

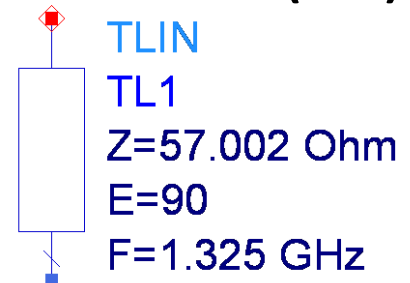
# Quarter-wave, $\lambda_0/4$ , Impedance Transformer

ISSUE: Consistency in FEM Simulations

# $\lambda/4$ Impedance Transformer

## Design Parameters

- Frequency of operation,  $f_0 = 1.325$ -GHz
- Parameters of the transmission line employed:
  - Electrical length at  $f_0$ ,  $\theta_c(f_0) = 90$ -degree
  - Characteristic impedance,  $Z_c = 57.002$ -Ohms
  - Port impedance,  $Z_0 = 50$ -Ohms
- ADS model for ideal transmission line (TL) based  $\lambda/4$  impedance transformer:



## S-Parameter Simulation of Ideal Transmission Line based $\lambda/4$ Impedance Transformer

# S-Parameter Simulation Set-Up

- Simulation of ideal transmission line based  $\lambda/4$  impedance transformer



S\_Param

SP1

Start=0.5025 GHz

Stop=2.1475 GHz

Step=0.5 MHz

Var  
Eqn

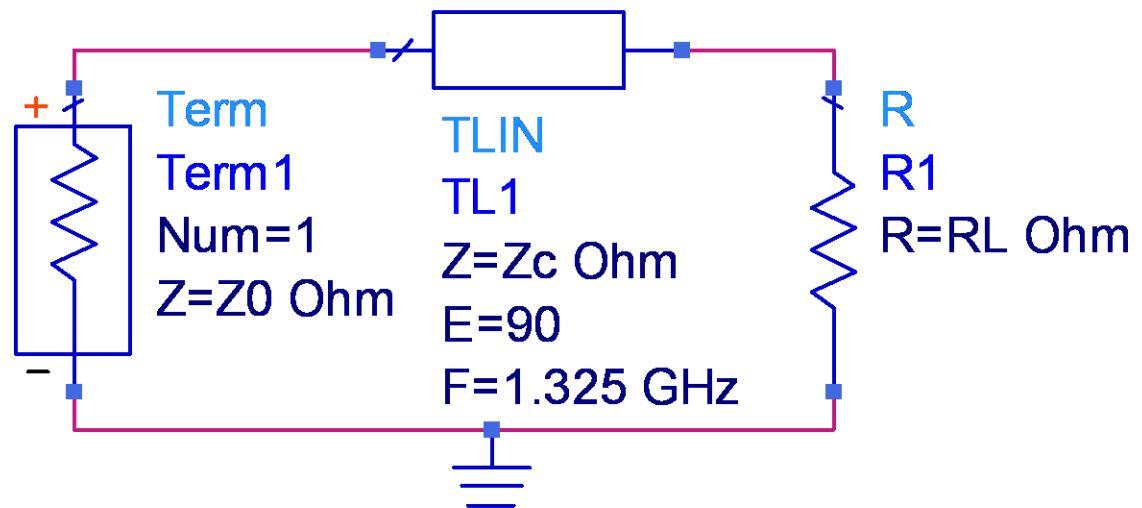
VAR

VAR1

Z0=50

Zc=57.002

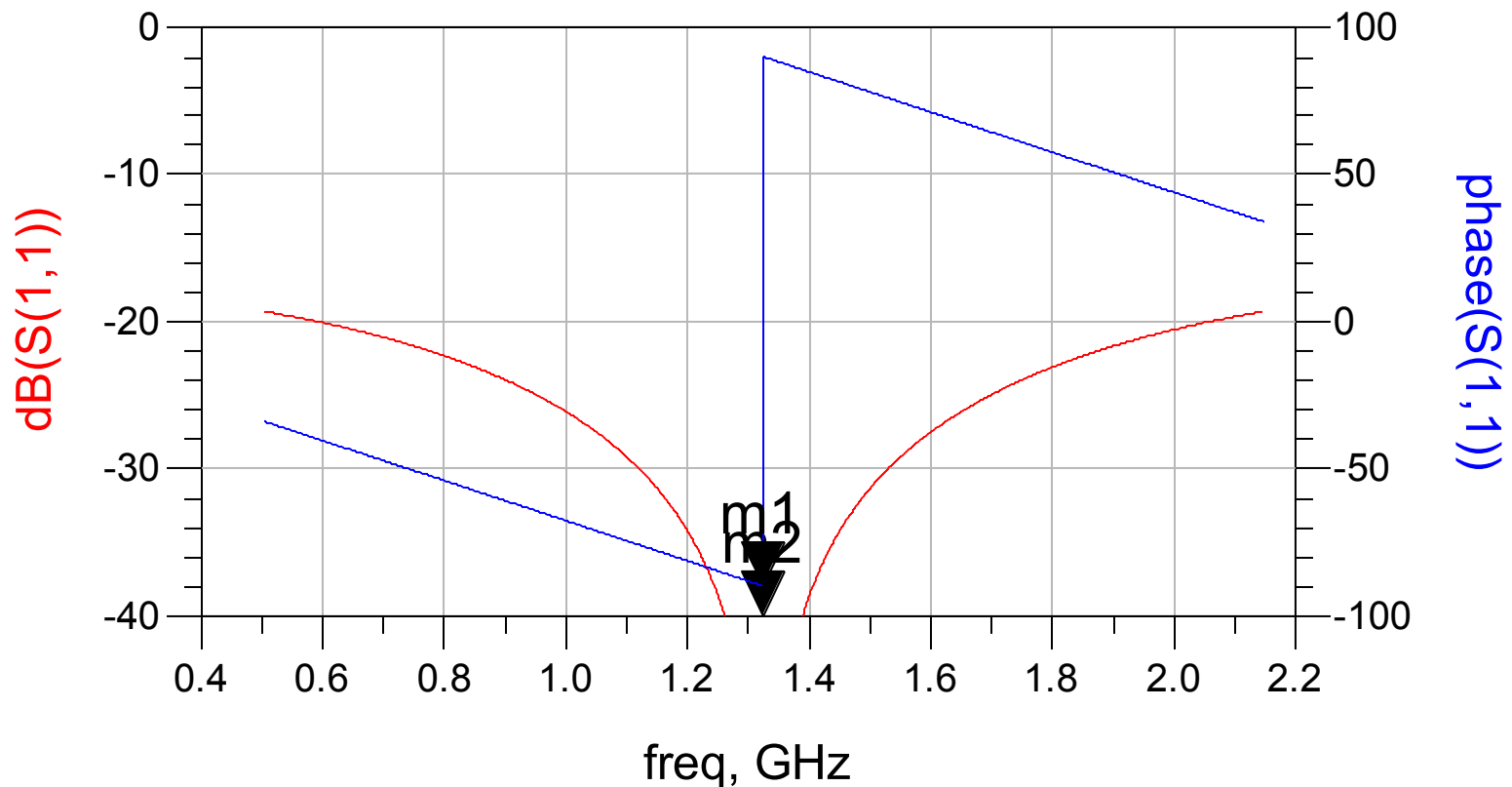
RL=Zc<sup>2</sup>/Z0



# S-Parameter Simulation Result

m1  
freq= 1.325GHz  
phase(S(1,1))=-89.966  
Valley

m2  
freq= 1.325GHz  
dB(S(1,1))=-313.065  
Min



- Simulation result, with ideal TL resonator, is as per the theory:  
 $S_{11} = 0$  at  $f_0$

# Substrate Parameters for Microstrip Transmission Line

- Substrate parameters:
  - Dielectric constant,  $\epsilon_r = 3.2$
  - Height,  $h = 1.524\text{-mm}$  (or 60 milli-inch)
  - Loss tangent,  $\tan \delta = 0.0024$
- Conductor parameters:
  - Thickness,  $t = 15\text{-microns}$
  - Conductivity (Copper),  $\sigma = 5.813 \times 10^7 \text{ S/m}$

# Quarterwave Impedance Transformer

## Physical Dimensions

LineCalc/nh9320.lcs

File Simulation Options Help

W = 2.93922-mm; L = 35.6476-mm

Component  
Type: MLIN ID: MLIN: MLIN\_DEFAULT

Substrate Parameters  
ID: MSUB\_DEFAULT

Er	3.200	N/A
Mur	1.000	N/A
H	60.000	mil
Hu	3.9e+34	mil
T	15.000	um
Cond	5.813e7	N/A
TanD	2.4e-3	N/A
Rough	0.000	mil
		N/A

Physical  
W: 2.939220 mm  
L: 35.647600 mm  
N/A  
N/A

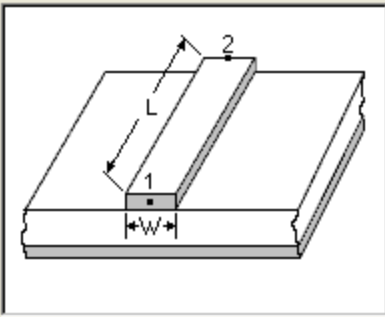
Synthesize Analyze

Electrical  
Z0: 57.002 Ohm  
E\_Eff: 90.000 deg  
N/A  
N/A

Calculated Results  
K\_Eff = 2.517  
A\_DB = 0.025  
SkinDepth = 0.001

Component Parameters  
Freq: 1.325 GHz  
Wall1: mil  
Wall2: mil

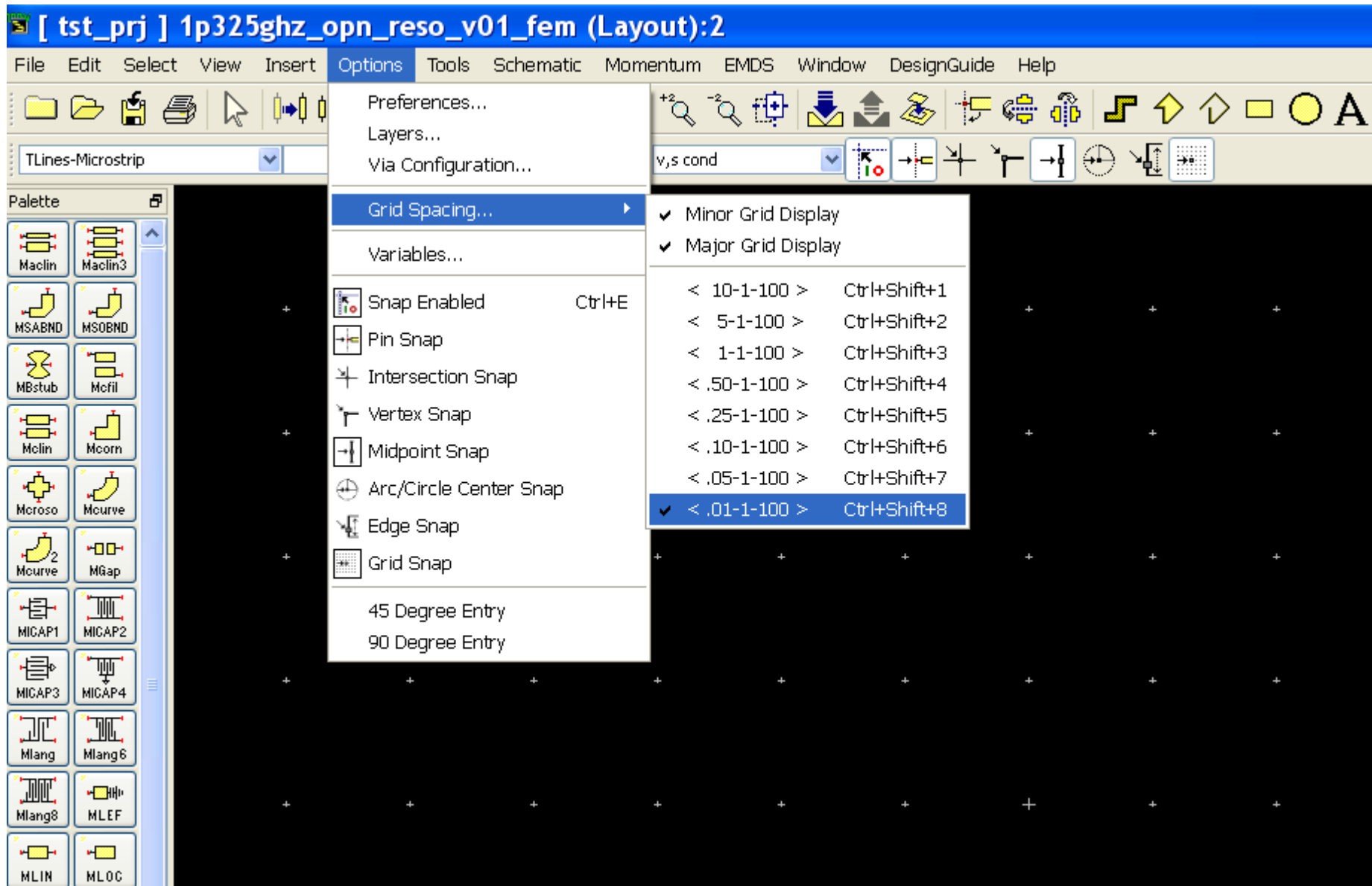
Values are consistent



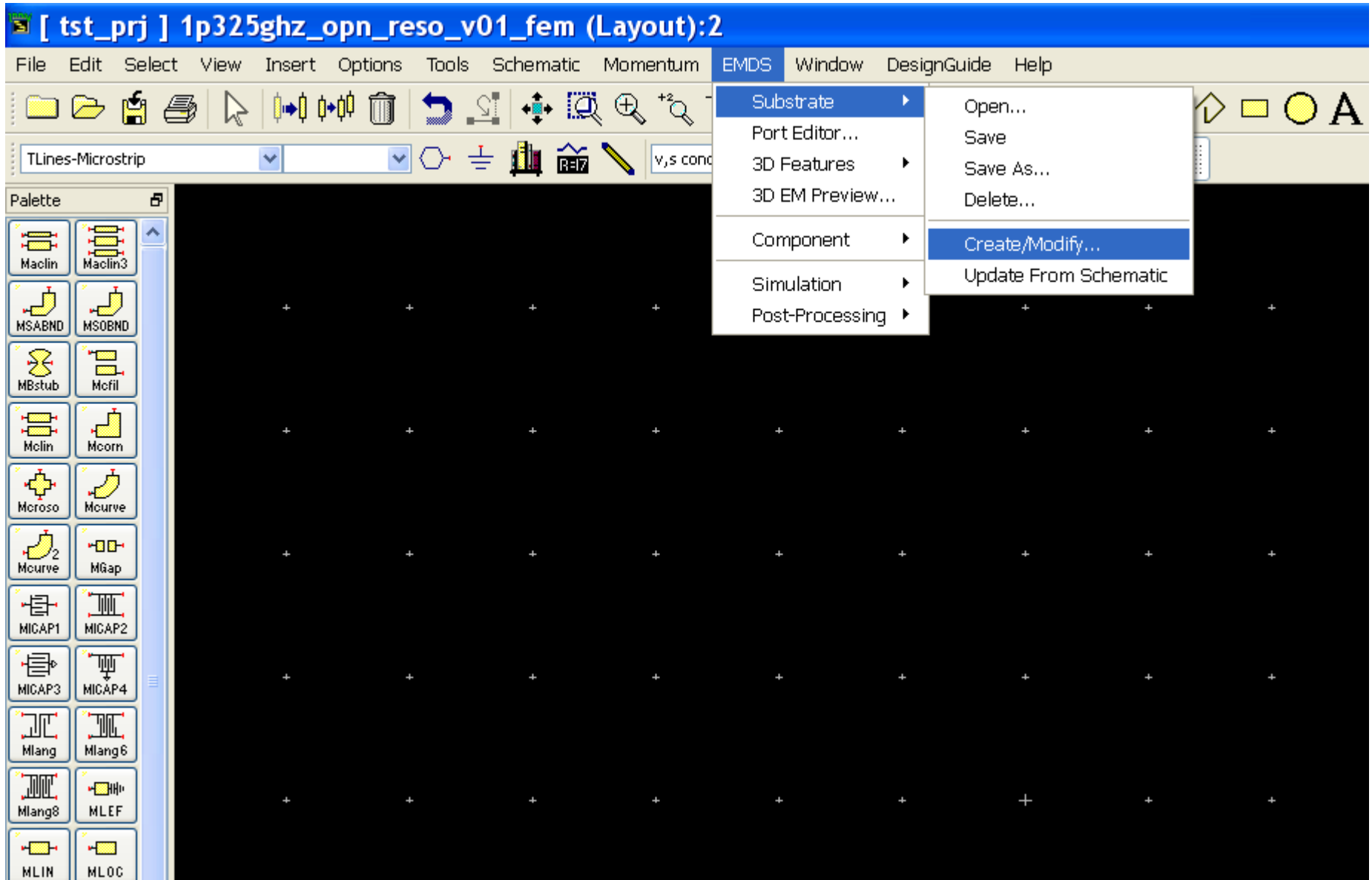
Layout Creation of the  $\lambda/4$  Microstrip Line Impedance Transformer



# Grid Spacing & Snap Options



# Defining Substrate for Layout



# Substrate Definition: Part 1

**Create/Modify Substrate:2**

Substrate Layers    Layout Layers

Name: 1p325ghz\_opn\_reso\_v01\_fem\_lay

Substrate parameters:  
Dielectric constant,  $\epsilon_r = 3.2$   
Height,  $h = 1.524\text{-mm}$  (or 60 milli-inch)  
Loss tangent,  $\tan \delta = 0.0024$

Select a substrate layer to edit OR define a new layer:

Substrate Layers	Thickness	Substrate Layer Name	Permittivity ( $\epsilon_r$ )	Permeability ( $\mu_r$ )
FreeSpace	60 mil	nh9320	Re, Loss Tangent	Re, Loss Tangent
nh9320			Real: 3.2	Real: 1
//////// GND //////////			Loss Tangent: 0.0024	Loss Tangent: 0

Add    Cut    Paste

OK    Apply    Cancel    Help

# Substrate Definition: Part 2

**Create/Modify Substrate:2**

Substrate Layers    Layout Layers

Select a layout layer to map to the substrate

**Layer Mapping**

Substrate Layers

- FreeSpace
- STRIP cond
- nh9320
- //////// GND //////////

**Conductor parameters:**  
Thickness,  $t = 15$ -microns  
Conductivity (Copper),  
 $\sigma = 5.813 \times 10^7$  S/m

**Layout Layer**

Name: cond

Model: Thick (Expansion Up)

Thickness: 15 um

Material: Conductor (Sigma)

Real: 5.813E+007 Siemens/m

Imag: 0 Siemens/m

Overlap Precedence: 0

**Info**

Layout layer mapped as STRIP

- Model: upwards expanded thick conductor
- Material: conductor (frequency dependent loss)

Strip    Slot    Via    Unmap

OK    Apply    Cancel    Help

# $\lambda/4$ Impedance Transformer's Layout

**Libra Microstrip Open-Circuited Stub:2**

MLOC  
Instance Name (name[<start:stop>])  
TL1

Parameter Entry Mode  
Standard

Select Parameter  
Subst="MSub1"  
W=2.93922 mm  
L=35.6476 mm  
Wall1=2.5e+028 mm  
Wall2=2.5e+028 mm  
Temp=  
Mod=Kirschning

W  
2.93922 mm

Equation Editor...

Tune/Opt/Stat/DOE Setup...

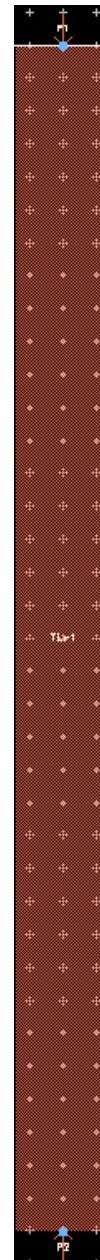
☒ Display parameter on schematic

Component Options...

Add Cut Paste

W : Line width

OK Apply Cancel Reset Help



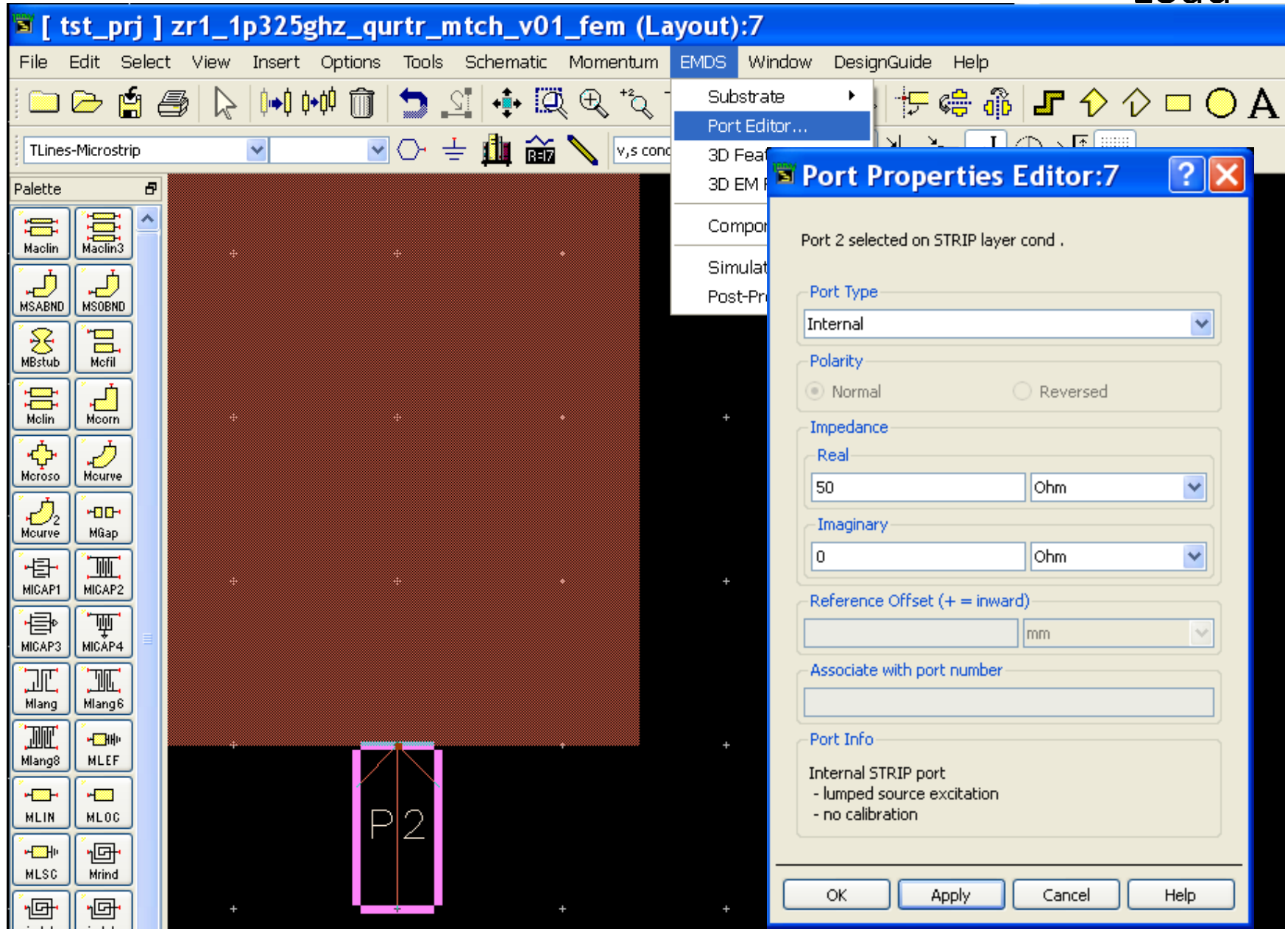
# Port 1: Single Mode

The screenshot displays the EMDS software interface with the title bar "[ tst\_prj ] zr1\_1p325ghz\_qurtr\_mtch\_v01\_fem (Layout):7". The menu bar includes File, Edit, Select, View, Insert, Options, Tools, Schematic, Momentum, EMDS, Window, DesignGuide, and Help. The toolbar contains various icons for file operations, navigation, and design tools. The left palette lists components such as Maclin, MSABND, MBstnb, Mcfil, Mclin, Moorn, Moroso, Mcurve, MGAP, MICAP1, MICAP2, MICAP3, MICAP4, Mlang, Mlang6, Mlang8, MLEF, MLIN, MLOC, MISC, and Mriod. The main workspace shows a layout with a central pink rectangular port labeled "P1" on a dark background. The "EMDS" menu is open, showing options: Substrate, Port Editor..., 3D Features, 3D EM Preview, Component, Simulation, and Post-Processing. The "Port Properties Editor:7" dialog box is open, displaying the following settings:

- Port 1 selected on STRIP layer cond .
- Port Type: Single Mode (dropdown)
- Polarity: ☒ Normal, ☐ Reversed
- Impedance:
  - Real: 50, Ohm (dropdown)
  - Imaginary: 0, Ohm (dropdown)
- Reference Offset (+ = inward): 0, mm (dropdown)
- Associate with port number: (empty text field)
- Port Info: Single Mode STRIP port
  - transmission line excitation
  - extended calibration

Buttons at the bottom: OK, Apply, Cancel, Help.

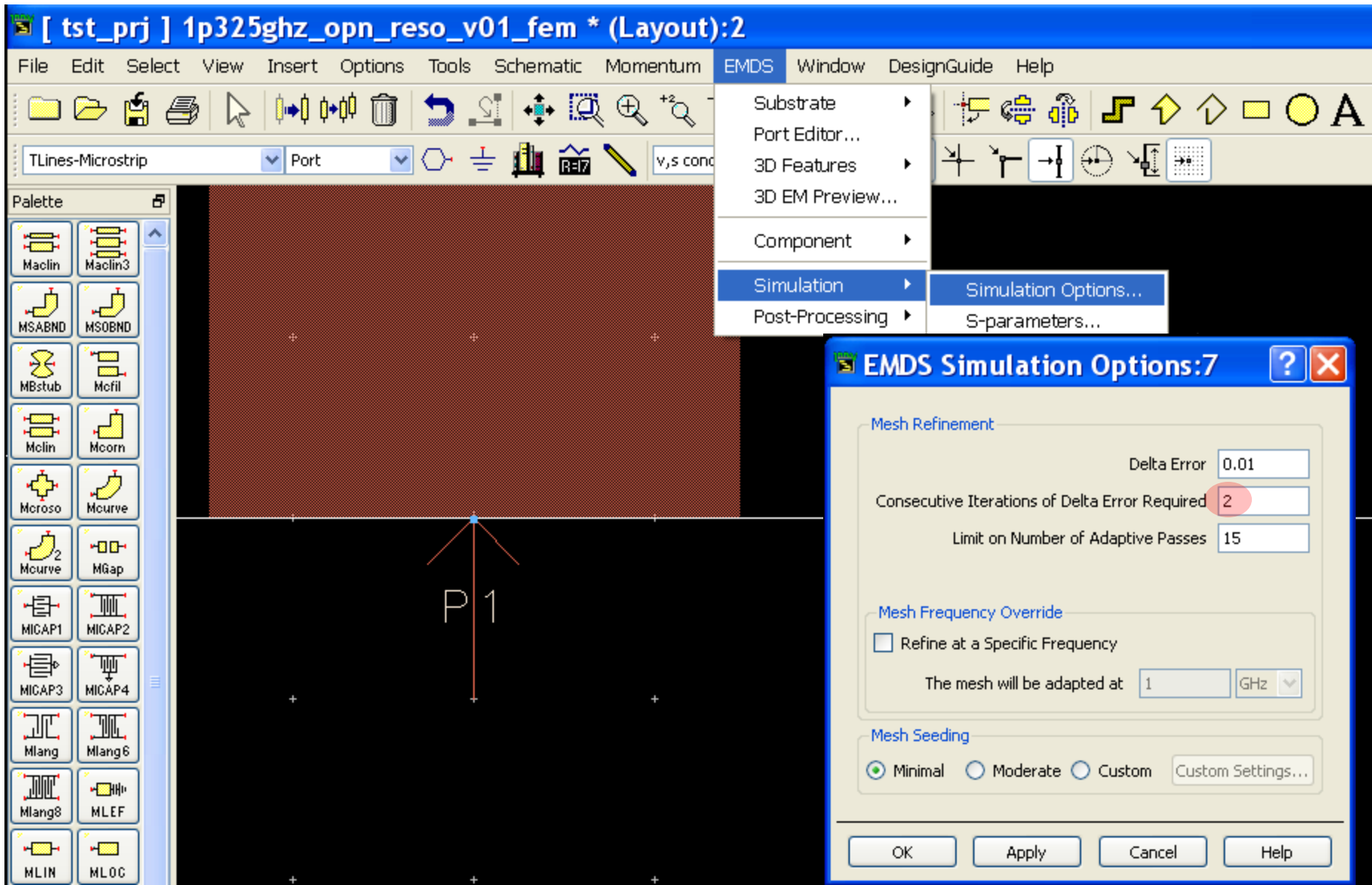
# Port 2: Internal Type (to connect $R_{Load}$ )



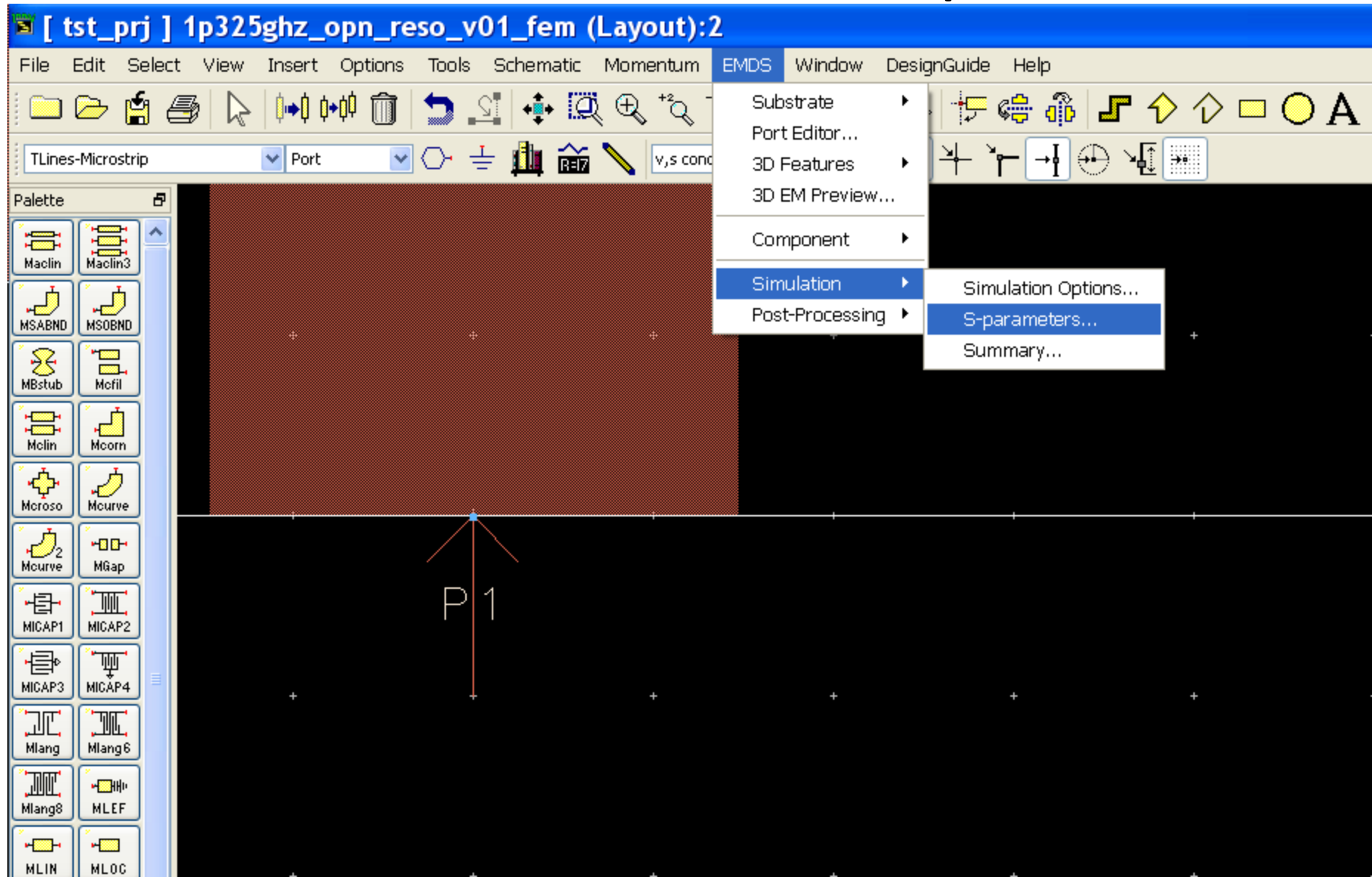
EMDS (FEM) based S-Parameters EM-circuit Co-Simulation of the  $\lambda/4$   
Microstrip Line Impedance Transformer Layout



# EMDS (FEM) Simulation Options



# EMDS (FEM) S-Parameters EM Simulation Set-Up



# EMDS (FEM) S-Parameters EM Simulation Set-Up

**Simulation Control:2** [?] [X]

**Stimulus**

Select a frequency plan from list to edit or define a new one

**Frequency Plans**

Type	F start	F stop	Npts/Step
Adaptive	0.5025 GHz	2.1475 GHz	201 max

**Edit/Define Frequency Plan**

Sweep Type: Adaptive [v]

Start: 0.5025 [GHz] [v]

Stop: 2.1475 [GHz] [v]

Sample Points Limit: 201

[Cut] [Paste] [Update] [Add to Frequency Plan List]

**Process mode: local**

Foreground [v]

**Solution Files**

☐ Reuse files from the previous simulation

Dataset: data\_1p325ghz\_opn\_r [Browse...]

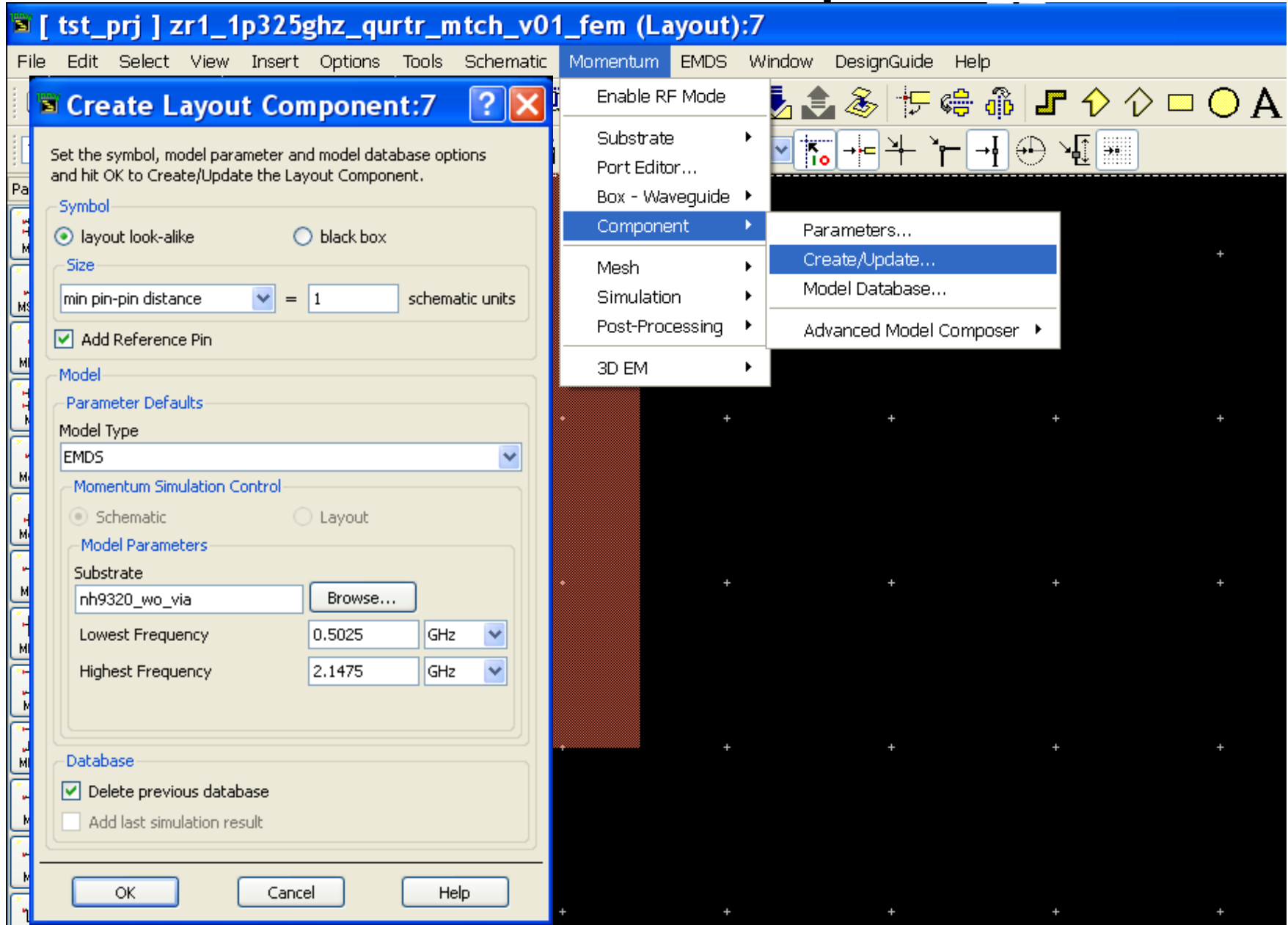
**Data Display**

☒ Open data display when simulation completes

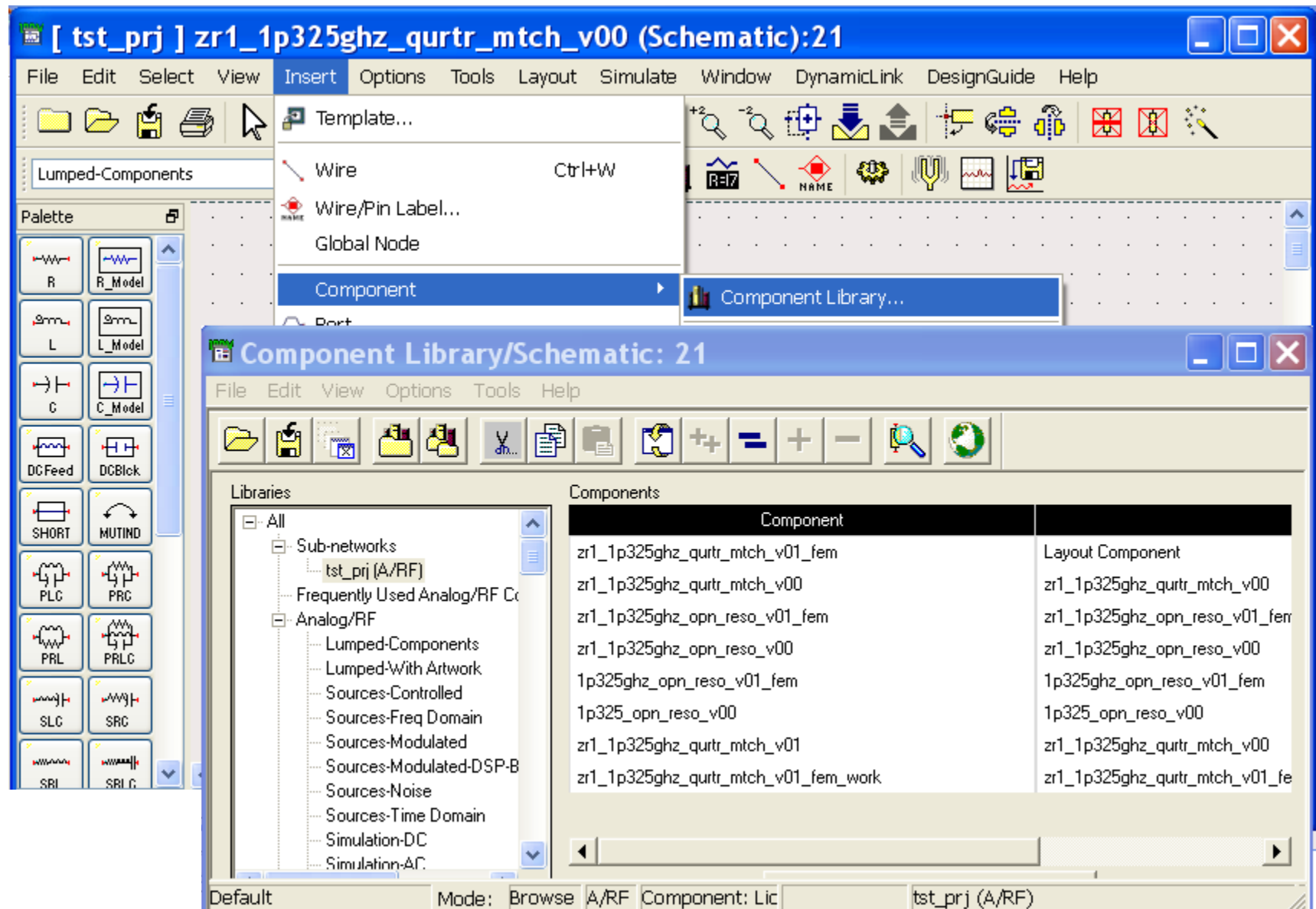
Template: Presentation1 [Browse...]

[Simulate] [Apply] [Cancel] [Help]

# Create FEM Component



# Insert FEM Component into Schematic



# ADS Schematic with FEM Component for EM-Circuit Co-Simulation



S\_Param

SP1

Start=0.5025 GHz

Stop=2.1475 GHz

Step=0.5 MHz

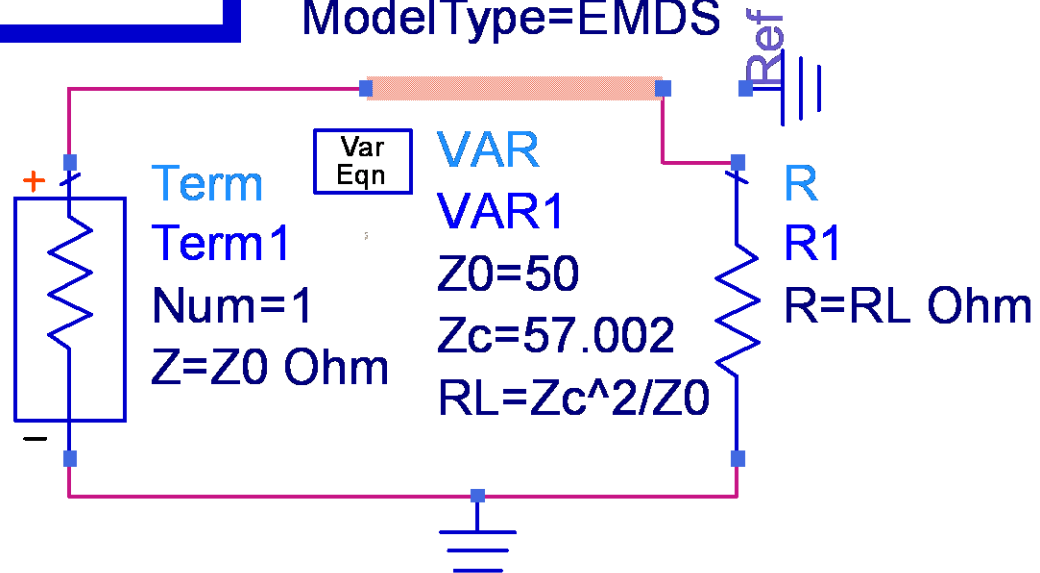
zr1\_1p325ghz\_qurtr\_mtch\_v01\_fem

zr1\_1p325ghz\_qurtr\_mtch\_v01\_fem\_1

Lr1=35.648 mm

Wr1=2.939 mm

ModelType=EMDS



Computer Operating System: Microsoft Windows XP Service Pack 3  
 Obtaining license to run zrl\_1p325ghz\_qurtr\_mtc\_v01\_fem\_work @ RFIC1: Fr:

Pass 1 : Fri Nov 30 20:36 2012

PORTS 1	CPU time:	00:00:00	
GRADE 1	CPU time:	00:00:01	
MESH 1	Node count after EDGE seeds:	41	
	Node count after FACE seeds:	41	
	Node count after VOLUME seeds:	41	
	Number of Elements:	48	
PORTS 1	CPU time:	00:00:00	
SOLVE 1	CPU time:	00:00:00	
	Frequency:	2.147500 GHz	Unknowns: 331
	CPU time:	00:00:00	Memory: 409.69 Kbyte

Pass 2 : Fri Nov 30 20:36 2012

ADAPT 2	Number of Elements:	264
PORTS 2	CPU time:	00:00:00

Pass 13 : Fri Nov 30 20:36 2012

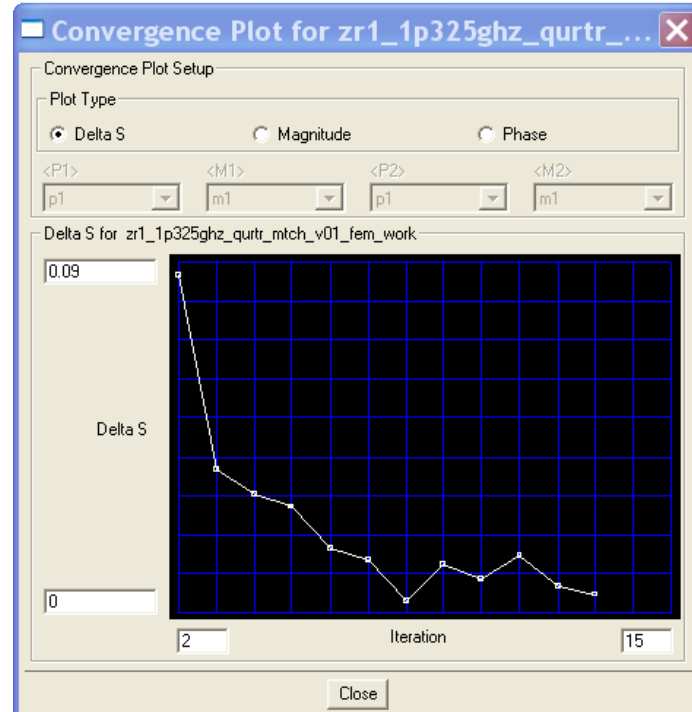
SOLVE 2	Frequency:	2.14750	ADAPT 13	Number of Elements:	7518
	CPU time:	00:00:00	PORTS 13	CPU time:	00:00:01
	Delta S:	0.086592	SOLVE 13	Frequency:	2.147500 GHz
				CPU time:	00:00:12
				Delta S:	0.004712
					[Target: 0.010000]

Computing Solution : Fri Nov 30 20:37 2012

PORTS	CPU time:	00:00:00
SOLVE	Frequency:	1.325000 GHz
	Fast Frequency Sweep:	502.500000 MHz to 2.147500 GHz
	CPU time:	00:00:12
	Unknowns:	38165
	Memory:	225.58 Mbyte

DONE

Total CPU Time = 00:00:56  
 Total Elapsed Time = 00:01:05

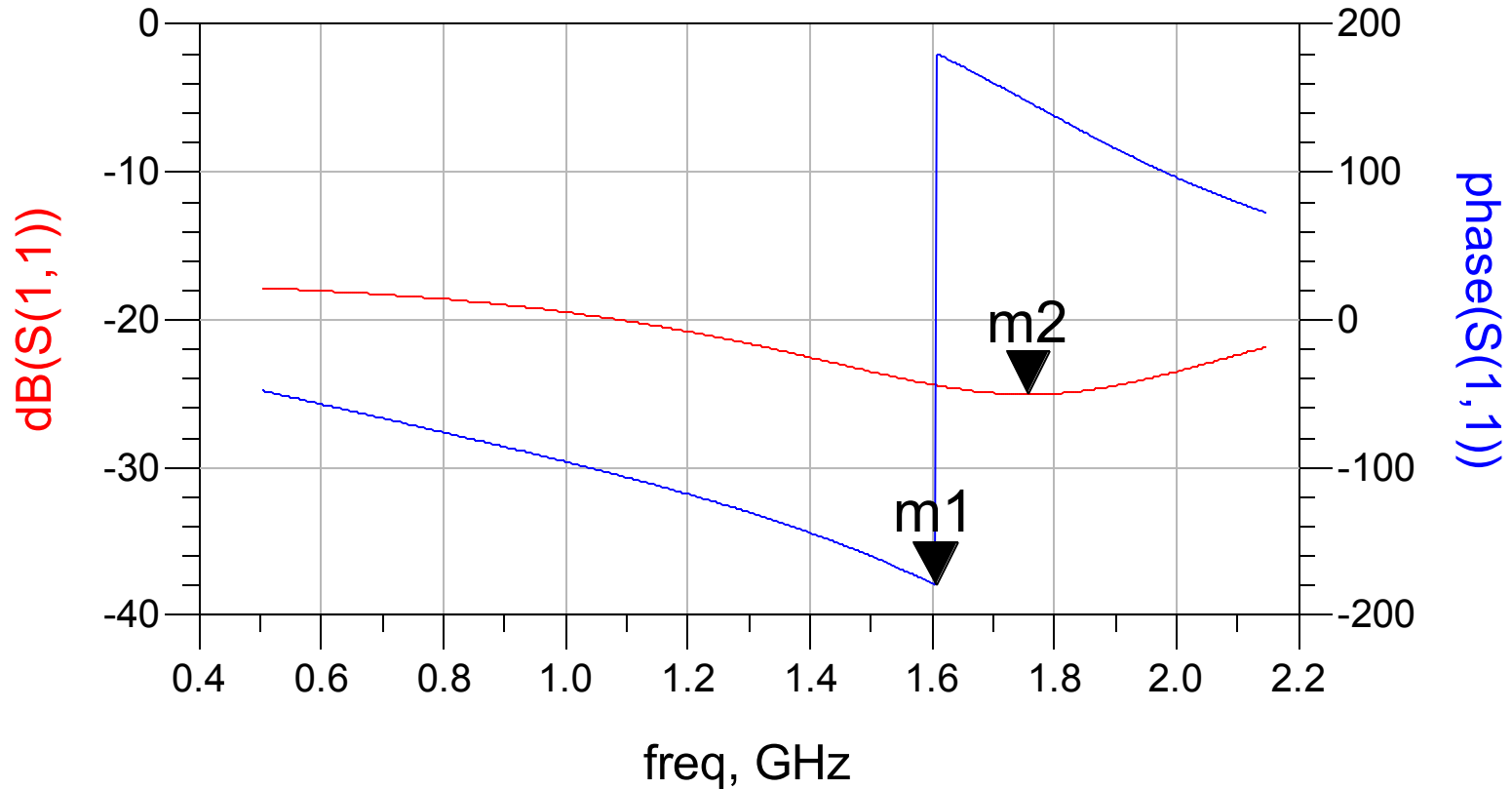


# EMDS (FEM) Simulation

# Co-Simulation Result

m1  
freq=1.606GHz  
phase(S(1,1))=-179.942  
Valley

m2  
freq=1.758GHz  
dB(S(1,1))=-25.079  
Min





# Co-Sim Results Inconsistency

- For same dimensions, same frequencies (at which phase-shift is  $180^\circ$  in BLUE) are not achieved:

Wr1 (mm)	Lr1 (mm)	Meshes			Iterations	Passes	Last $\Delta$ err	Time	180-deg	Input Match	
		Feed	Start	Stop						S11	freq (GHz)
2.939	35.952	Minimal	253	11829	15	2	0.015	2:04	1.676	-23.7	1.792
2.939	35.952	Minimal	253	36552	20	2	0.01	11:34	1.742	-21	1.81

2.939	36.000	Minimal	250	1725	7	2	0.009	0:10	1.373	-23	1.665
2.939	36.000	Minimal	250	35826	20	3	0.01	11:25	1.739	-21	1.808
2.939	36.000	Minimal	250	56301	22	3	0.01	24:20		Memory	ISSUE
2.939	36.000	Moderate	1058	4573	8	2	0.004	0:24	1.525	-22.7	1.768
2.939	36.000	Moderate	1058	23569	15	3	0.008	4:38	1.702	-22.1	1.799

- As length increases, frequency (at which phase-shift is  $180^\circ$ ) does not consistently reduce:

Wr1 (mm)	Lr1 (mm)	Meshes			Iterations	Time	180-deg	Input Match	
		Feed	Start	Stop				S11	freq (GHz)
2.939	35.648	Minimal	264	7554	13	1:02	1.606	-25	1.758
2.939	35.952	Minimal	253	36552	20	11:34	1.742	-21	1.81
2.939	35.987	Minimal	365	9477	14	1:24	1.641	-24	1.781
2.939	36.000	Minimal	250	1725	7	0:10	1.373	-23	1.665
2.939	36.002	Minimal	265	1776	7	0:13	1.375	-23.5	1.651
2.939	36.072	Minimal	351	6141	12	0:40	1.634	-24	1.849