

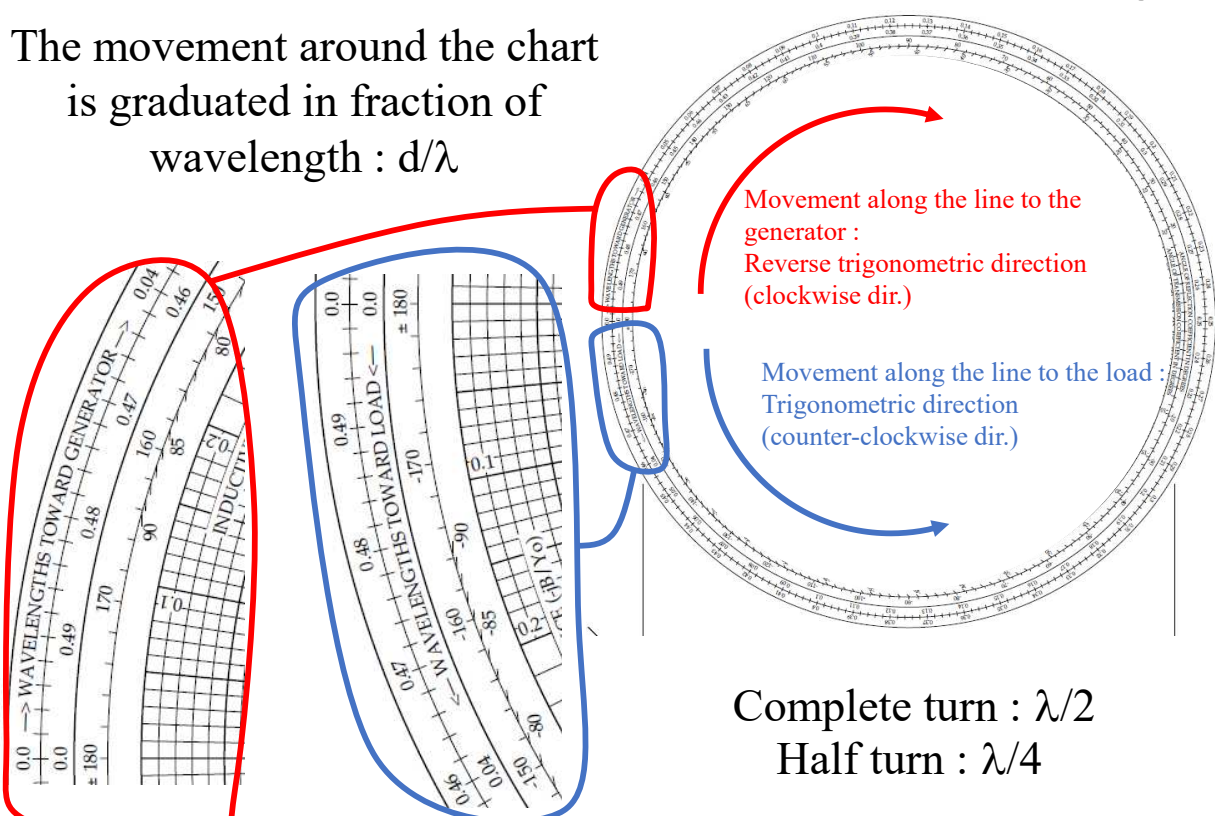
Chapters:

0. Microwave domain
1. S-parameters and transmission line
 - a. Microwave signals - time and frequency domains
 - b. Description of microwave devices by scattering parameters
 - c. Exercices on the parameters S
 - d. Description of microwave devices by chain matrix
2. Theory of transmission lines
3. Smith Chart and impedance matching
 - a. Introduction, uses and principles
 - b. Movement along the line
 - c. Different methods for impedance matching
 - d. Matching by a stub
 - e. Matching by double stubs

3. Smith Chart and impedance matching

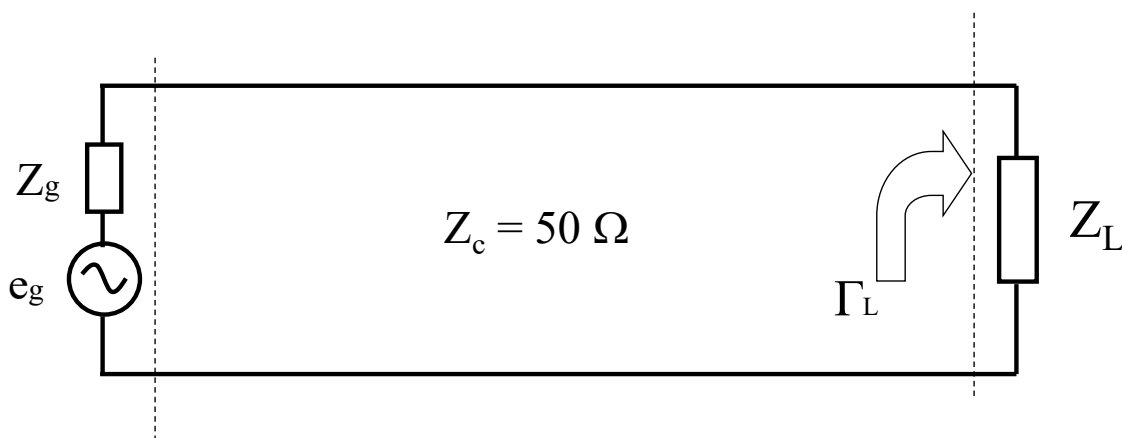
1. Movement along the line

The movement around the chart
is graduated in fraction of
wavelength : d/λ



3. Smith Chart and impedance matching

2. Movement along the line



50 Ω line terminated by $Z_L = 20 + j 60 \Omega$ impedance

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3. Smith Chart and impedance matching

3. Movement along the line

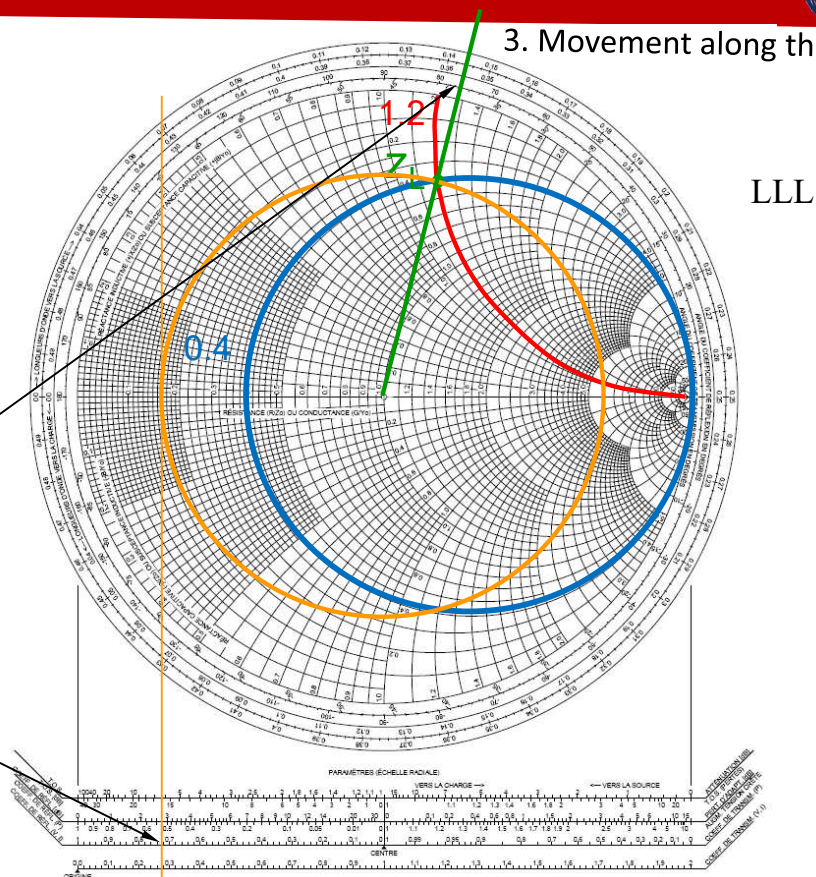
$$Z_L = 20 + j 60 \Omega$$

Reduced impedance :

$$z_L = (20 + j 60) / Z_c$$

$$z_L = 0.4 + j 1.2$$

$$\Gamma_L = 0.73 e^{j.76^\circ}$$



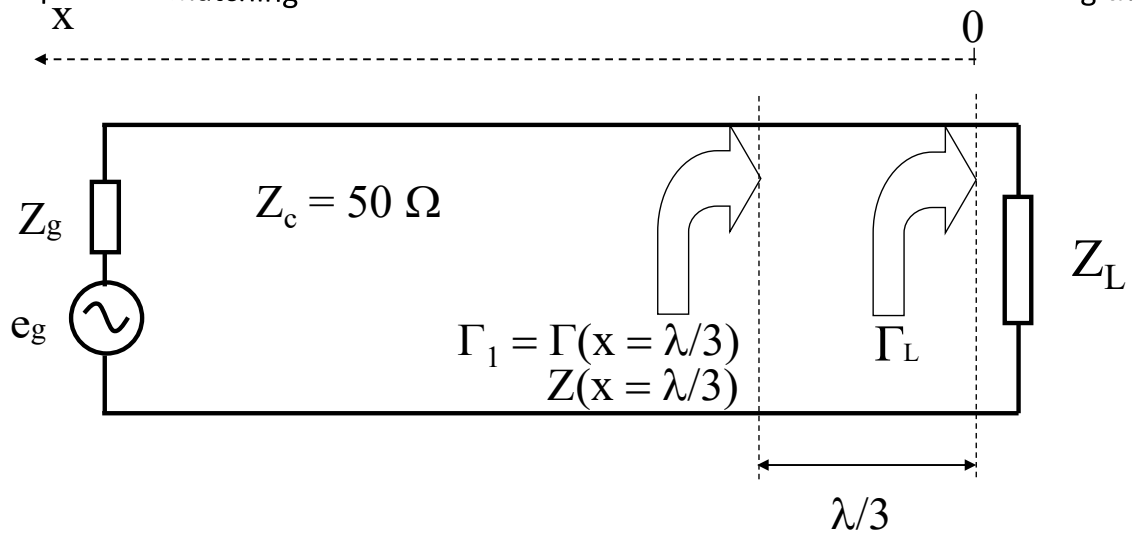
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3. Smith Chart and impedance matching

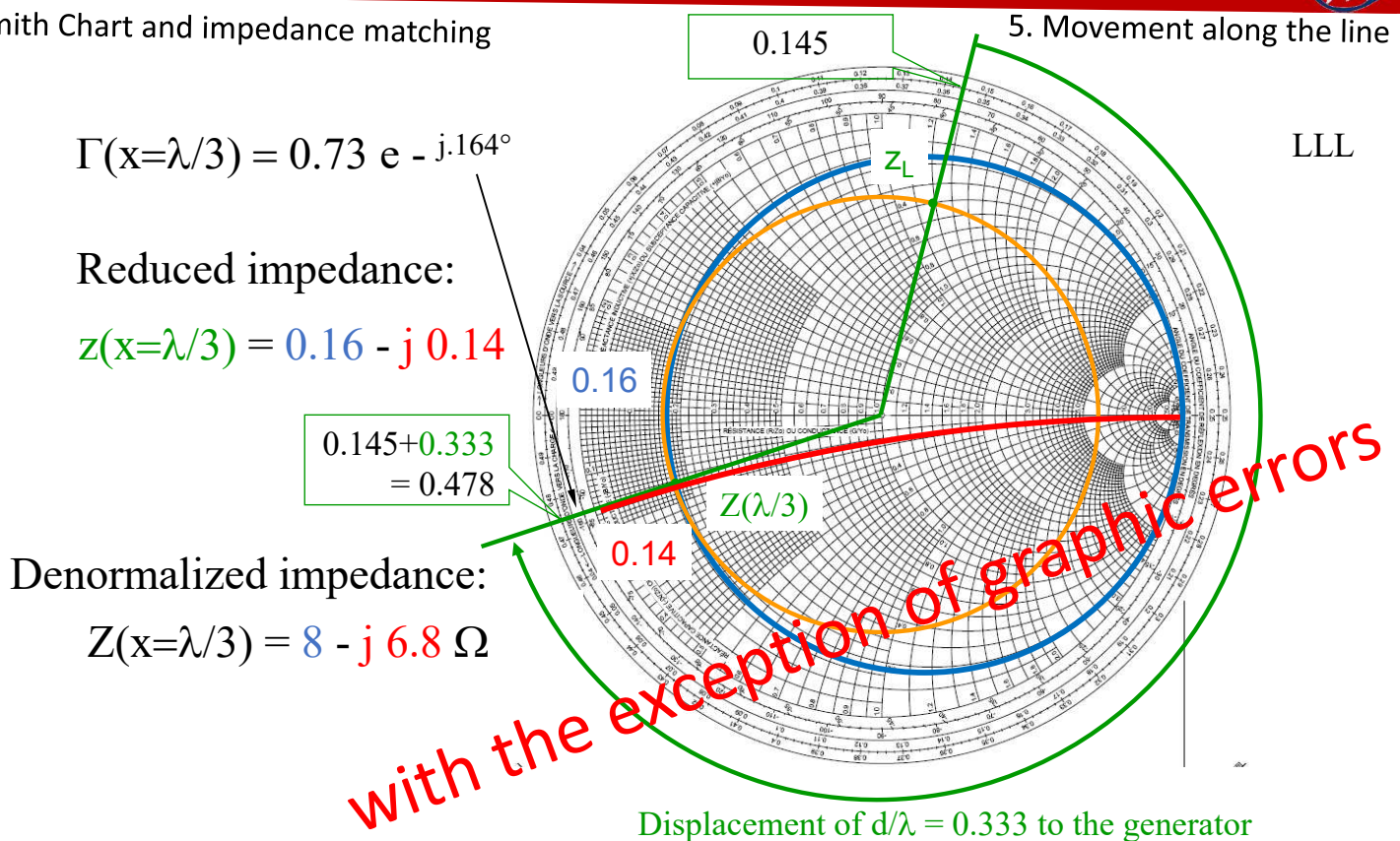
4. Movement along the line



To calculate the impedance and reflection coefficient in $x = \lambda/3$, we move from the load to the generator of a normalized distance $d/\lambda = 1/3 = 0.333$

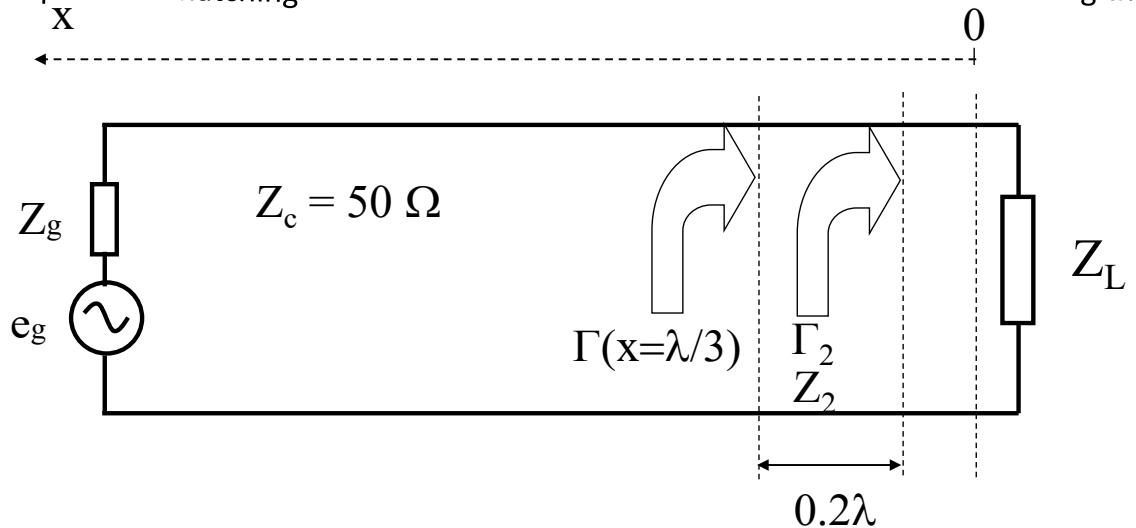
3. Smith Chart and impedance matching

5. Movement along the line



3. Smith Chart and impedance matching

6. Movement along the line



To calculate the impedance Z_2 and the reflection coefficient Γ_2 from a point returning from 0.2λ to the load, we move from the generator to the load by a normalized distance $d/\lambda = 0.2$

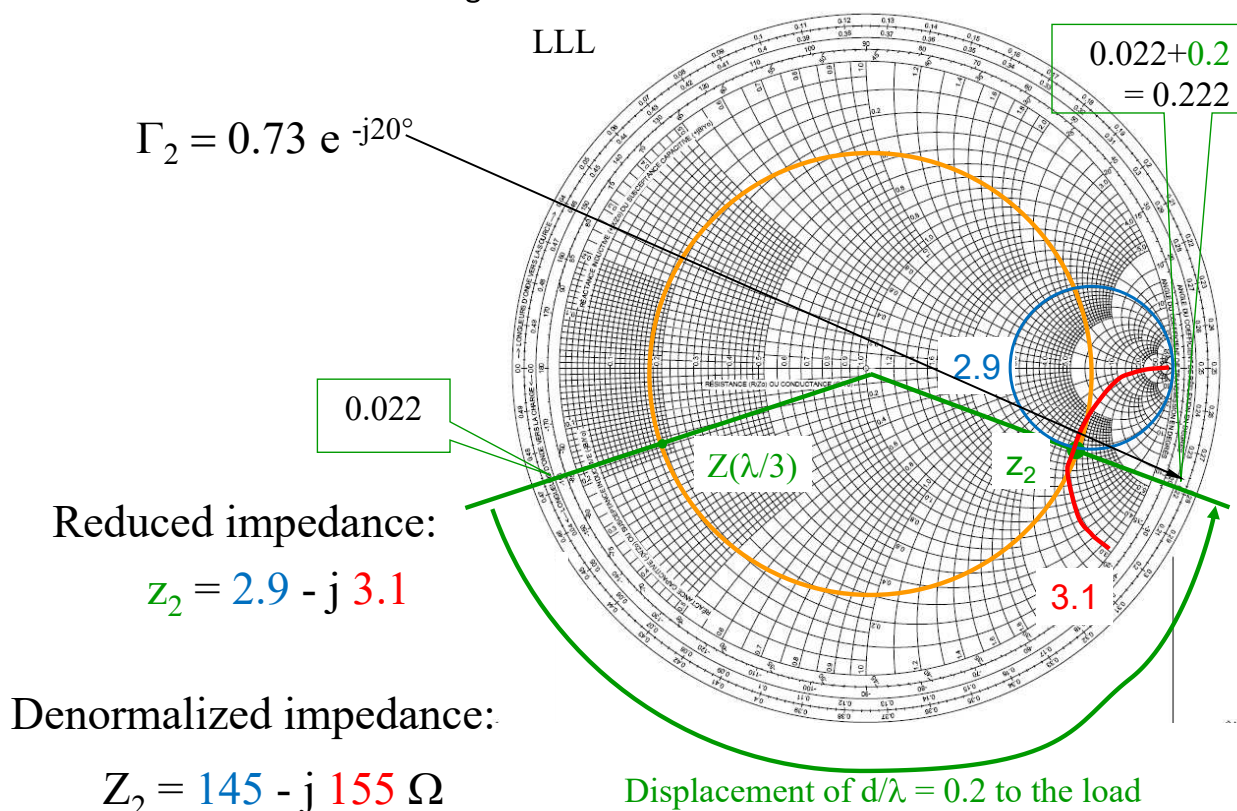
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3. Smith Chart and impedance matching

7. Movement along the line



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3. Smith Chart and impedance matching

Impedance :

$$Z_L = 7.5 + j 30 \Omega$$

Reduced impedance :

$$z_L = 0.15 + j 0.6$$

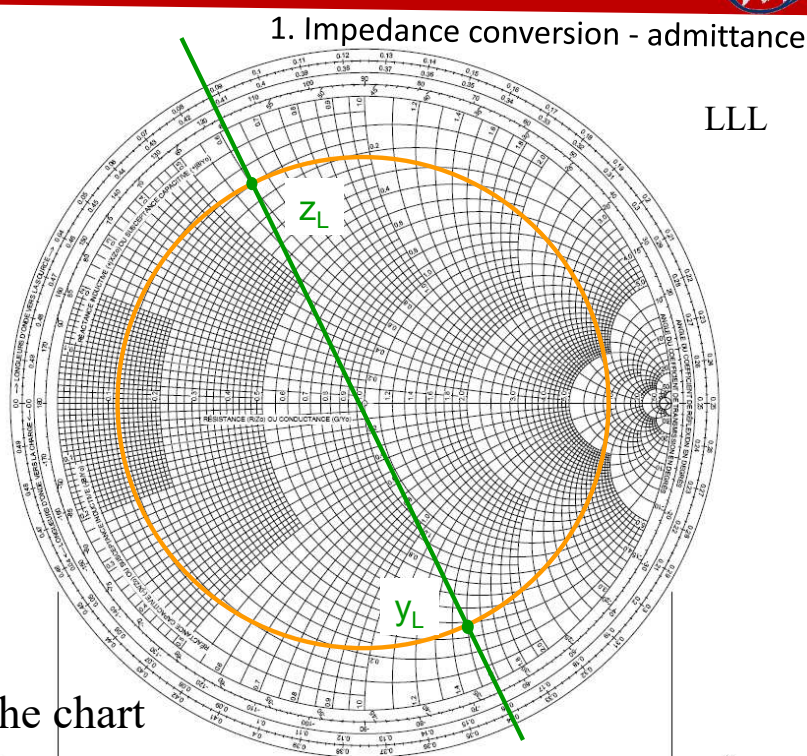
Reduced admittance:

$$y_L = 0.4 - j 1.6$$

unreduced admittance:

$$Y_L = 0.008 - j 0.032 \Omega^{-1}$$

y_L is the symmetrical of z_L with respect to the center of the chart



$$z(x) = \frac{1 + \Gamma(x)}{1 - \Gamma(x)} \longleftrightarrow \text{Addition of } \pi \text{ to } \psi \longleftrightarrow y(x) = \frac{1 - \Gamma(x)}{1 + \Gamma(x)}$$

3. Smith Chart and impedance matching

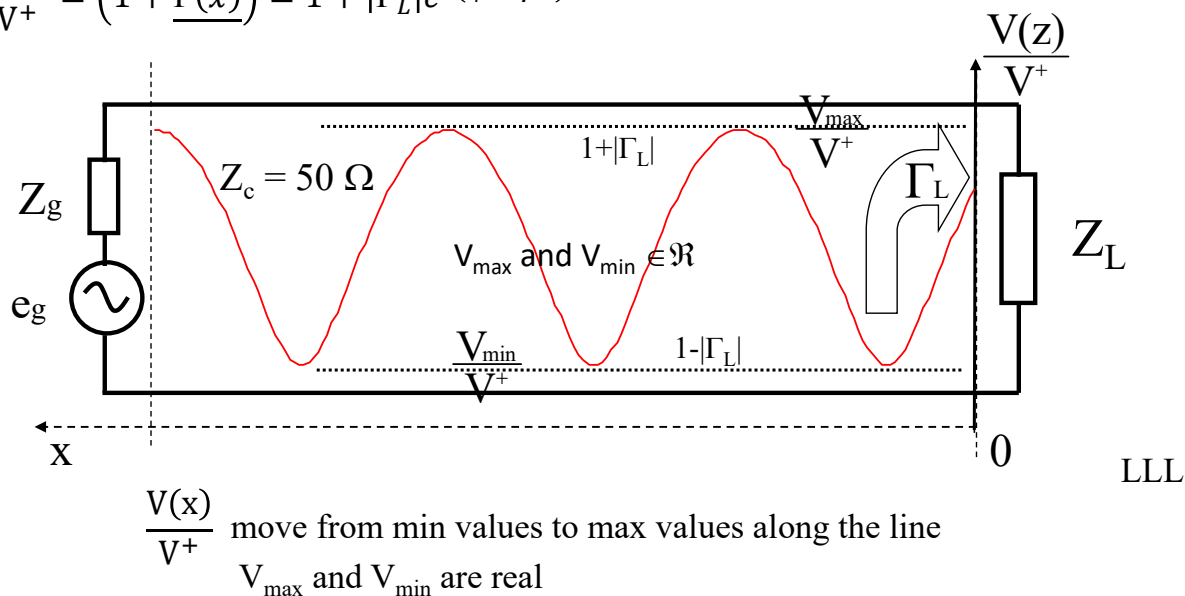
1. Representation of voltages and currents

Voltage $V(x) = \underline{V}_i e^{j\beta x} + \underline{V}_r e^{-j\beta x} = V^+ + V^-$

$$\frac{V(x)}{V^+} = (1 + \Gamma(x)) = 1 + |\Gamma_L| e^{j(\varphi - 2\beta x)}$$

Current

$$I(x) = \frac{V_i}{Z_c} e^{j\beta x} - \frac{V_r}{Z_c} e^{-j\beta x} = \frac{V^+}{Z_c} - \frac{V^-}{Z_c}$$



3. Smith Chart and impedance matching

1. Representation of voltages and currents

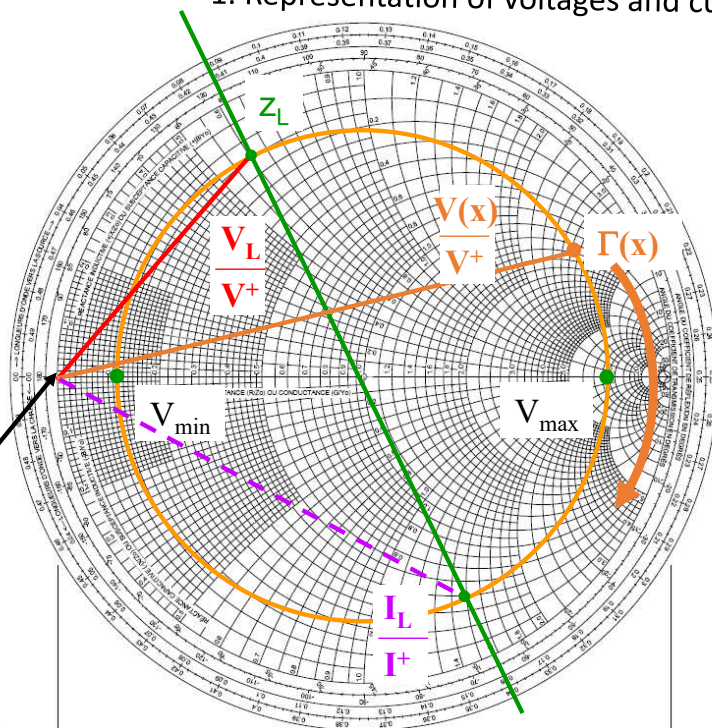
Reduced voltage : $\frac{V_L}{V^+}$

LLL

Reduced current : $\frac{I_L}{I^+}$

⇒ Take the opposite of the Z_L point

Voltage origin
Short-circuit, $z = 0$



Evolution of $v(x)$ reduced along the line that goes through V_{max} and V_{min}

3. Smith Chart and impedance matching

1. Representation of voltages and currents

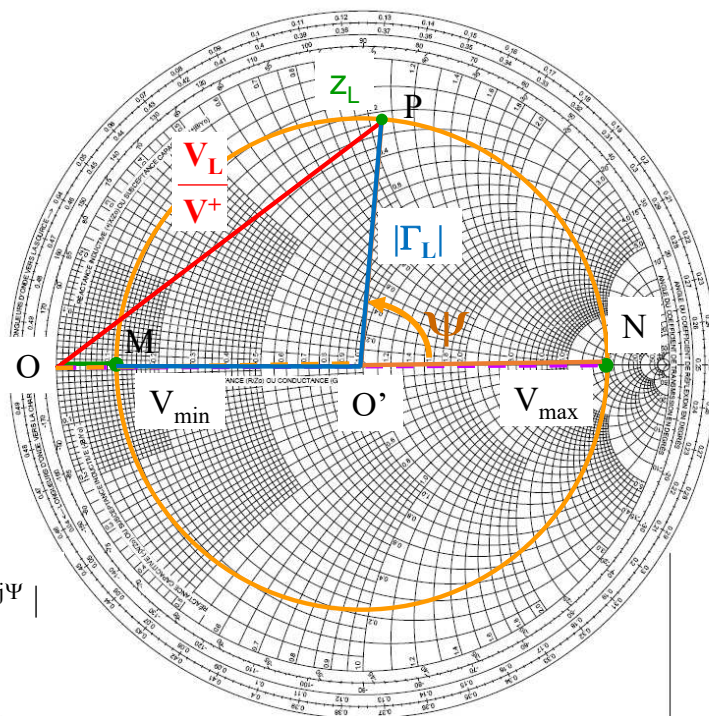
LLL

$|OO'| = 1$

$V_{min}/V^+ = |OM| = 1 - |\Gamma_L|$

$V_{max}/V^+ = |ON| = 1 + |\Gamma_L|$

$V_L/V^+ = |OP| = |1 + \Gamma_L| = |1 + |\Gamma_L|e^{j\Psi}|$



3. Smith Chart and impedance matching

1. Reflection coefficient calculations

Exercise #1 : Analytical calculations versus Smith chart ([tutorial n1 Smith chart.pptx](#))

An air line, with a characteristic impedance of $Z_C = 250 \Omega$, is powered at the frequency $f_0 = 500$ MHz.

It is 2m long and ends at an impedance Z_L . The SWR along the line is $s = 5$ and the first maximum voltage is at $d = 12$ cm from the load.

- Calculate $|\rho_L|$, ρ_L module and argument of the reflection coefficient on the load.
- Calculate Z_L .
- The input voltage is 10V. What is the value of the voltage at the load terminals. Give V_{\max} and V_{\min} on the line.

3. Smith Chart and impedance matching

1. Reflection coefficient calculations

Exercise #2 : Graphical calculations on Smith chart ([tutorial #2 Smith chart](#))

An air line, with a characteristic impedance of $Z_C = 20 \Omega$, is loaded at its end on an impedance $Z_L = R_L + j X_L = (24 + j 36) \Omega$. At the frequency of $f_0 = 3$ GHz, the length of the line is $\ell = \lambda_0 / 4$.

1) Give, using the Smith chart:

- The reflection coefficient ρ_L , the SWR s_L on the load Z_L .
- The reflection coefficient ρ_{in} , the SWR s_{in} and the impedance Z_{in} at the distance ℓ , for $f_0 = 3$ GHz and $f_1 = 4$ GHz

3. Smith Chart and impedance matching

1. Reflection coefficient calculations

Exercise #2 : Graphical calculations on Smith chart

2) A line of length ℓ_1 , with a characteristic impedance $Z_C = 20 \Omega$, short-circuited at one end, is placed in parallel on the previous load admittance $Y_L = 1 / Z_L$.

Let :

- Y_a the input admittance of this line with ℓ_1 length
- $Y_t = Y_a + Y_L$ the total admittance in $x = 0$

ℓ_1 is selected to obtain a real Y_t named R_t . Use Smith chart to give ℓ_1 and R_t at $f = 3 \text{ GHz}$.

