Microwave Techniques

Impedance Matching

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Autumn 2016
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ELECTRICAL AND ELECTRONICS ENGINEERING

Impedance Matching and Tuning

Impedance matching is important because it provides

- maximum power delivered to the load,
- improvement of the Signal-to-Noise ratio.

❖ Matching networks are ideally lossless.

❖ It is always possible to design a matching network as long as the load has a non-zero real part.

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Selection Criteria of Matching Network

Complexity – As with most engineering solutions, the simplest design that satisfies the required specifications is generally preferable. A simpler matching network is usually cheaper, smaller, more reliable, and less lossy than a more complex design.

Bandwidth – Any type of matching network can ideally give a perfect match (zero reflection) at a single frequency. In many applications, however, it is desirable to match a load over a band of frequencies. There are several ways of doing this, with, of course, a corresponding increase in complexity.

Implementation – Depending on the type of transmission line or waveguide being used, one type of matching network may be preferable to another. For example, tuning stubs are much easier to implement in waveguide than are multisection quarter-wave transformers.

Adjustability – In some applications the matching network may require adjustment to match a variable load impedance. Some types of matching networks are more amenable than others in this regard.

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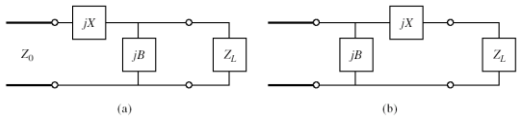
Matching with Lumped Elements (L Networks)

❖ L section uses two reactive elements to match an arbitrary load impedance to the line.

❖ There are two possible configurations:



L-section matching networks.
(a) Network for z_L inside the $1 + jx$ circle.
(b) Network for z_L outside the $1 + jx$ circle.

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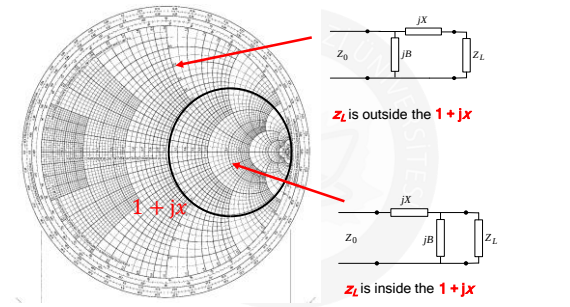
Matching with Lumped Elements (L Networks)



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Matching with Lumped Elements (L Networks)

❖ Actual lumped element capacitors and inductors can be used up to several GHz. However,

❖ there is a large range of frequencies and circuit sizes where lumped elements cannot be realized.

This is the major limitation of the L-Section networks.

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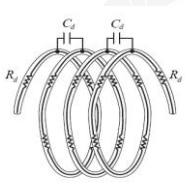
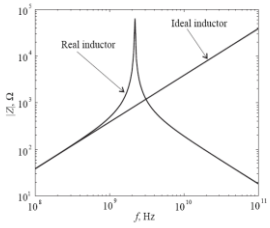
Matching with Lumped Elements (L Networks)

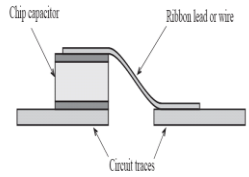
Frequency response of a lumped inductor:

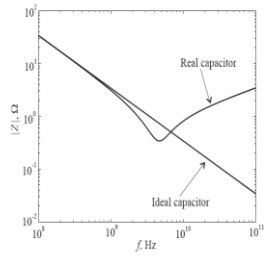




Matching with Lumped Elements (L Networks)

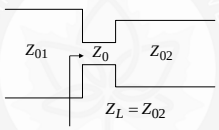
Frequency response of a lumped capacitor:





Matching with Lumped Elements (L Networks)

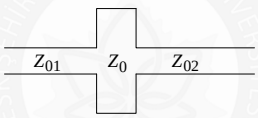
Realizations of inductors from transmission line sections



$$Z_{in} = Z_L + j\omega\frac{Z_0 l}{v} = Z_L + j\omega L$$

Matching with Lumped Elements (L Networks)

Realizations of capacitors from transmission line sections

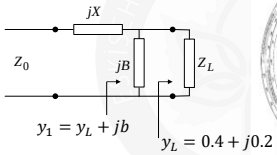


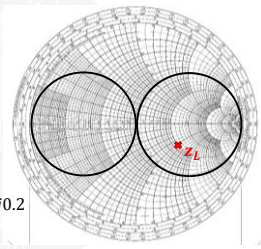
$$Y_{in} = Y_L + j\omega\frac{Y_0 l}{v} = Y_L + j\omega C$$

Example 1

Design an L section matching network to match a load $Z_L = (100 - j50)$ Ω to a 50 Ω line at 1 GHz.

$z_L = 2 - j1$ is inside the $1 + jx$ circle





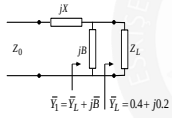
Example 1

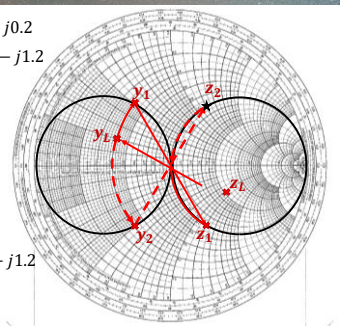
1. $z_L = 2 - j1 \Rightarrow y_L = 0.4 + j0.2$

2a. $y_1 = y_L + j0.3 \Rightarrow z_1 = 1 - j1.2$

3. $z_{in} = z_1 + j1.2 = 1.0$

4. $b = 0.3 \quad x = 1.2$





2b. $y_2 = y_L - j0.7 \Rightarrow z_2 = 1 + j1.2$

3. $z_{in} = z_2 - j1.2 = 1.0$

4. $b = -0.7 \quad x = -1.2$

Example 1

$b = 0.3 \Rightarrow B = \frac{b}{50} = 6 \times 10^{-3}\ S$ *capacitive* $\Rightarrow B = \omega C \Rightarrow C = \frac{6 \times 10^{-3}}{2\pi \times 10^9} = \frac{3}{\pi} pF$

$x = 1.2 \Rightarrow X = x \times 50 = 60\ \Omega$ *inductive* $\Rightarrow X = \omega L \Rightarrow L = \frac{60}{2\pi \times 10^9} = \frac{30}{\pi} nH$

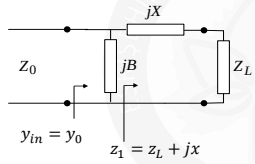
$b = -0.7 \Rightarrow B = -\frac{0.7}{50}\ S$ *inductive* $\frac{0.7}{50} = \frac{1}{\omega L} \Rightarrow L = \frac{50}{0.7 \times 2\pi \times 10^9} H$

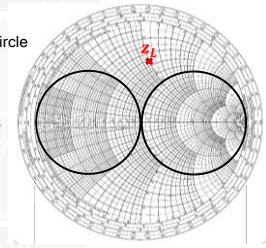
$x = -1.2 \Rightarrow X = x \times 50 = -60\ \Omega$ *capacitive* $60 = \frac{1}{\omega C} \Rightarrow C = \frac{1}{60 \times 2\pi \times 10^9} F$

Example 2

Design an L section matching network to match a load $Z_L = (50 + j100)\ \Omega$ to a $100\ \Omega$ line at 1 GHz.

$z_L = 0.5 + j1$ is outside the $1 + jx$ circle





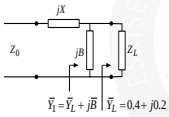
Example 2

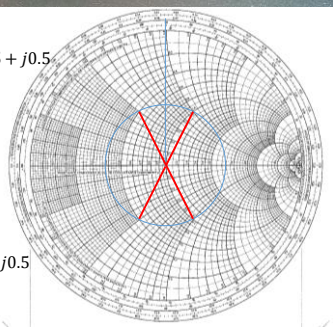
1. $z_L = 0.5 + j1$

2a. $z_1 = z_L - j0.5 \Rightarrow z_1 = 0.5 + j0.5$

3. $y_1 = 1.0 - j1.0$

4. $x = -0.5\ \ b = 1.0$





2b. $z_2 = z_L - j1.5 \Rightarrow z_2 = 1 - j0.5$

3. $y_2 = 1.0 + j1.0$

4. $x = -1.5\ \ b = -1.0$

In-class

Design two lossless L-section matching circuits to match each of the following loads to a 100 Ω generator at 3 GHz.

(a) Z_L = 150 − j200 Ω

(b) (b) Z_L = 20 − j90 Ω.