Impedance Matching

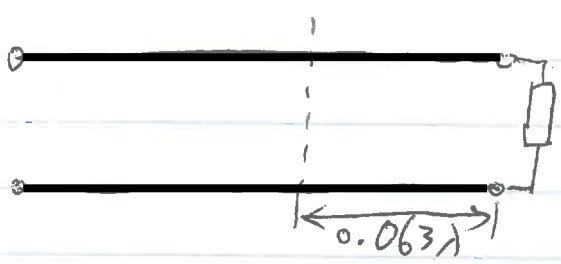
One method:

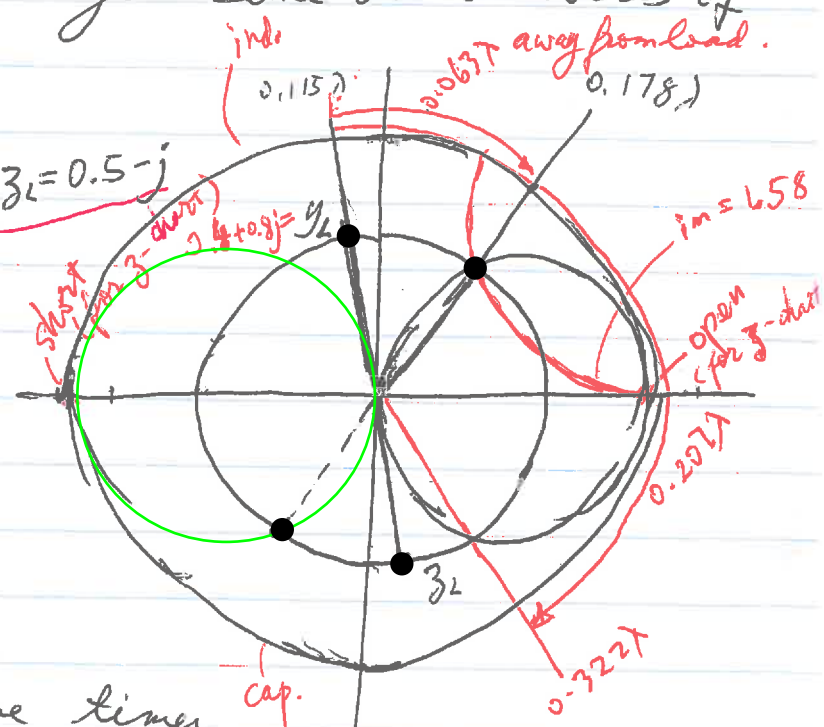
For a general load $Z_L = R_L + jX_L$, you first move along the transmission line to either d_{min} or d_{max}. The impedance there is purely resistive. Then you can use a $\lambda/4$ transformer to match that resistive impedance to Z_0.
Basically, you need to tune two #'s R_L & X_L so you need to "turn two knobs"
In that case, they are the distance from the load to the $\lambda/4$ transformer and the characteristic impedance of the $\lambda/4$ transformer.

I then said that you can pick up two other knobs to turn.
Now I'm gonna show you some other choices of the two knobs.

pp. 105 (6/E)
Fig. 2-36

pp. 106
in 7/E





Get a new, clean copy of the Smith Chart.
The old copy is quite crowded now.
and we've used the old example quite some times.
We've beaten that old horse to death. So let's start w/ a new example

This time, $z_L = 0.5 - j$

Locate this load on the chart.

Now, let's find y_L using the chart:

$y_L = 0.4 + 0.8j$

Now, we move along the transmission line away from the load, i.e., along the constant-SWR circle clockwise.

We will hit this circle: $\boxed{g = 1}$

When we use the chart for $z \leftrightarrow \Gamma$ mapping, we called this circle the $r = 1$ circle.

The Smith chart is whichever you consider it to be (a z-chart or a y-chart).

On this circle, $y = 1 + jb$, i.e., $Y = Y_0 + jB$

The real part (conductance) is already matched to Y_0.

If we can somehow cancel the jB part, we are done.

Now, read one of the two sets of ticks of the outer scale.

How far do we need to move to reach this point?

I use the outer set of ticks: $0.178\lambda - 0.115\lambda = 0.063\lambda$

What is the normalized admittance at this point?

$y(0.063\lambda) = 1 + 1.58j$

$Y(0.063\lambda) = Y_0 + j1.58Y_0$

Is the susceptance inductive or capacitive?

Let's keep in mind that we are dealing with admittance!

For a capacitor C, $\quad Y = j\omega C$

For an inductor L, $\quad Y = \dfrac{1}{j\omega L} = -j\dfrac{1}{\omega L}$

So, the susceptance is capacitive. How to cancel it?

Impedance Matching Using Lumped Elements

Let's say $Z_0 = 50\ \Omega$.

Then the susceptance we need to cancel is $1.58 \times (1/50)\ \Omega^{-1}$.

We can use an inductor L to cancel it:

$$\frac{1}{\omega L} = 1.58 \times \frac{1}{50}\ \Omega^{-1} \quad \Rightarrow \quad L = (50\ \Omega) / (1.58\omega)$$

Given the frequency, we can calculate the needed L.

To keep in mind:

- Any matching is frequency specific
- Not just L, but also distance d, because d is in terms of λ, which is frequency dependent
- We are dealing with admittance. The impedance is the diametrical point
- If you want to find out what the SWR is at d (where you put your inductor) in absence of the inductor, what do you do? (Or, how do you find $z(d)$ of the line in absence of the inductor?) – Refer to the chart.

You can also use a capacitor to achieve matching.

You rotate further (i.e., moving further along the constant-SWR circle), and you will hit the $g = 1$ circle again.

That means, you move further along the transmission line, until you have $G = Y_0$.

Apparently, this point is symmetric with that point of the last solution (where you used an inductor).

So, the admittance here (of the main branch) is

$$y(d) = 1 - 1.58j$$

Now, find out how far this point is from the load:

$$d = 0.322\lambda - 0.115\lambda = 0.207\lambda$$

Again, we are dealing with admittance (the impedance is the point diametrical to the admittance).

So, the reactive part of $y(d)$ is inductive.

You need a capacitor to cancel it.

If $Z_0 = 50\ \Omega$,

$$\omega C = 1.58 \times (1/50)\ \Omega^{-1}$$

$$C = (1.58/\omega) \times (1/50)\ \Omega^{-1}$$

Again, matching is frequency specific.

To keep in mind:

Here, we deal with admittance. The circle we call the $r = 1$ circle (when talking about impedance) is now the "$g = 1$" circle.

However, if you are talking about impedance (i.e. using the Smith chart as the "z-chart," the $g = 1$ circle is the green circle:

Each point on this circle is diametrical to a point on the "$g = 1$" circle of the "y-chart."

Question: where is the "$r = 1$" circle on the y-chart?

In the lab, you will use the "network analyzer," which measures impedance and displays it on the Smith Chart (as the z-chart).

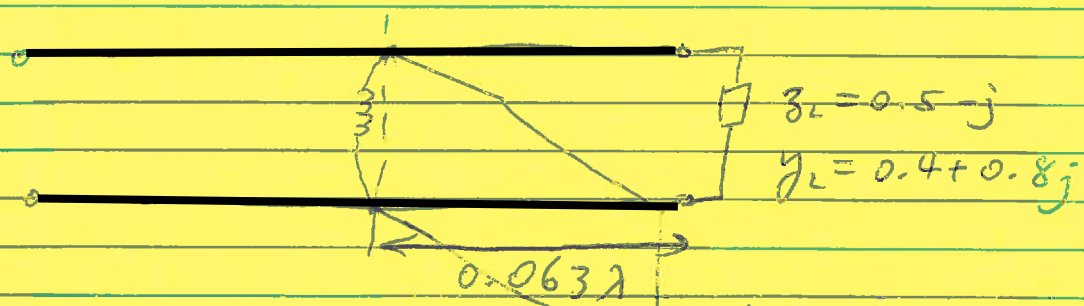
But you deal with admittance, because you will connect something in parallel with the main branch. You need to first get $z(d)$ onto the $g = 1$ circle (on the z-chart). (Where is it?)

To help you, the TAs cover the screen with a transparent sheet on which the $g = 1$ circle is printed.

Finish HW4: Problems 4 & 5, to be prepared for the discussion of single stub matching

Single stub matching

Now, I'll show you two more ways to get the match, which is derived from the two ways I just showed.



You put an inductor @ $d = 0.063\lambda$

Recall that if you short a transmission line, the impedance @ any position is purely reactive.

We talked about this several classes back.

It goes short, inductive, open, capacitive, short, inductive, ... and repeats over & over.

☆ On the Smith Chart....

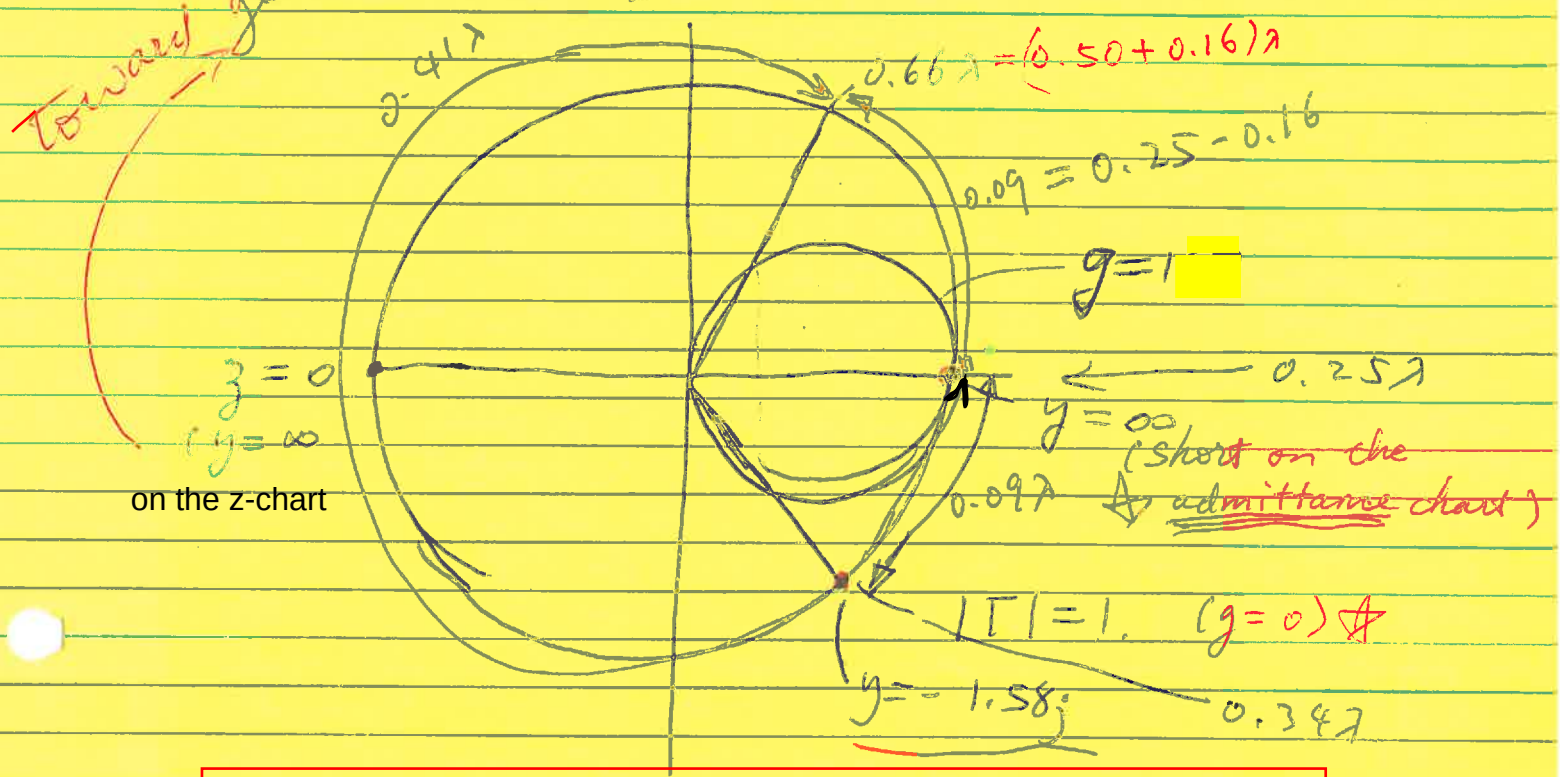
So, you can add a branch to this transmission line, short it at the other end, and adjust its length to get the right input conductance that we need. We call this branch a "stub"

In this case,

$$y(d=0.063\lambda) = 1 + 1.58j$$

So we need the input ~~impedance~~ admittance of the stub to be $y_{in}^{stub} = -1.58j$

Now, get a copy of the Smith Chart.



But remember, we are working w/ y

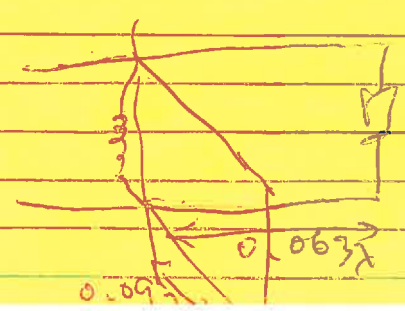
Because the stub is shorted @ the end, we are on the $|\Gamma| = 1$ circle.

On this big circle, let's locate the point for which $y_{in}^{stub} = -1.58j$

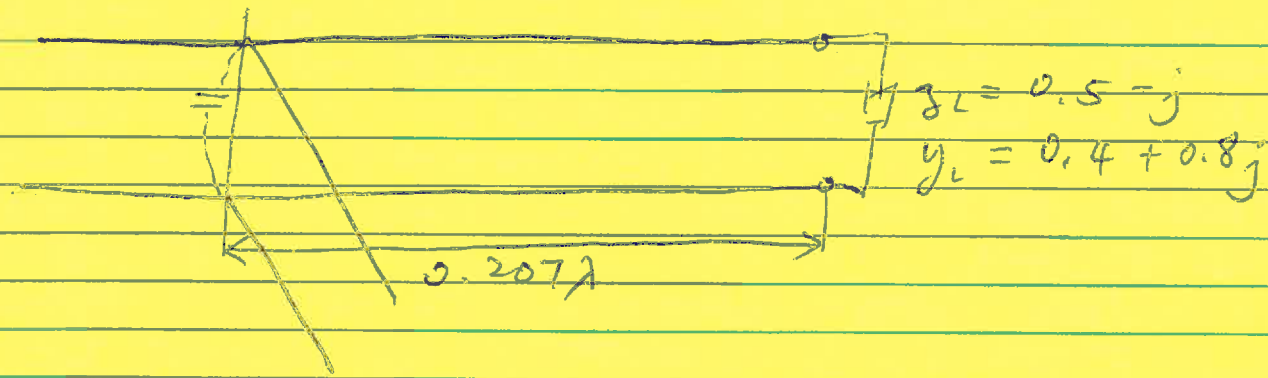
Let's find out how long the stub should be.

Let's use the outer-most scale.

$0.34\lambda - 0.25\lambda = 0.09\lambda$



Similarly, we can use a stub to replace the capacitor.



$y(d = 0.207\lambda) = 1 - 1.58j$

So, we need

$y_{in}^{stub} = +1.58j$

$0.66\lambda - 0.25\lambda = 0.41\lambda$

$\frac{41}{66}$

Or, $0.5\lambda - 0.09\lambda = 0.41\lambda$

These two methods are called "single stub" matching.

The methods using an inductor or a capacitor is called "lumped element" matching.

In all these methods, you need to adjust the position of either the stub or the lumped element, which isn't always convenient in the lab.

Finish Homework #5.

Say your transmission line is a coax cable