5.2 – Single-Stub Tuning

Reading Assignment: *pp. 228-235*

Q: *If we cannot use "lumped" elements like inductors or capacitors to build lossless matching networks, what **can** we use?*

A: Recall that a section of **lossless transmission line** is purely reactive, thus we can build lossless matching networks using specific lengths of transmission lines.

We call these lengths of transmission line **"distributed" elements**.

The distributed element analogue of the lumped element L-network is the **single-stub tuner**.

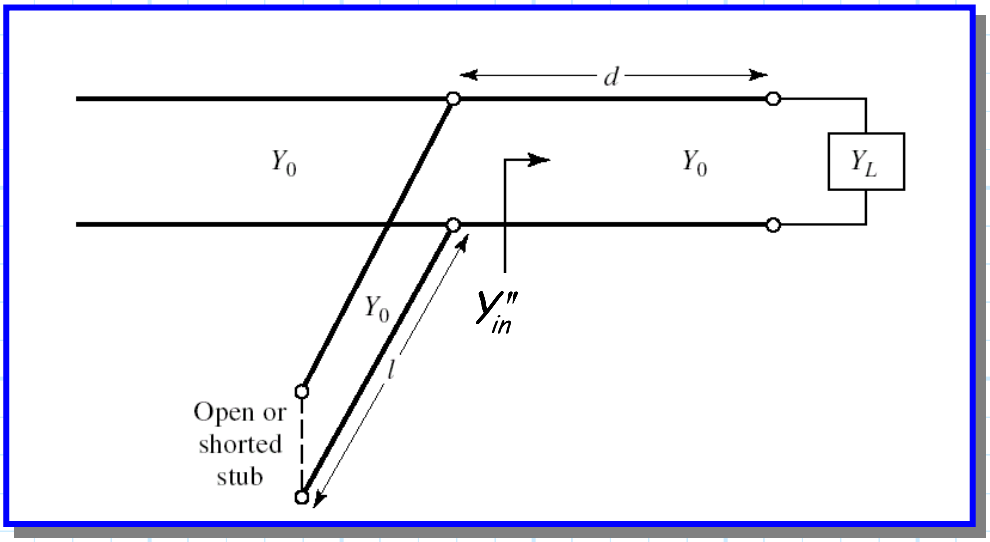
Just like the L-network, there are **two** versions of this design:

HO: THE SHUNT-STUB TUNER

HO: THE SERIES-STUB TUNER

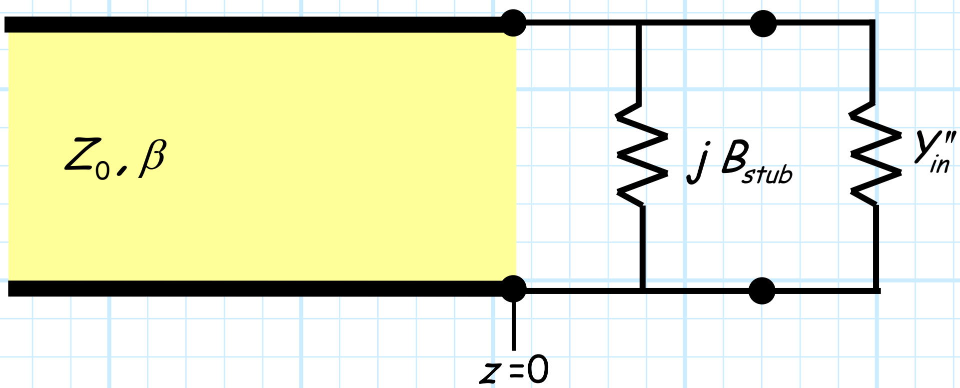
Shunt Stub Tuning

Consider the follow transmission line structure, with a **shunt stub**:



The two **design parameters** of this matching network are lengths ℓ and d.

An equivalent circuit is:



where of course:

$$Y_{in}'' = Y_0 \left(\frac{Y_L + j\,Y_0 \tan \beta d}{Y_0 + j\,Y_L \tan \beta d} \right)$$

and the reactance jB_{stub} of transmission line stub of length ℓ is either:

$$jB_{stub} = \begin{cases} jY_0 \tan\beta\ell & \text{for an \textbf{open}-circuit stub} \\ \\ -jY_0 \cot\beta\ell & \text{for an \textbf{short}-circuit stub} \end{cases}$$

Therefore, for a matched circuit, we require:

$$jB_{stub} + Y_{in}'' = Y_0$$

Note this complex equation is actually **two real equations**!

i.e.,

$$\text{Re}\{Y_{in}''\} = Y_0$$

and

$$\text{Im}\{jB_{stub} + Y_{in}''\} = 0 \quad \Rightarrow \quad B_{stub} = -B_{in}''$$

where

$$B_{in}'' \doteq \text{Im}\{Y_{in}''\}$$

Since y''_{in} is dependent on d only, our **design procedure** is:

1) Set d such that $\text{Re}\{Y''_{in}\} = Y_0$.

2) Then set ℓ such that $B_{stub} = -B''_{in}$.

We have **two choices** for determining the lengths d and ℓ. We **can** use the design equations (5.9, 5.10, 5.11) on p. 232,

OR

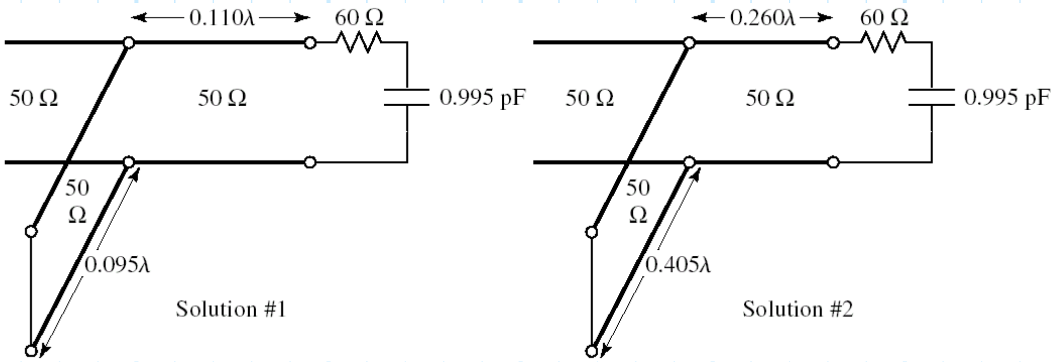
we can use the **Smith Chart** to determine the lengths!

1) Rotate **clockwise** around the Smith Chart from y_L until you intersect the ***g* =1 circle**. The "length" of this rotation determines the value d. Recall there are **two** possible solutions!

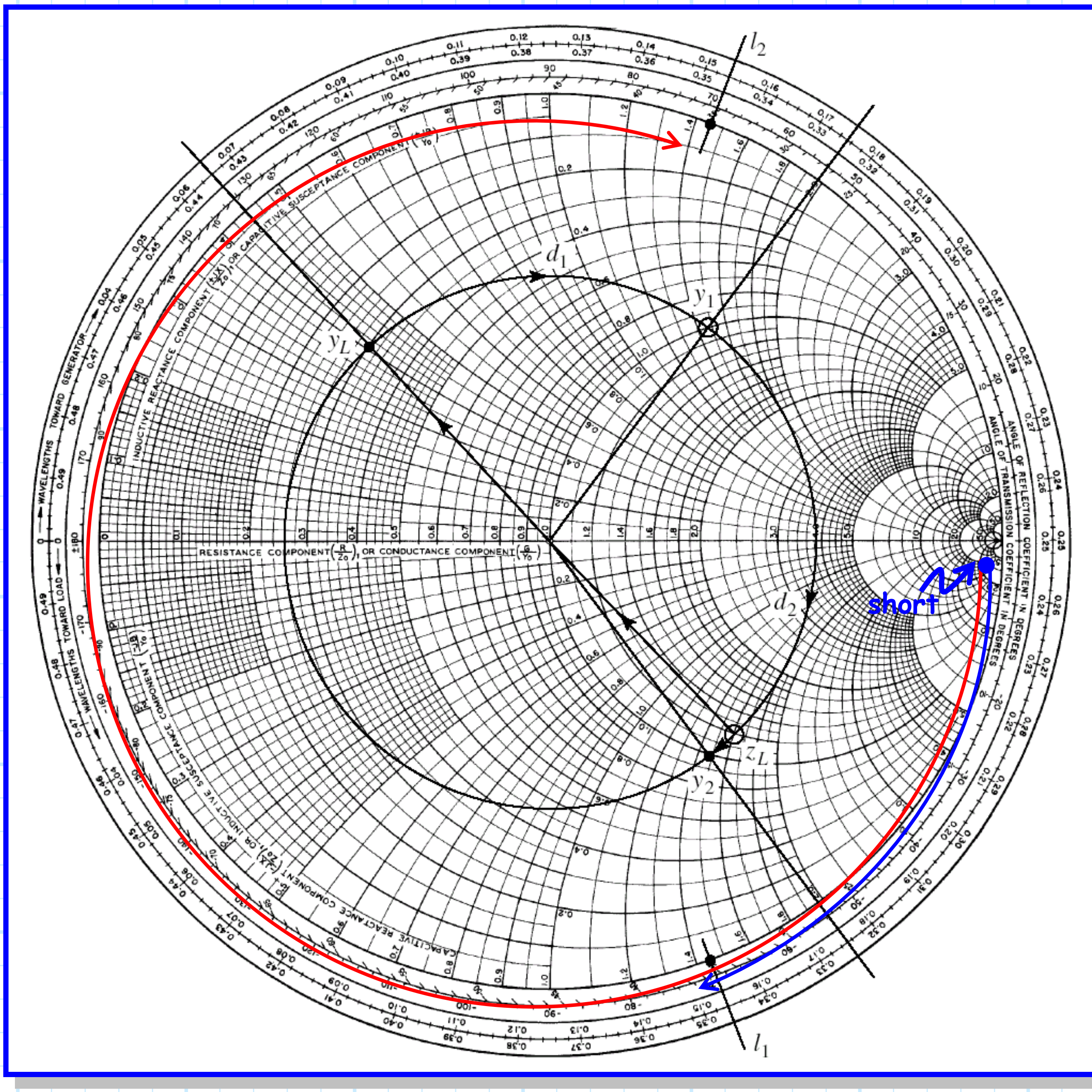
2) Rotate **clockwise** from the short/open circuit point around the ***g* = 0 circle**, until b_{stub} equals $-b''_{in}$. The "length" of this rotation determines the stub length ℓ.

For example, your **book** describes the case where we want to match a load of $Z_L = 60 - j80$ (at 2 GHz) to a transmission line of $Z_0 = 50\Omega$.

Using **shorted** stubs, we find **two** solutions to this problem:



Whose length values d and ℓ where determined from a Smith Chart:



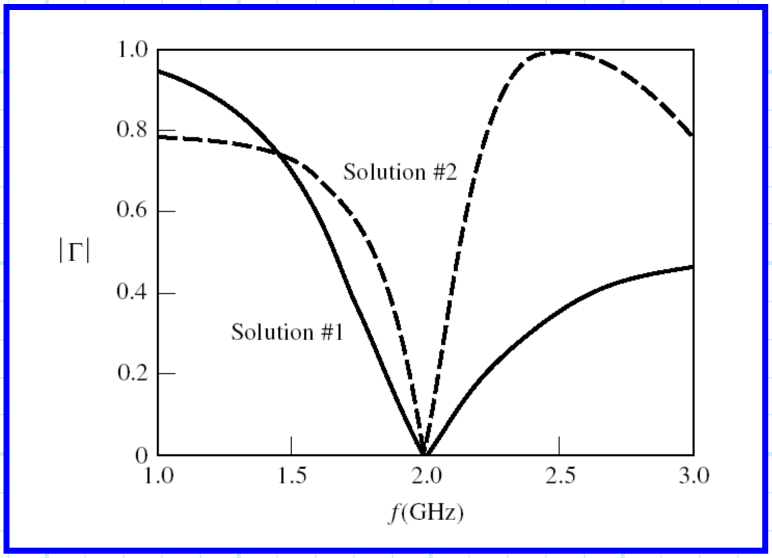
Q: ***Two** solutions! Which one do we use?*

A: The one with the **shortest** lengths of transmission line!

Q: *Oh, I see! Shorter transmission lines provide **smaller** and (slightly) cheaper matching networks.*

A: True! But there is a more **fundamental** reason why we select the solution with the **shortest** lines—the matching **bandwidth** is **larger**!

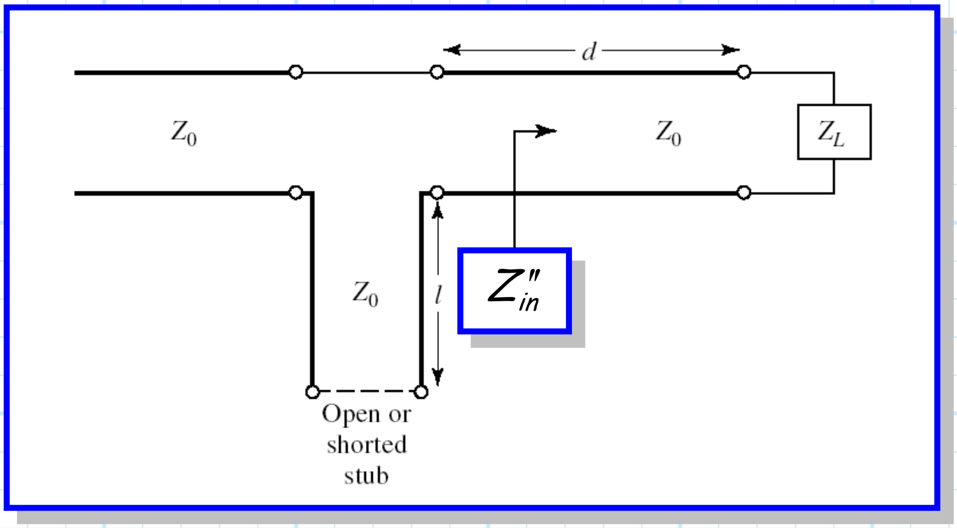
For example, consider the **frequency response** of the two examples:



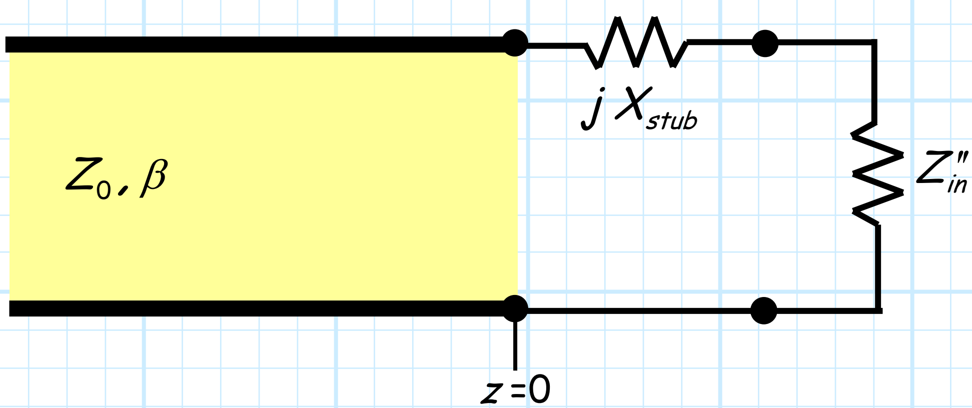
Clearly, solution 1 provides a **wider** bandwidth!

Series Stub Tuning

Consider the following transmission line structure, with a **series** stub:



Therefore an **equivalent** circuit is:



where of course:

$$Z_{in}'' = Z_0 \left(\frac{Z_L + j\,Z_0 \tan \beta d}{Z_0 + j\,Z_L \tan \beta d} \right)$$

and the **reactance** jX_{stub} is either:

$$jX_{stub} = \begin{cases} -jZ_0 \cot\beta\ell & \text{for an open-circuit stub} \\ jZ_0 \tan\beta\ell & \text{for an short-circuit stub} \end{cases}$$

Therefore, for a **matched** circuit, we **require**:

$$jX_{stub} + Z_{in}'' = Z_0$$

i.e.,

$$\text{Re}\{Z_{in}''\} = Z_0$$

and

$$\text{Im}\{jX_{stub} + Z_{in}''\} = 0 \quad \Rightarrow \quad X_{stub} = -X_{in}''$$

where

$$X_{in}'' \doteq \text{Im}\{Z_{in}''\}$$

Note the **design parameters** for this stub tuner are transmission line **lengths** d and ℓ. More specifically we:

1) Set d such that $\text{Re}\{Z_{in}''\} = Z_0$.

2) Then set ℓ such that $X_{stub} = -X_{in}''$.

We have **two** choices for determining the lengths d and ℓ. We **can** use the design equations (5.14, 5.15, 5.16) on pp. 235.

OR

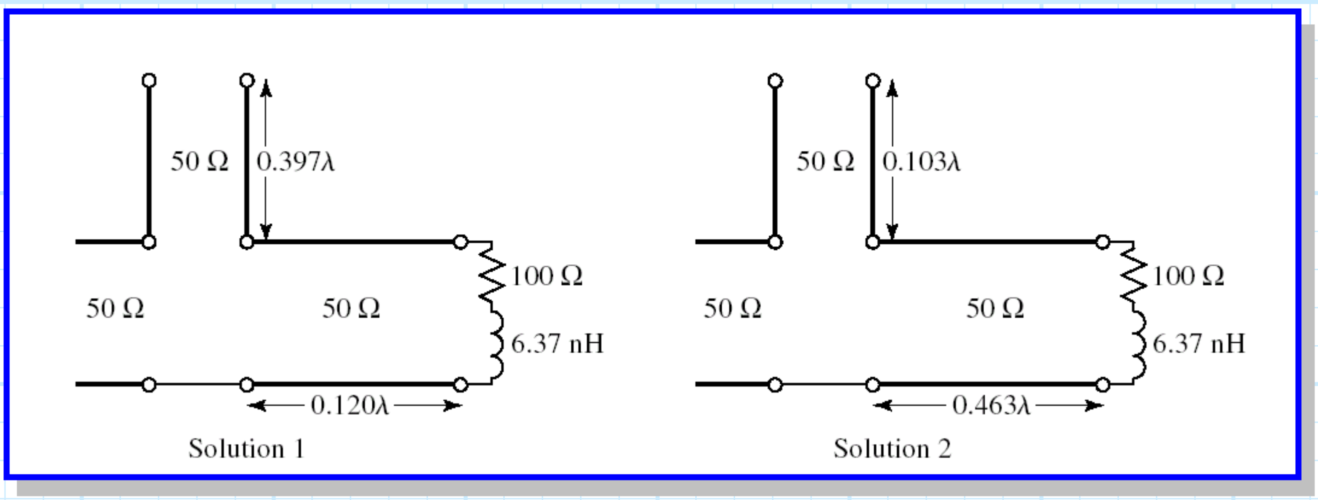
we can use the **Smith Chart** to determine the lengths!

1) Rotate clockwise around the Smith Chart from z_L until you intersect the ***r* = 1 circle**. The "length" of this rotation determines the value *d*. Recall there are **two** possible solutions!

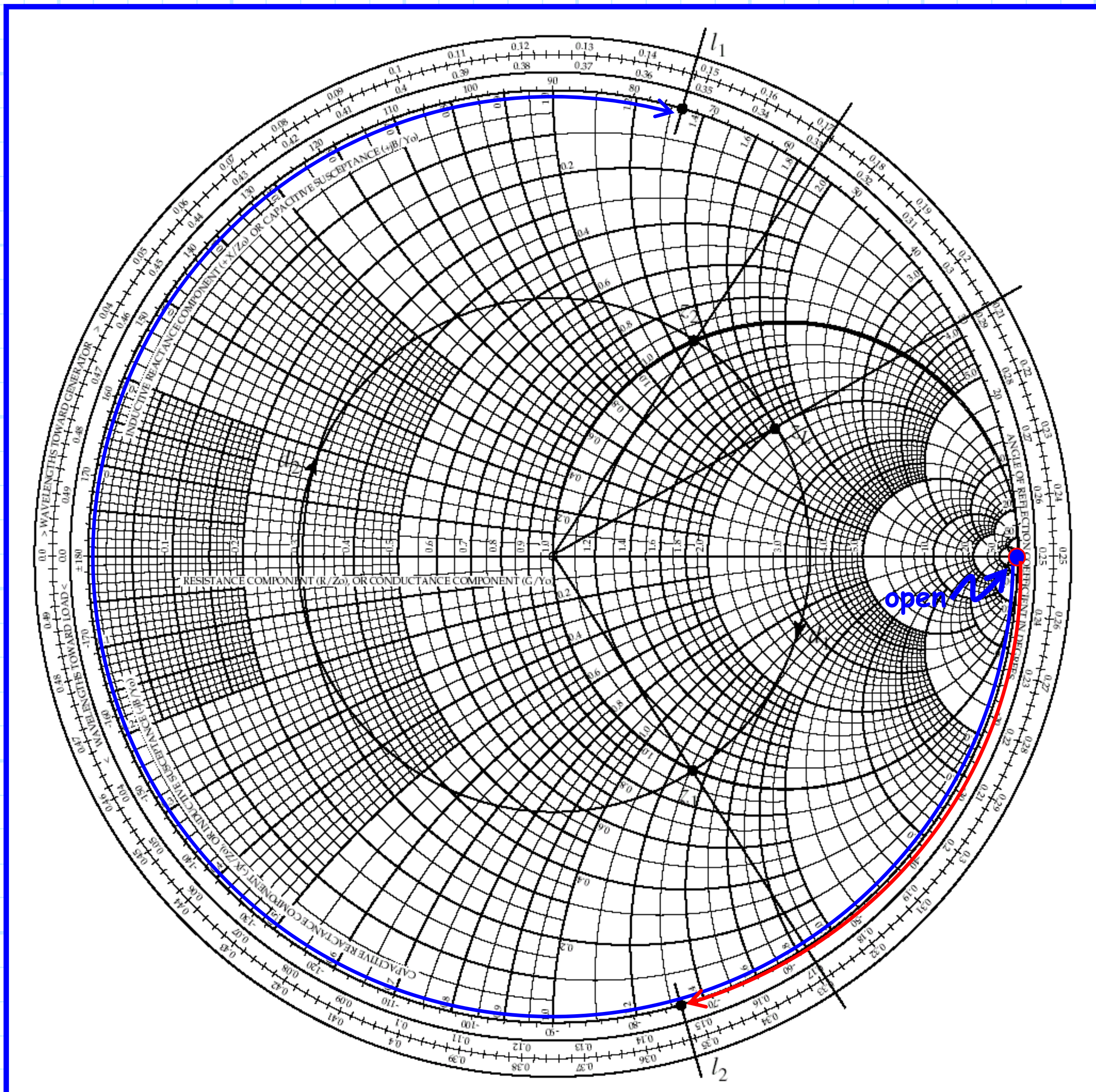
2) Rotate clockwise from the short/open circuit point around the ***r* = 0 circle** until x_{stub} equals $-x''_{in}$. The "length" of this rotation determines the stub length ℓ.

For example, your **book** describes the case where we want to match a load of $Z_L = 100 + j80$ (at 2 GHz) to a transmission line of $Z_0 = 50\Omega$.

Using **open** stubs, we find **two** solutions to this problem:



Whose values where determined from a **Smith Chart**:



Again, we should use the solution with the **shortest** transmission lines, although in **this** case that distinction is a bit **ambiguous**. As a result, the bandwidth of each design is about the same (depending on how **you** define **bandwidth**!).