 & S22

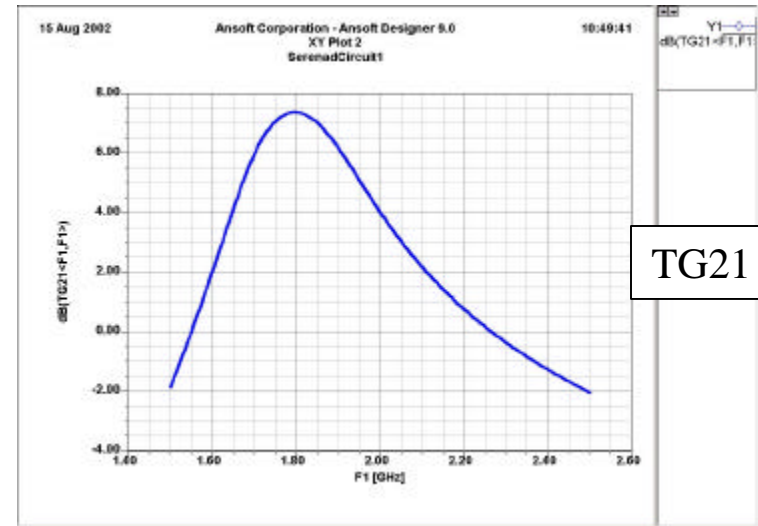




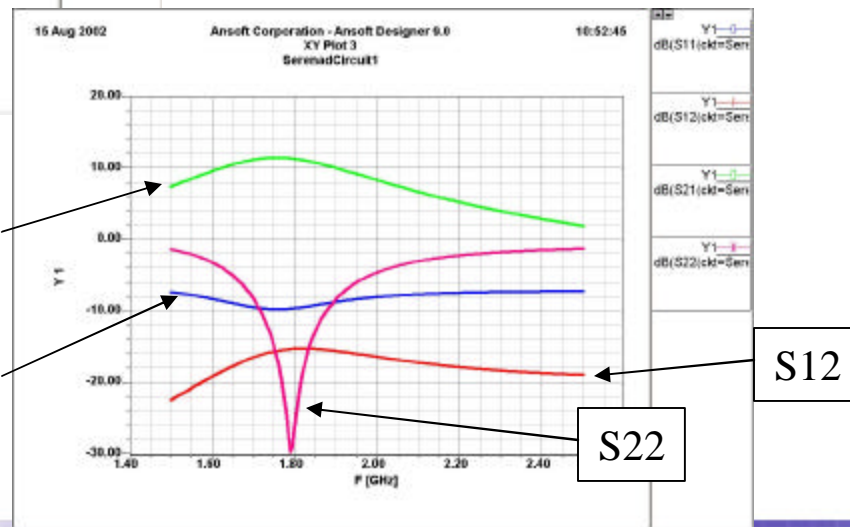
# Buffer amp performance



S11 & S22



TG21



S21

S11

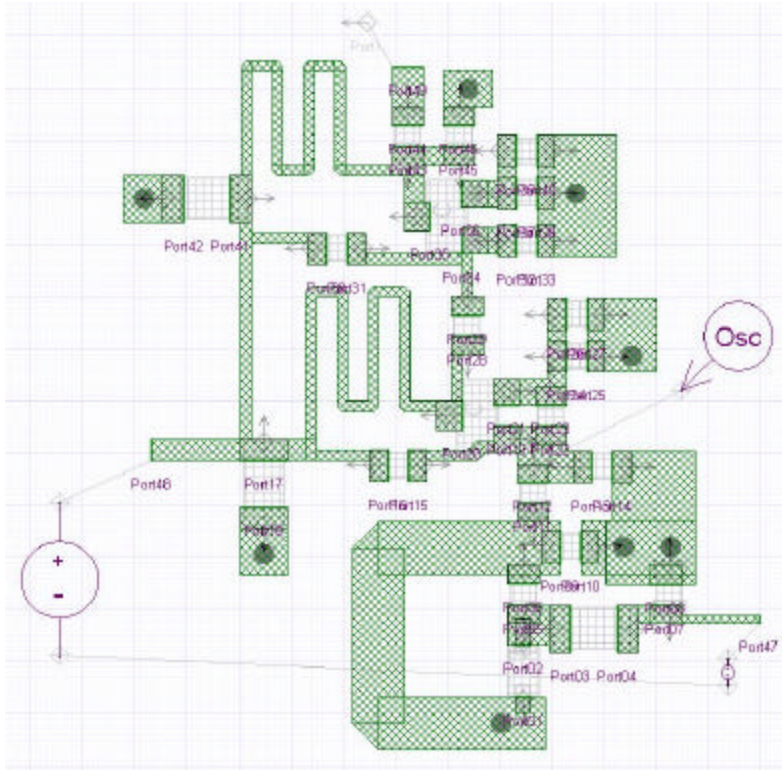
S22

S12

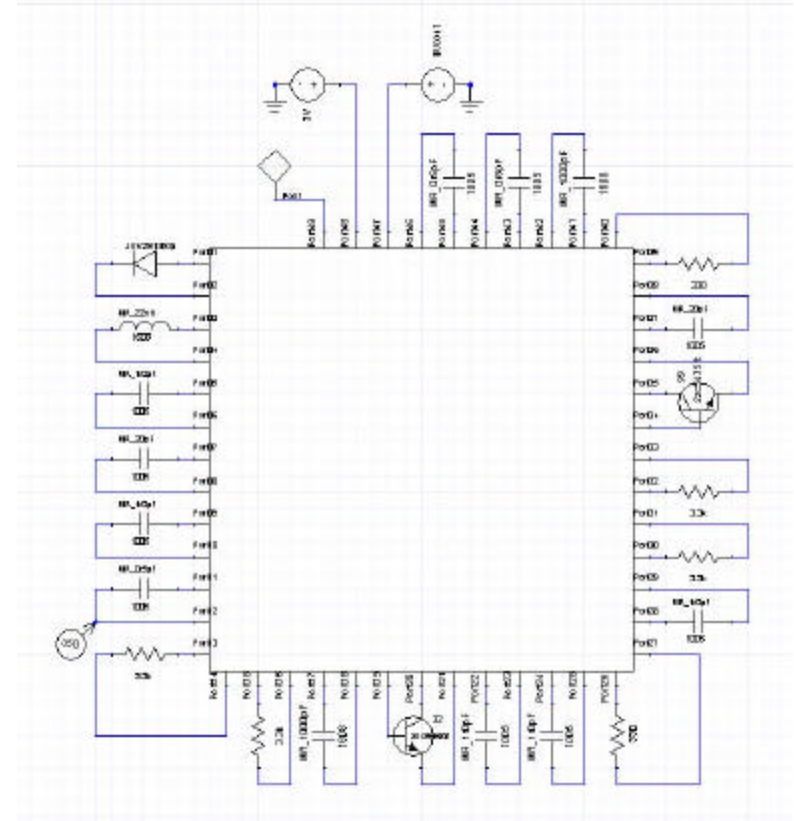
# Total simulation

- ▶ Final step of VCO design
  - ▶ Merge oscillator and buffer amp layout.
  - ▶ Make schematic which include EnsembleCircuit's symbol
  - ▶ Adjust oscillation frequency
  - ▶ Adjust other performances.

# Merged layout and schematic

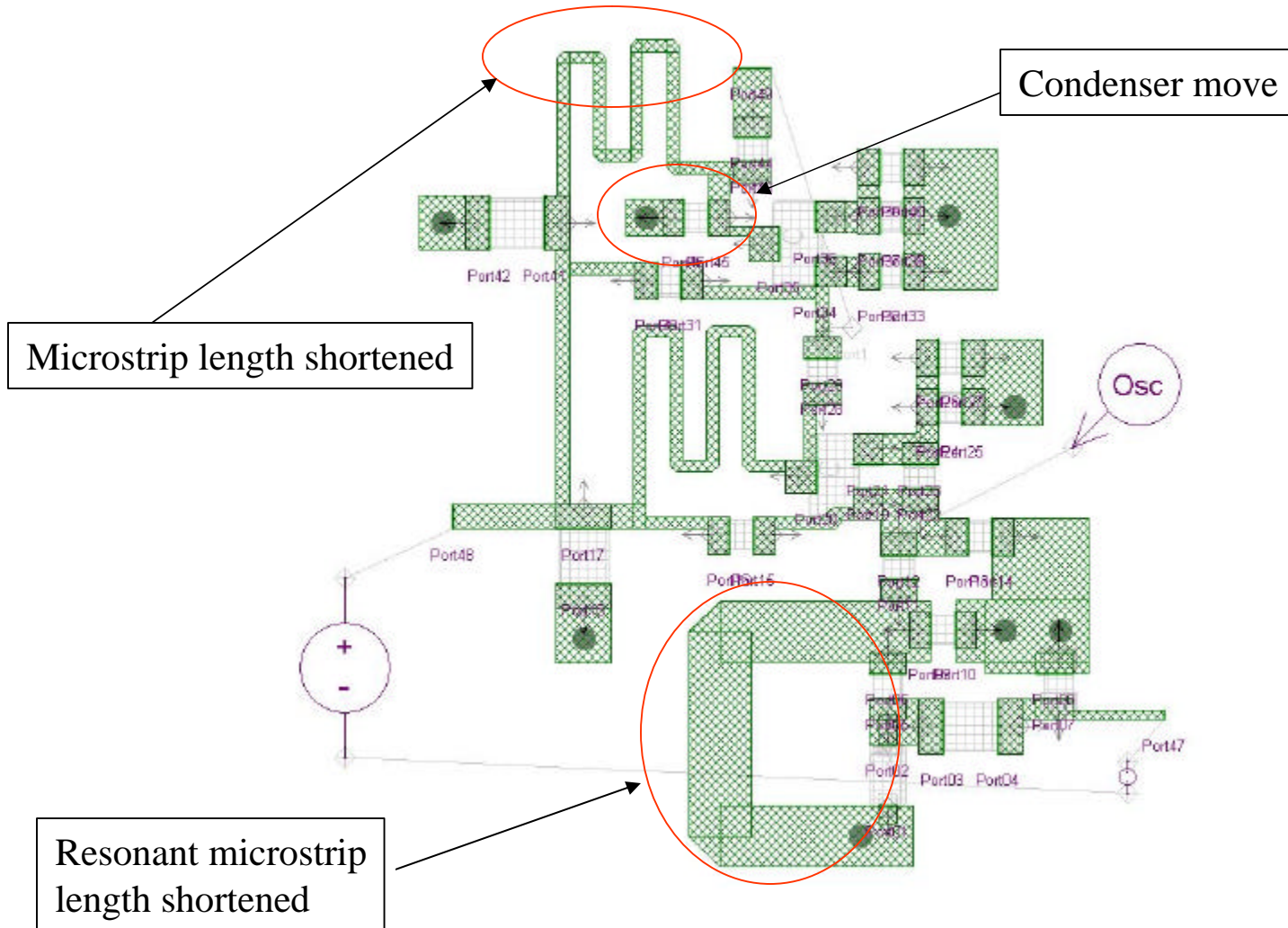


Merged layout



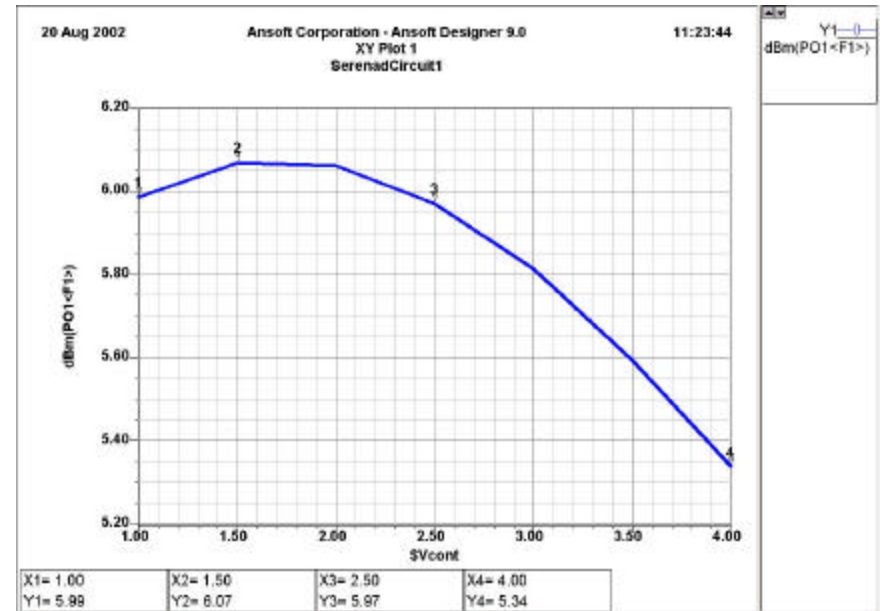
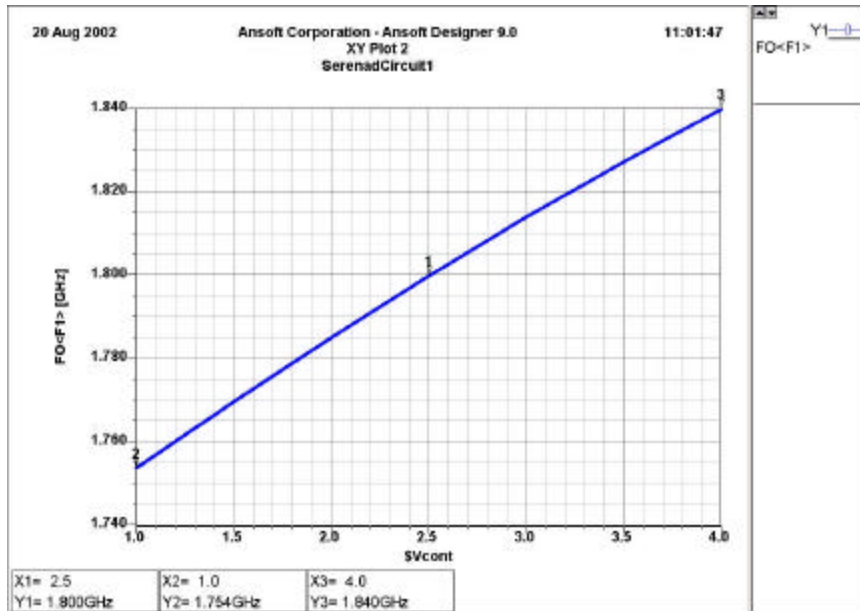
VCO schematic

# Adjusted layout



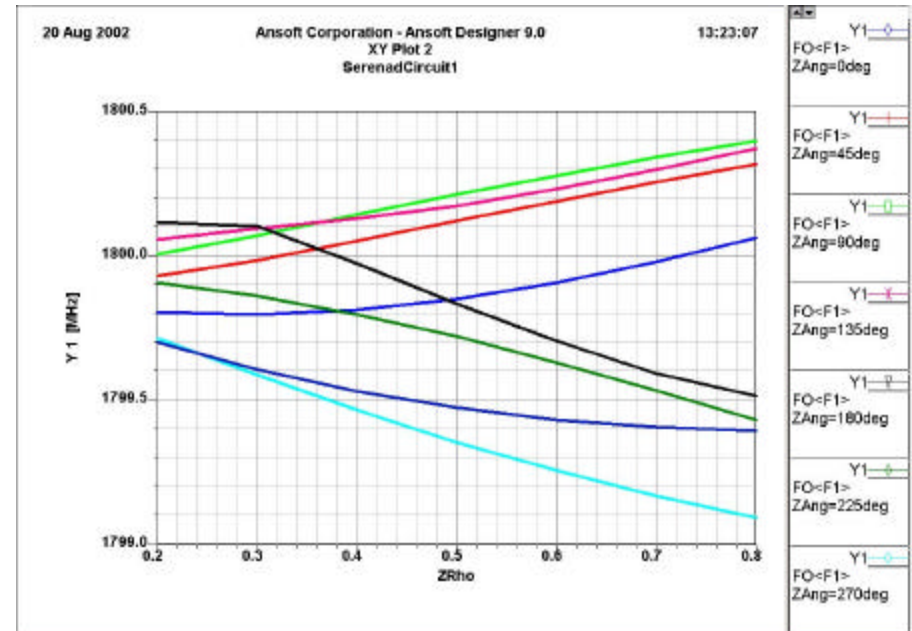
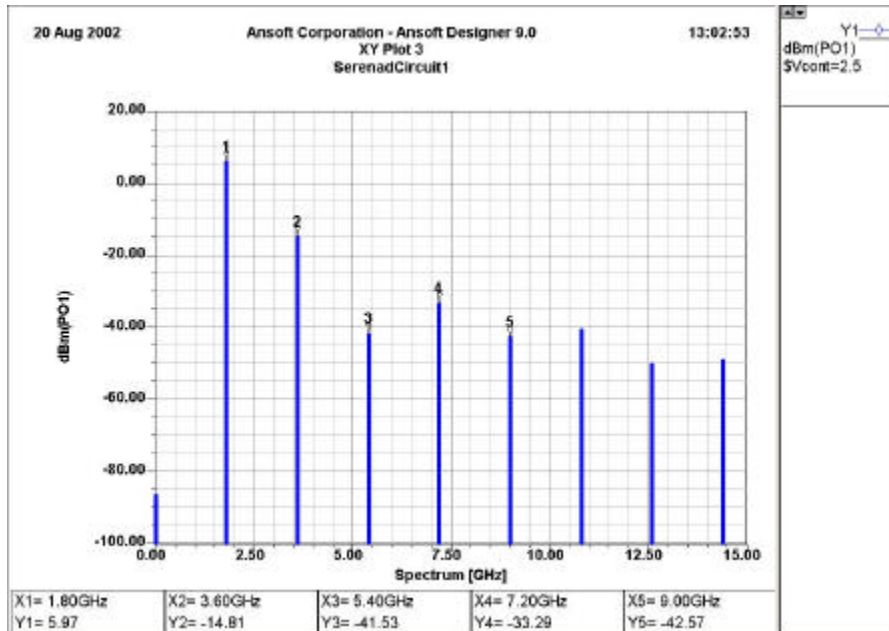
# Final result

- Oscillation frequency and output power



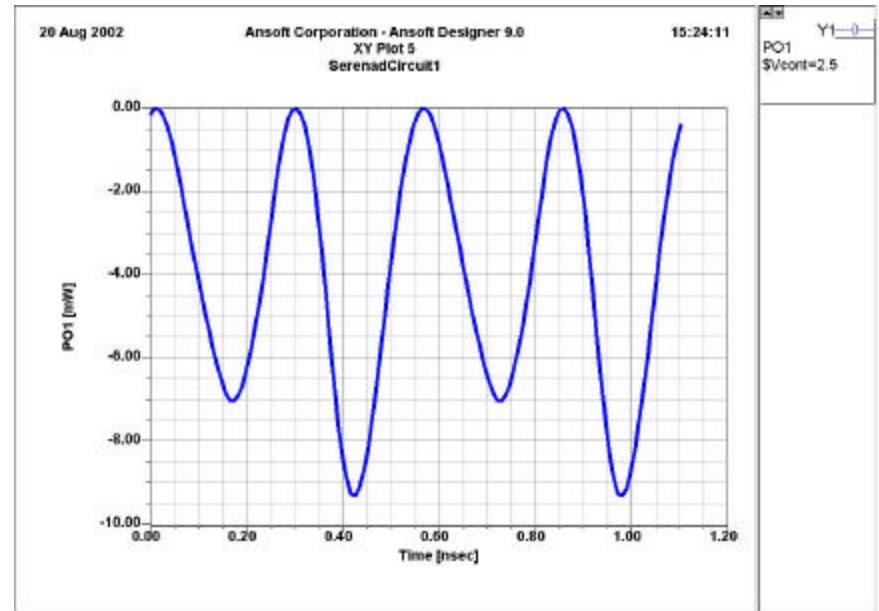
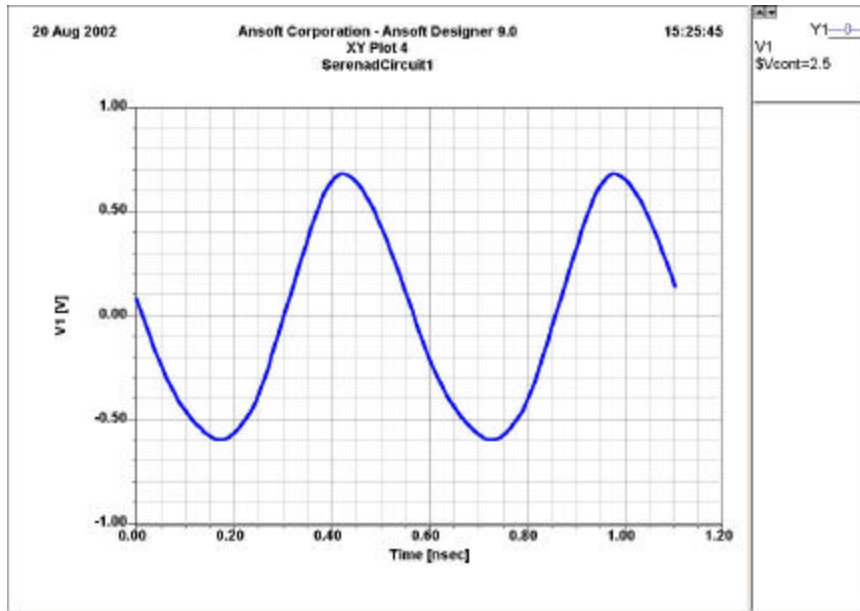
# Final result

- Output spectrum and load-pull characteristics



# Final result

- Output voltage and power waveform



# Conclusion

- ▶ VCO design is showed step by step
- ▶ Ansoft Designer™ is powerful tool
  - ▶ Seamless environment between circuit and electro magnetic simulator makes short time design.