ECE320: Fields and Waves

Lab 3 Report: Design of a Double Stub Matching Network

PRA106

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1 Introduction

This laboratory session was focused on investigating the input impedance and reflection coefficient at the load, and making transformations to the load impedance using a double stub network such that we are able to match the input impedance to the characteristic impedance of the transmission line. We also measured the voltage standing wave ratio (VSWR) for the same matching network to characterize its bandwidth. Figure 1 shows the schematic for a double-stub tuner and its equivalent circuit. Our theoretical work and measurements are based on the unknown "orange" labelled load given to us.

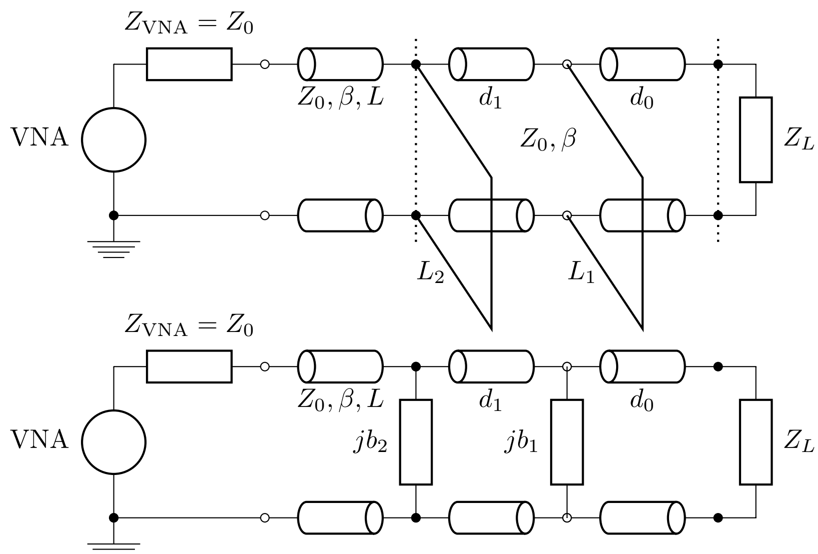


Figure 1: A double-stub matching network with $d_0 = 3.4$ cm and $d_1 = 3.8$ cm

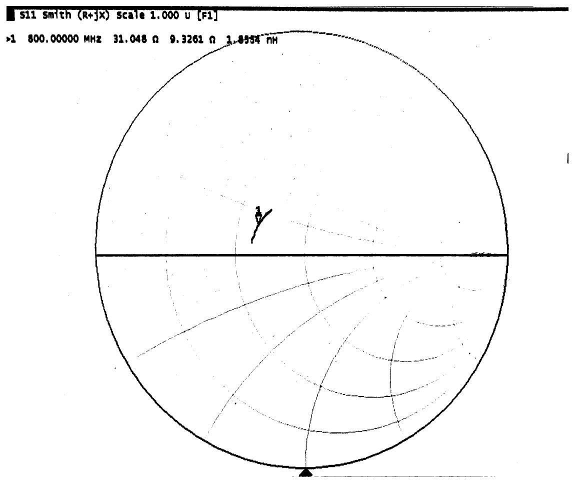
2 Measurement of the Unknown Load Impedance

The unknown load impedance was measured over a frequency range of [300MHz, 1.3GHz], with and without de-embedding, using the VNA on a Smith Chart shown in Figure 2 (a) and (b). The values of the load impedance and admittance with its normalized form taking $Z_0 = 50\Omega$ are given in Table 1.

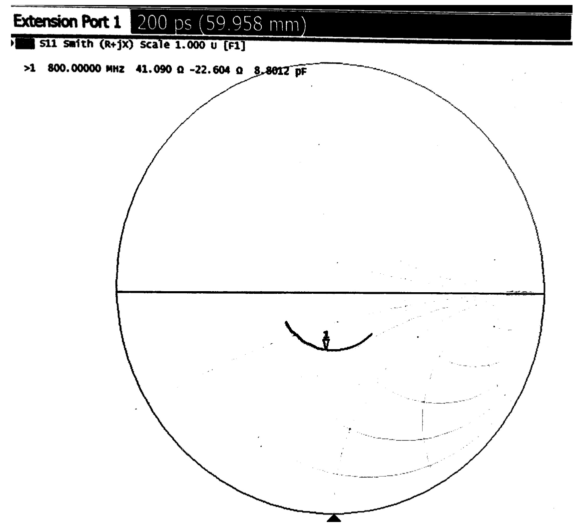
Parameter	**Value**
Z_L	$31.08 + 9.32j\,[\Omega]$
$Z_{\text{L,N}}$	$0.622 + 0.186j$
$Y_{\text{L,N}}$	$1.476 - 0.441j$

Table 1: Measured load parameters using the VNA

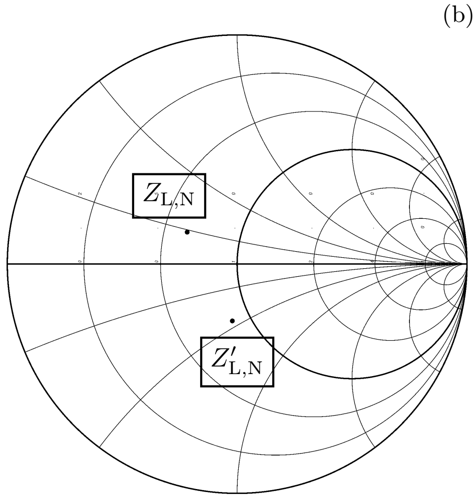
Also, if we rotate $Z_{\text{L,N}}$ by 0.16λ at $f = 800$Mhz, we end up very near Y_A, coincidently (see section 3), giving us $Z'_{\text{L,N}} = 0.85 - 0.45j$ corresponding to $Z'_L = 42.5 - 22.5j[\Omega]$ which closely matches the result shown by the VNA in Figure x.



(a) Load



(b) Port D (30m)



(c) Port D (30m)

Figure 2: Measured

3 Smith Charts and the Graphical Matching Process

4 Designing a Double-stub Matching Network

We are asked to do a double stub matching. However, it requires some extra steps compared to single stub matching including the rotation of the unit circle and movement of vertain values along with it. Addition of the second stub causes this complication as explained in the lab document. The smith chart and our calculations for the lengths of our stubs are attached. (First we find the rotated unit circle for the first stub length) and then calculate the corresponding stub length for matching the mapped impendance on the g=1 circle.

Fundamental Solution	**Length in wavelengths,** λ
$\hat{L}_1$	0.324λ
$\hat{L}_2$	0.21λ
$\hat{L}_1'$	0.449λ
$\hat{L}_2'$	0.445λ

(a) Experimentally measured stub lengths

Fundamental Solution	**Length in** cm
L_1	12.15 cm
L_2	7.88 cm
L_1'	16.84 cm
L_2'	16.69 cm

(b) Theoretically calculated stub length pairs

5 Experimental Determination

6 Bandwidth Calculations

a) Bandwidth smaller than 2 The y-axis is VSWR and VSWR=(1+gamma)/(1-gamma). For this value to be less than or equal to 2, gamma has to be less than or equal to 0.33. b) Bandwidth limitation In terms of the bandwidth, shorter lines perform better. Longer lines change impedance faster compared to shorter lines when the frequency is modified. The reason for that is the following: Consider a lossless line, alpha is zero in this case and we only have j beta. This expression is also equal to w*sqrt(LC)*j. So w*sqrt(LC)=beta. Now, Zin = Z0(Zl+jZ0tan(beta*l)/(Z0+jZltan(beta*l))) and reflection coef.= (Zl-Z0)/(Zl+Z0). When l in the first equation is large then a small change in beta (meaning in w) is going to result in a large change in Zin because of tan(beta*l) function. Consequently a large jump in reflection coefficient. Since reflection coefficient has to be less than 0.33 there is a smaller window of frequencies we can use and fit in this constraint. However, when l is smaller (ie. shorter line) we can modify w much more and still stay in the necessary bound of values for the reflection coefficient. For 20log(|gamma|) when gamma=1/3 20log(|gamma|) -10dB. This suggests magnitudes smaller than -10 dB are acceptable values for gamma (so that the reflection doesn't modify the final value as much). c) Measurements Our measurements were pretty close within an error of 2 cm. Considering the number of operations we did on the smith chart with pencil and paper, we received accurate values. Additionally measurements on the double stub matching network are also susceptible to error.

7 Notes

All images taken during the lab were post-processed in a batch using a custom script that bit-wise inverts the pixels and binarizes the resulting image based on a custom threshold. No adjustments or modifications were made to the readings, for which the measurements on the VNA are also shown alongside the waveforms. All scripts and related work can be found at `github.com/pranshumalik14/ece320-labs`.