ANTENNA AND WAVE PROPAGATION

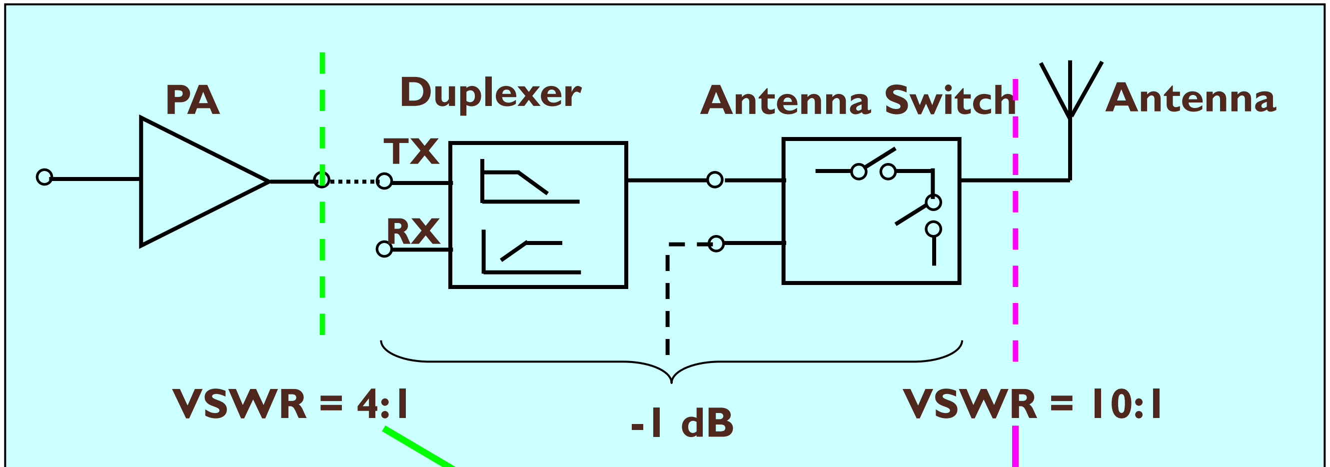
Antenna

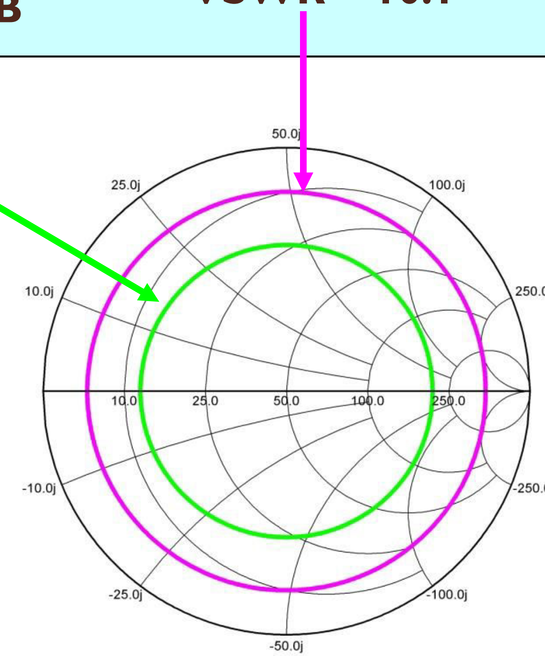
Impedance

Outline

- Introduction
- Antenna load impedance measurement using sectioned transmission line
- Measurement results and discussion
- Future work and summary

Introduction



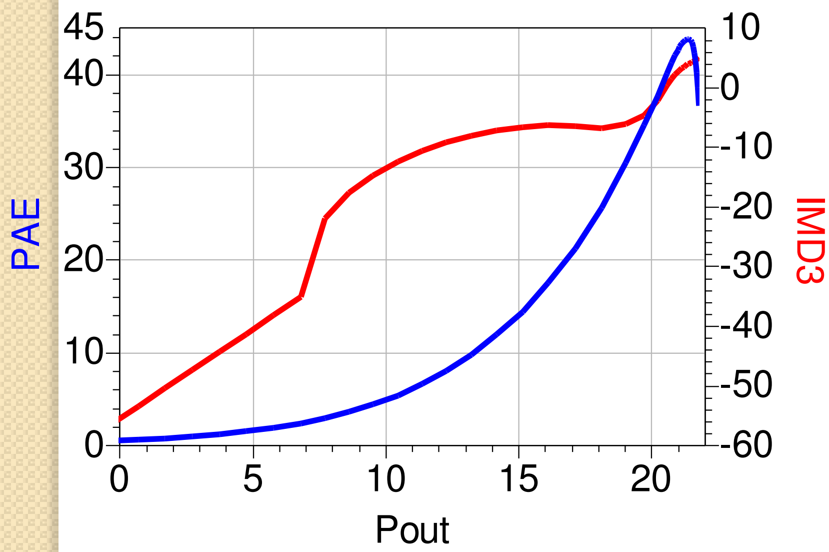


- VSWR at antenna ref. plane can vary to 10:1 with any phase. Typical PA to antenna path loss ~ 1dB, which results in 4:1 VSWR at PA ref. plane.

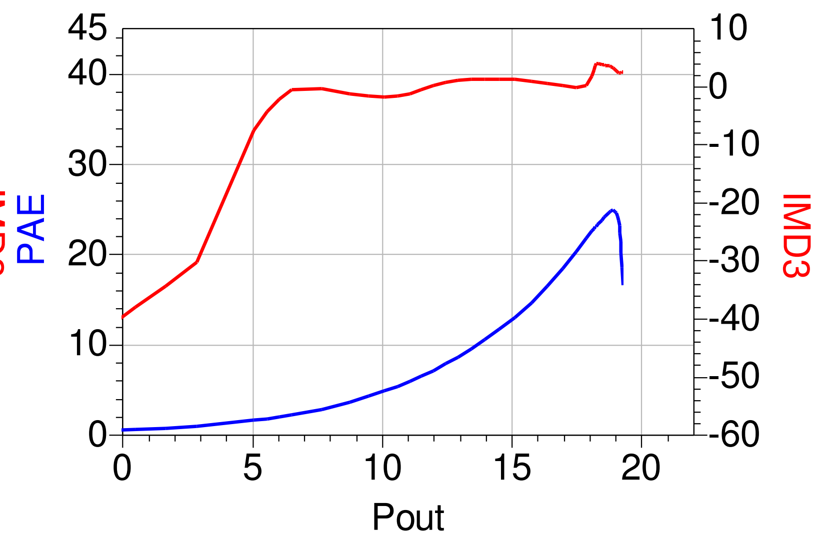
- It is a challenge to maintain operation of the amplifier with such a wide range of impedances.

Performance of PA with Mismatched Load

ADS simulation results for a class AB amplifier



VSWR = 1:1

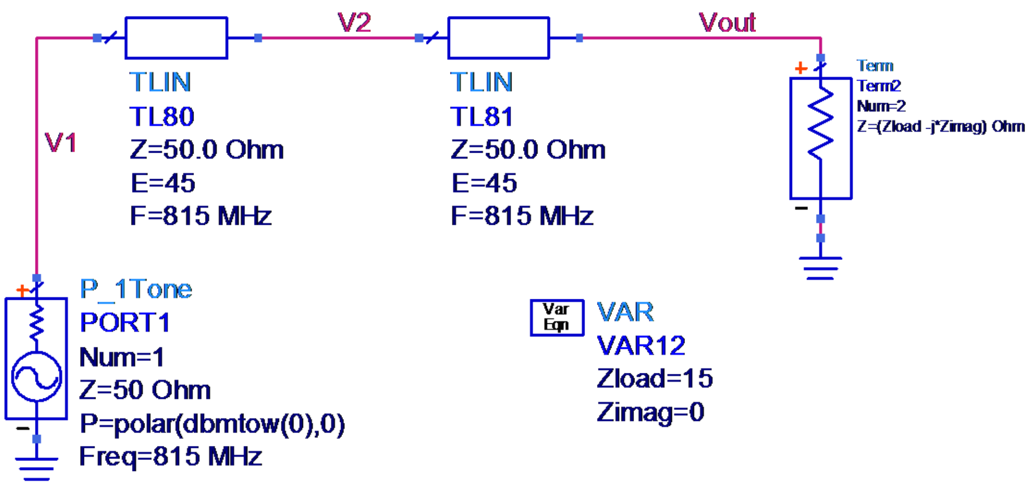


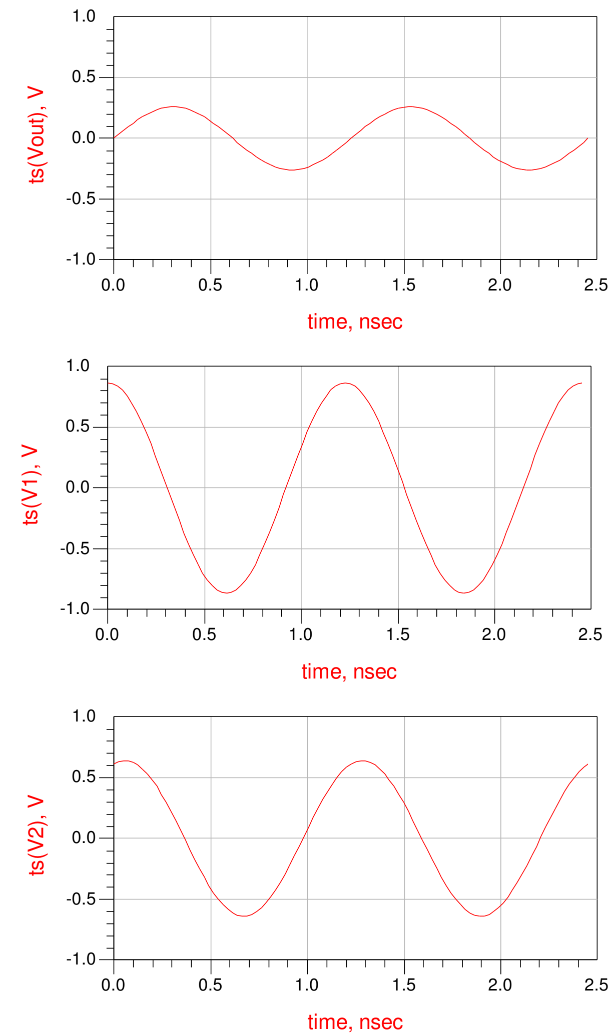
VSWR = 4:1

Mismatch causes:

- PAE↓
- Pout ↓: need to change bias to maintain the necessary Pout. This may hurt the linearity.
- Possible oscillation of power amplifier thus damaging the amplifier

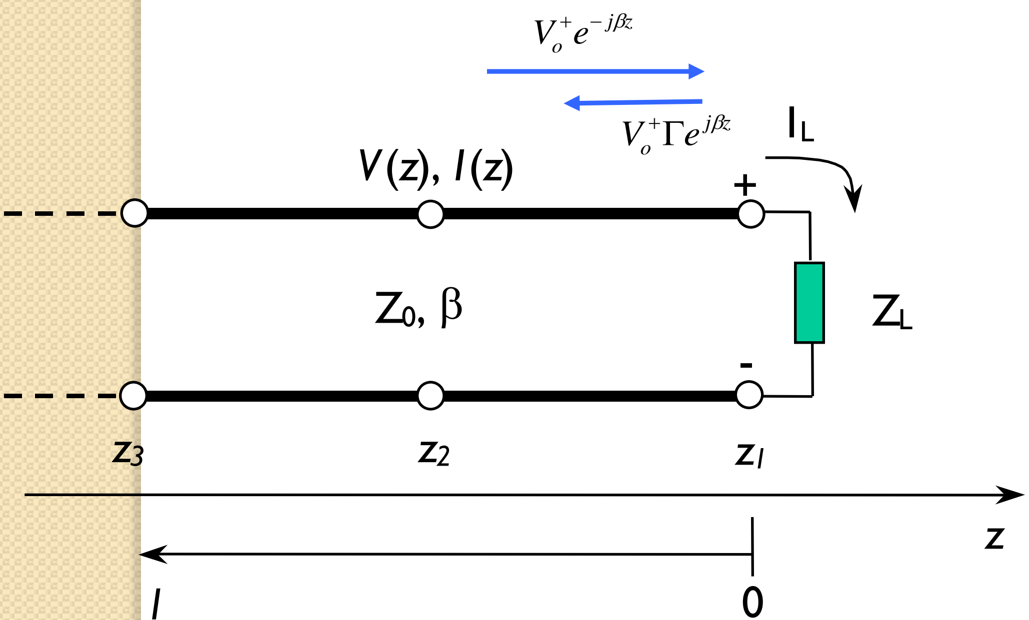
Voltage on Transmission Line for Unmatched Load





Z_0 = 50 ohm
Z_L = 15 ohm
815 MHz
90° Transmission Line

Measurement of Load Impedance Using Transmission Line



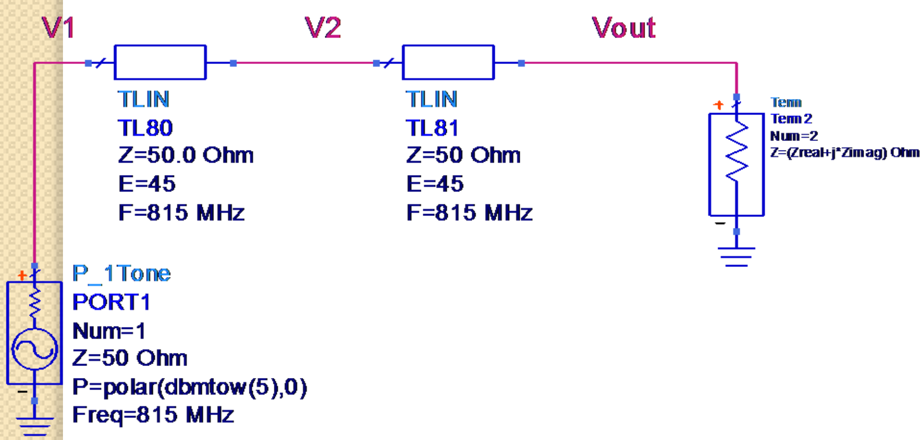
$$V(z) = V_o^+\left[e^{-j\beta z} + \Gamma e^{j\beta z}\right]$$

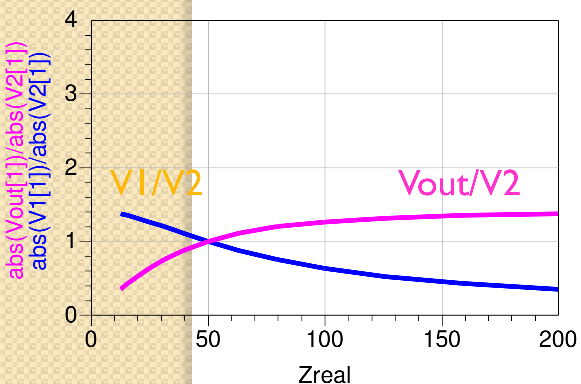
$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} \qquad \beta = w\sqrt{LC}$$

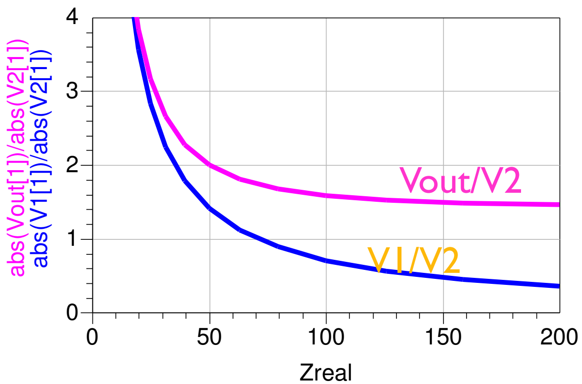
$$r = \frac{V_{z1}}{V_{z2}} = \frac{e^{-j\beta z_1} + \Gamma e^{j\beta z_1}}{e^{-j\beta z_2} + \Gamma e^{j\beta z_2}}$$

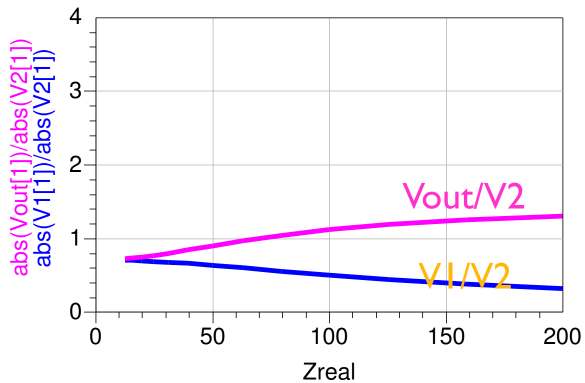
$$= \frac{\cos(-\beta z_1) - j\sin(-\beta z_1) + (\Gamma_{real} + j\Gamma_{imag})(\cos(j\beta z_1) + j\sin(\beta z_1))}{\cos(-\beta z_2) - j\sin(-\beta z_2) + (\Gamma_{real} + j\Gamma_{imag})(\cos(j\beta z_2) + j\sin(\beta z_2))}$$

Dependence of Voltage Ratio Along Transmission Line on Load Impedance









$Im(Z_L)$ = 0 ohm

$Im(Z_L)$ = 50 ohm

$Im(Z_L)$ = -50 ohm

Measurement of Load Impedance Using Transmission Line

Procedure

- Voltages are measured at 3 different points on a 90° transmission line
- Two voltage ratios are obtained from the 3 voltages

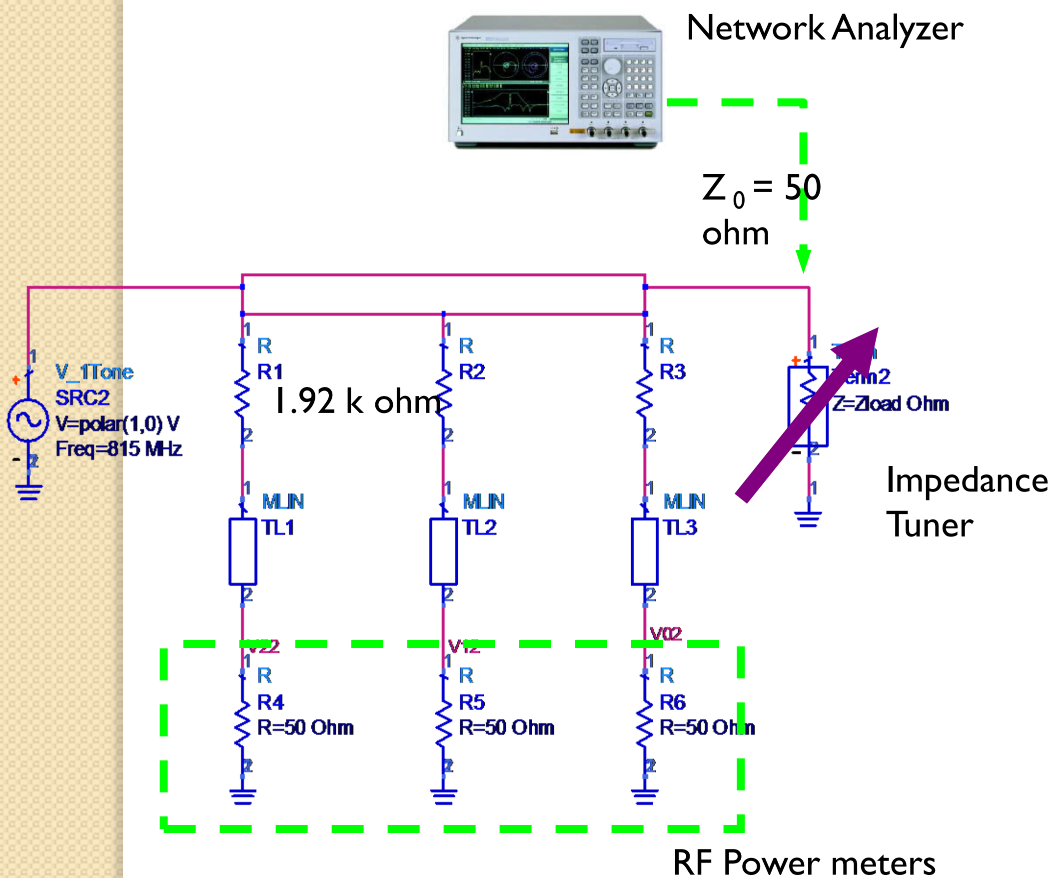
$$r_1 = \frac{V_{z1}}{V_{z2}} \qquad r_2 = \frac{V_{z3}}{V_{z2}}$$

- Numerically solve equations for r_1 and r_2 to obtain the Γ_{real} and Γ_{imag} and thus Z_L

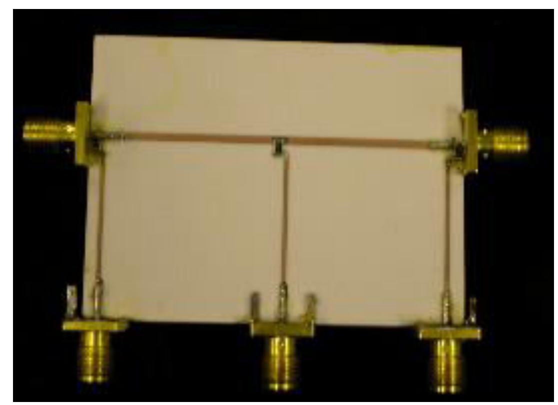
Characteristics

- Measurement results depend on voltage ratio, not the voltage
- Measurement results are independent of input power and the source impedance
- It is found there is only one solution for the equations for $|\Gamma| <= 1$

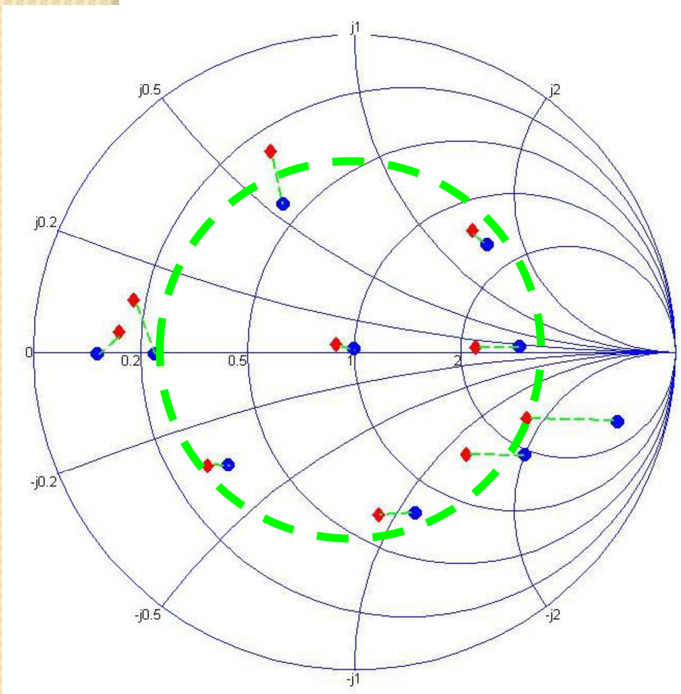
Measurement Setup

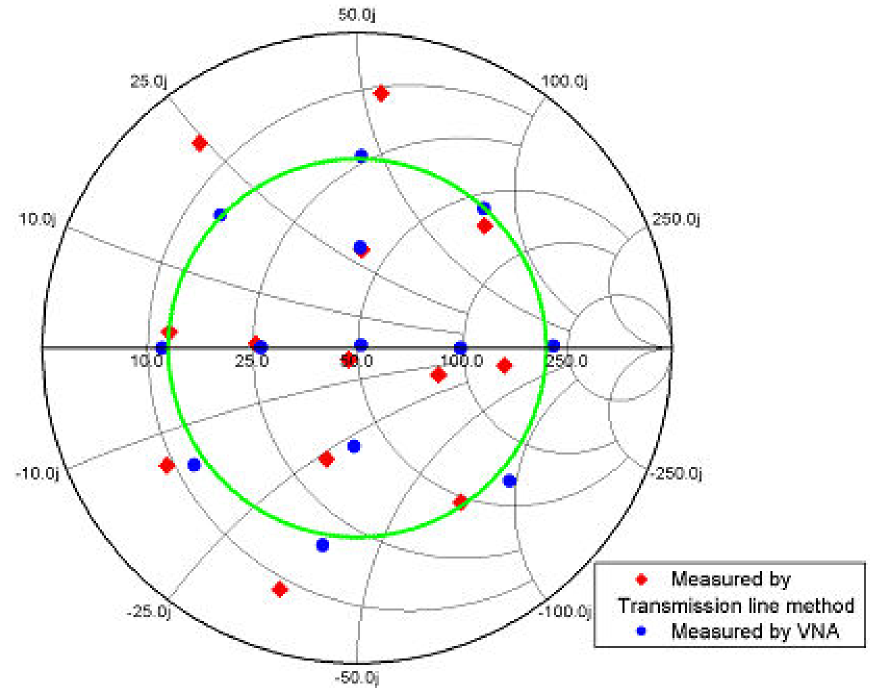


- Fabricated on PCB board
- ¼ λ transmission line
- 815 MHz
- Single tone and CDMA IS-95
- Loss caused by the setup is ~ 0.4 dB at 815 MHz



Measurement Results





Single Tone

815 MHz
Three input power levels (15, 18 and 20 dBm)

CDMA

815 MHz
Three input power levels (12, 14 and 16 dBm)

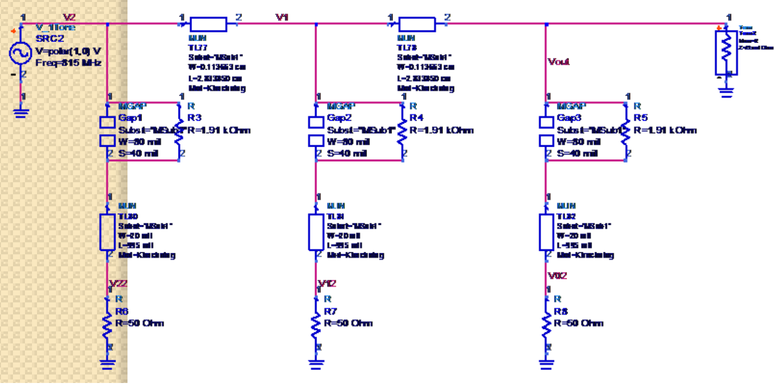
Observations:

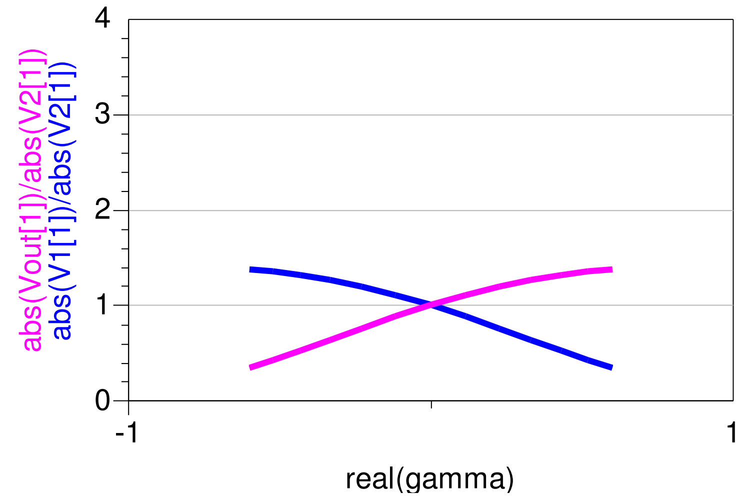
Error increases with increasing VSWR

Results do not depend on the input power

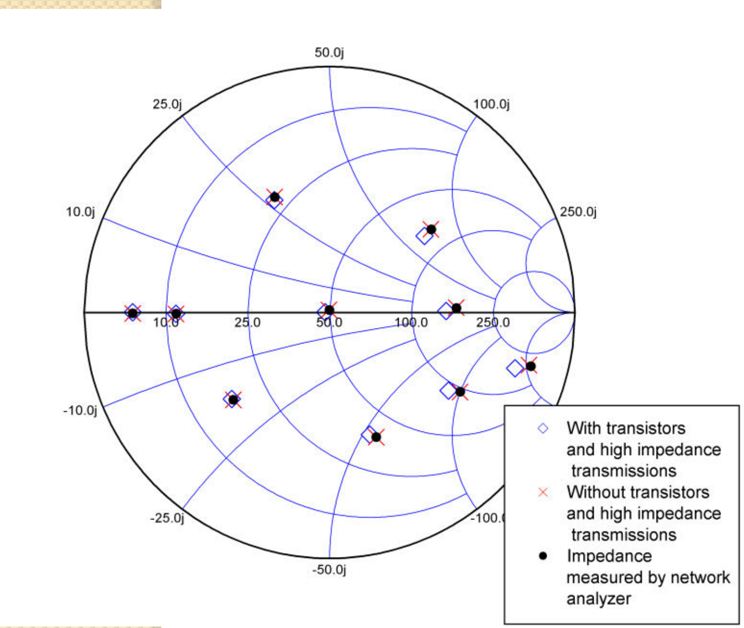
Accuracy Analysis

Use the voltages obtained from ADS simulation to calculate the load impedance





When Zl is too low or too high, one of the voltages is too small , thus affecting the accuracy.



When Zl is high, the measurement circuit is comparable with Zl

Other possible error sources:

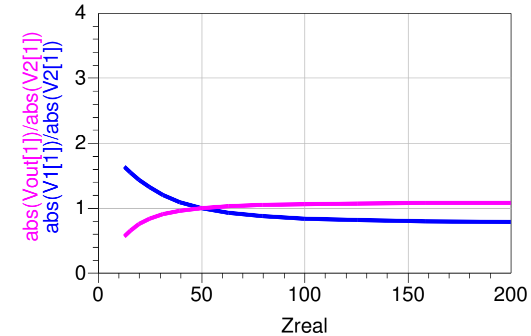
Non-perfect soldering positions for resistors

Lossy transmission line

Non-identical resistors

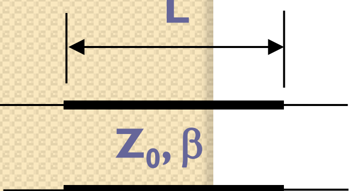
Reduce the Dimension of Transmission Line

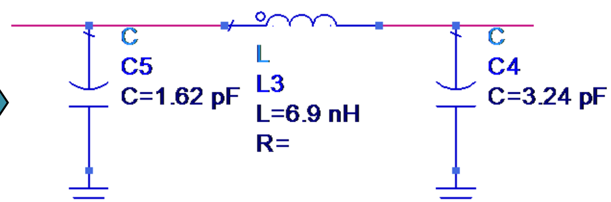
-Using shorter transmission line



βL = 45°
Z_L imag = 50 ohm

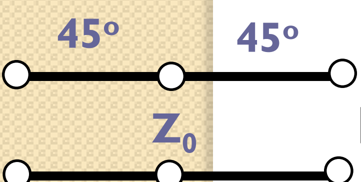
-Using lumped elements

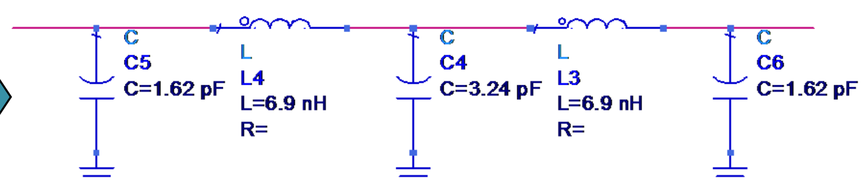


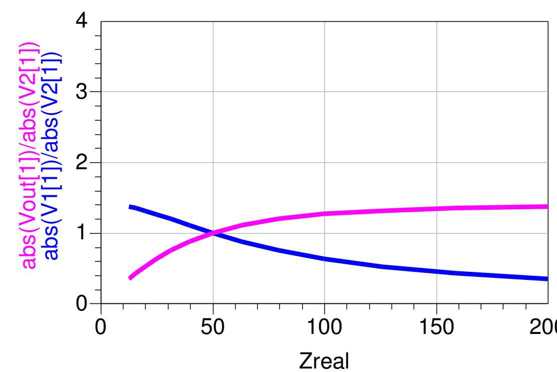


$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} \cos\beta L & jZ_0 \sin\beta L \\ jY_0 \sin\beta L & \cos\beta L \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 \\ jB_C & 1 \end{bmatrix} \begin{bmatrix} 1 & jX_L \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ jB_C & 1 \end{bmatrix} = \begin{bmatrix} 1 - X_L B_C & jX_L \\ jB_C(2 - X_L B_C) & 1 - X_L B_C \end{bmatrix}$$







Simulation shows the transmission line can be replaced by lumped elements

Summary

- A simple method has been developed to measure the antenna load impedance based on the measurement of the voltages at three points along a transmission line.
  - The method is independent of input power and source impedance.
  - Scalar voltage measurements give complex load impedance.
- The size of the measurement setup can be reduced by using shorter transmission line or lumped elements.
- The complex load impedance information can be used with tunable matching networks or bias control circuits to facilitate compensation of load mismatch.