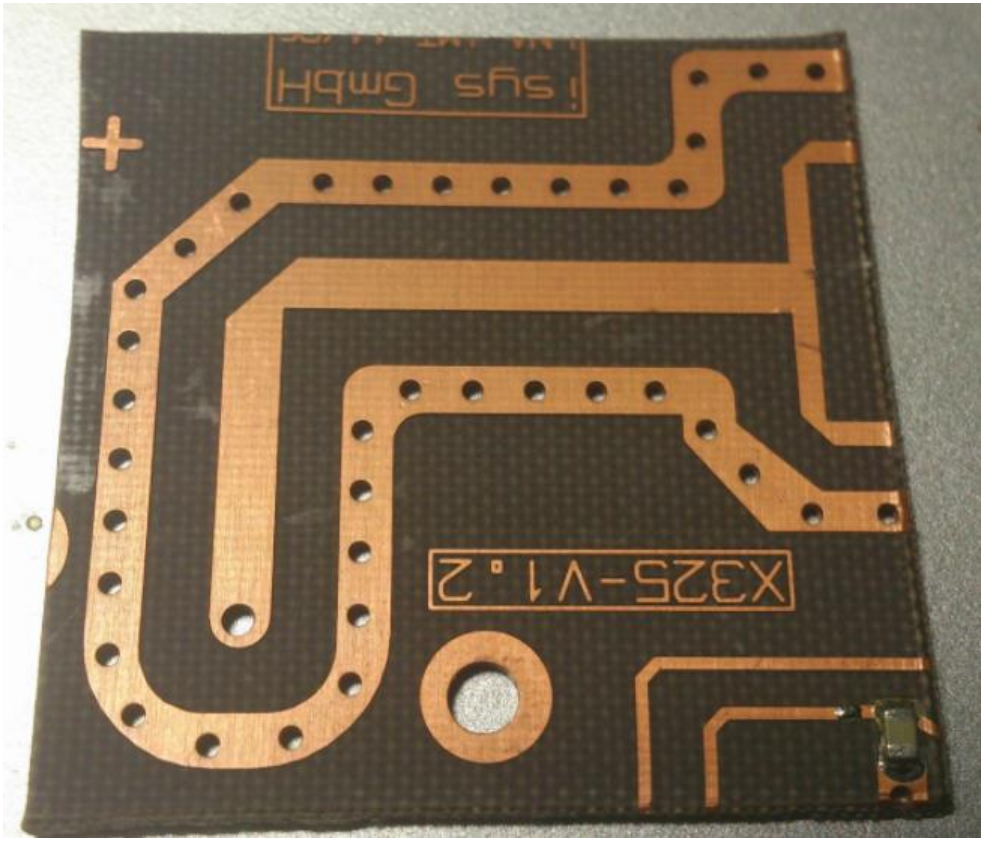
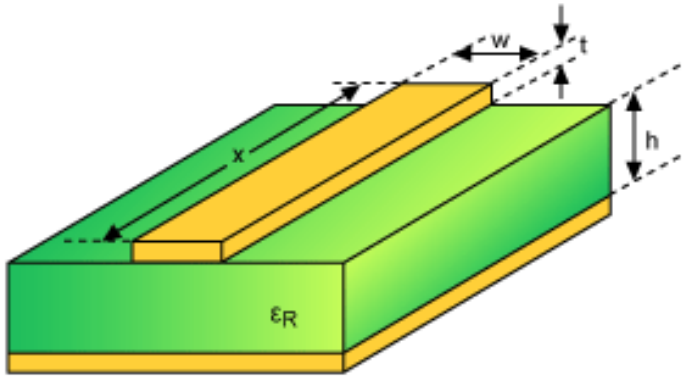
High-Speed Serial Interface Circuits and Systems

Design Exercise 5 –

S-parameters

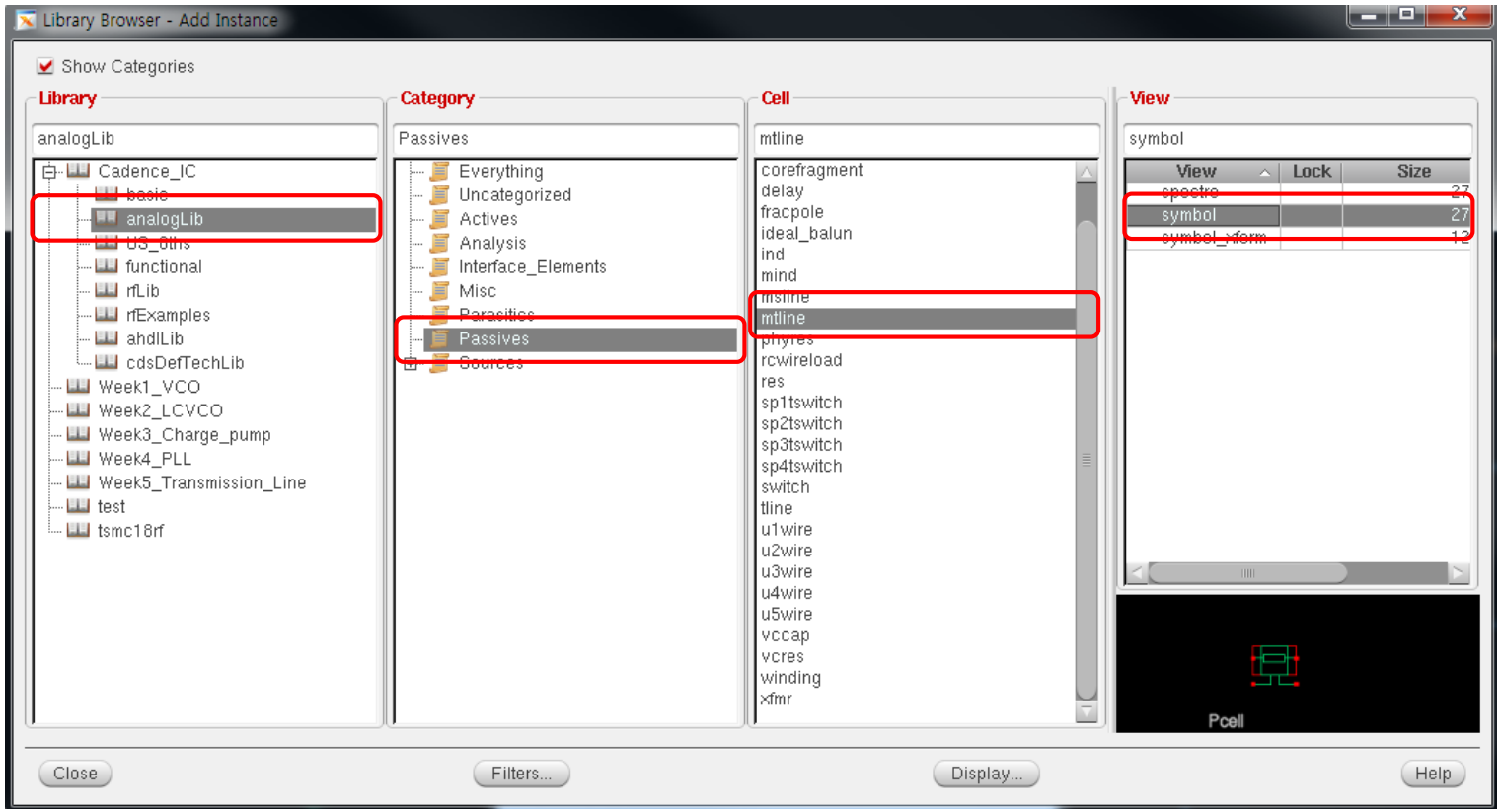
PCB Microstrip Line





mtline Setting

- mtline selection
  - Cadence_IC → analogLib → Passives → mtline → symbol

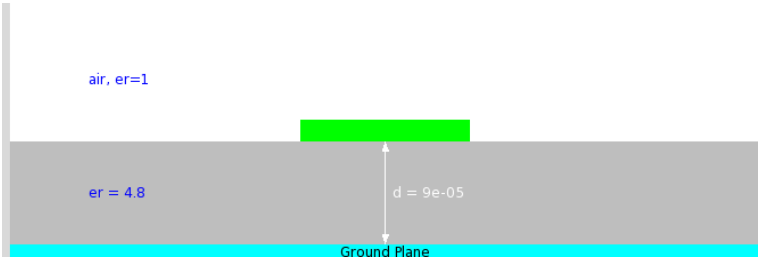


mtline Setting

- mtline design 1 – Z_0 : 50Ω
  - Micro-strip transmission line type

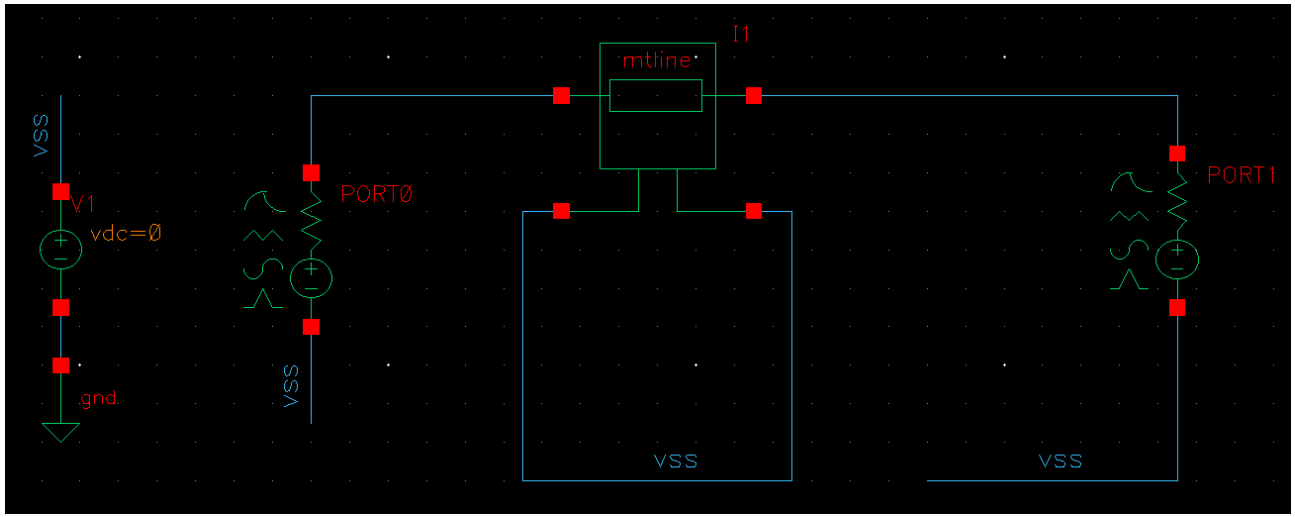
CDF Parameter	Value
Num of lines (excluding ref.)	1
Model name	
Physical length	508m M
Multiplicity factor	1
Max signal frequency	
Type of Input	FieldSolver
Generate noise?	no
Transmission line type	microstrip
Model type	wideband
Rel dielectic const of layers(er)	4.8
Dielectric layer thickness (d)	90u
Signal line width	147u
Signal line thickness	17.78u
Signal line spacing	
Gnd Plane thickness	
Ground plane conductivity	
Signal line conductivity	
Display Cross-section	

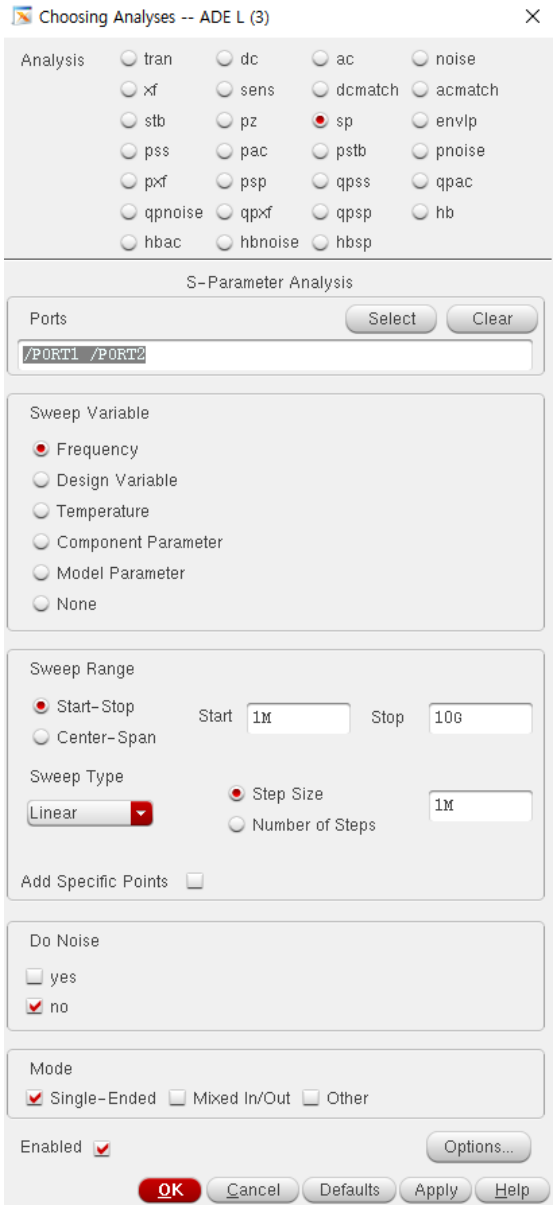
  - Physical length: 508mm
  - Type of Input : FieldSolver
  - Transmission line type : microstrip
  - Model type : wideband
  - Real dielectric const of layers : 4.8 (FR4)
  - Dielectric layer thickness : 90u
  - Signal line width : 147u
  - Signal line thickness : 17.78u
  - Display Cross-section



S-Parameters

- Simulation condition

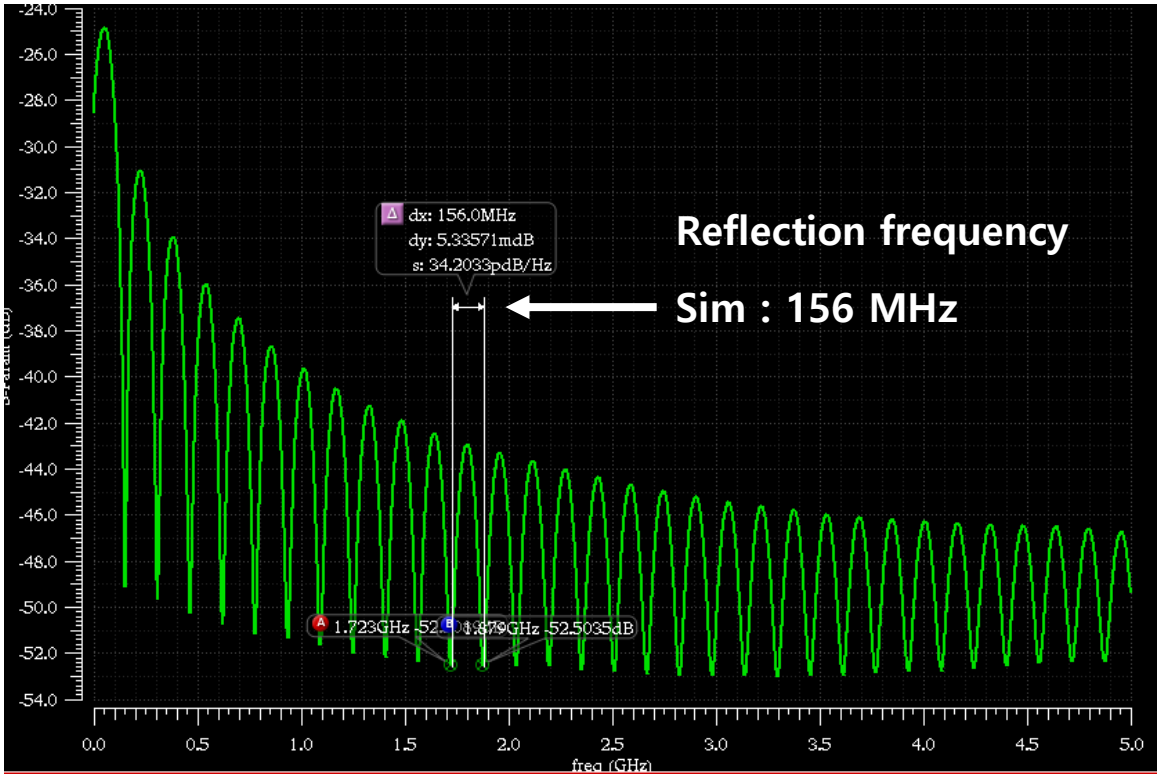




  - Simulation setting
    - Analysis : sp
    - Ports : Port0 and Port1 choice
    - Source resistance : 50Ω / Termination resistance : 50Ω
    - Sweep variable : frequency
    - Sweep range : 1M ~ 5G
    - Sweep type : Linear (Step size : 1M)
  - Direct plot from
    - S11 dB20 & S21 dB20 & S11 Z-chart

S-Parameters

- Simulation results – S11 frequency response



Reflection frequency

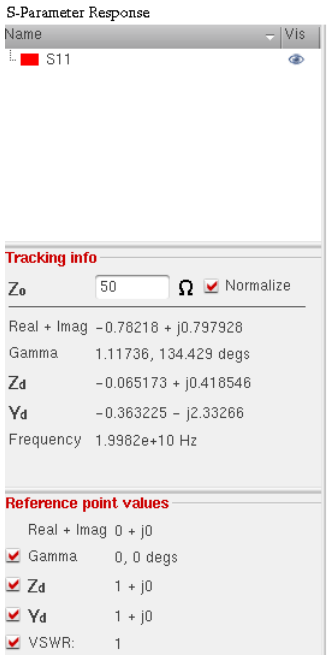
$$= \frac{v}{2L} = \frac{c}{\sqrt{\varepsilon_r}} \bullet \frac{1}{2L} = 134.7MHz$$

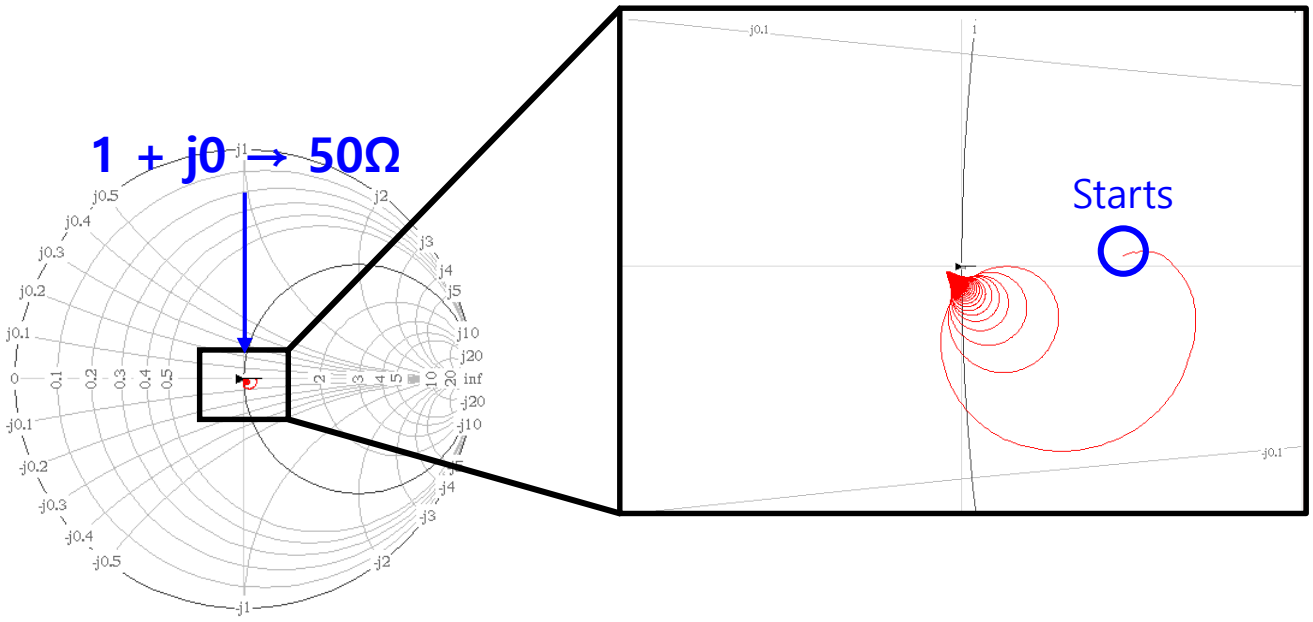
S-Parameters

- Simulation results – S21 frequency response

S-Parameters

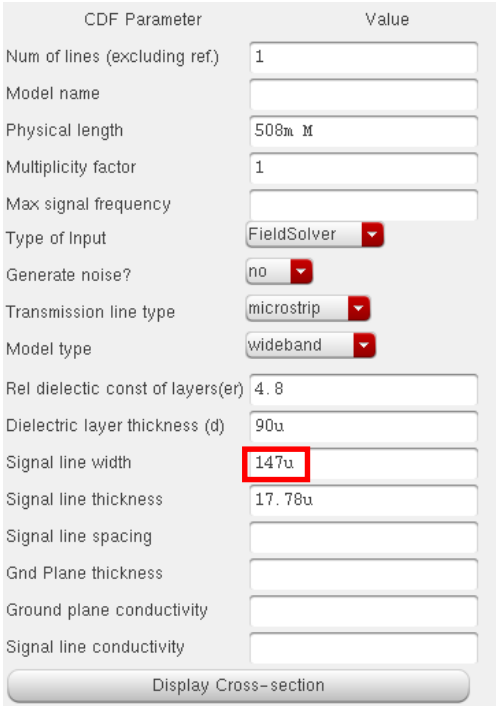
- Simulation results – S11 impedance smith chart





mtline Setting

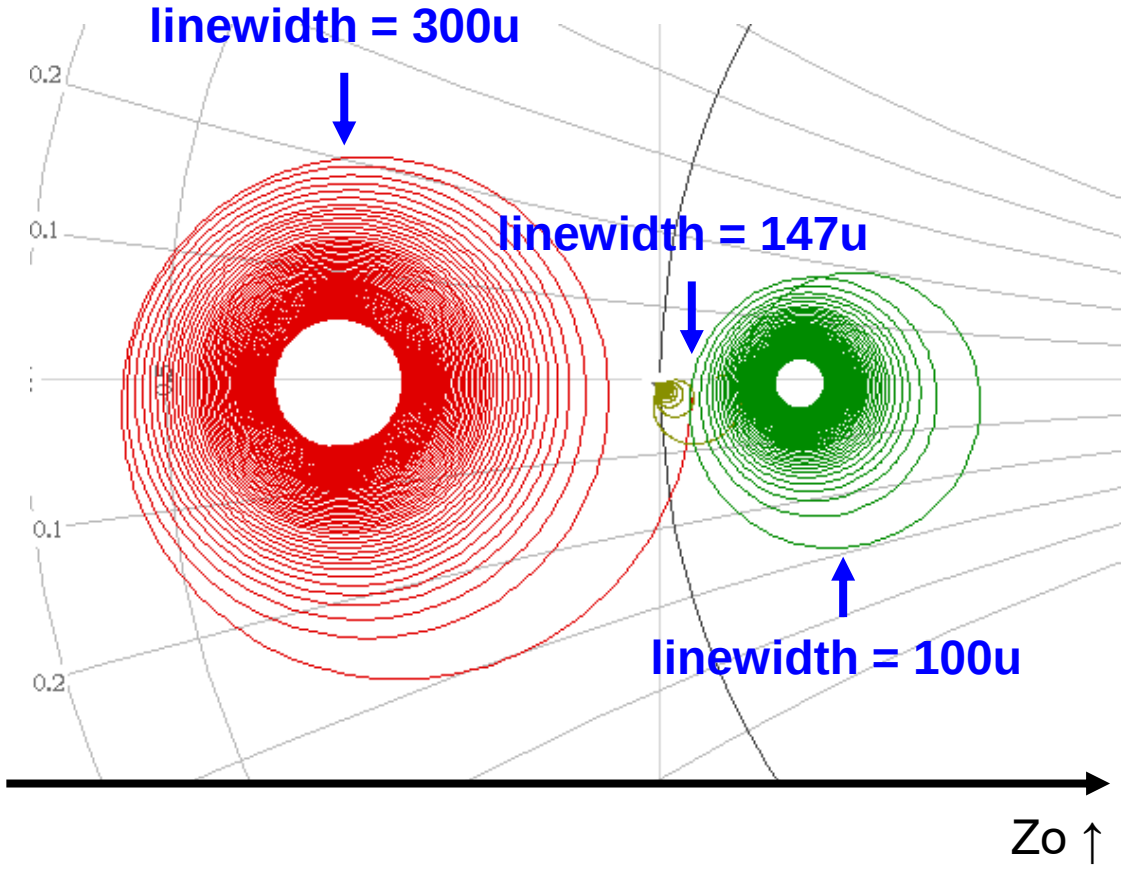
- line width change
  - Micro-strip transmission line type

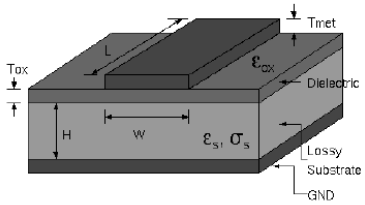


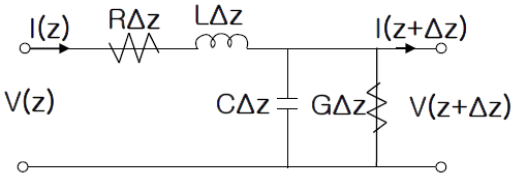
  - Physical length: 508mm
  - Type of Input : FieldSolver
  - Transmission line type : microstrip
  - Model type : wideband
  - Real dielectric const of layers : 4.8 (FR4)
  - Dielectric layer thickness : 90u
  - Signal line width : **100u, 147u, 200u**
  - Signal line thickness : 17.78u
  - Display Cross-section

mtline Setting

- Simulation results – S11, linewidth change





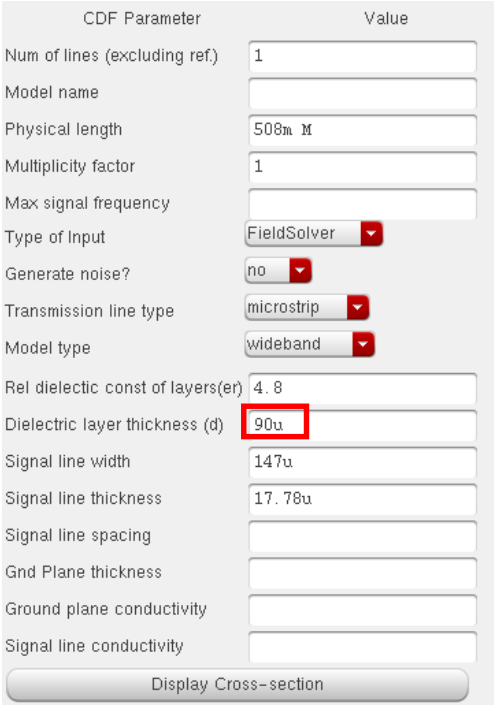


$$Z_0 = \frac{V(z)}{I(z)} = \frac{(R + j\omega L)}{\gamma} = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

line width ↓
= R ↑ / L ↑
= C ↓ / G ↓
= Zo ↑

mtline Setting

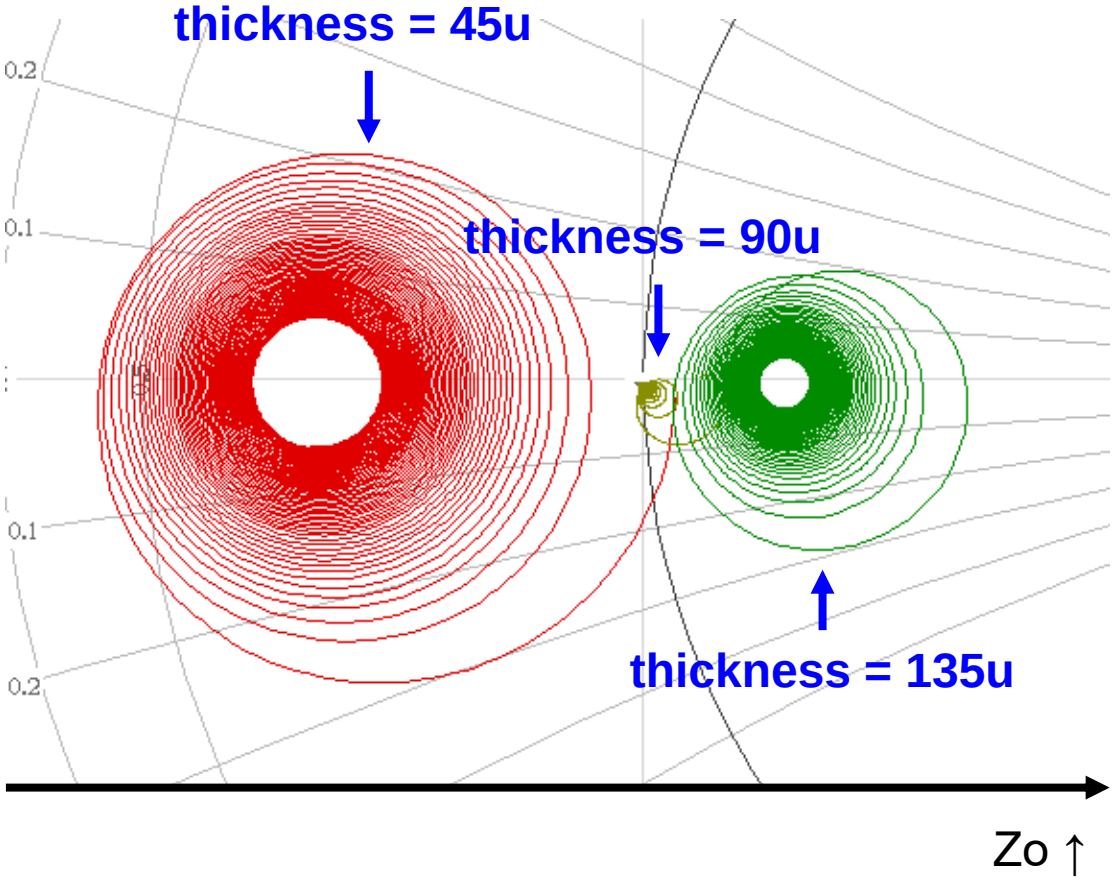
- Dielectric layer thickness change
  - Micro-strip transmission line type

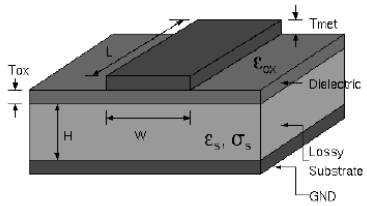


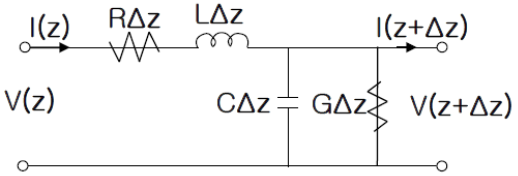
- Physical length: 508mm
- Type of Input : FieldSolver
- Transmission line type : microstrip
- Model type : wideband
- Real dielectric const of layers : 4.8 (FR4)
- Dielectric layer thickness : **45u, 90u, 135u**
- Signal line width : 147u
- Signal line thickness : 17.78u
- Display Cross-section

mtline Setting

- Simulation results – S11, Dielectric layer thickness





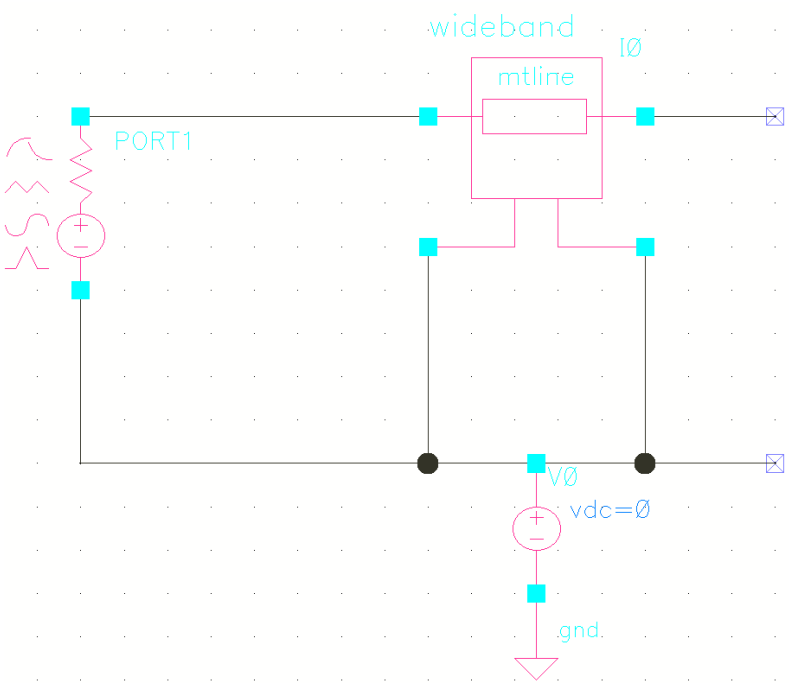


$$Z_0 = \frac{V(z)}{I(z)} = \frac{(R + j\omega L)}{\gamma} = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

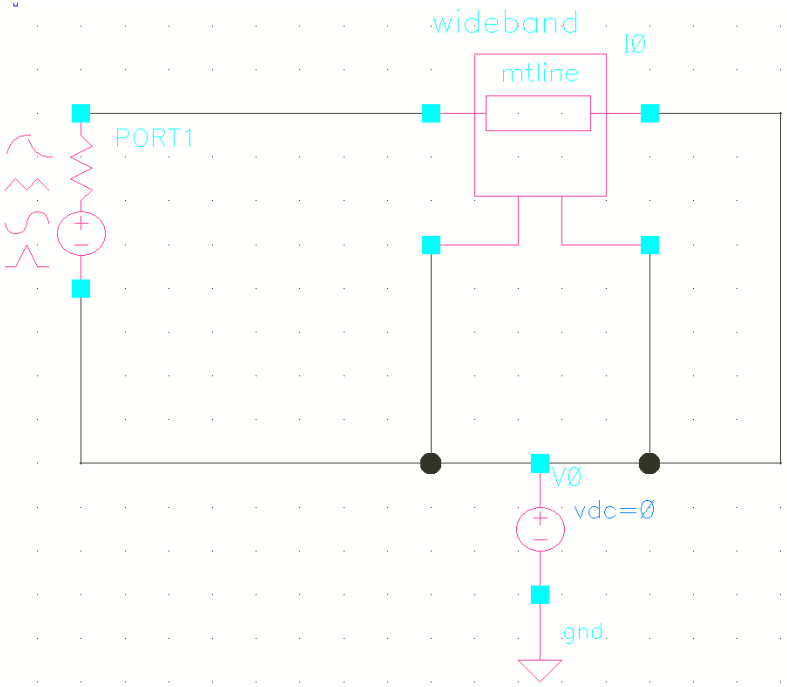
die. layer thickness ↓
= L ↓
= C ↑ / G ↑
= Zo ↓

S-Parameters

- Simulation setup – S11, mtline open / short



<Open>

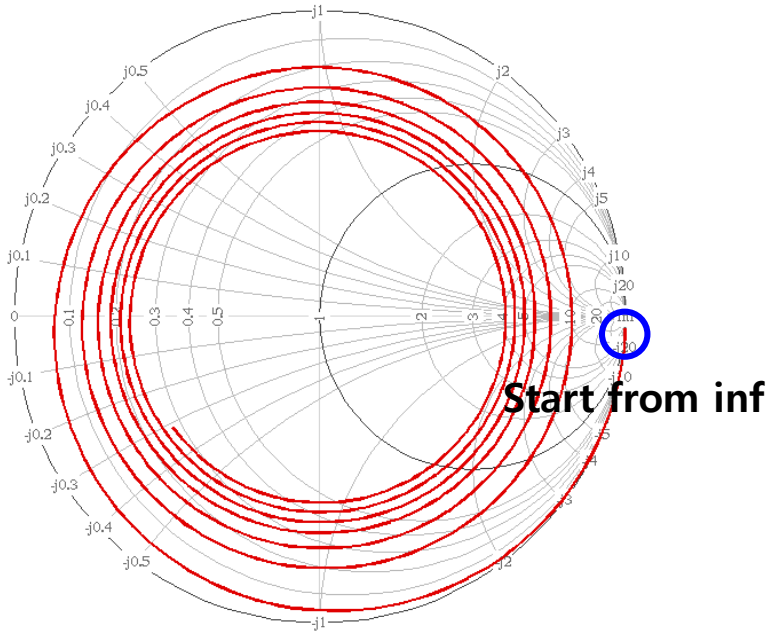


<Short>

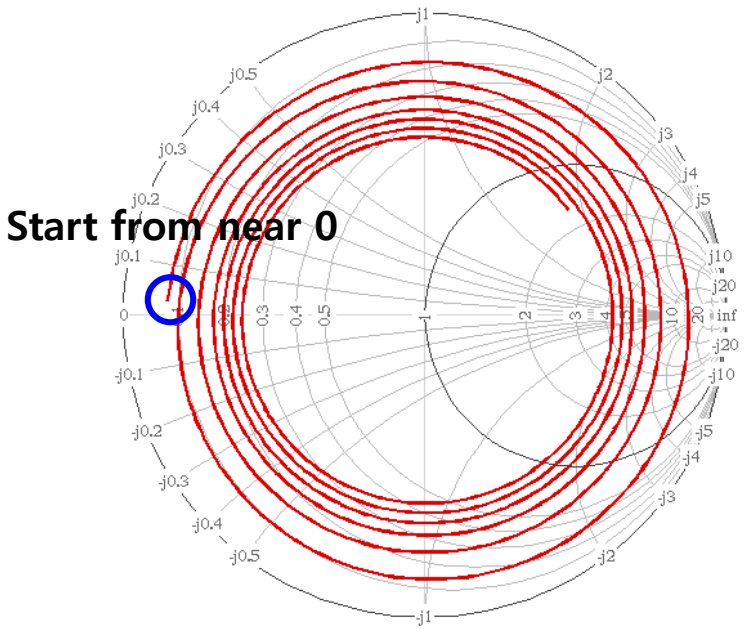
  - Simulation setting
    - Sweep range : 1M ~ 1G

S-Parameters

- Simulation results – S11, mtline open / short (1M~1G)



<Open>



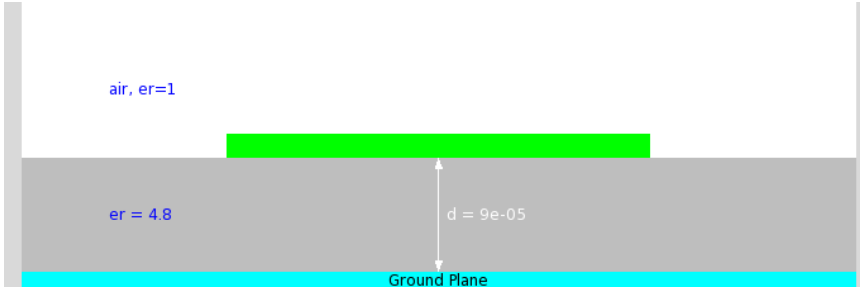
<Short>

mtline Setting

- mtline design 2 – Z_0 : 30Ω
  - Micro-strip transmission line type

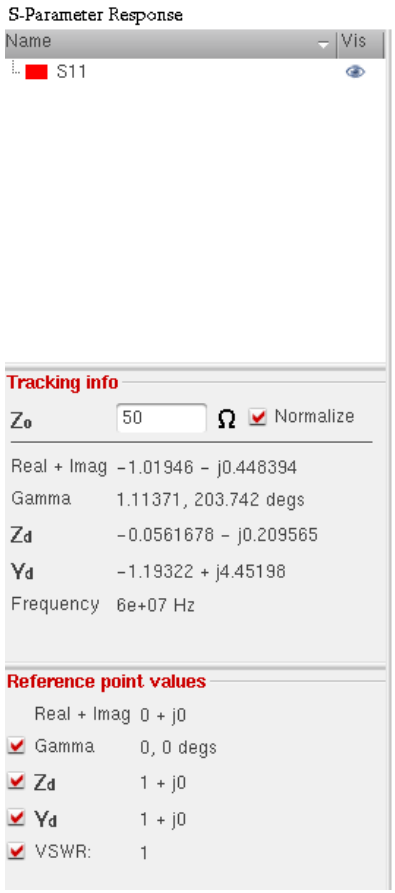
CDF Parameter	Value
Num of lines (excluding ref.)	1
Model name	
Physical length	508m M
Multiplicity factor	1
Max signal frequency	
Type of Input	FieldSolver
Generate noise?	no
Transmission line type	microstrip
Model type	wideband
Rel dielectic const of layers(er)	4.8
Dielectric layer thickness (d)	90u
Signal line width	147u
Signal line thickness	17.78u
Signal line spacing	
Gnd Plane thickness	
Ground plane conductivity	
Signal line conductivity	
Display Cross-section	

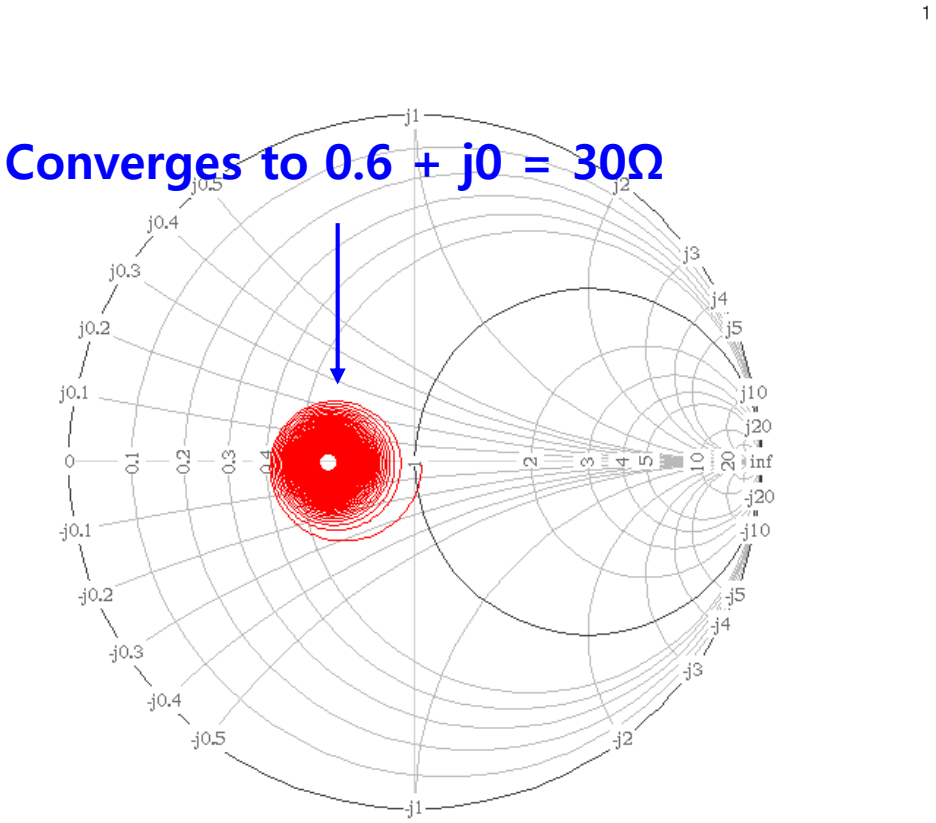
  - Physical length: 508mm ➔ ~1n delay
  - Type of Input : FieldSolver
  - Transmission line type : microstrip
  - Model type : wideband
  - Real dielectric const of layers : 4.8 (FR4)
  - Dielectric layer thickness : 90u
  - Signal line width : **333u**
  - Signal line thickness : 17.78u
  - Display Cross-section



S-Parameters

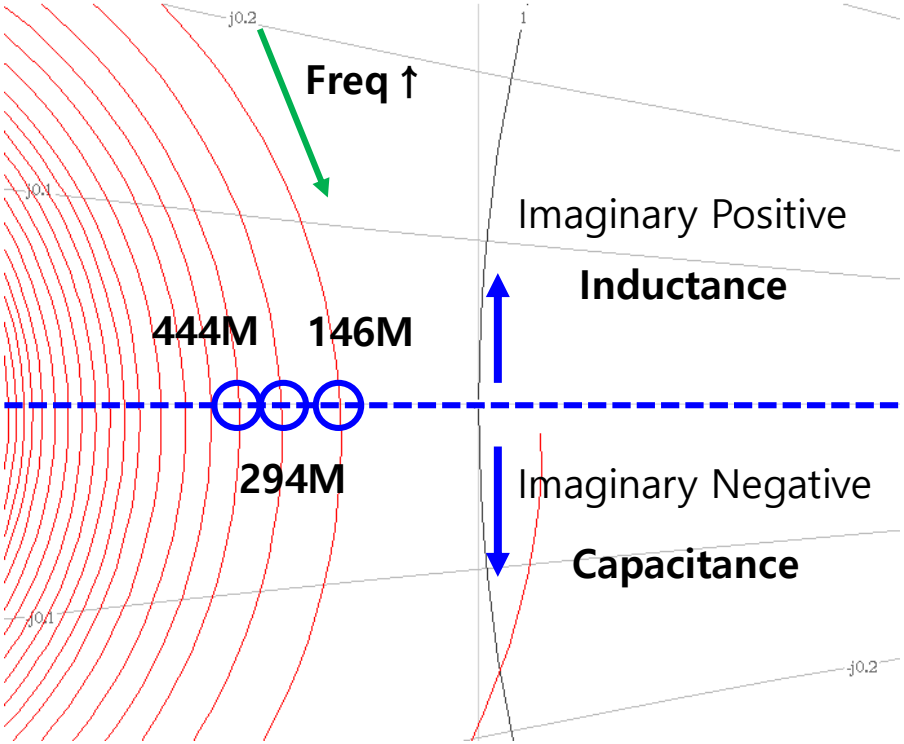
- Simulation results – S11 impedance smith chart

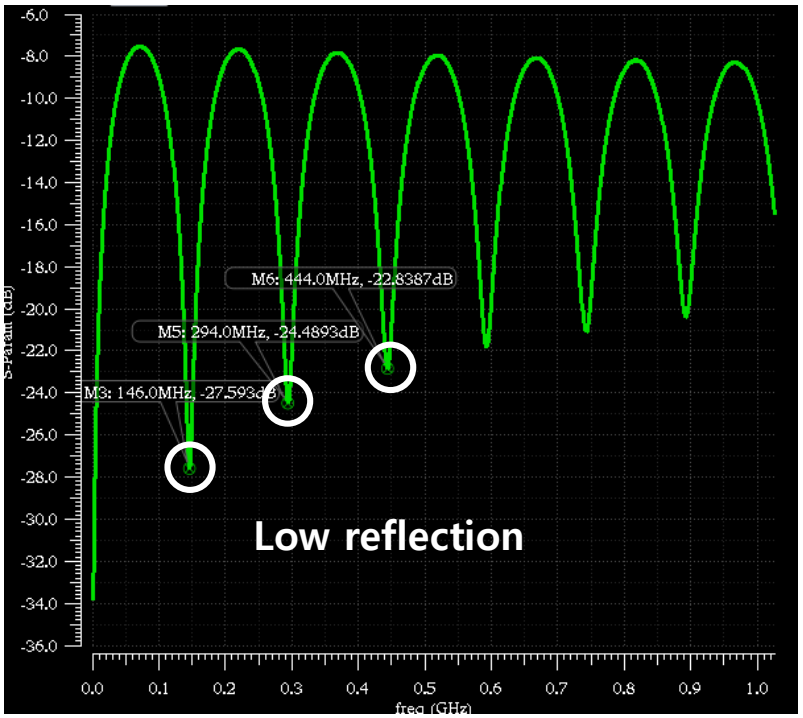




S-Parameters

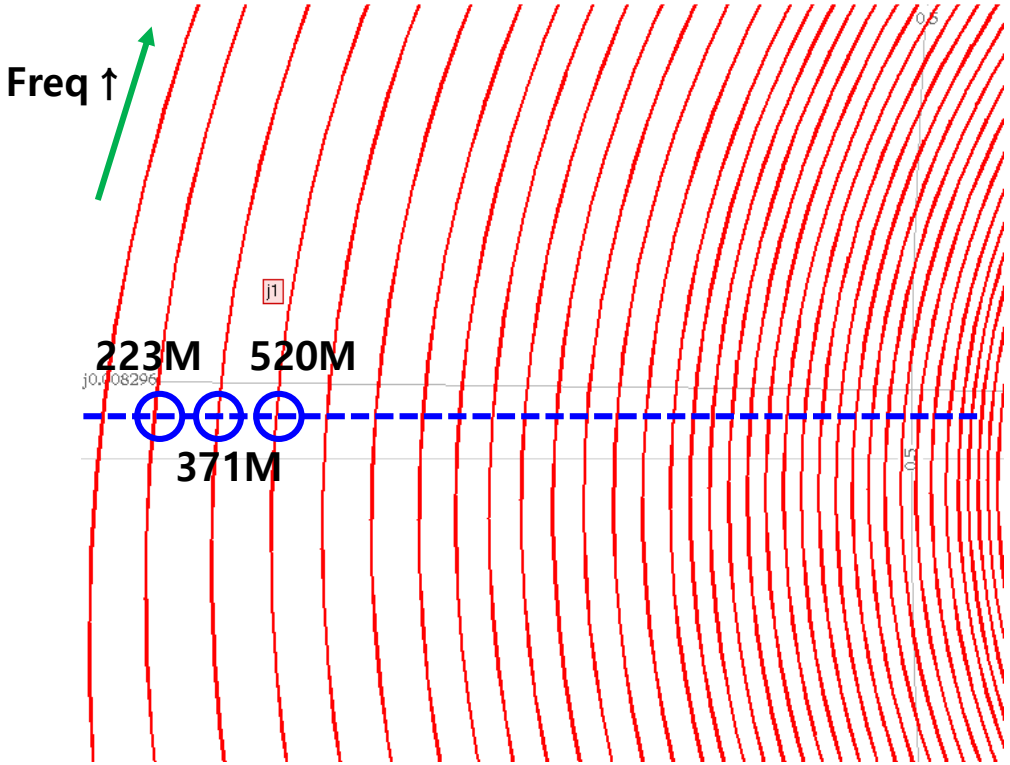
- Compare S11 Smith chart w/ S11 freq response

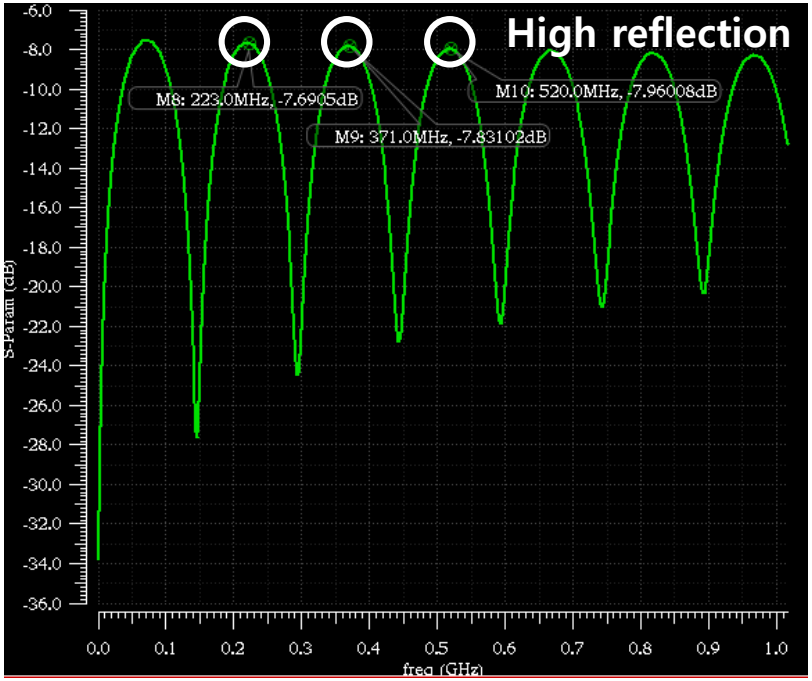




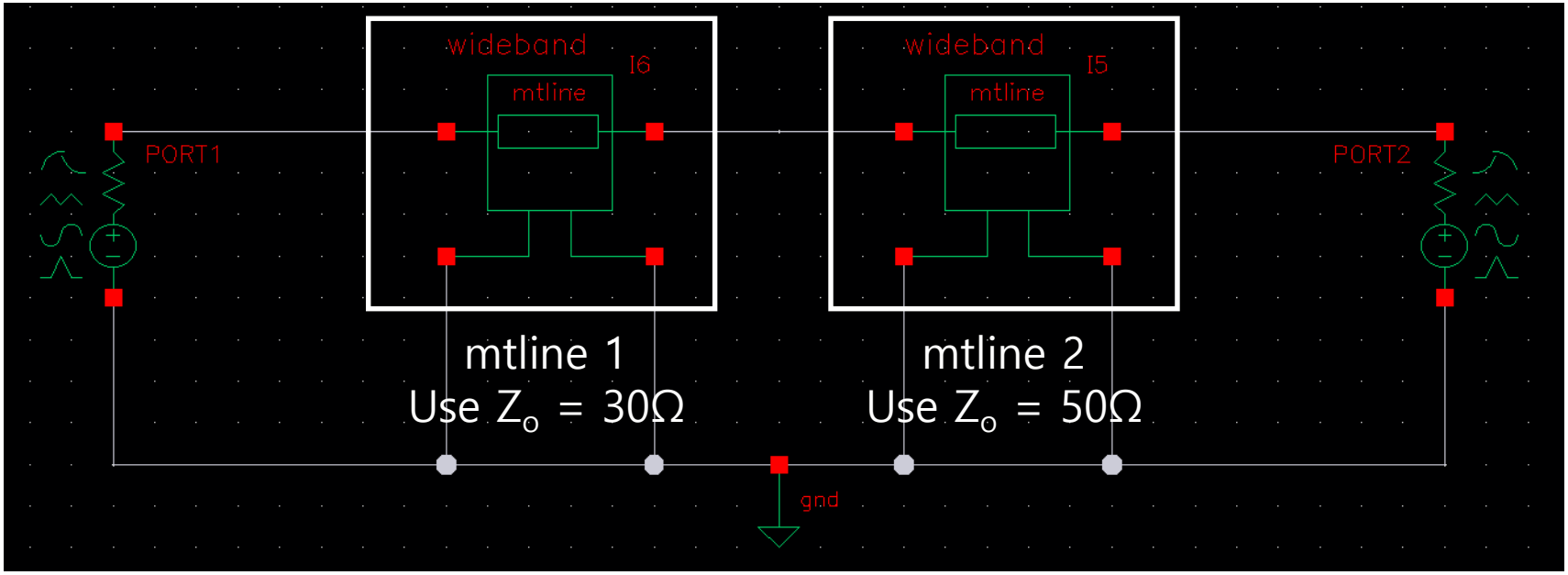
S-Parameters

- Compare S11 Smith chart w/ S11 freq response





Cascaded Microstrip Line

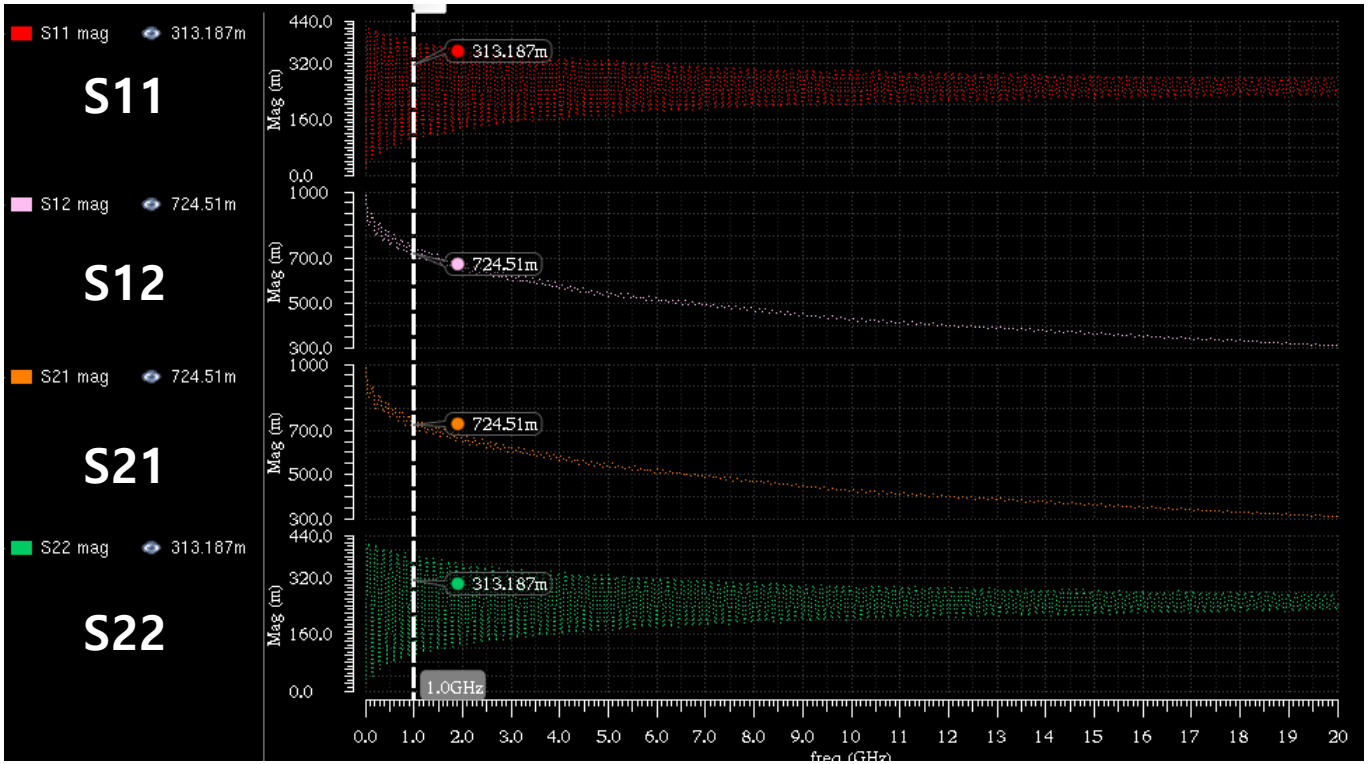


$$\begin{bmatrix} b_{1,1} \\ b_{2,1} \end{bmatrix} = \begin{bmatrix} S_{11,1} & S_{12,1} \\ S_{21,1} & S_{22,1} \end{bmatrix} \begin{bmatrix} a_{1,1} \\ a_{2,1} \end{bmatrix} \qquad \begin{bmatrix} b_{1,2} \\ b_{2,2} \end{bmatrix} = \begin{bmatrix} S_{11,2} & S_{12,2} \\ S_{21,2} & S_{22,2} \end{bmatrix} \begin{bmatrix} a_{1,2} \\ a_{2,2} \end{bmatrix}$$

$$\begin{bmatrix} b_{1,1} \\ b_{2,1} \end{bmatrix} = \begin{bmatrix} ? & ? \\ ? & ? \end{bmatrix} \begin{bmatrix} a_{1,2} \\ a_{2,2} \end{bmatrix}$$

Cascaded Microstrip Line

- S-parameters : mtline1, Zo = 30Ω, 1 GHz

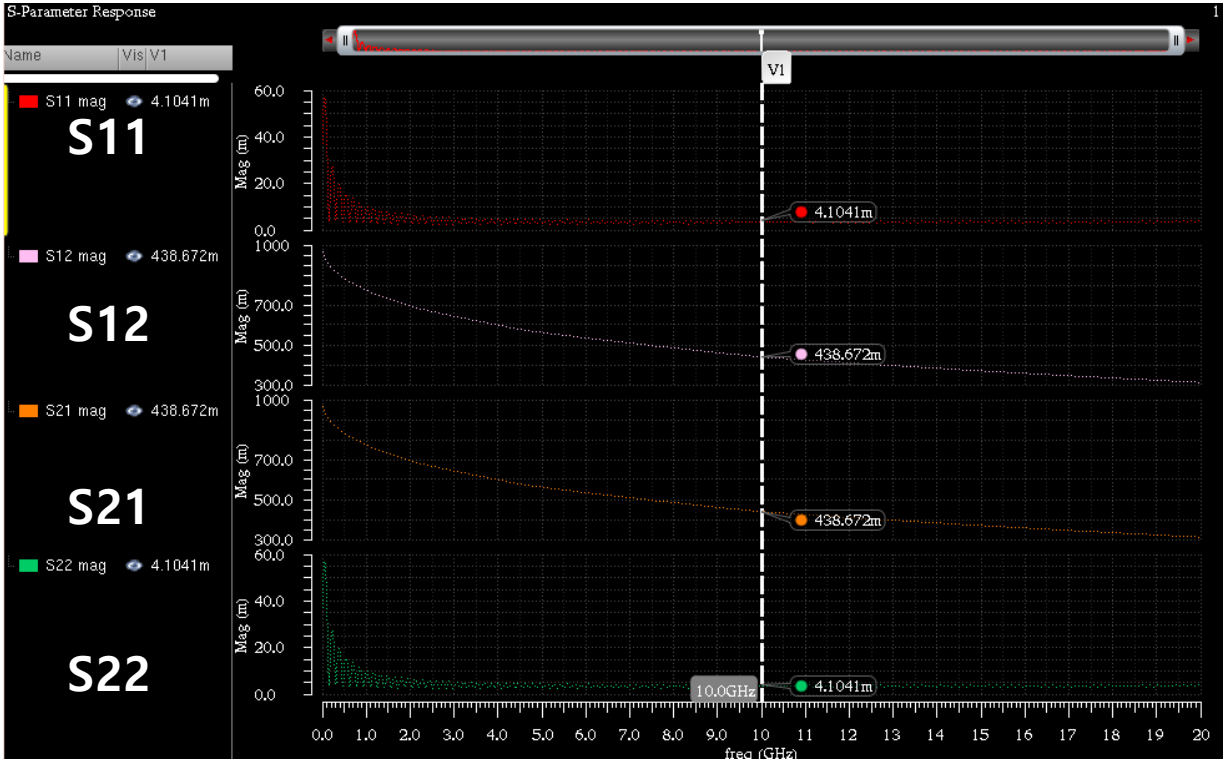


!) Do not use dB scale

$$\begin{bmatrix} b_{1,1} \\ b_{2,1} \end{bmatrix} = \begin{bmatrix} 313.187m & 724.51m \\ 724.51m & 313.187m \end{bmatrix} \begin{bmatrix} a_{1,1} \\ a_{2,1} \end{bmatrix}$$

Cascaded Microstrip Line

- S-parameters : mtline 2, Zo = 50Ω, 1 GHz



$$\begin{bmatrix} b_{1,2} \\ b_{2,2} \end{bmatrix} = \begin{bmatrix} 4.1041m & 438.672m \\ 438.672m & 4.1041m \end{bmatrix} \begin{bmatrix} a_{1,2} \\ a_{2,2} \end{bmatrix}$$

!) Do not use dB scale

Cascaded Microstrip Line

- Calculate T-parameter of each mtline

T-parameters

$$\begin{bmatrix} a_1 \\ b_1 \end{bmatrix} = \begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix} \begin{bmatrix} b_2 \\ a_2 \end{bmatrix}$$

$$\begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix} = \begin{bmatrix} s_{12} - \frac{s_{11}s_{22}}{s_{21}} & \frac{s_{11}}{s_{21}} \\ -\frac{s_{22}}{s_{21}} & \frac{1}{s_{21}} \end{bmatrix}$$

✓ s-param

$$\begin{bmatrix} b_{1,1} \\ b_{2,1} \end{bmatrix} = \begin{bmatrix} 313.2m & 724.5m \\ 724.5m & 313.2m \end{bmatrix} \begin{bmatrix} a_{1,1} \\ a_{2,1} \end{bmatrix}$$

✓ t-param

$$\begin{bmatrix} a_{1,1} \\ b_{1,1} \end{bmatrix} = \begin{bmatrix} 0.589 & 0.432 \\ -0.432 & 1.38 \end{bmatrix} \begin{bmatrix} b_{2,1} \\ a_{2,1} \end{bmatrix}$$

< Zo = 30Ω, 1 GHz >

✓ s-param

$$\begin{bmatrix} b_{1,2} \\ b_{2,2} \end{bmatrix} = \begin{bmatrix} 4.104m & 438.7\,m \\ 438.7m & 4.104m \end{bmatrix} \begin{bmatrix} a_{1,2} \\ a_{2,2} \end{bmatrix}$$

✓ t-param

$$\begin{bmatrix} a_{1,1} \\ b_{1,1} \end{bmatrix} = \begin{bmatrix} 0.771 & 0.013 \\ -0.013 & 1.296 \end{bmatrix} \begin{bmatrix} b_{2,1} \\ a_{2,1} \end{bmatrix}$$

< Zo = 50Ω, 1 GHz >

Cascaded Microstrip Line

- Calculate T-parameter of each mtline

$$\begin{bmatrix} a_{1,1} \\ b_{1,1} \end{bmatrix} = \begin{bmatrix} T_{11,1} & T_{12,1} \\ T_{21,1} & T_{22,1} \end{bmatrix} \begin{bmatrix} T_{11,2} & T_{12,2} \\ T_{21,2} & T_{22,2} \end{bmatrix} \begin{bmatrix} b_{2,2} \\ a_{2,2} \end{bmatrix} \qquad \begin{bmatrix} a_{1,1} \\ b_{1,1} \end{bmatrix} = \begin{bmatrix} 0.449 & 0.568 \\ -0.351 & 1.784 \end{bmatrix} \begin{bmatrix} b_{2,2} \\ a_{2,2} \end{bmatrix}$$

mtline1 T param

mtline2 T param

Cascaded mtline T param

- T-parameters to S-parameters

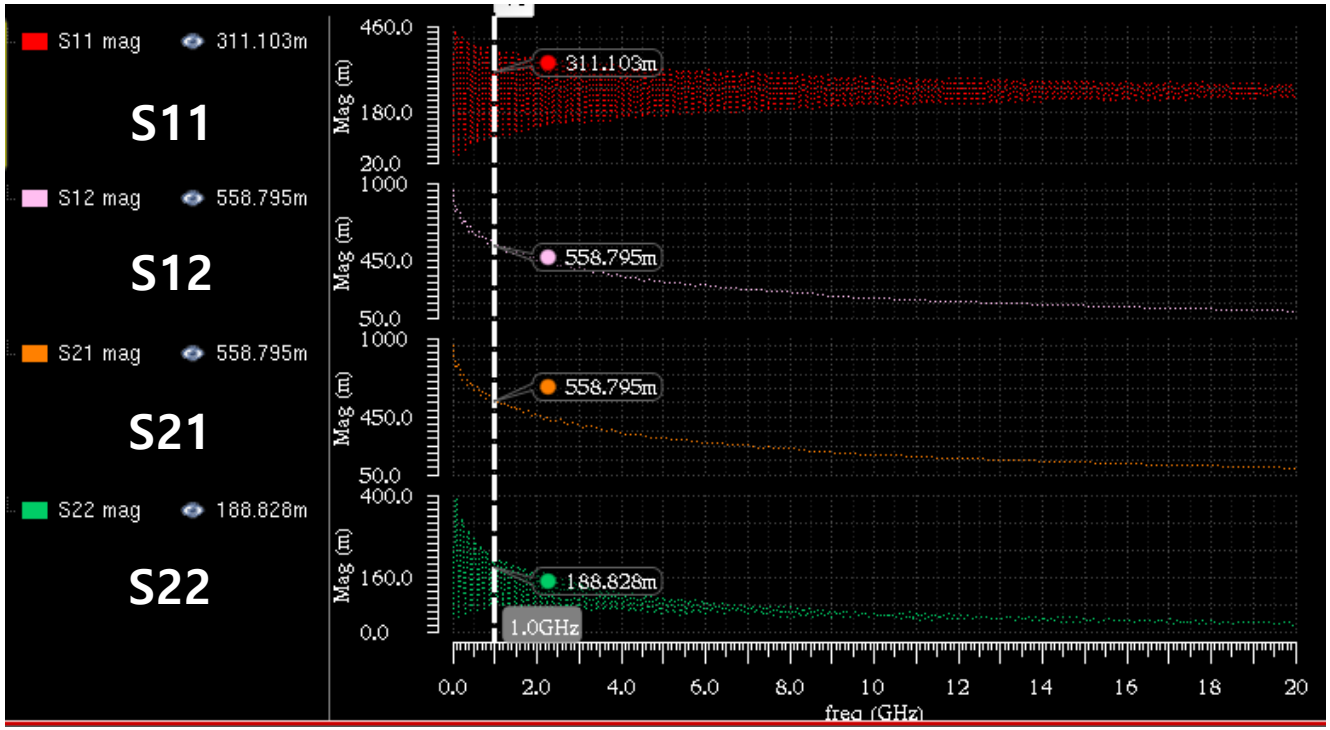
$$\begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} = \begin{bmatrix} \frac{T_{12}}{T_{22}} & T_{11} - \frac{T_{12}T_{21}}{T_{22}} \\ \frac{1}{T_{22}} & -\frac{T_{21}}{T_{22}} \end{bmatrix}$$

$$\begin{bmatrix} b_{1,1} \\ b_{2,1} \end{bmatrix} = \begin{bmatrix} 0.318 & 0.560 \\ 0.560 & 0.197 \end{bmatrix} \begin{bmatrix} a_{1,2} \\ a_{2,2} \end{bmatrix}$$

Cascaded mtline S param

Cascaded Microstrip Line

- S-parameters : mtline1 + mtline2, 1GHz



$$\begin{bmatrix} b_{1,2} \\ b_{2,2} \end{bmatrix} = \begin{bmatrix} 0.311 & 0.559 \\ 0.559 & 0.189 \end{bmatrix} \begin{bmatrix} a_{1,2} \\ a_{2,2} \end{bmatrix}$$

< Simulation >

$$\begin{bmatrix} b_{1,2} \\ b_{2,2} \end{bmatrix} = \begin{bmatrix} 0.318 & 0.560 \\ 0.560 & 0.197 \end{bmatrix} \begin{bmatrix} a_{1,2} \\ a_{2,2} \end{bmatrix}$$

< Calculation >

Homework

- ✓ Compare s-parameters simulation and calculation result of cascaded microstrip line used today @ 10 GHz
- ✓ Attach the simulation results of s-parameters and calculation results of T-parameters at 10 GHz of each mtline.
- ✓ Deadline : 10/15(Thu) 19:00
  - ➢ Upload pdf file to YSCEC