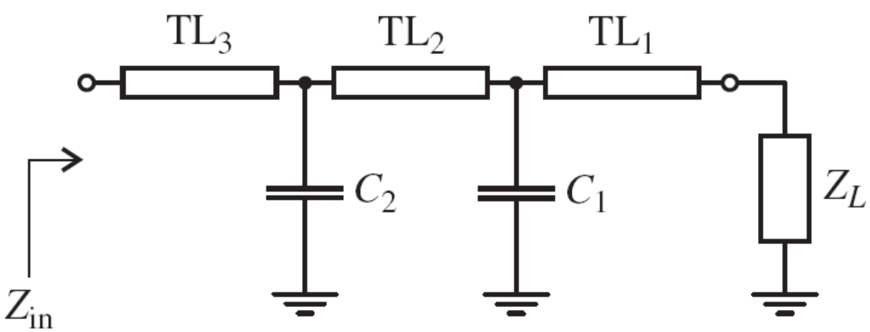
Lecture – 12 Date: 09.02.2017

- Microstrip Matching Networks
- Series- and Shunt-stub Matching
- Quarter Wave Impedance Transformer

Microstrip Line Matching Networks

- In the lower RF region, its often a standard practice to use a hybrid approach that combines lumped and distributed elements → These types of matching circuits usually contain TL segments in series and capacitors in shunt.



- Inductors are avoided in these designs as they tend to have higher resistive losses as compared to capacitors.
- In principle, only one shunt capacitor with two TL segments connected in series on both sides is sufficient to transform any given load impedance to any input impedance.

- Similar to the L-type matching network, these configurations may also involve the additional requirement of a fixed Q_n, necessitating additional components to control the bandwidth of the circuit.

Microstrip Line Matching Networks (contd.)

- In practice, these configurations are extremely useful as they permit tuning of the circuits even after manufacturing → changing the values of capacitors as well as placing them at different locations along the TL offers a wide range of flexibility → In general, all the TL segments have the same width to simplify the actual tuning →the tuning ability makes these circuits very appropriate for prototyping.

Example – 1

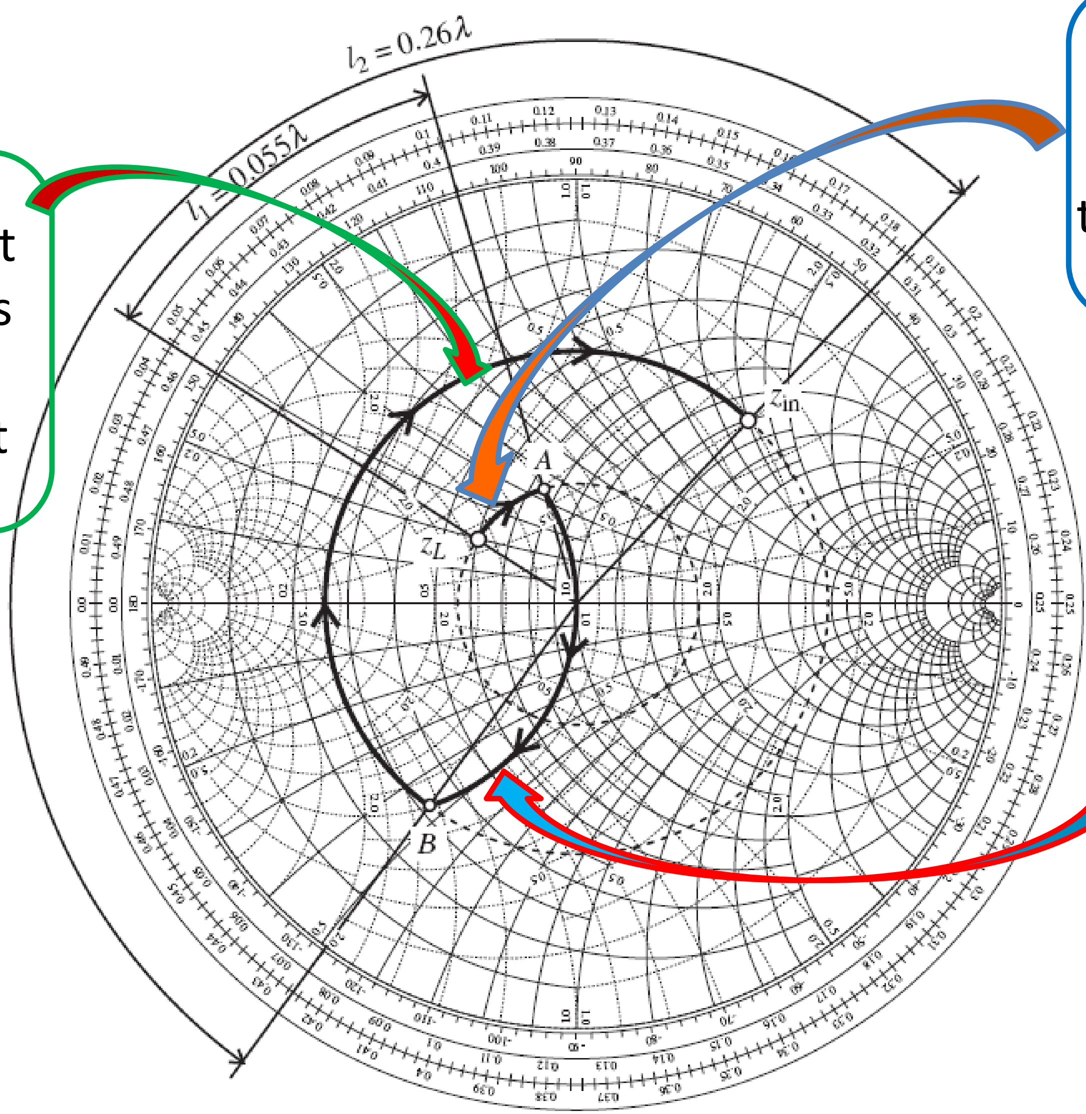
Design a hybrid matching network that transforms the load $Z_L = (30 + j10)\Omega$ to an input impedance $Z_{in} = (60 + j80)\Omega$. The matching network should contain only two series TL segments and one shunt capacitor. Both TLs have a 50Ω characteristic impedance, and the frequency at which the matching is required is f = 1.5 GHz

Solution

- Mark the normalized load impedance (0.6 + j0.2) on the Smith chart.
- Draw the corresponding SWR circle.
- Mark the normalized input impedance (1.2 + j1.6) on the Smith chart.
- Draw the corresponding SWR circle.
- The choice of the point from which we transition from the load SWR circle to the input SWR circle can be made arbitrarily.

Example – 1 (contd.)

point B to normalized input impedance gives length of the second segment of TL

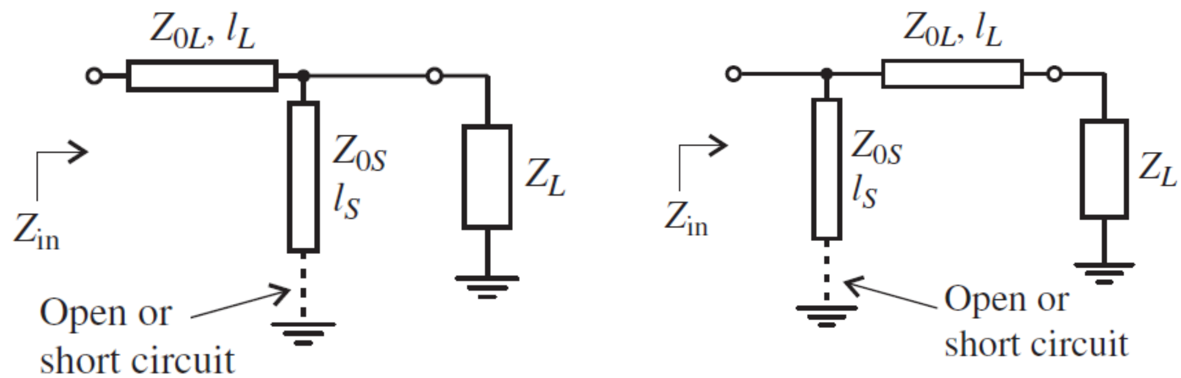


Normalized load to the point A gives length of the first segment of TL

A to B provides the necessary susceptance value for the shunt capacitor

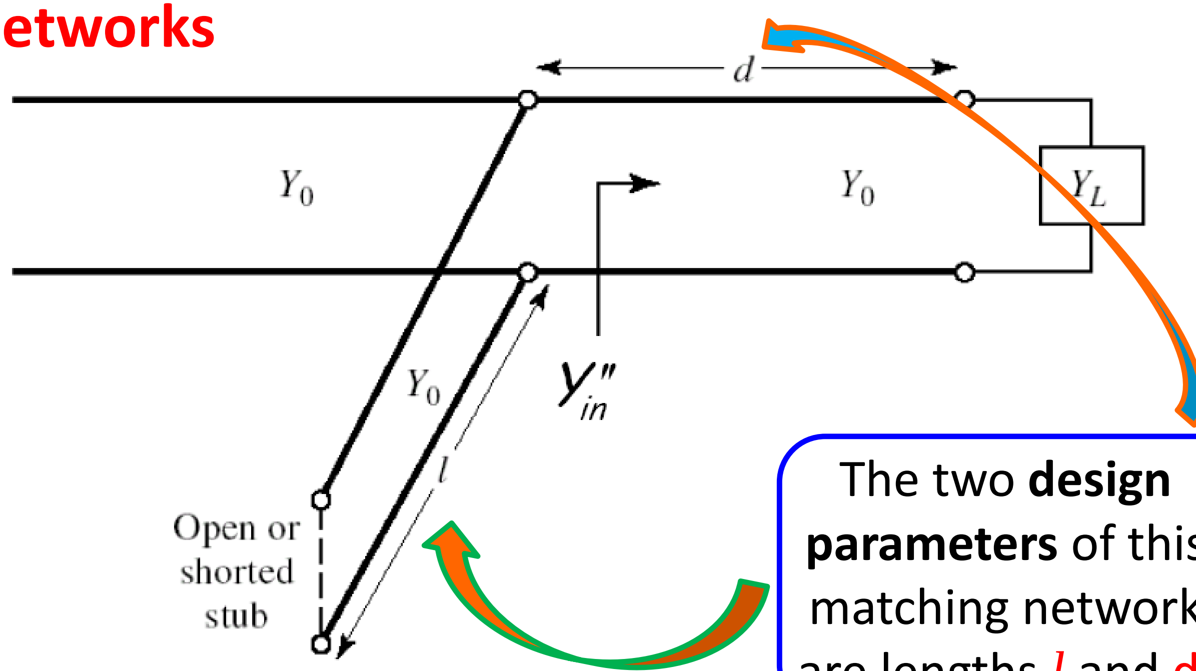
Stub Matching Networks

- The next logical step is the complete elimination of all lumped components → this can be achieved by employing open – and/or short – circuited stub lines



Shunt-stub Matching Networks

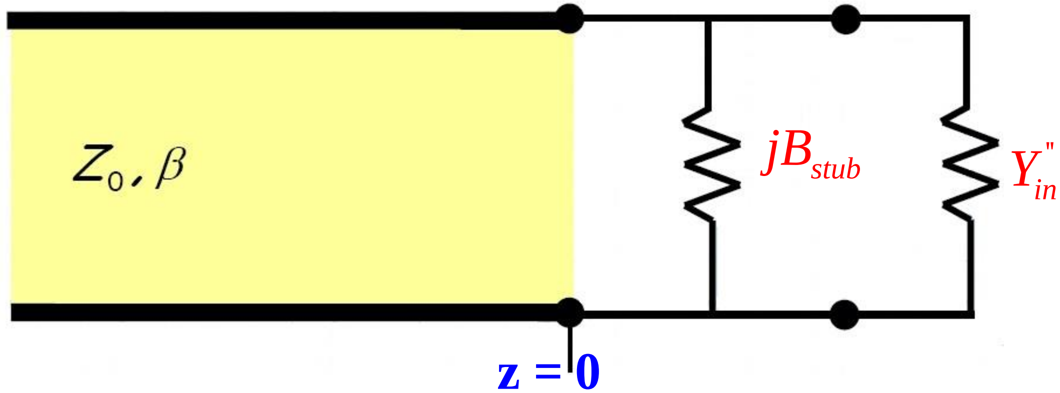
- Let us consider this configuration with shunt stub.



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

Shunt-stub Matching Networks (contd.)

- An equivalent circuit for the shunt-tub TL can be:



Where:

$$Y_{in}'' = Y_0 \left(\frac{Y_L + jY_0 \tan(\beta d)}{Y_0 + jY_L \tan(\beta d)} \right)$$

$$jB_{stub} = \begin{cases} jY_0 \tan(\beta l) & \text{For open-stub} \\ -jY_0 \cot(\beta l) & \text{For short-stub} \end{cases}$$

- Therefore, for a matched circuit, we require: $jB_{stub} + Y_{in}'' = Y_0$

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

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

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

Where: $B_{in}'' = \text{Im}\{Y_{in}''\}$

Shunt-stub Matching Networks (contd.)

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

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

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

We have two choice, either Analytical or Smith chart for finding out the lengths d and l

Use of the **Smith Chart** to determine the lengths!

- Rotate **clockwise** around the Smith Chart from y_l until you intersect the $\boldsymbol{g_s}$**=1 circle**. The "length" of this rotation determines the value $\boldsymbol{d}$. Recall there are **two** possible solutions!
- Rotate **clockwise** from the short/open circuit point around the $\boldsymbol{g = 0}$ **circle**, until b_{stub} equals $-b_{in}''$. The "length" of this rotation determines the stub length l.

Example – 2

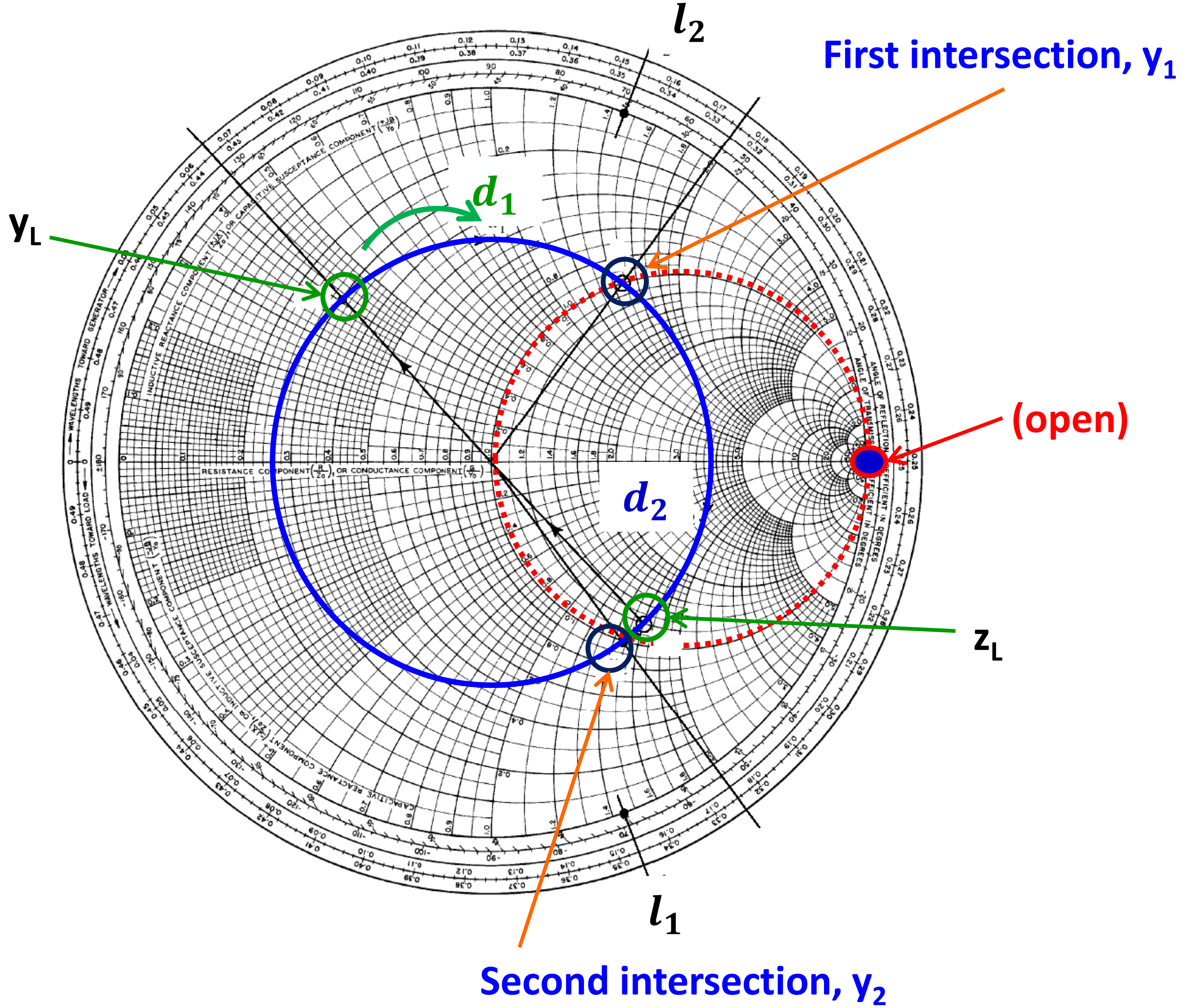
Let us take the case where we want to match a load of Z_L= (60−j80)Ω (at 2 GHz) to a transmission line of Z_0 =50Ω.

Example – 2 (contd.)

Solution

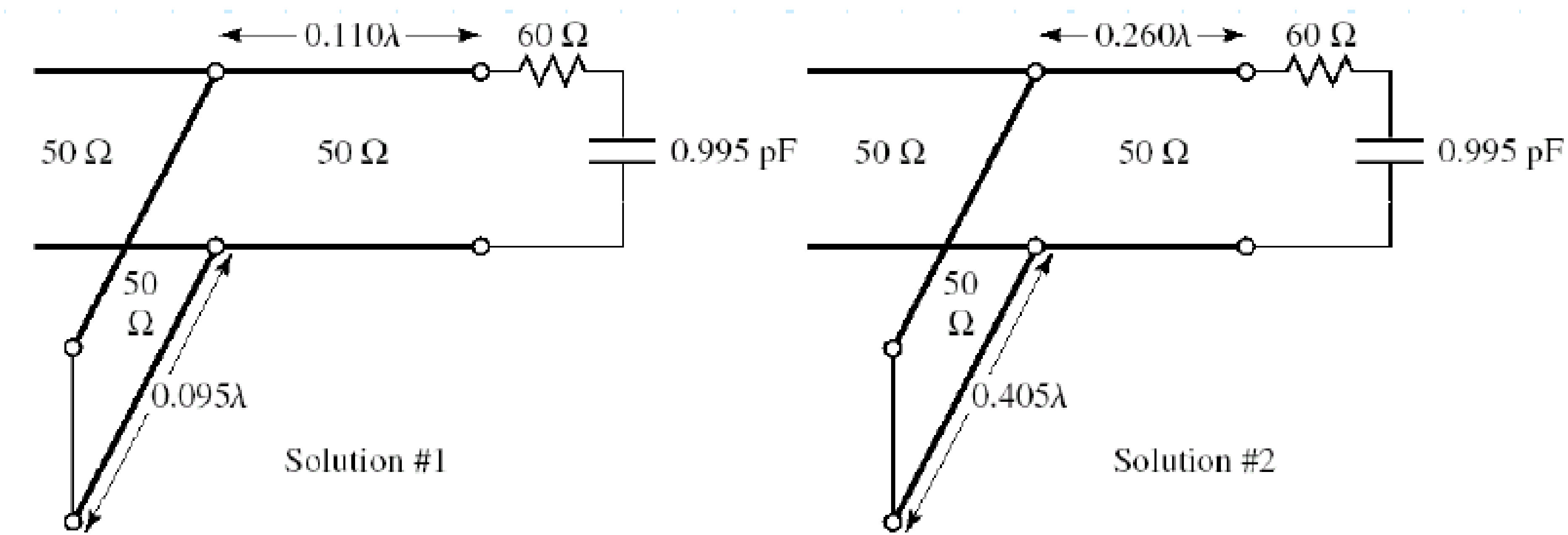
y_L to y_1 towards generator (clockwise) gives length d_1 (first solution)

y_L to y_2 towards generator (clockwise) gives length d_2 (second solution)



Example – 2 (contd.)

- Determine the respective admittances at the two intersection points
- These are of the form 1 + jx and 1 – jx
- Cancel these imaginary part of the admittances by introducing shunt-stubs of length l_1 and l_2 respectively
- l_1 and l_2 are the lengths from open circuit point in the Smith chart (if open stub is used) along the g = 0 circle until the achieved admittances are of opposite signs to those at the intersection points in the earlier step



Example – 2 (contd.)

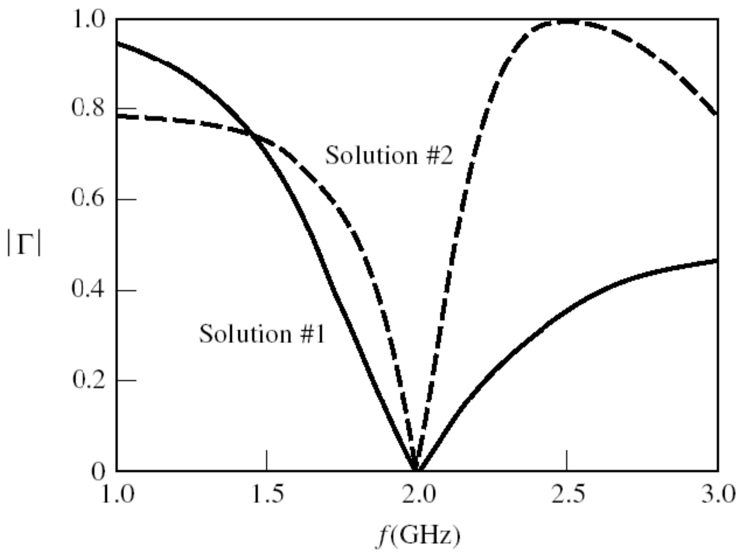
Q: **Two** solutions! Which one do we use?

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**!

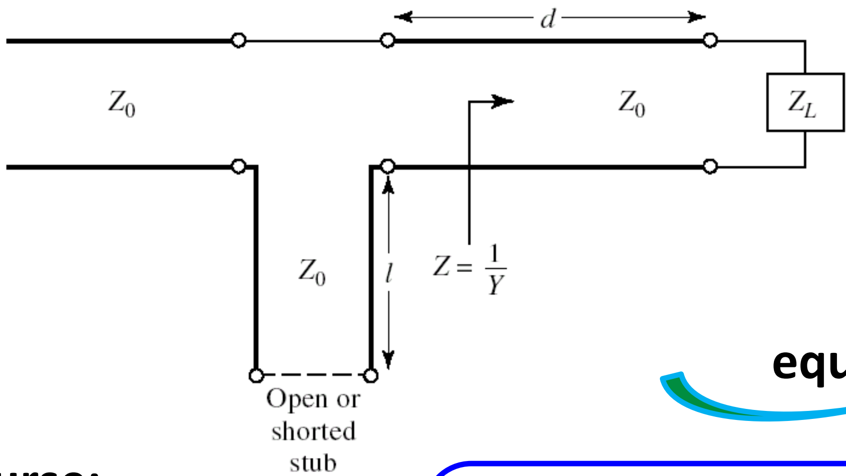
- For example, consider the **frequency response** of the two solutions:



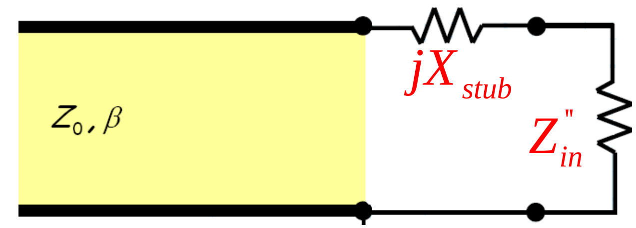
Clearly, solution 1 provides a **wider** bandwidth!

Series-stub Matching Networks

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



Therefore an **equivalent** circuit is:



where of course:

$$Z''_{in} = Z_0\left(\frac{Z_L + jZ_0\tan(\beta d)}{Z_0 + jZ_L\tan(\beta d)}\right)$$

$$jX_{stub} = \begin{cases} -jZ_0\cot(\beta l) & \text{For open-stub} \\ jZ_0\tan(\beta l) & \text{For short-stub} \end{cases}$$

Example – 3

Let us take the case where we want to match a load of Z_L= (100 + j80)Ω (at 2 GHz) to a transmission line of Z_0 =50Ω.

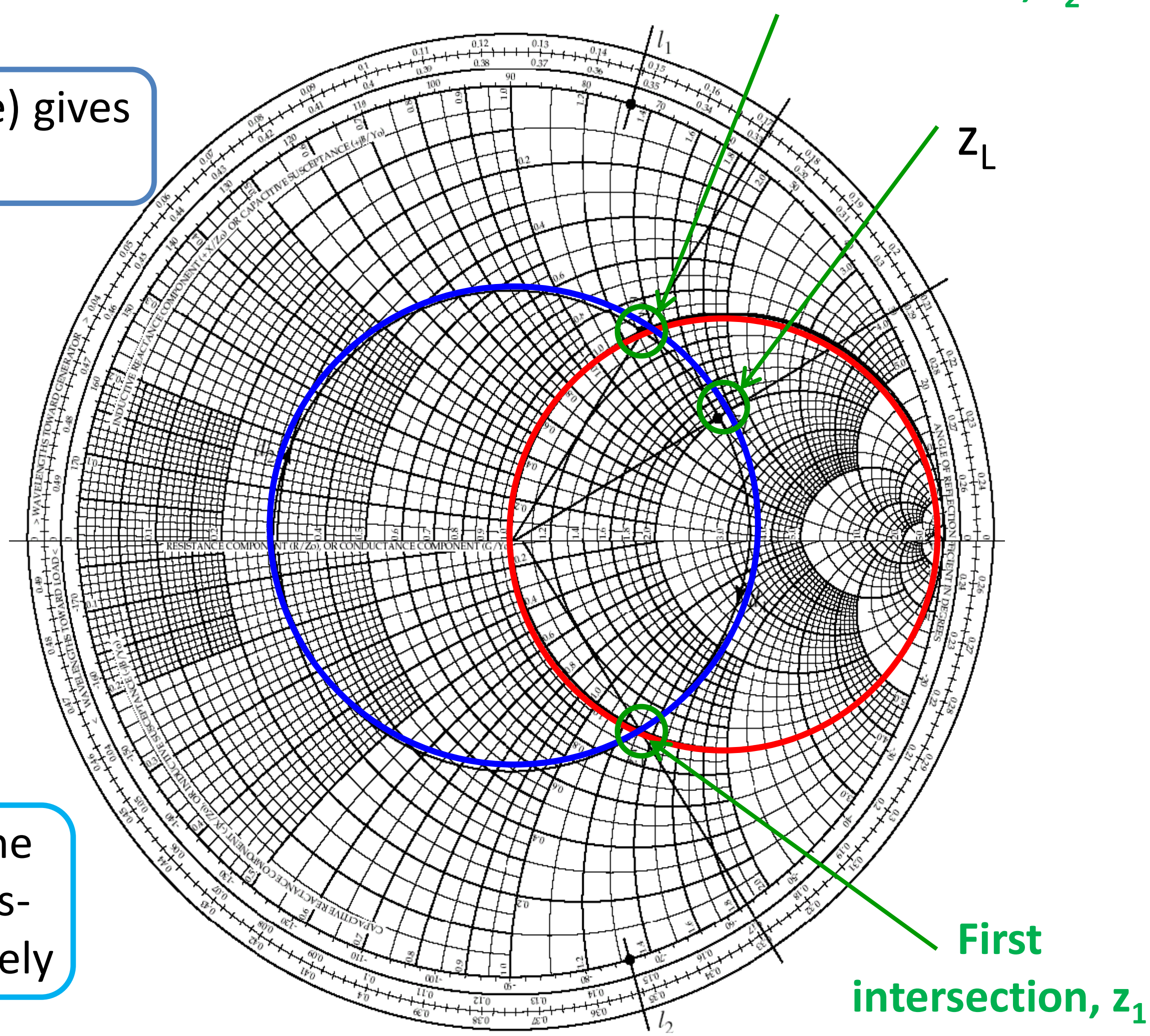
Example – 3 (contd.)

z_l to z_1 towards generator (clockwise) gives length d_1 (first solution)

z_l to z_2 towards generator (clockwise) gives length d_2 (second solution)

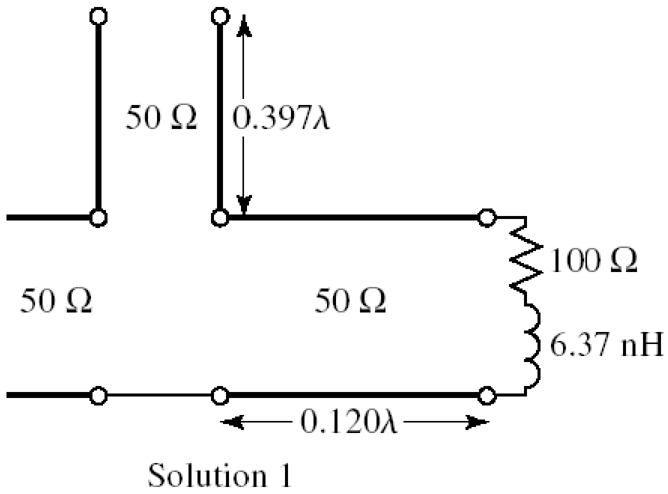
Determine the respective impedances at the two intersection points and these are of the form 1 + jx and 1 – jx

Cancel these imaginary part of the impedances by introducing series-stubs of length l_1 and l_2 respectively

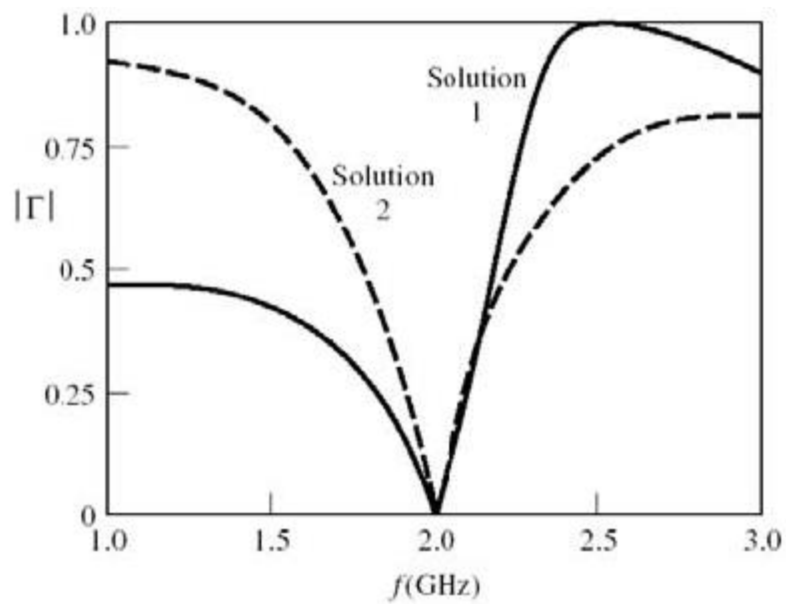


- l_1 and l_2 are the lengths from open circuit point in the Smith chart (if open stub is used) along the r = 0 circle until the achieved impedances are of opposite signs to those at the intersection points in the earlier step

Example – 3 (contd.)



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**!).



Example – 4

For a load impedance of Z_L= (60 – j45)Ω, design single-stub (shunt) matching networks that transform the load to a Z_{in} =(75 + j90)Ω input impedance. Assume both the stub and transmission line have a characteristic impedance of Z_0 = 75Ω

Solution

- Normalize the Z_L and Z_{in} with 75Ω
- Mark these normalized impedances on the Z-Smith chart
- Move to Y-Smith chart or better use ZY-Smith chart
- Plot constant conductance (g_L) circle
- Plot SWR circle for normalized input impedance (z_{in})
- Two intersection points between constant conductance circle and SWR circle can be observed
- Rotation from intersection points to z_{in} give the lengths d_1 and d_2 and corresponding changes in admittance
- Look for cancelling the additional admittances using shunt stub by equating corresponding stub lengths from **'open'** in Smith chart

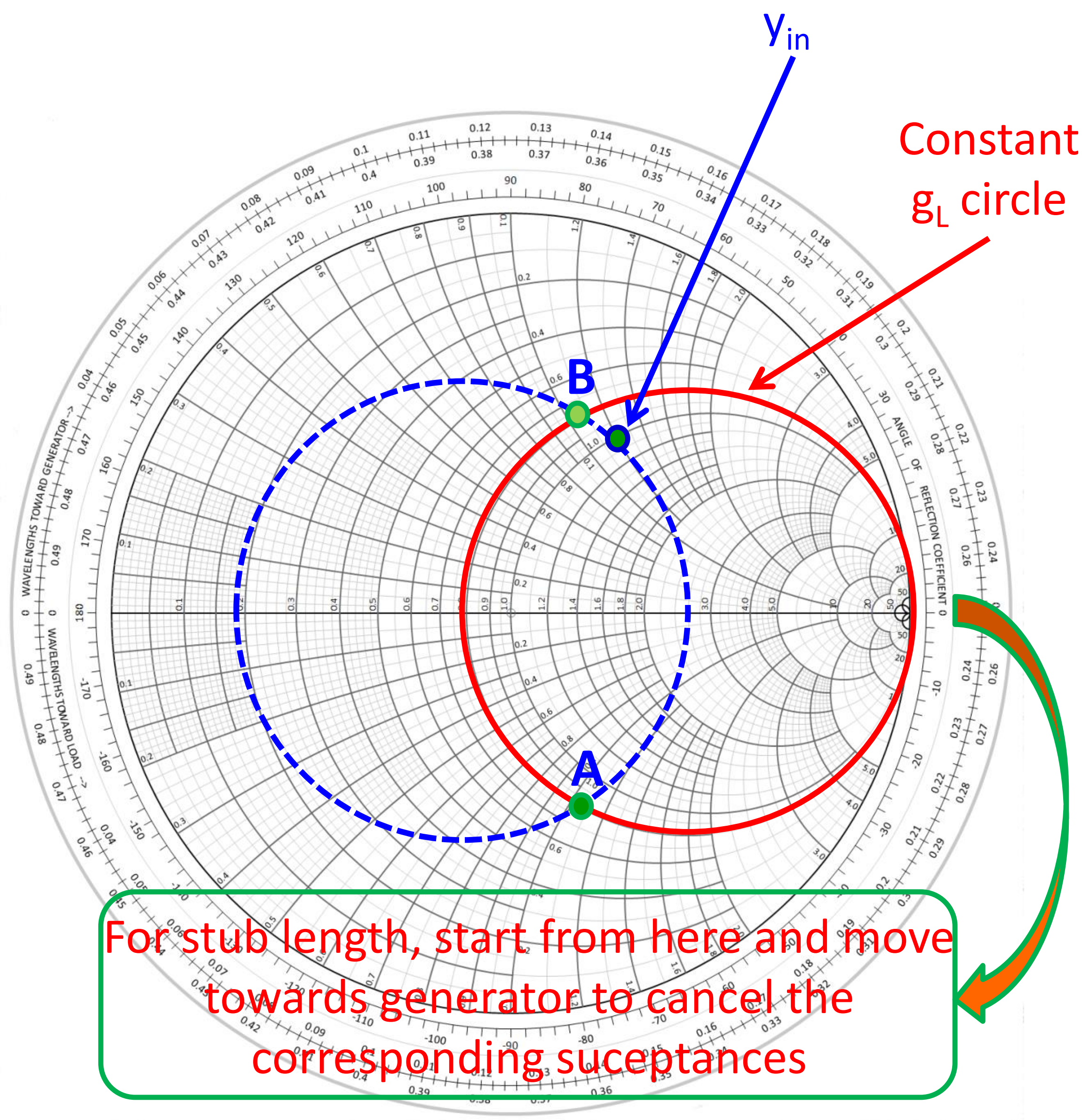
Example – 4 (contd.)

Here:

$z_L = 0.8 - j0.6$

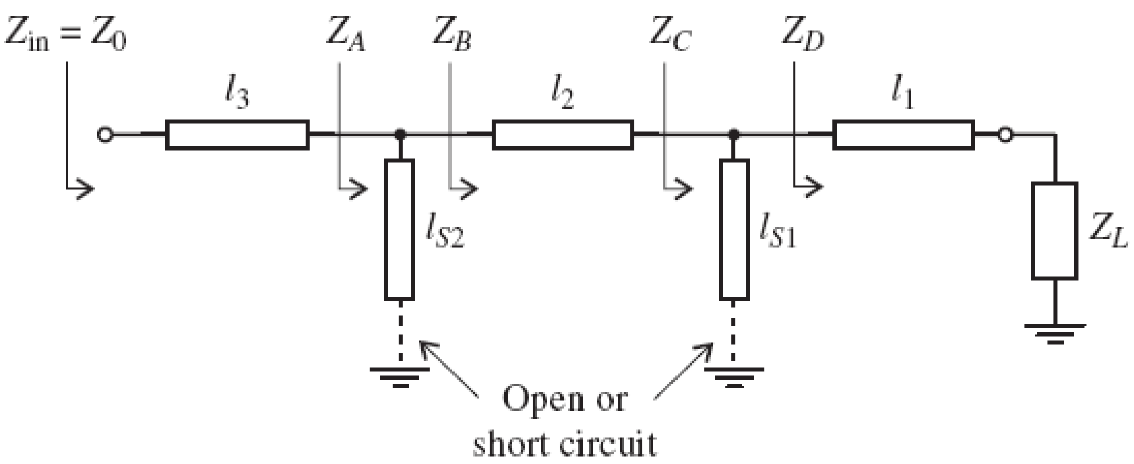
y_{in} to A towards generator (clockwise) gives length d_1 (first solution)

y_{in} to B towards generator (clockwise) gives length d_2 (second solution)



Double-stub Matching Networks

- The single-stub matching networks are quite versatile → allows matching between any input and load impedances, so long as they have a non-zero real part.
- Main drawback is the requirement of variable length TL between the stub and the input port or the stub and the stub and the load impedance → many a times problematic when variable impedance tuner is needed.
- In a double-stub matching networks, **two short- or open-circuited stubs are connected in shunt** with a fixed-length TL separating them → the usual separation is $\lambda/8$, $3\lambda/8$ or $5\lambda/8$.



Self Study