EMPossible

Electromagnetics:

Microwave Engineering

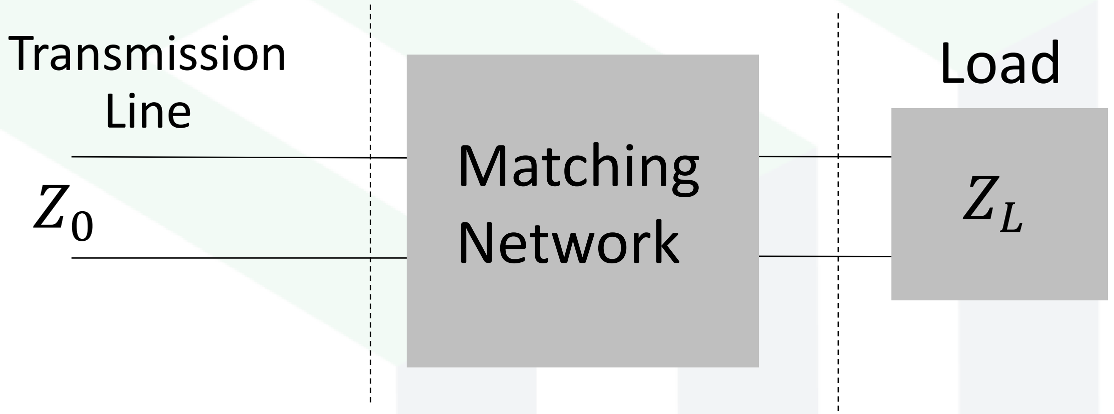
Impedance Matching Using Smith Charts

Lecture Outline

- Why use impedance matching?
- Two element impedance matching
- Example 1
- Single stub impedance matching
- Example 2

Why use impedance matching?

Why use impedance matching?

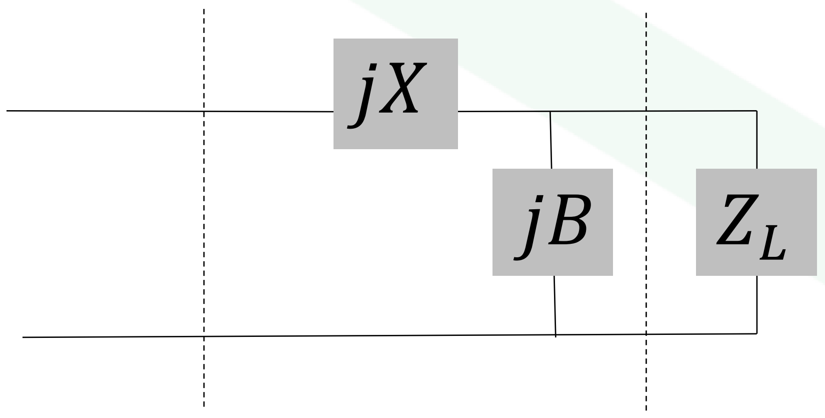


- Maximum power delivered
- Improved SNR
- Reduce amplitude and phase errors in power distribution networks
- Consider factors such as complexity, frequencies of operation, ease of implementation, and behavior with variable loads.

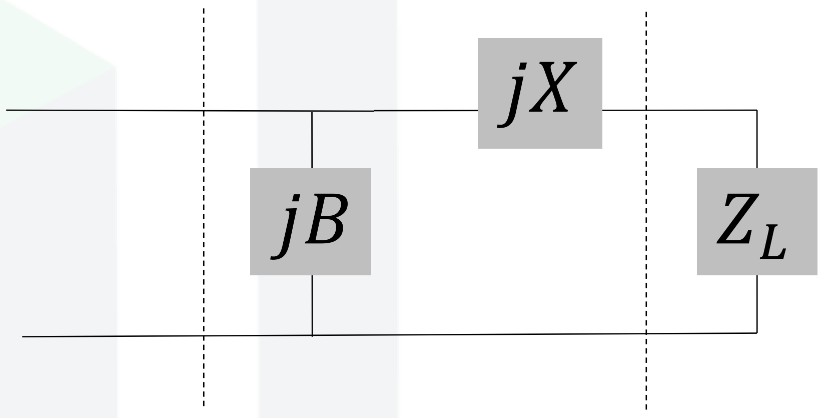
Two Element Impedance Matching

Two-Element Matching
L Network

The most common impedance matching circuit is the L network.



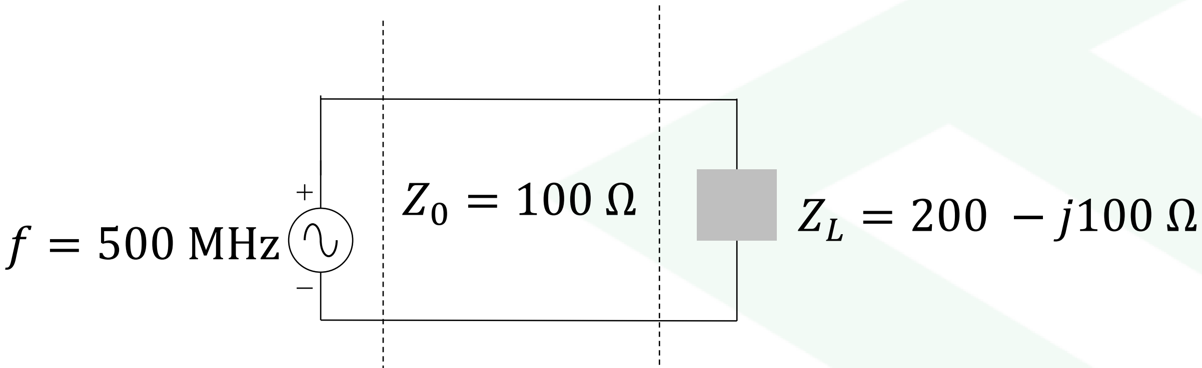
1. z_L inside $1 + jx$



2. z_L outside $1 + jx$

Example 1

Example 1 – L Network Impedance Matching

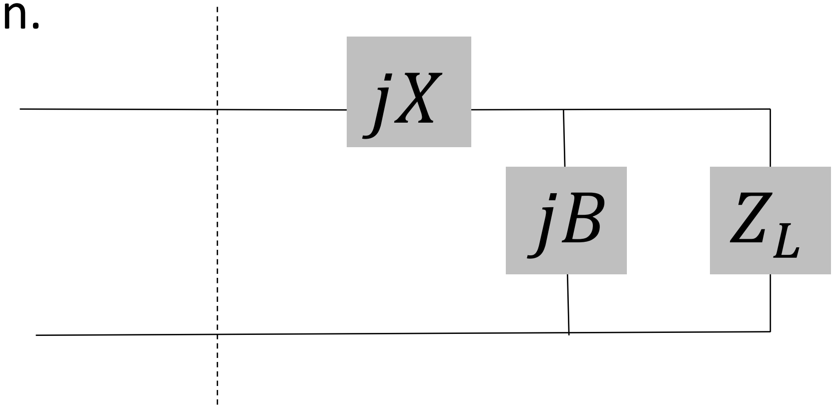


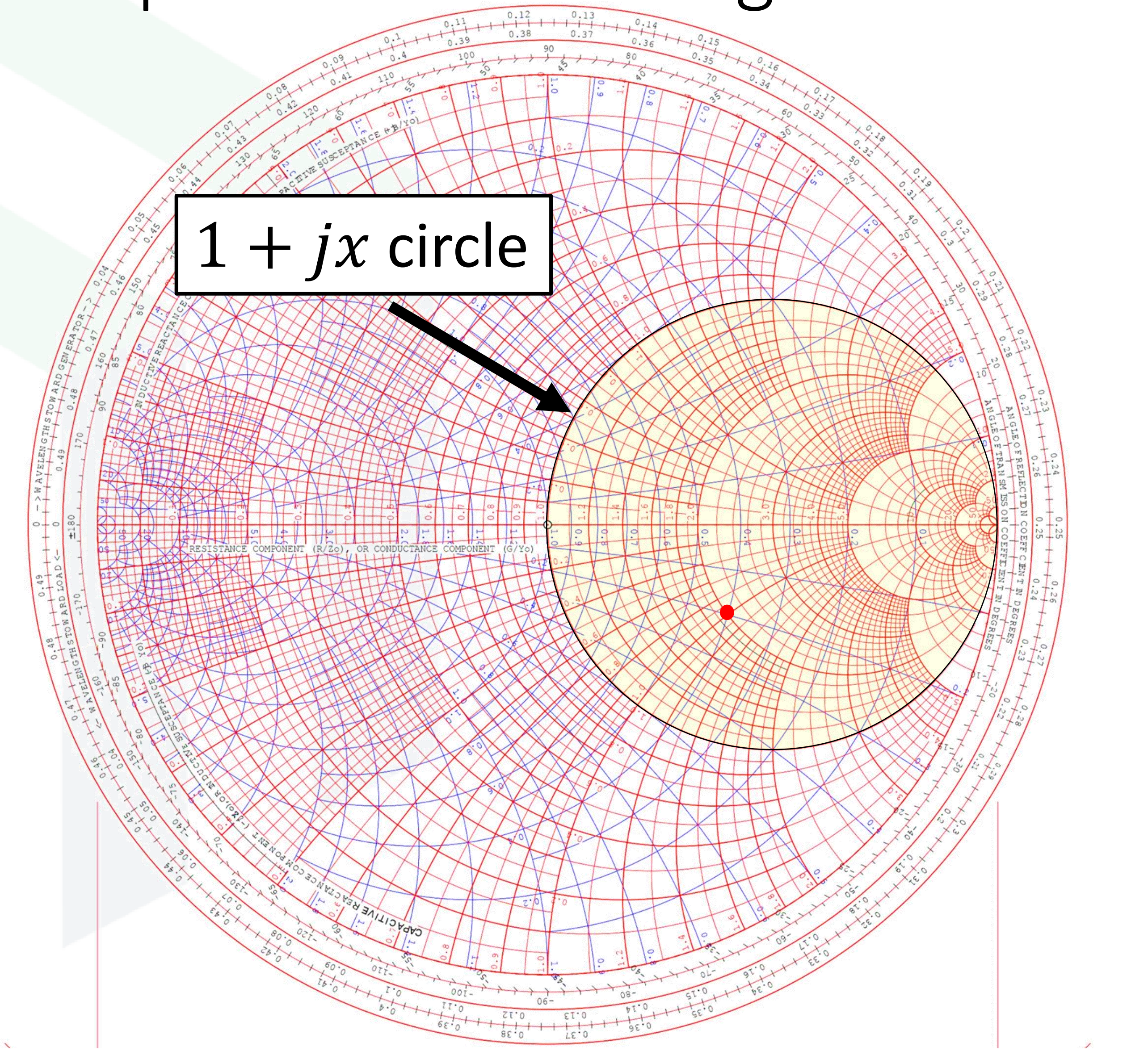
<u>Solution</u>

1. Normalize load impedance

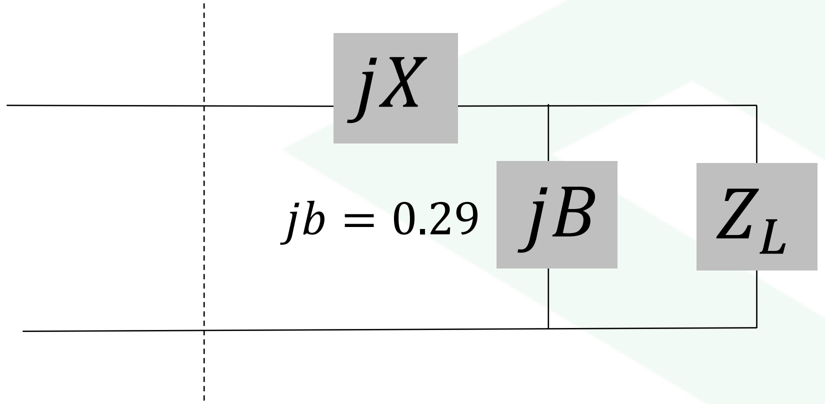
$$z_L = \frac{Z_L}{Z_0} = 2 - j1\ \Omega$$

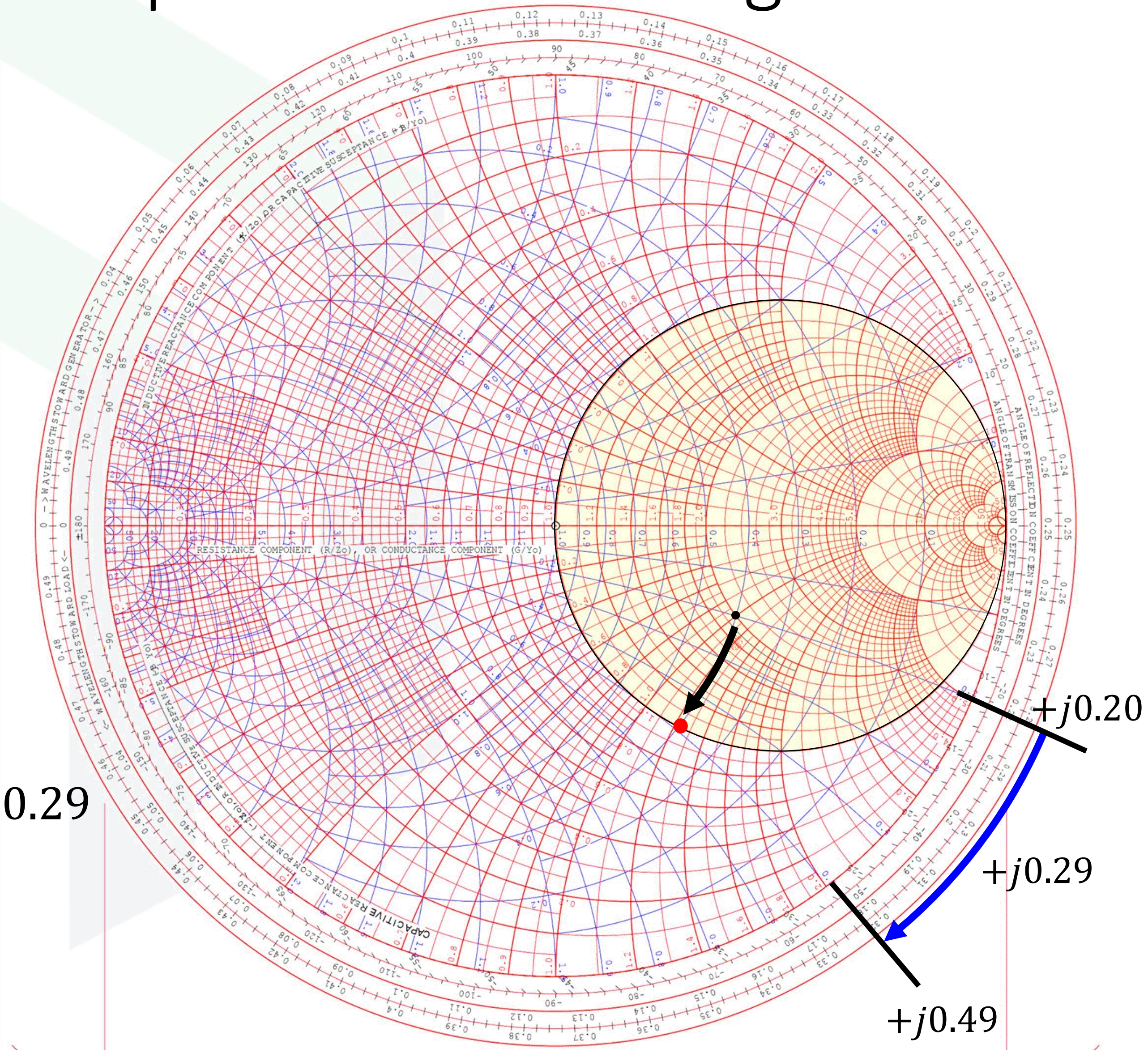
z_L is located inside the $1 + jx$ circle, so option 1 is chosen.





Example 1 – L Network Impedance Matching





Solution

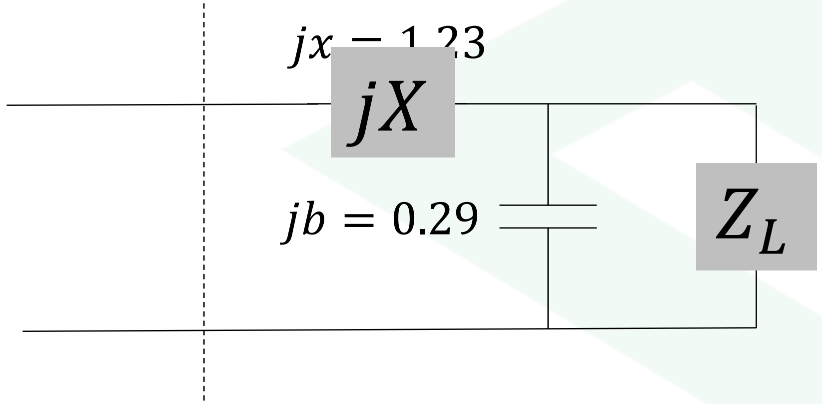
3. The admittance of z_L is

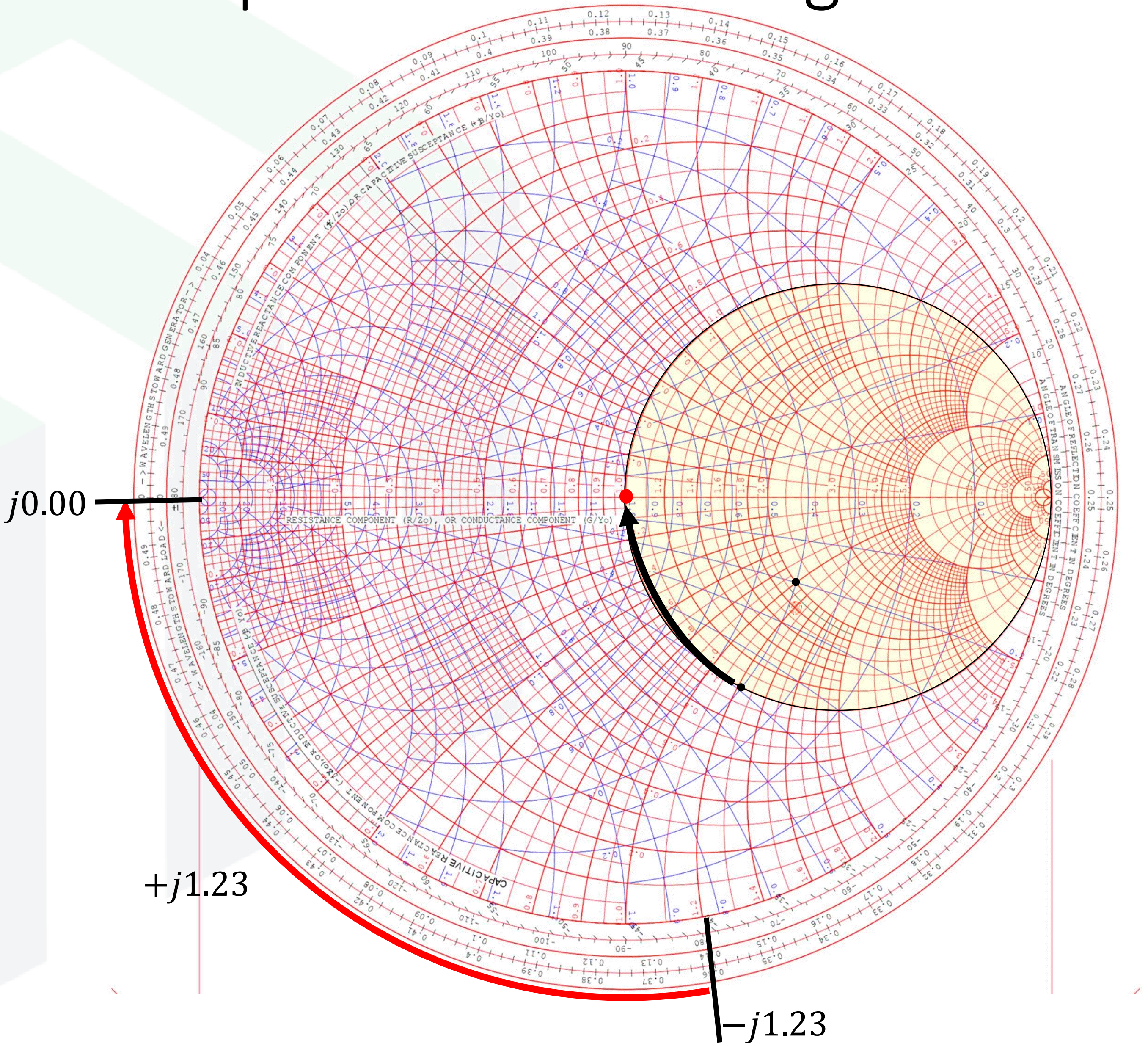
$$y_L = 0.4 - j0.2\ \Omega$$

since the first element is in parallel, we move along the ADMITTANCE circle to intersect the $1 + jx$ circle.

The element will be a shunt capacitor of value $jb = j0.29$

Example 1 – L Network Impedance Matching



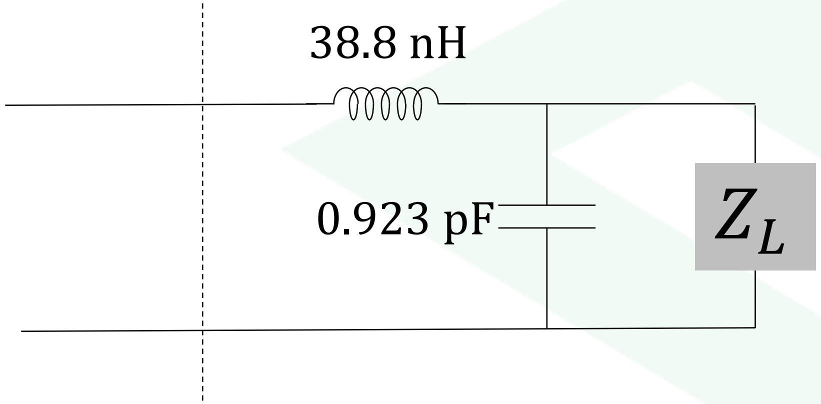


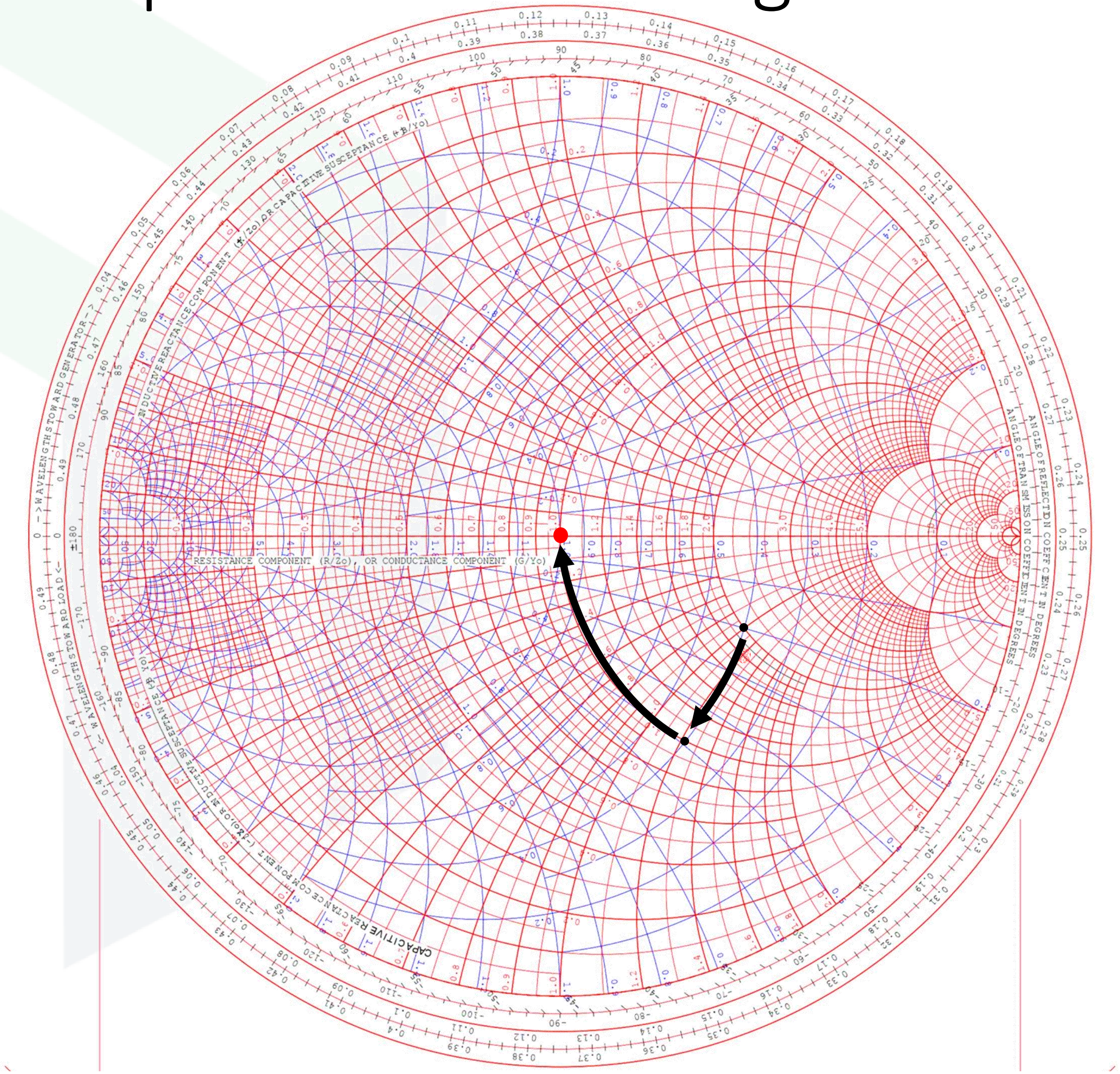
Solution

4. Now we move along the IMPEDANCE circle to the center of the chart.

The element will be a series inductor of value $jx = +j1.23$

Example 1 – L Network Impedance Matching





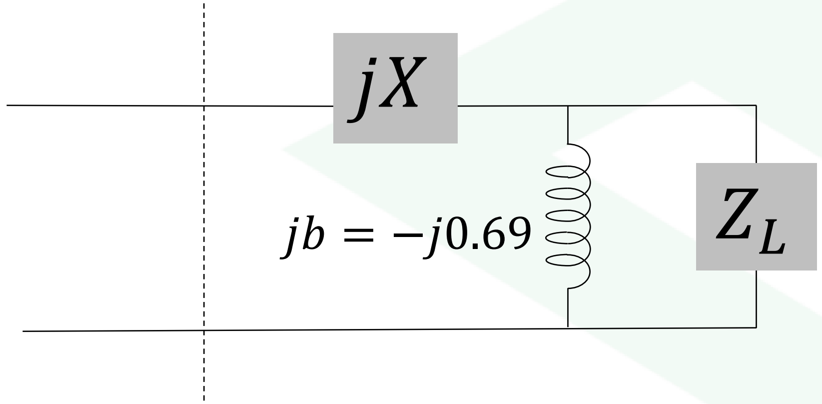
<u>Solution</u>

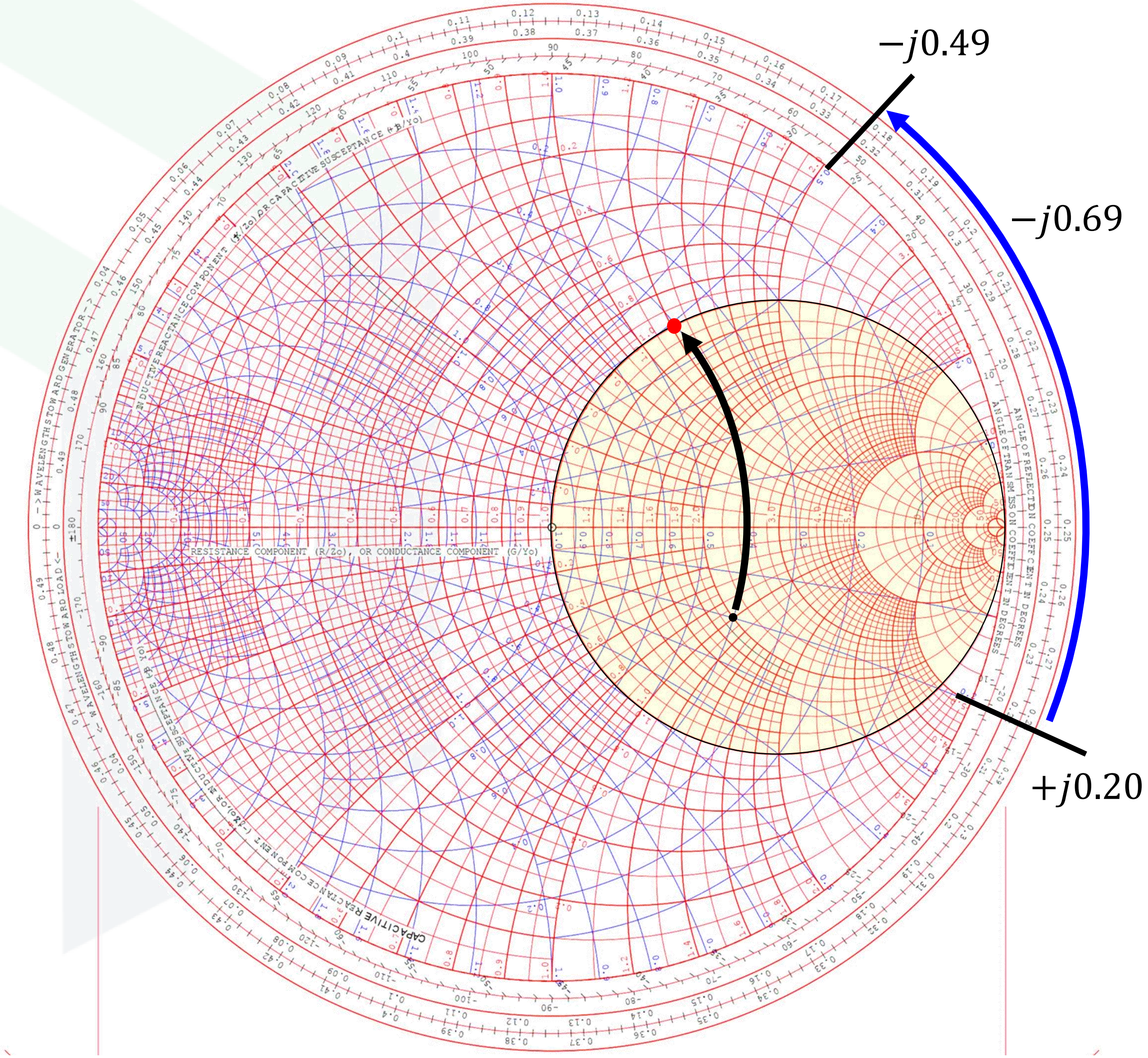
5. Now we obtain the values for the circuit elements:

$$C = \frac{b}{2\pi f Z_0} = 0.923\ \text{pF}$$

$$L = \frac{xZo}{2\pi f} = 39.15\ \text{nH}$$

Example 1 – Another Solution

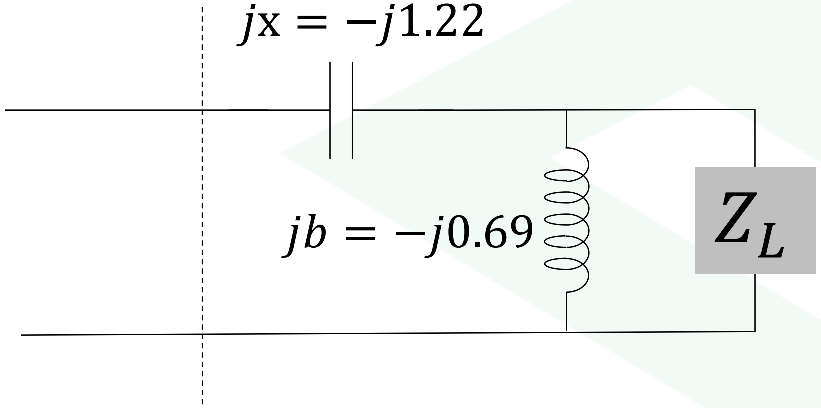


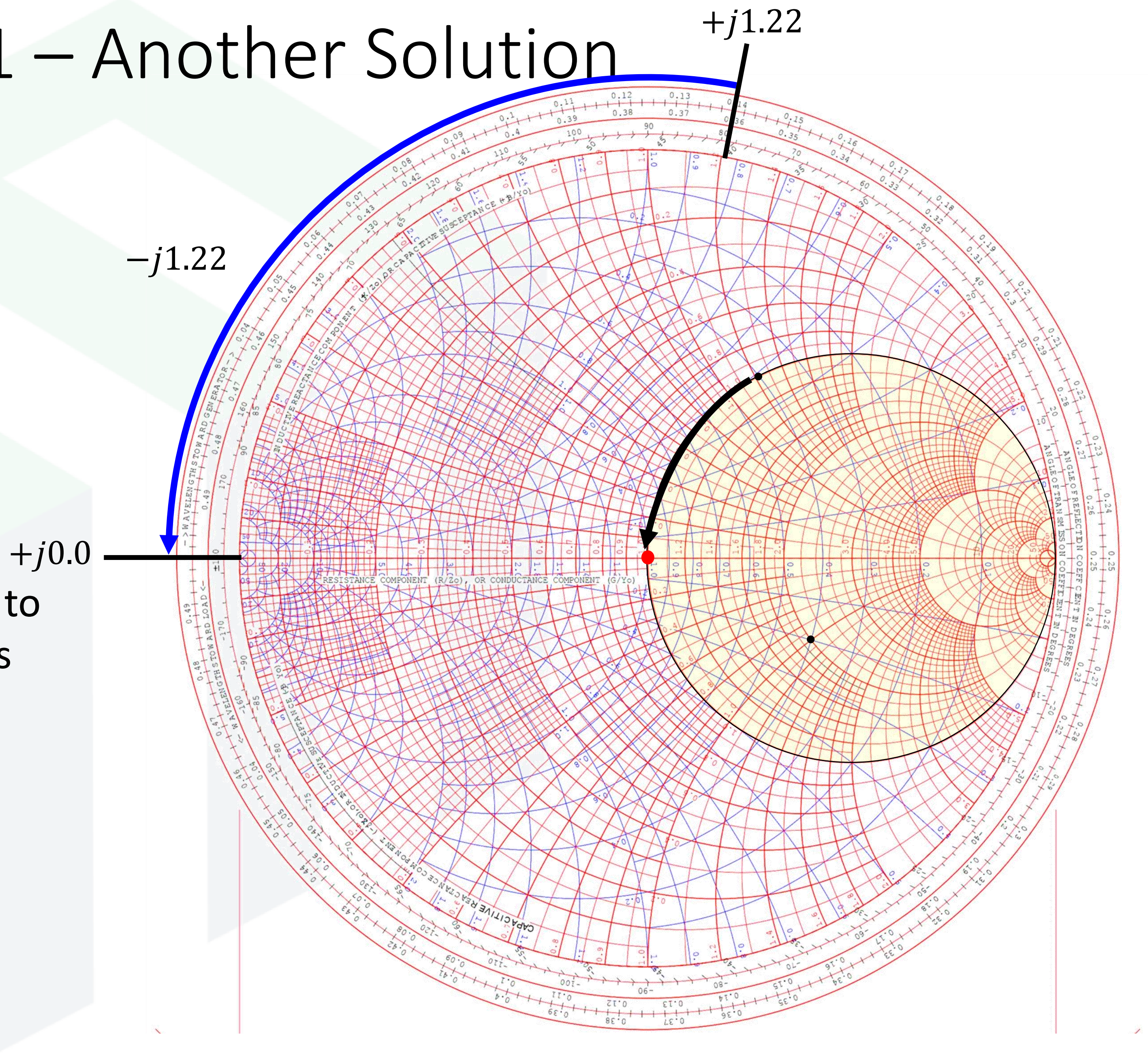


<u>Another Solution</u>

1. We can also walk along the ADMITTANCE circles in the other direction to intersect the $1 + jx$ circle. This will yield a shunt inductor with $jb = -j0.69$

Example 1 – Another Solution

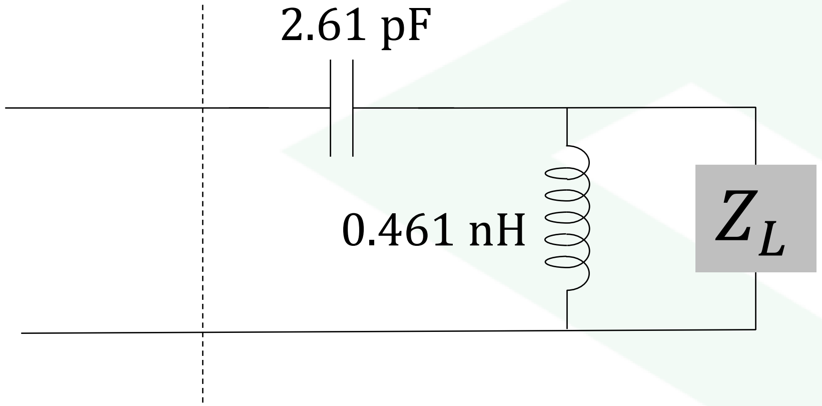


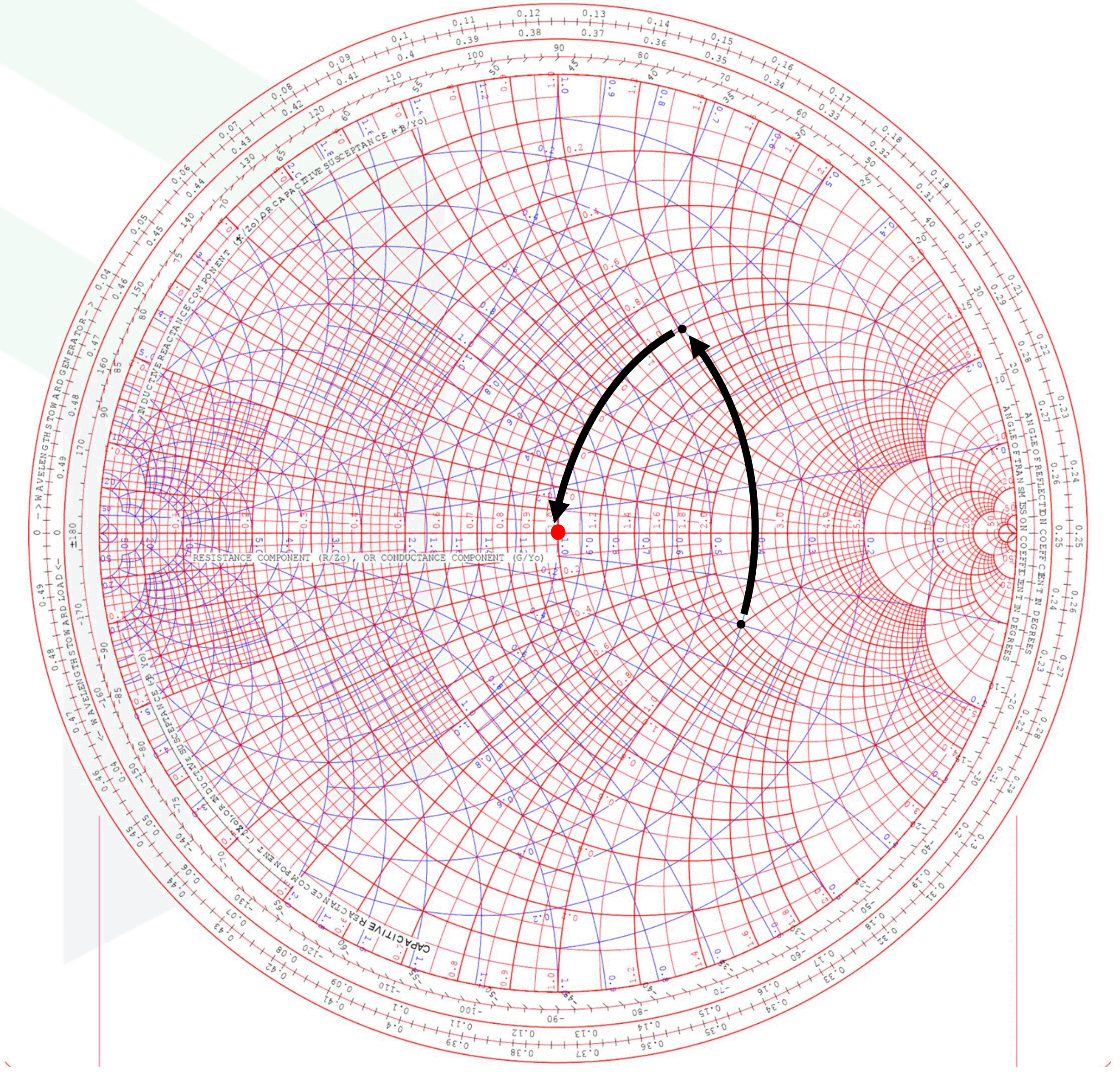


<u>Another Solution</u>

2. Now we walk along the IMPEDANCE circle to the center of the chart. This will yield a series capacitor with $jx = -1.22$

Example 1 – Another Solution





<u>Another Solution</u>

3. Now we obtain the values for the circuit elements:

$$C = \frac{-1}{2\pi f x Z_0} = 2.609 \text{ pF}$$

$$L = -\frac{Zo}{2\pi f b} = 46.13 \text{ nH}$$

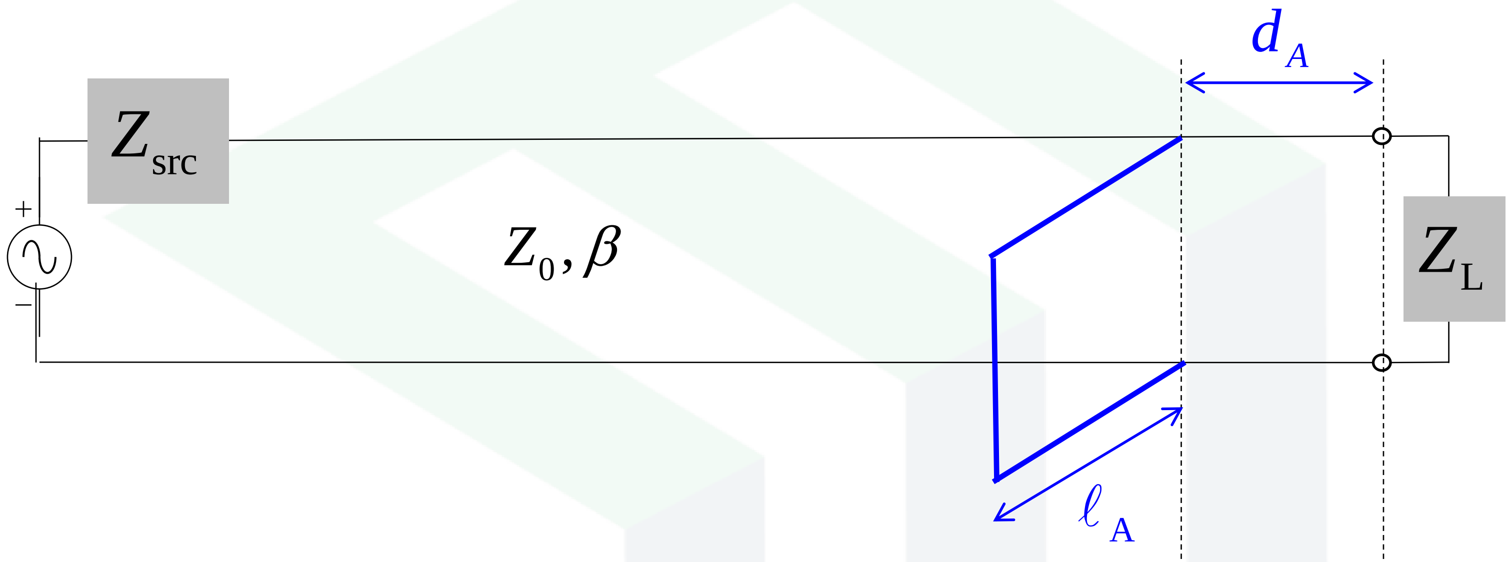
Single Stub Impedance Matching

What is Stub Tuning? (1 of 6)

Power is reflected due to an impedance mismatch.

$$\Gamma = \frac{Z_{\text{L}} - Z_0}{Z_{\text{L}} + Z_0}$$

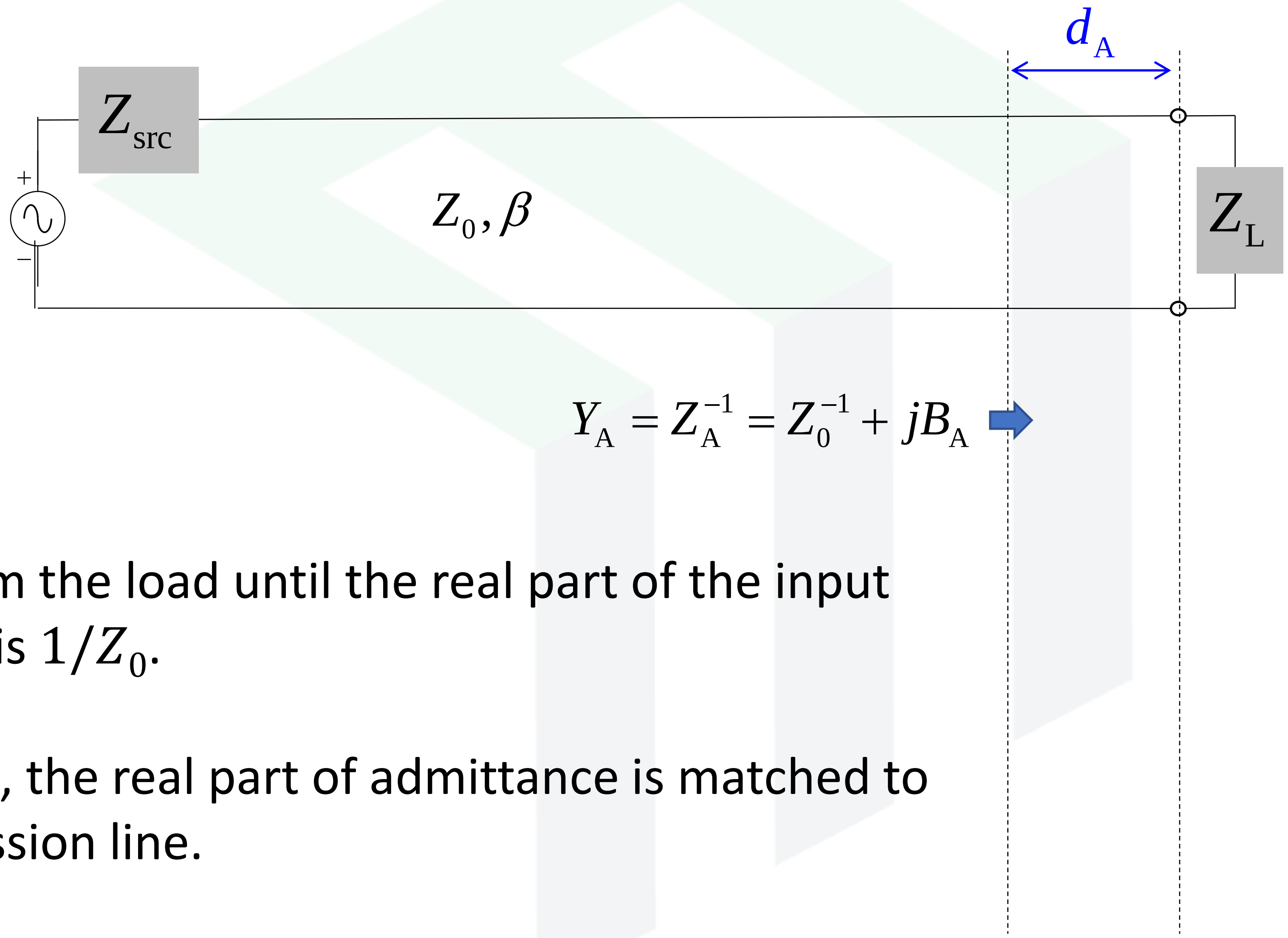
What is Stub Tuning? (2 of 6)



It is desired to add a short circuit stub to match the impedance.

$$\Gamma = 0$$

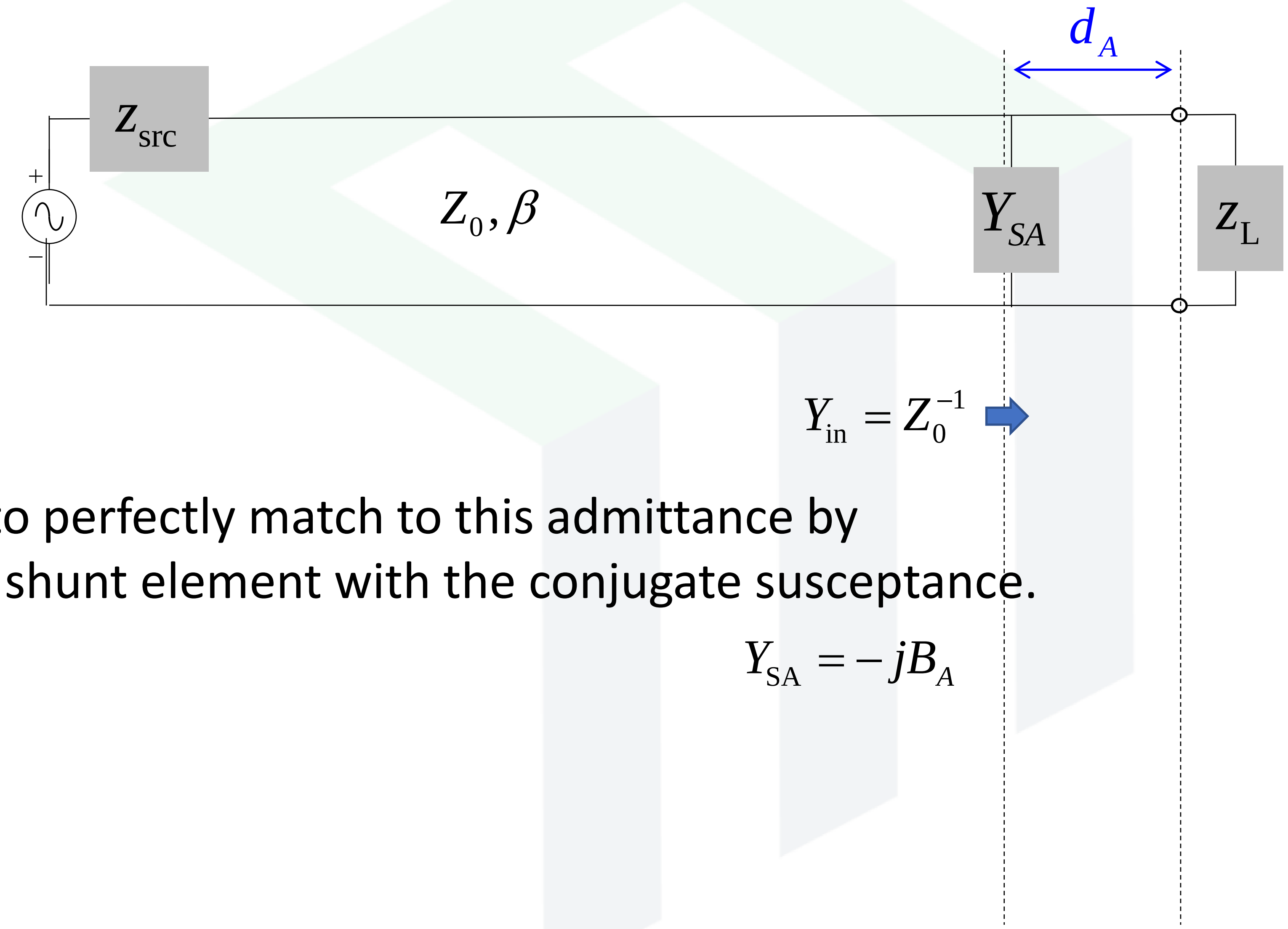
Stub Tuning Concept (3 of 6)



Back off from the load until the real part of the input admittance is $1/Z_0$.

At this point, the real part of admittance is matched to the transmission line.

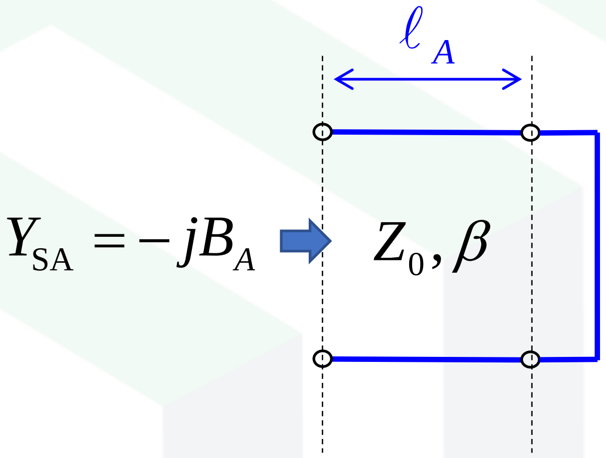
Stub Tuning Concept (4 of 6)



It is possible to perfectly match to this admittance by introducing a shunt element with the conjugate susceptance.

$$Y_{SA} = -jB_A$$

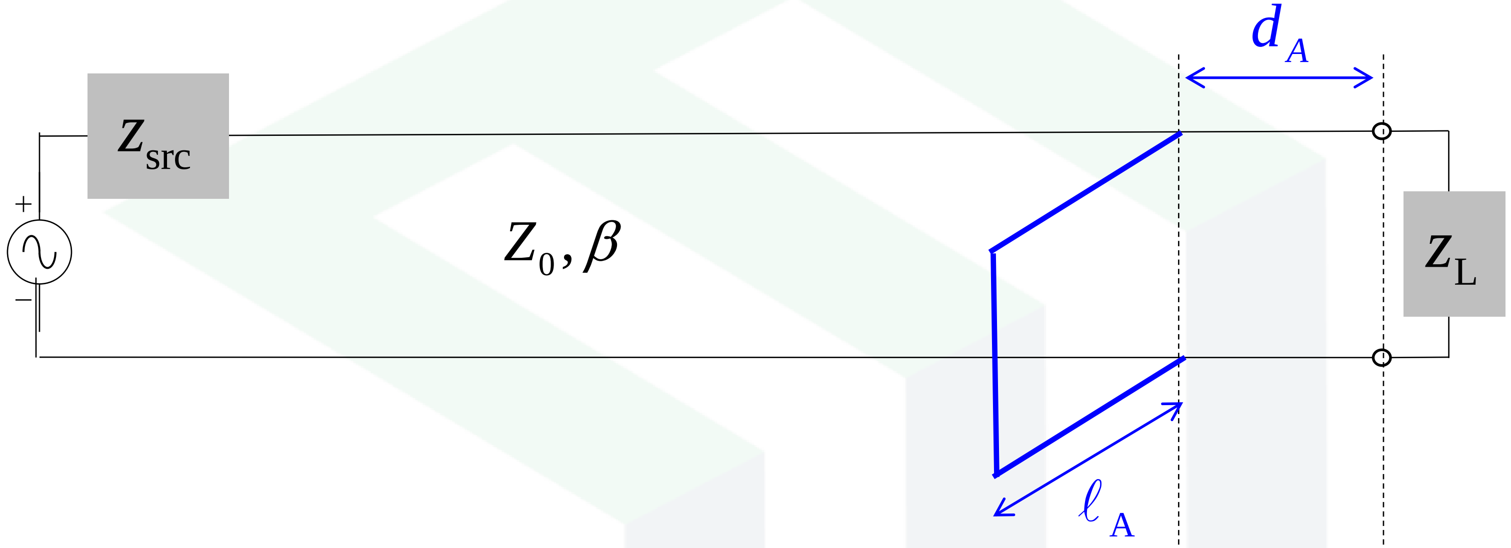
Stub Tuning Concept (5 of 6)



To realize this shunt susceptance with a short-circuit stub, back off some distance ℓ_{A} from a short circuit load until the input admittance is $-jB_{\mathrm{A}}$.

This is the stub.

Stub Tuning Concept (6 of 6)



Last, add the stub at position d_A from the load to cancel the susceptance of the load.

$Y_{\text{in}} = Z_0^{-1}$

The load is matched and there will be zero reflection!

Single-Stub Tuning
Example – Step 1

Problem:
A 50 Ω transmission line with an air-core operates at 100 MHz and is connected to a load impedance of $Z_L = 27.5 + j35\ \Omega$. Design a single-stub tuner.

Step 1 – Normalize impedance and calculate λ.

$$z_L = \frac{Z_L}{Z_0} = \frac{27.5 + j35\ \Omega}{50\ \Omega} = 0.55 + j0.7$$

$$\lambda = \frac{c_0}{nf} \cong \frac{3\times10^8\ \text{m/s}}{(1.0)\left(100\times10^6\ \text{Hz}\right)} = 3\ \text{m}$$

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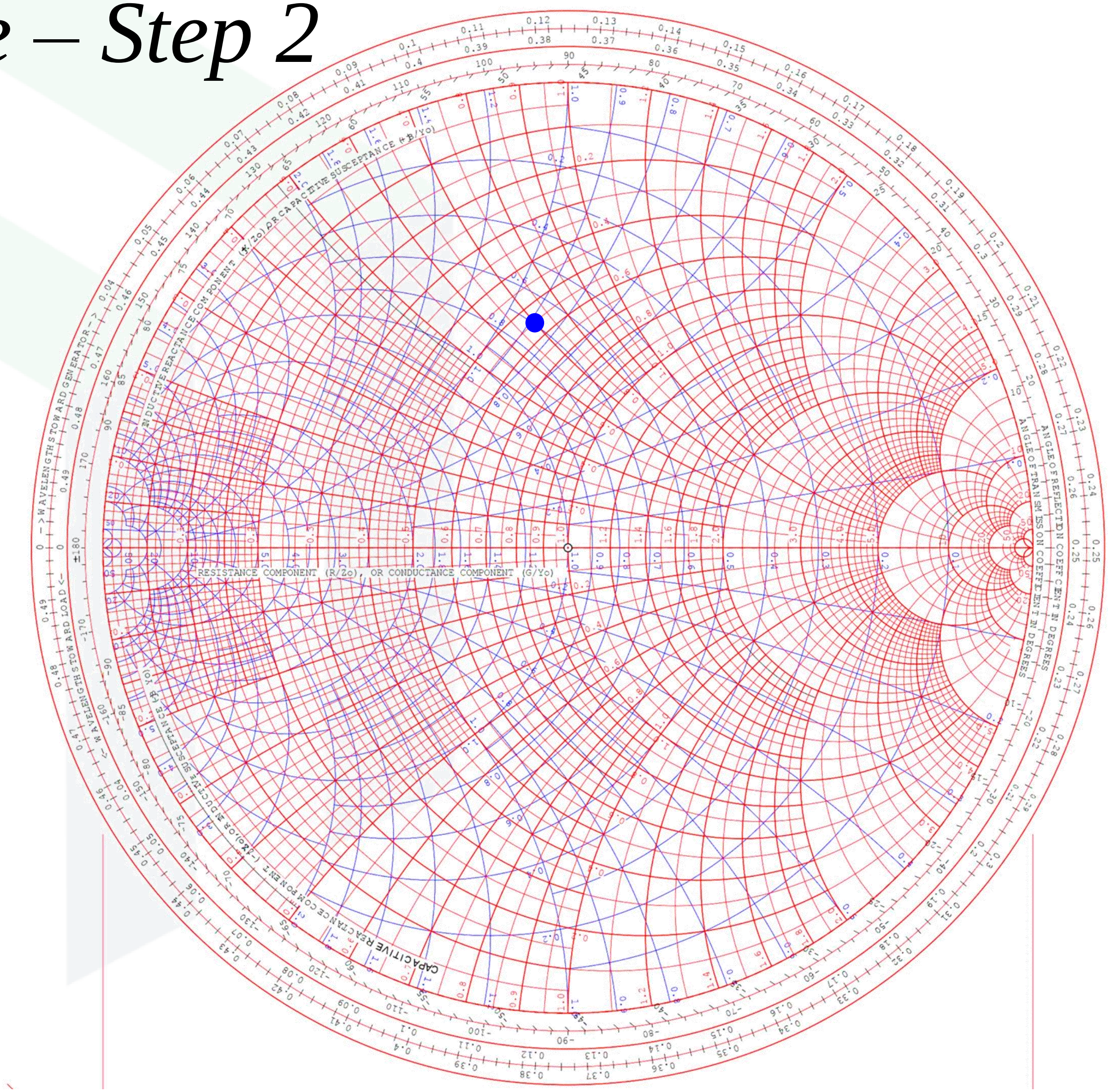
Single-Stub Tuning

Example – Step 2

Plot impedance and find admittance.

We read

$$z_L = 0.55 + j0.7\ \Omega$$
$$y_L \cong 0.70 - j0.88\ \Omega^{-1}$$



Single-Stub Tuning

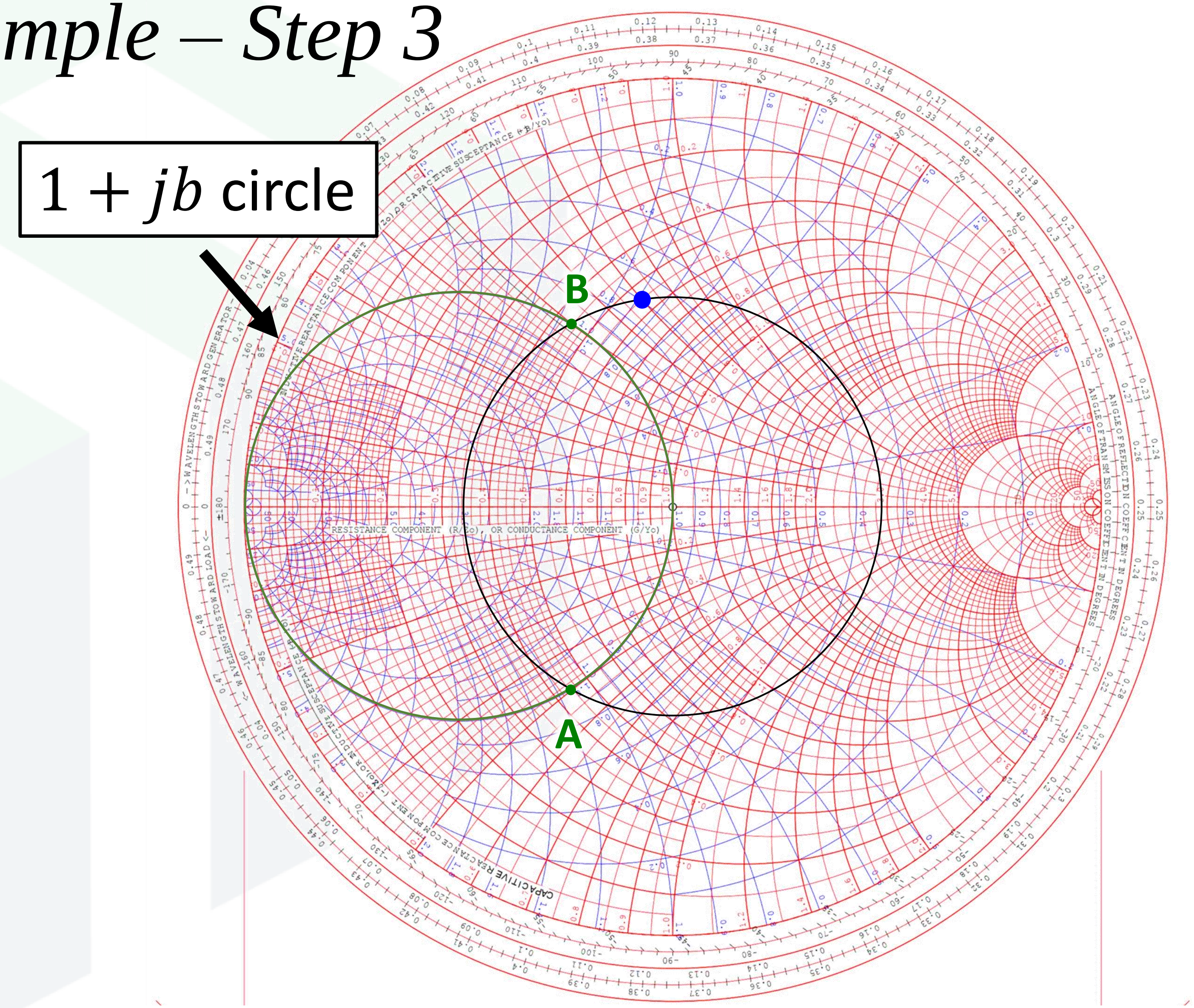
Example – Step 3

Walk CW around the constant VSWR circle until the $1 + jb$ circle intersects it.

We read

$$y_A \cong 1 + j1.1$$
$$y_B \cong 1 - j1.1$$

We will pick A because it leads to the shortest stub.

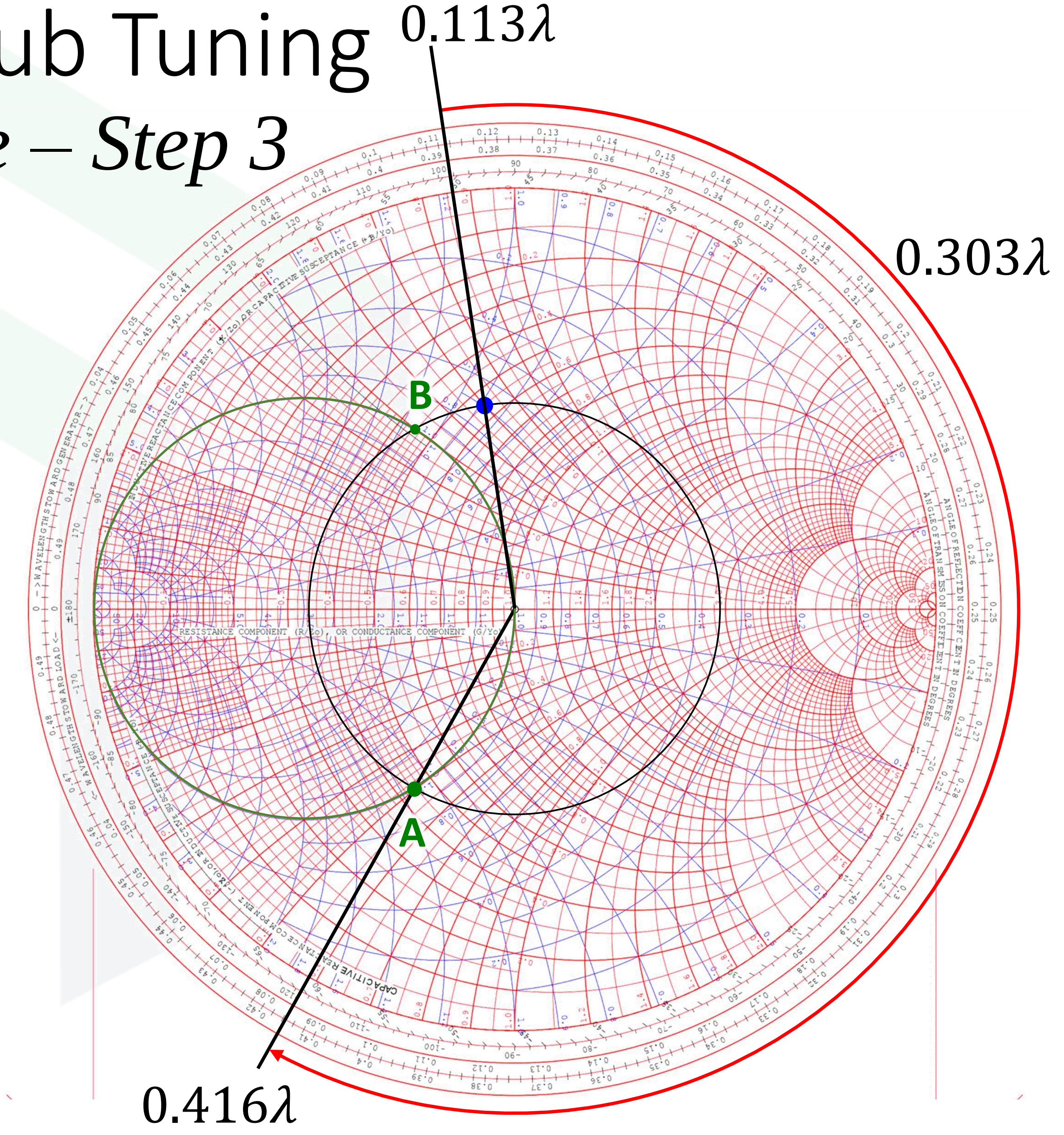


Single-Stub Tuning
Example – Step 3

How far CW did we traverse to get to A?

$$0.416\lambda - 0.113\lambda = 0.303\lambda$$

$$d_A \approx 0.303\lambda$$
$$d_A \approx 90.9 \text{ cm}$$



Single-Stub Tuning

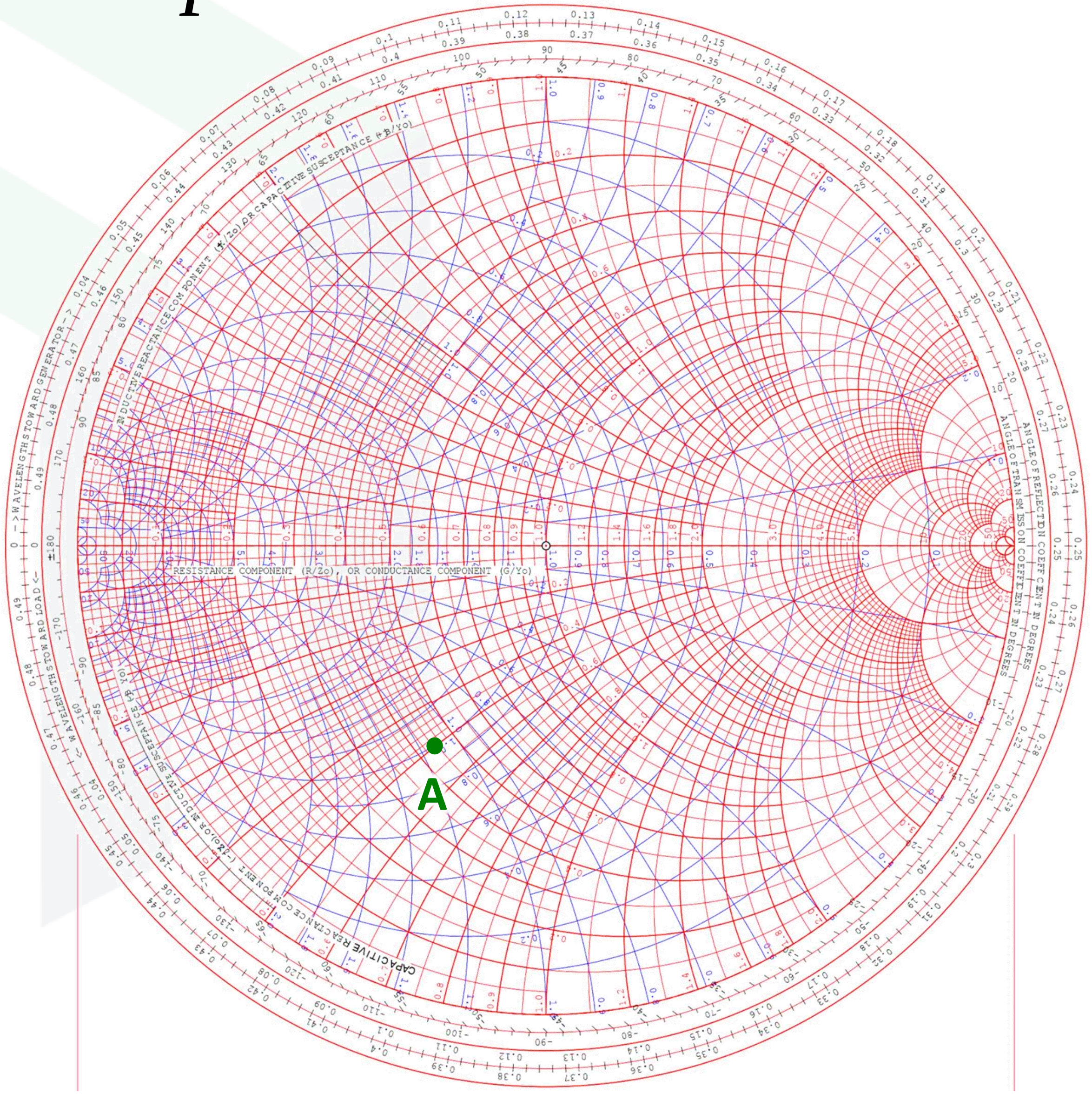
Example – Step 4

y_{A} is the admittance where the stub is about to be placed. We chose point A.

$$y_A \cong 1 + j1.1$$

$$y_{SA} = -j1.1$$

We need to cancel the reactive component χ_{A} of this.



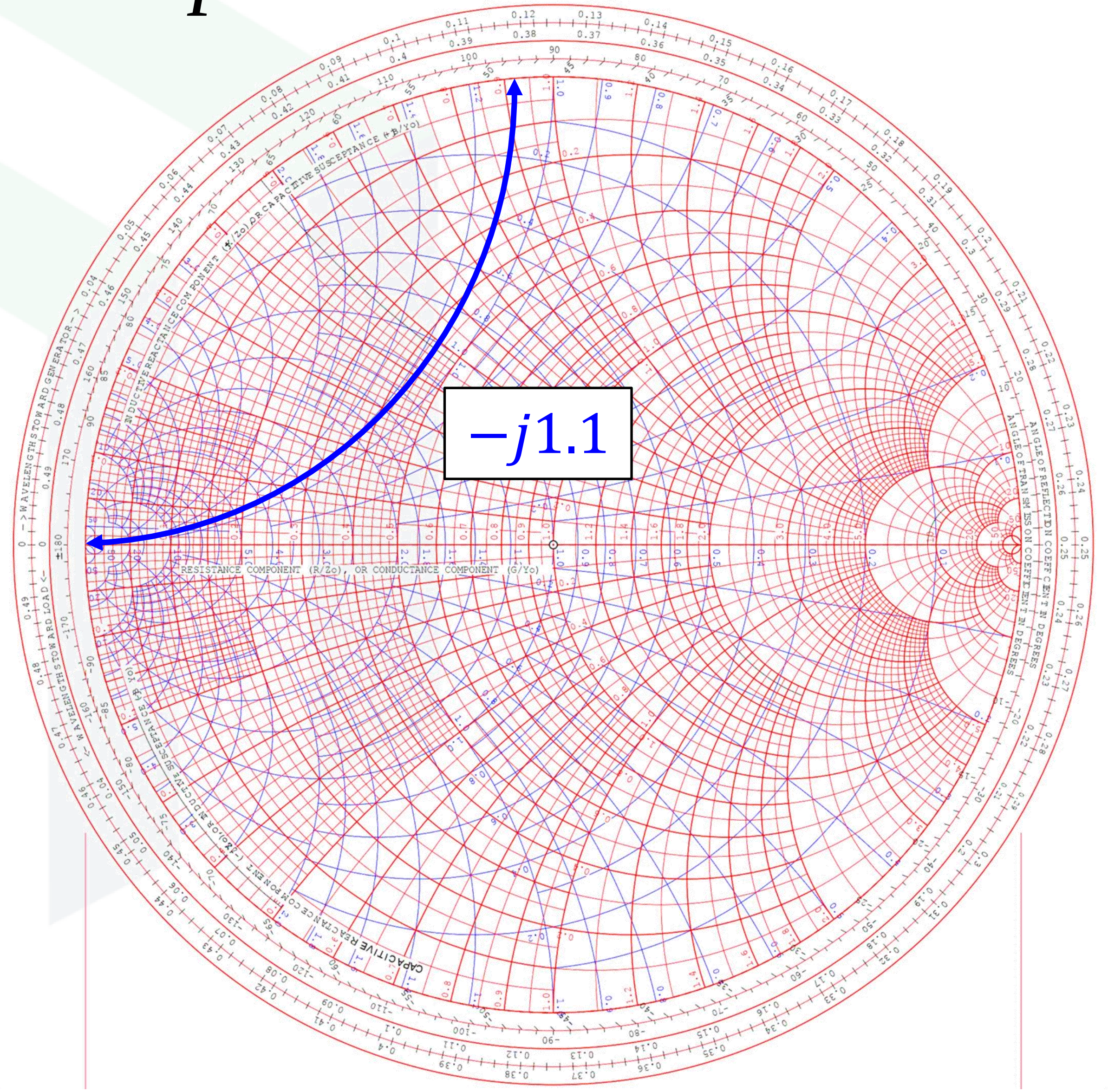
Single-Stub Tuning

Example – Step 5

Find the $-j\chi_{\text{A}}$ circle on the chart and follow it to the outside of the chart.

$$y_{SA} = -j1.1$$

We are setting up to do an admittance transformation in the stub to realize a $-j1.1$ input admittance.



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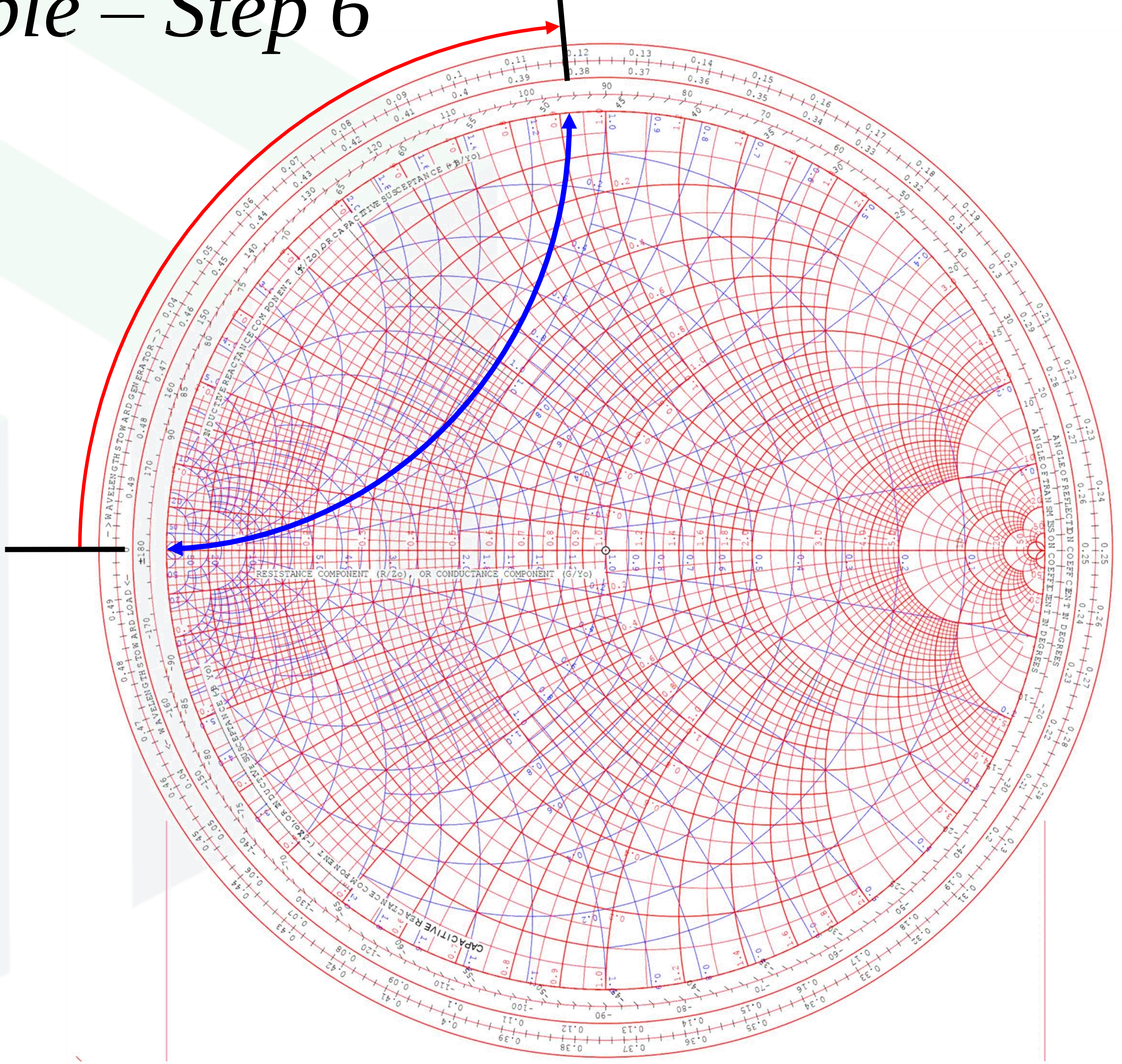
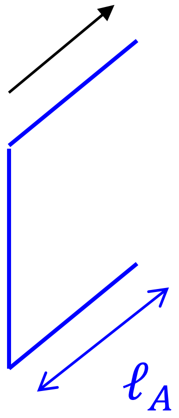
Single-Stub Tuning

Example – Step 6

Start at the far left side of the chart and move CW to the point above (move away from short).

Here we are doing an admittance transformation to realize $-j1.1$.





Single-Stub Tuning

Example – Step 7

Determine the distance (in wavelengths) this represents. This is l_{A}.

$$\ell_A = 0.118\lambda$$
$$\ell_A = 0.118(3\ \mathrm{m})$$
$$= 0.354\ \mathrm{m} = \boxed{35.4\ \mathrm{cm}}$$