Laboratory #3: Impedance Matching with Quarter Wave Transformer

I. OBJECTIVE

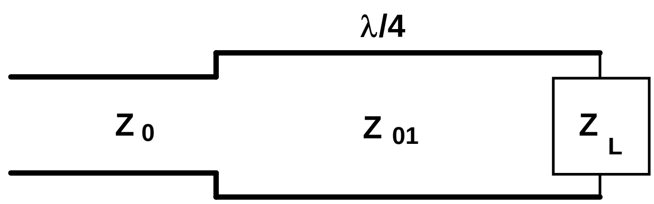
Design a quarter-wave transformer to match a 50 Ω generator (source) with a designated load.

II. INTRODUCTION

Quarter-wave transmission line transformers are a simple, but bulky, method of matching impedances. At band center, a quarter wave transformer has an input impedance that is

$$Z = Z_{01}{}^2 / Z_L,$$

that is simply the general formula for input impedance with θ = π/2.



The bandwidth of such a matching transformer depends upon the ratio of Z_L / Z_o, which is the load impedance normalized to the desired input impedance. The reflection coefficient is approximately

$$|\Gamma| \approx \cos\theta \; \frac{Z_L / Z_o - 1}{2\sqrt{Z_L / Z_o}}$$

To determine the bandwidth for a given impedance ratio and maximum SWR, solve for θ at each band edge in terms of the band-edge reflection coefficient for that SWR. As an example, for maximum SWR of 1.5 and an impedance ratio of 4, the bandwidth for 1.5 SWR is approximately 34% (±17%).

A Network Analyzer will be used to In order to measure $Z(-l)$ at $l = \lambda/4$, measure the S_{11} :

$$S_{11} = \Gamma = \frac{Z(-l) - Z_G}{Z(-l) + Z_G} \quad .$$

We can calibrate out the transmission line so that the Network Analyzer can directly measure the impedance at the location desired. This is accomplished by utilizing the Network Analyzer calibration menu. The calibration is a three step process using short circuit, open circuit, and 50 Ω loads.

The loads will be soldered on a copper clad printed circuit board (PCB). Isolation from the ground plane shall be made using Kapton tape.

III. PROCEDURE

A. Calibrate the Network Analyzer directly at Port A of the instrument

Use a $\lambda = 0.75$ length of conformable coax between the Network Analyzer Port A and the PCB. Use the “loads” (open, short, and 50 Ω) from Lab #1 to calibrate the Network Analyzer directly at Port A.

B. Determine S_{11} (Smith Chart) for given load

Find using S_{11}, confirm the load of as measured for the 95 Ω resistor using the network analyzer at 500 MHz and 1.0 GHz. Plot your reflection results either on a Smith Chart or $|\Gamma|$ and phase of Γ.

C. Design a Quarter-Wave Transformer Match

Design a quarter-wave matching transformer to match the 50 Ω conformable coax to the 95 Ω load. Determine the line width of the trace required. The operational frequency is 1.0 GHz. To fine the trace width of the quarter-wave transformer, you may use the MathCAD routine attached, Agilent AppCAD, RFDude LLSmith, or Smith Chart.

D. Construct the Quarter-Wave Transformer and Load

Construct the quarter-Wave Transformer with the load on a PCB

E. Measure and Compare to Theory. Comment on your results.

Measure the S_{11} at 500 MHz and at 1.0 GHz. Compare to theoretical expectations.

Microstripline Calculation in MathCAD

$\mu o := 400\cdot\pi\cdot 10^{-9}$ [H/m] $\varepsilon o := 8.85\cdot 10^{-12}$ [F/m]

$\varepsilon r := 3.9$ $h := 1.6\cdot 10^{-3}$ [mm] $Zo := 69$

$Zf := \sqrt{\frac{\mu o}{\varepsilon o}}$ $Zf = 376.819$ [Ω]

Guess

$w\_h := 1.88$

Given

$$Zo = \frac{Zf}{\left[\sqrt{\frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2}\cdot\frac{1}{\sqrt{1 + \frac{12}{w\_h}}}}\cdot\left(1.393 + w\_h + \frac{2}{3}\cdot\ln(w\_h + 1.444)\right)\right]}$$

$\text{Find}(w\_h) = 1.18$