Impedance Matching Circuits

(Part 1)

Dr. José Ernesto Rayas-Sánchez

Outline

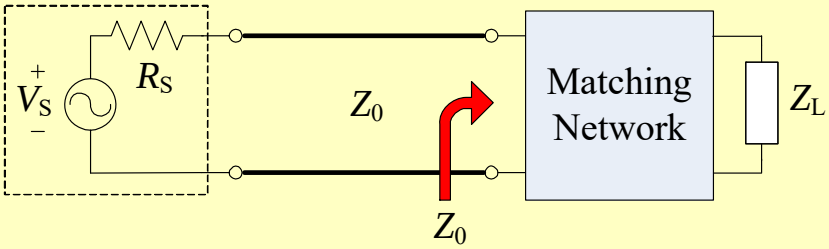
- Benefits of impedance matching
- Properties of an impedance matching network
- Techniques for impedance matching
- Matching with L-sections
- Example of matching with L-sections

Impedance Matching Benefits

- Maximum power delivered to the load (assuming the source is also matched)
- Power loss in the feeding line is minimized
- Reflections are eliminated on the feeding line
- Impedance matching sensitive loads (such as antennas, low-noise amplifiers, etc.) improve the signal-to-noise ratio of the system

Properties of an Impedance Matching Network

- Physical complexity
- Bandwidth
- Adjustability (to match a variable load impedance)

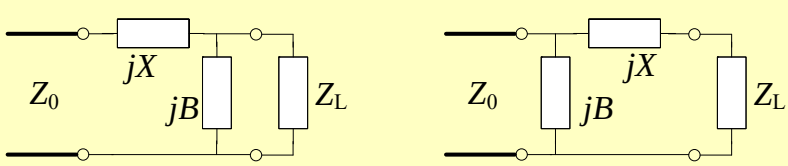


Techniques for Impedance Matching

- Matching with L-Sections (lumped elements)
- Single-stub tuning
- Double-stub tuning
- Multi-section impedance transformers
- Tapered lines

Matching with L-Sections

- Since it uses lumped elements, it is applicable only if the frequency is low enough or the circuit size is small enough
- Two possible L-Sections:



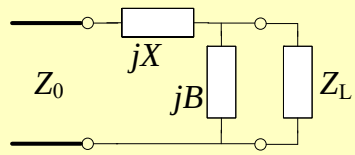
X: Reactance, B: Suceptance

If $X > 0$, X is an inductor; if $X < 0$, X is a capacitor

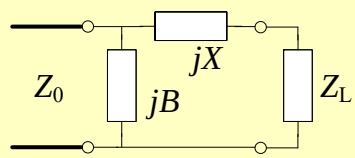
If $B > 0$, B is an capacitor; if $B < 0$, B is an inductor

Finding *X* and *B* in L-Sections

- Analytical solutions
- Smith-Chart solutions
- If $R_L > Z_0$ use:



- If $R_L < Z_0$ use:



$$Z_L = R_L + jX_L$$

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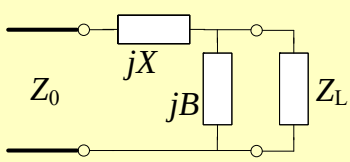
Analytical Solutions for L-Sections

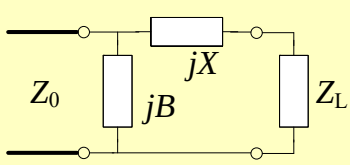
- If $R_L > Z_0$ use:



$$B = \frac{X_L \pm \sqrt{R_L / Z_0}\sqrt{X_L^2 - R_L Z_0 + R_L^2}}{X_L^2 + R_L^2}$$

$$X = (Z_0 / R_L)[B(R_L^2 + X_L^2) - X_L]$$

- If $R_L < Z_0$ use:



$$X = \pm\sqrt{R_L(Z_0 - R_L)} - X_L$$

$$B = \frac{X + X_L}{(X + X_L)^2 + R_L^2}$$

Each case yields 2 valid solutions

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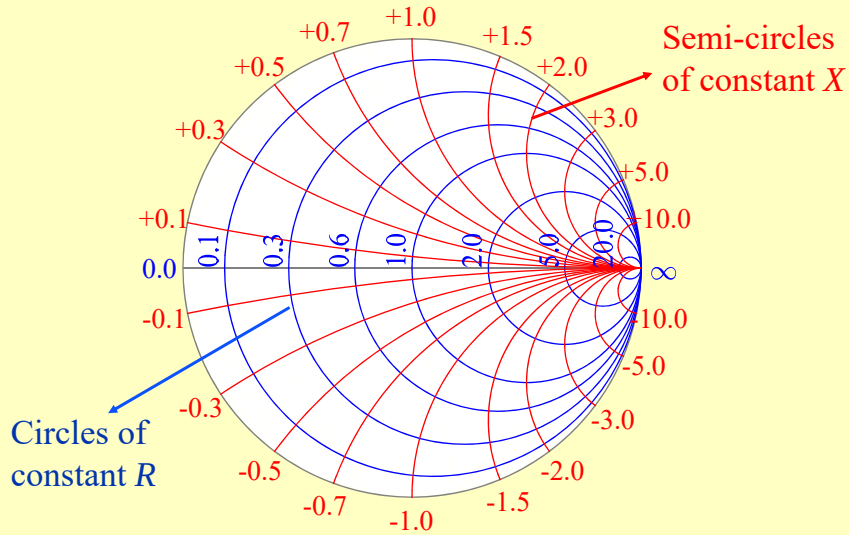
Smith Chart



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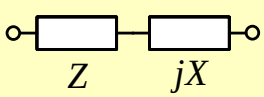
Smith Chart: Z in Series with jX – Example 1



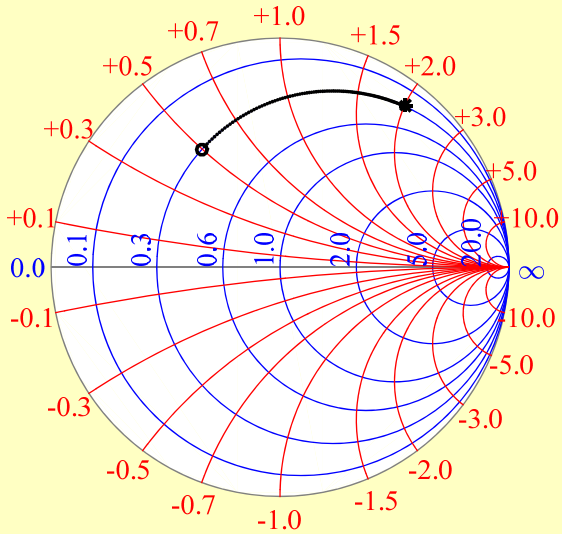
Example 1:

$Z = (15 + j25)\ \Omega$

$X = 75\ \Omega$

$Z_{eq} = (15 + j100)\ \Omega$

$Z_0 = 50\ \Omega$



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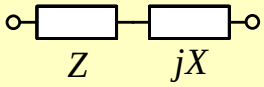
Smith Chart: Z in Series with jX – Example 2

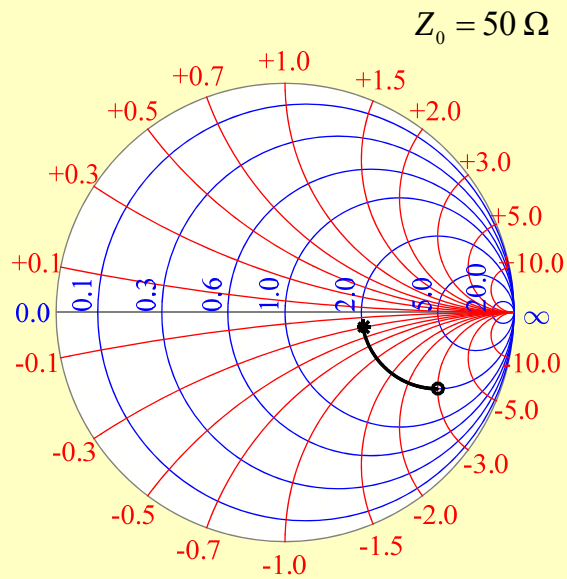


Example 2:

$Z = (100 - j150)\ \Omega$

$X = 135\ \Omega$

$Z_{eq} = (100 - j15)\ \Omega$



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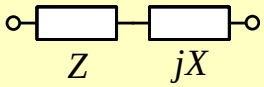
Smith Chart: Z in Series with jX – Example 3

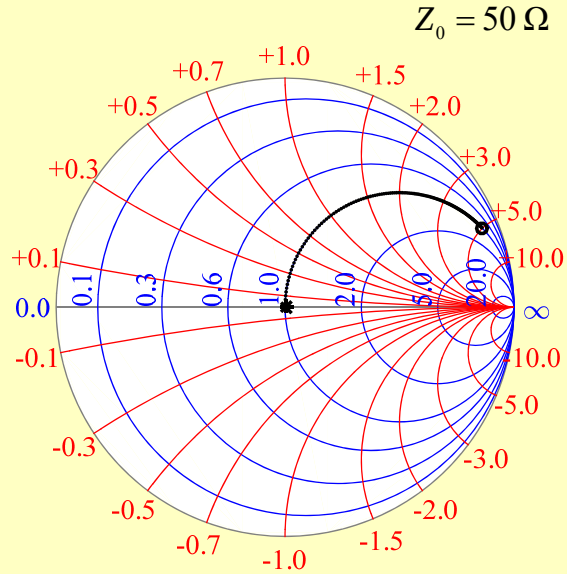


Example 3:

$Z = (50 + j250)\ \Omega$

$X = -250\ \Omega$

$Z_{eq} = 50\ \Omega$



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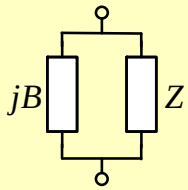
Smith Chart: Z in Parallel with jB – Example 1



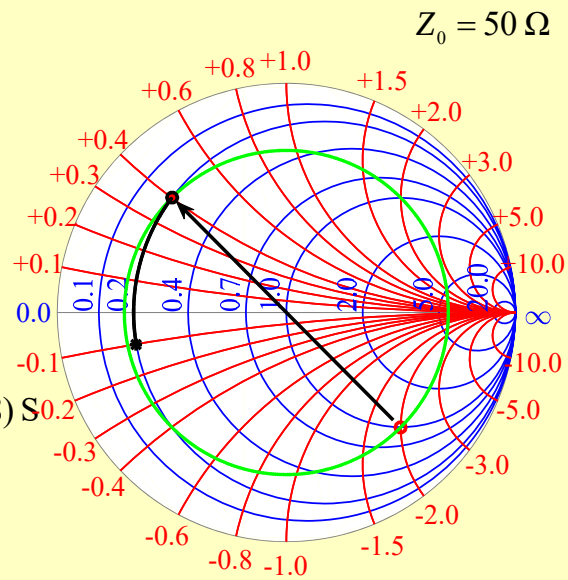
Example 1:

$Z = (50 - j100)\ \Omega$

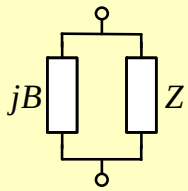
$B = -0.01\ \text{S}$

$Y = Z^{-1} = (0.004 + j0.008)\ \text{S}$

$Y_{eq} = (0.004 - j0.002)\ \text{S}$



Smith Chart: Z in Parallel with jB – Example 2



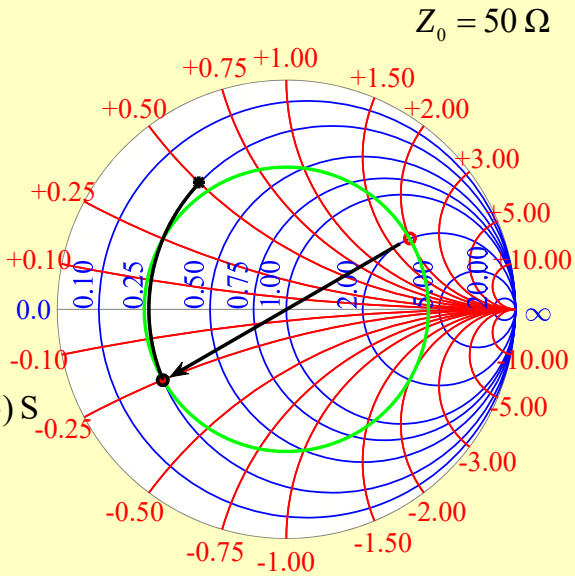
Example 2:

$Z = (100 + j100)\ \Omega$

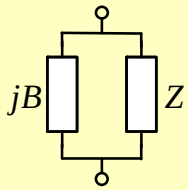
$B = 0.015\ \text{S}$

$Y = Z^{-1} = (0.005 - j0.005)\ \text{S}$

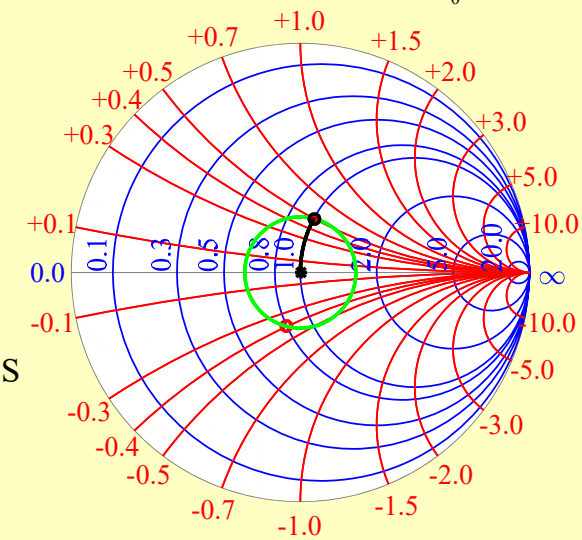
$Y_{eq} = (0.005 + j0.01)\ \text{S}$



Smith Chart: Z in Parallel with jB – Example 3



$Z_0 = 50\ \Omega$



Example 3:

$Z = (40 - j20)\ \Omega$

$B = -0.01\ \text{S}$

$Y = Z^{-1} = (0.02 + j0.01)\ \text{S}$

$Y_{\text{eq}} = 0.02\ \text{S}$

Matching with L-Sections – Example 1

Find a matching network for a 100-Ω system at 500 MHz to match a load consisting of a 200-Ω resistor in series with a 3.18-pF capacitor.

$$Z_{\text{L}} = R_{\text{L}} + \frac{1}{j2\pi f C_{\text{L}}} = (200 - j100)\ \Omega$$

$$Z_0 = 100\ \Omega$$

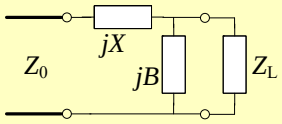
$$z_{\text{L}} = \frac{Z_{\text{L}}}{Z_0} = 2 - j$$

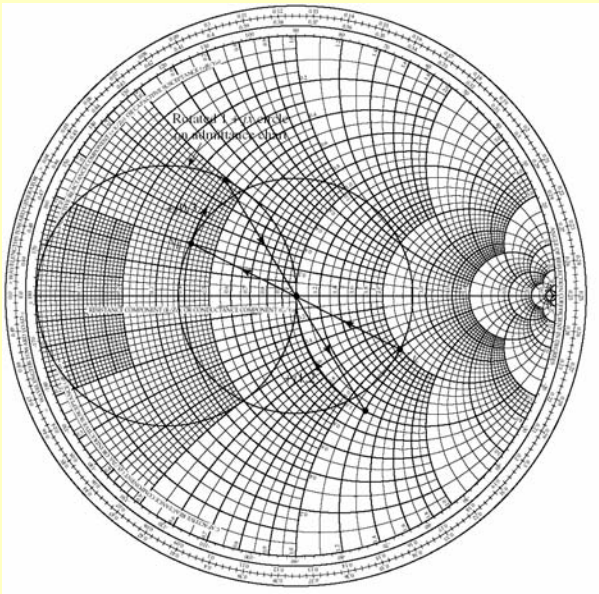
(D. M. Pozar, Microwave Engineering, Wiley, 2005)

Matching with L-Sections – Example 1 (cont.)

$$z_L = \frac{Z_L}{Z_0} = 2 - j$$

z_L is inside the circle $1+jx$, then we use:





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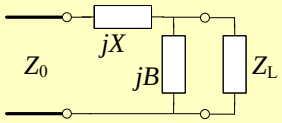
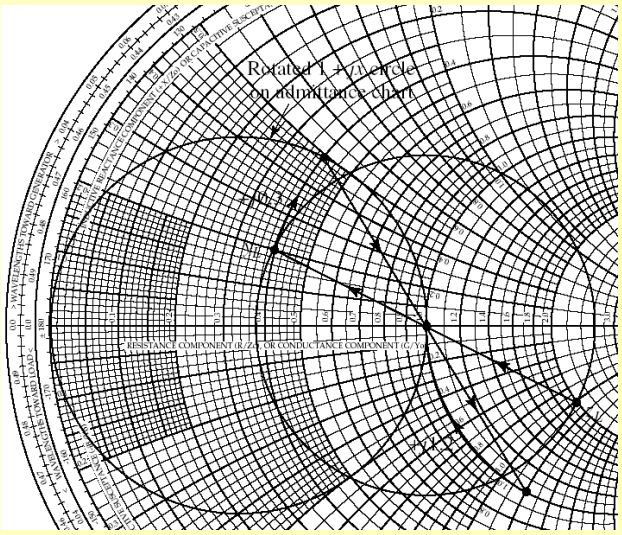


$$jb = +j0.29$$
$$jx = +j1.22$$
$$B = b / Z_0 = 0.0029 \text{ S}$$
$$X = (1.22) Z_0 = 122\ \Omega$$



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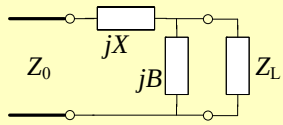
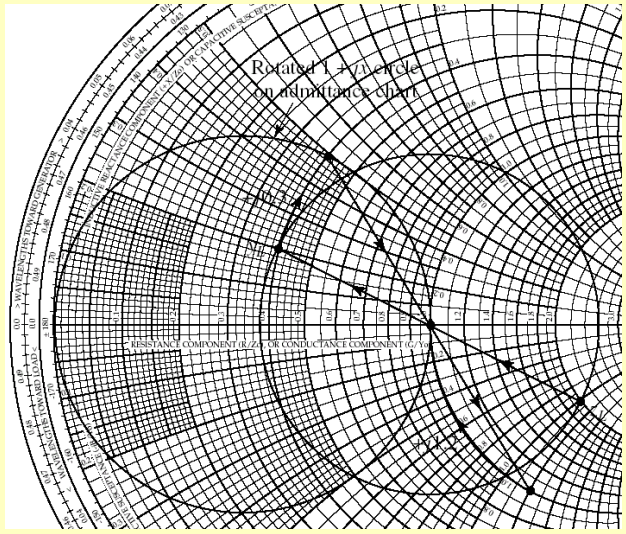


$$B = 0.0029\ \text{S}$$

$$X = 122\ \Omega$$

$$C_B = \frac{B}{2\pi f} = 0.92\text{pF}$$

$$L_X = \frac{X}{2\pi f} = 38.8\text{nH}$$



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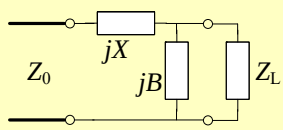
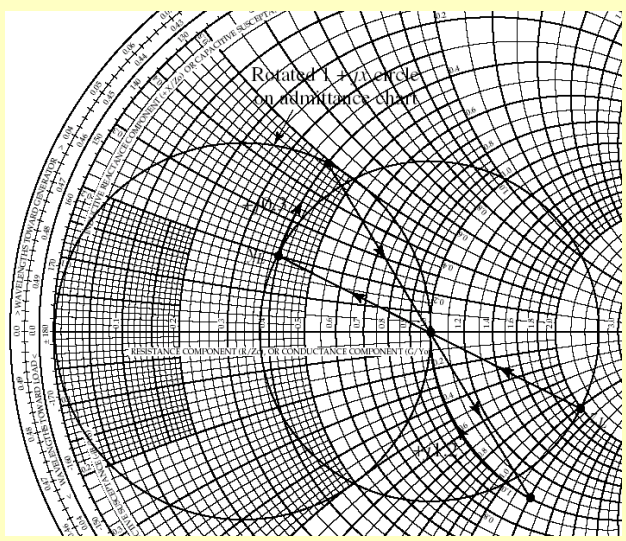


Second solution:

$$jb = -j0.69$$
$$jx = -j1.22$$

$$L_B = \frac{-1}{2\pi f B} = 46.1\text{nH}$$

$$C_X = \frac{-1}{2\pi f X} = 2.61\text{pF}$$



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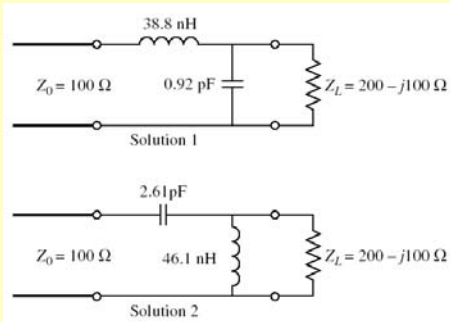
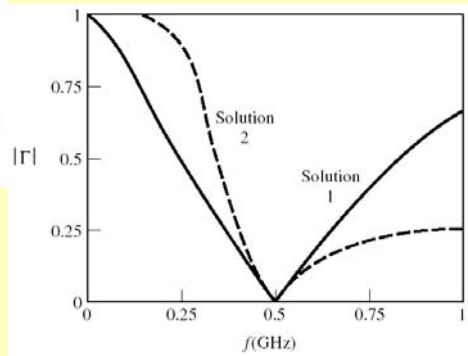
Matching with L-Sections – Example 1 (cont.)

Two solutions:





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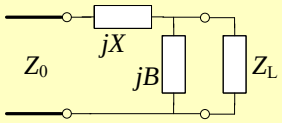
Matching with L-Sections – Example 1 (cont.)

$$z_L = \frac{Z_L}{Z_0} = 2 - j$$

z_L is inside the circle $1+jx$, then we use:



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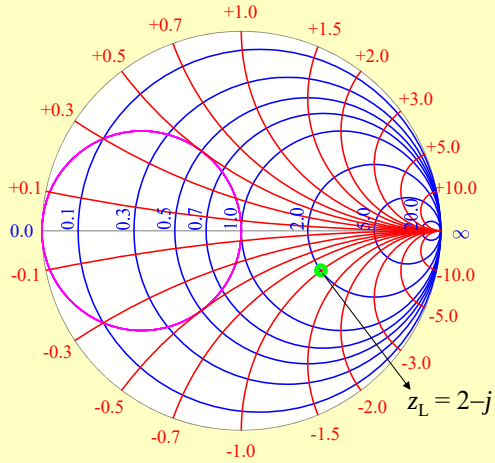

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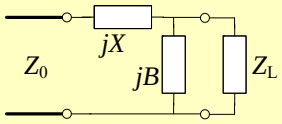

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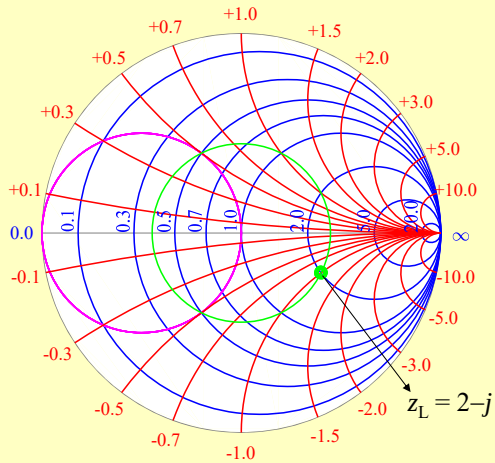

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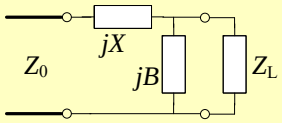

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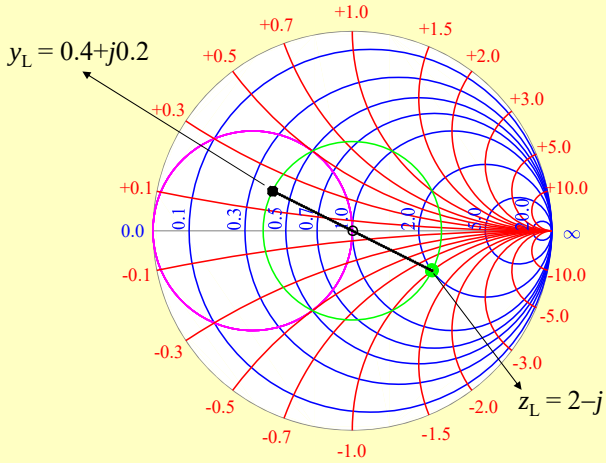

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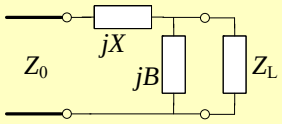

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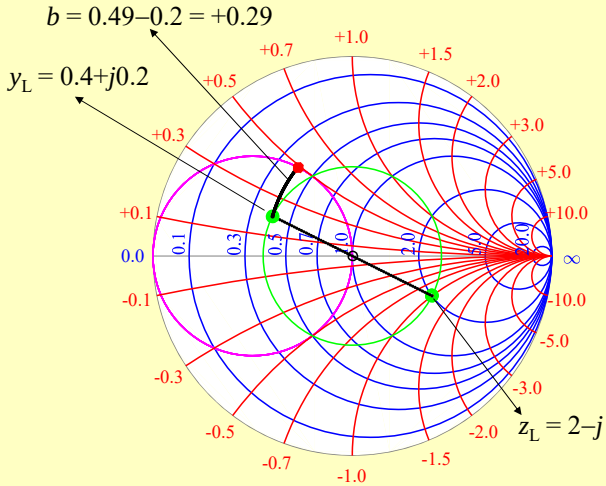

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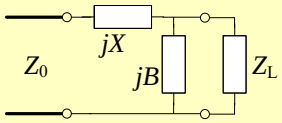

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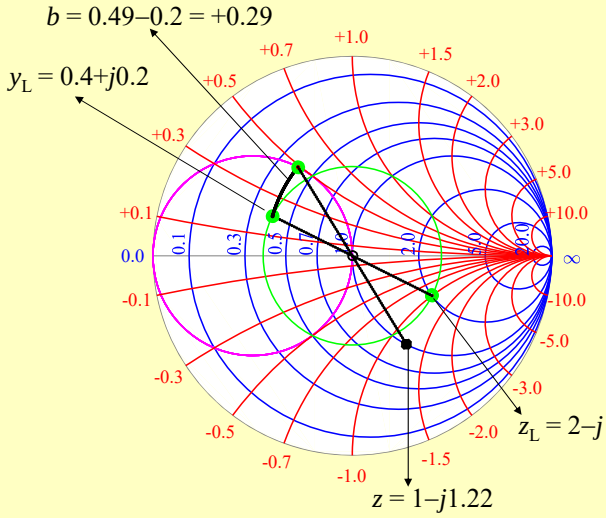

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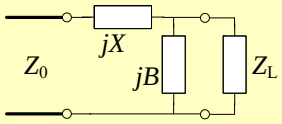

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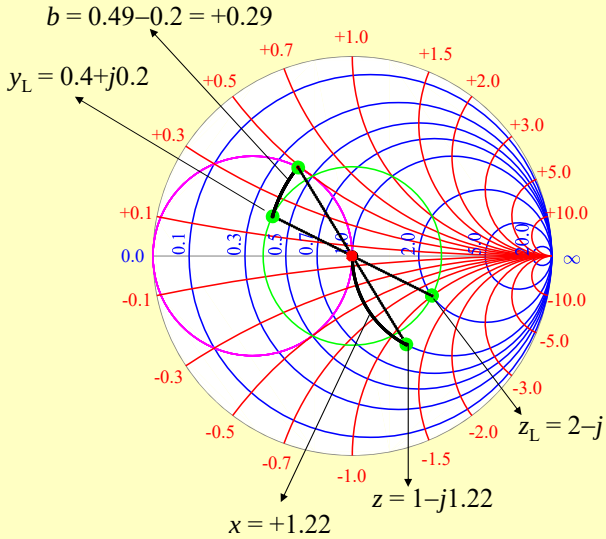

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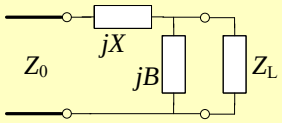

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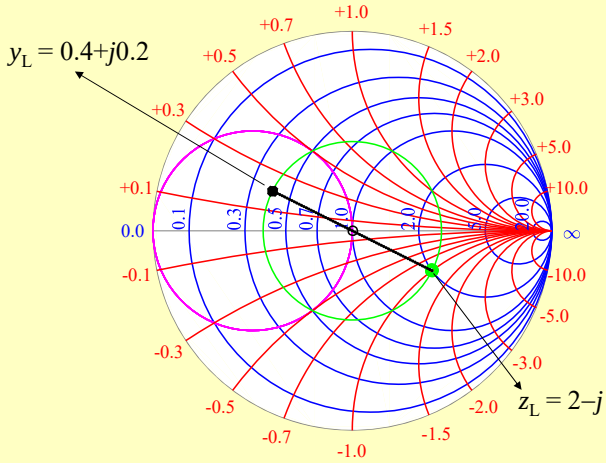

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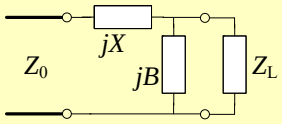

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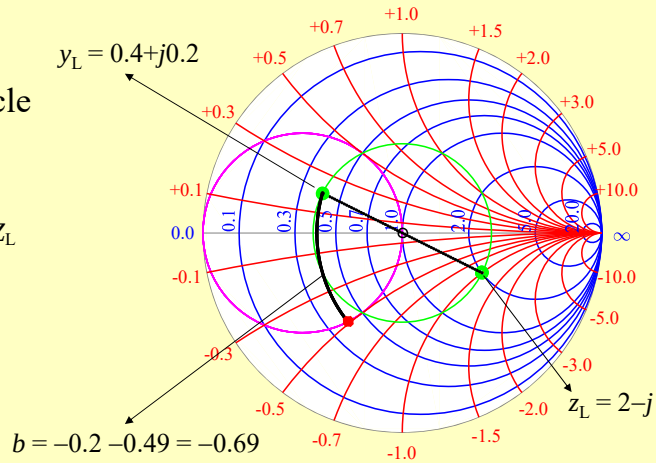
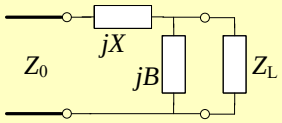


Matching with L-Sections – Example 1 (cont.)

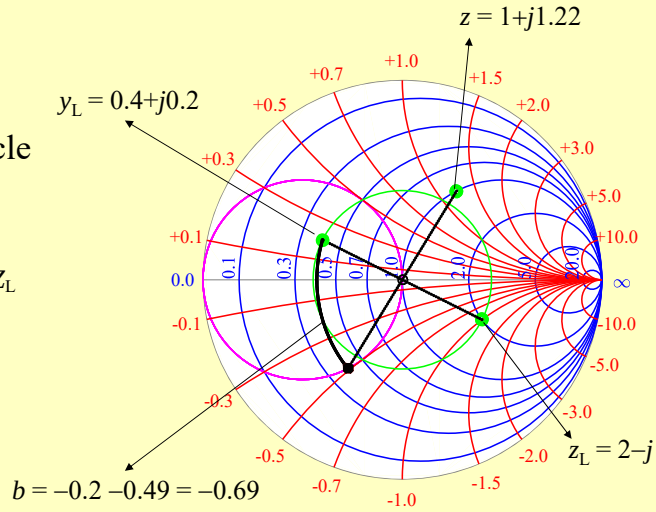
$$z_L = \frac{Z_L}{Z_0} = 2 - j$$

z_L is inside the circle $1+jx$, then we use:



Second solution:

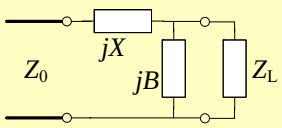
$$jb = -j0.69$$
$$jx = -j1.22$$



Matching with L-Sections – Example 1 (cont.)

$$z_L = \frac{Z_L}{Z_0} = 2 - j$$

z_L is inside the circle $1+jx$, then we use:



Second solution:

$$jb = -j0.69$$
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