

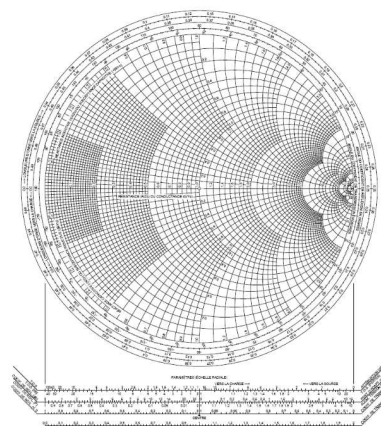
Chapters:

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

4. Smith Chart and impedance matching

1. Introduction, uses and principles

Smith chart (1939) : graphical tool to link the reflection coefficient along the line to the variation of the complex impedance along this waveguide

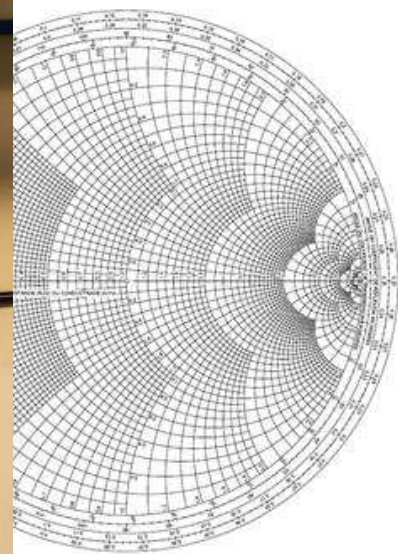
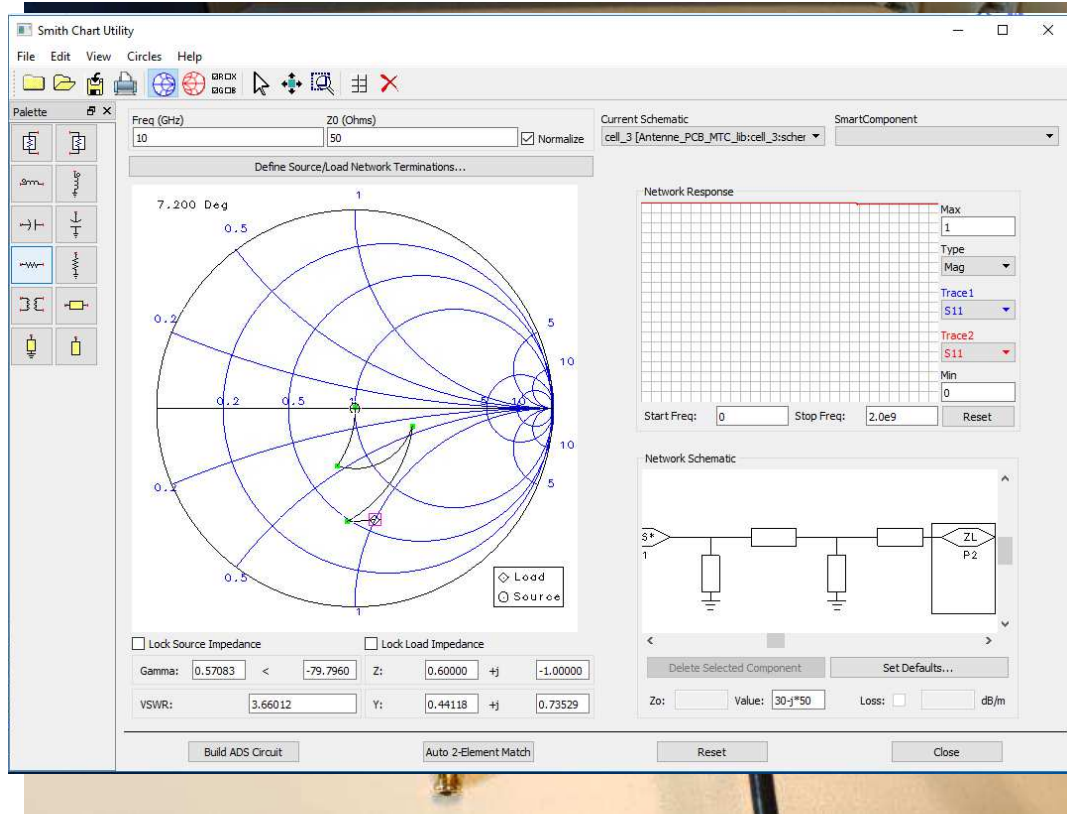


Phillip H. Smith (1905-1987) :
American electrical engineer who has worked for
Radio Corporation of America and BELL
laboratories



3. Smith Chart and impedance matching

2. Introduction, uses and principles



3. Smith Chart and impedance matching

3. Introduction, uses and principles

Either the reflection coefficient $\underline{\Gamma}(x) = \underline{\Gamma}_L e^{-2\gamma x}$, the impedance $Z(x)$ at a point x of the line can be written :

$$Z(x) = Z_c \frac{1 + \underline{\Gamma}(x)}{1 - \underline{\Gamma}(x)}$$

Round trip, z origin : at the location of load

Likewise, the load impedance $Z_L = Z_c \frac{1 + \underline{\Gamma}_L}{1 - \underline{\Gamma}_L}$ is expressed in terms of the load reflection coefficient $\underline{\Gamma}_L$

Or the ratio $z(x) = \frac{Z(x)}{Z_c}$ which corresponds to a normalized impedance $z(x)$

The two previous impedances in normalized form are written :

$$z(x) = \frac{1 + \underline{\Gamma}(x)}{1 - \underline{\Gamma}(x)}$$

$$z_L = \frac{1 + \underline{\Gamma}_L}{1 - \underline{\Gamma}_L}$$

1. Smith Chart and impedance matching

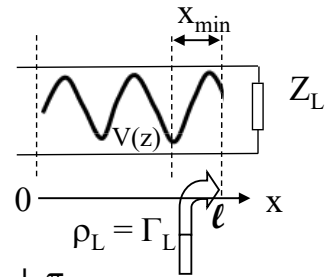
4. Introduction, uses and principles

Note :

Or the reflection coefficient $\underline{\Gamma}_L = |\underline{\Gamma}_L| e^{j\varphi}$, its determination

is made through the knowledge of the VSWR $|\underline{\Gamma}_L| = \frac{s-1}{s+1}$

and by the distance from the first minimum voltage : $\varphi = 2 \cdot \beta \cdot x_{min} + \pi$



Which leads to the determination of :

$$\underline{\Gamma}(x) = |\underline{\Gamma}_L| e^{j\varphi} \cdot e^{-2\gamma x} = |\underline{\Gamma}_L| e^{-2\alpha x} \cdot e^{j(\varphi - 2\beta x)} \quad \text{with} \quad \underline{\Gamma}(x) = \frac{z(x) - 1}{z(x) + 1}$$

for a lossless line

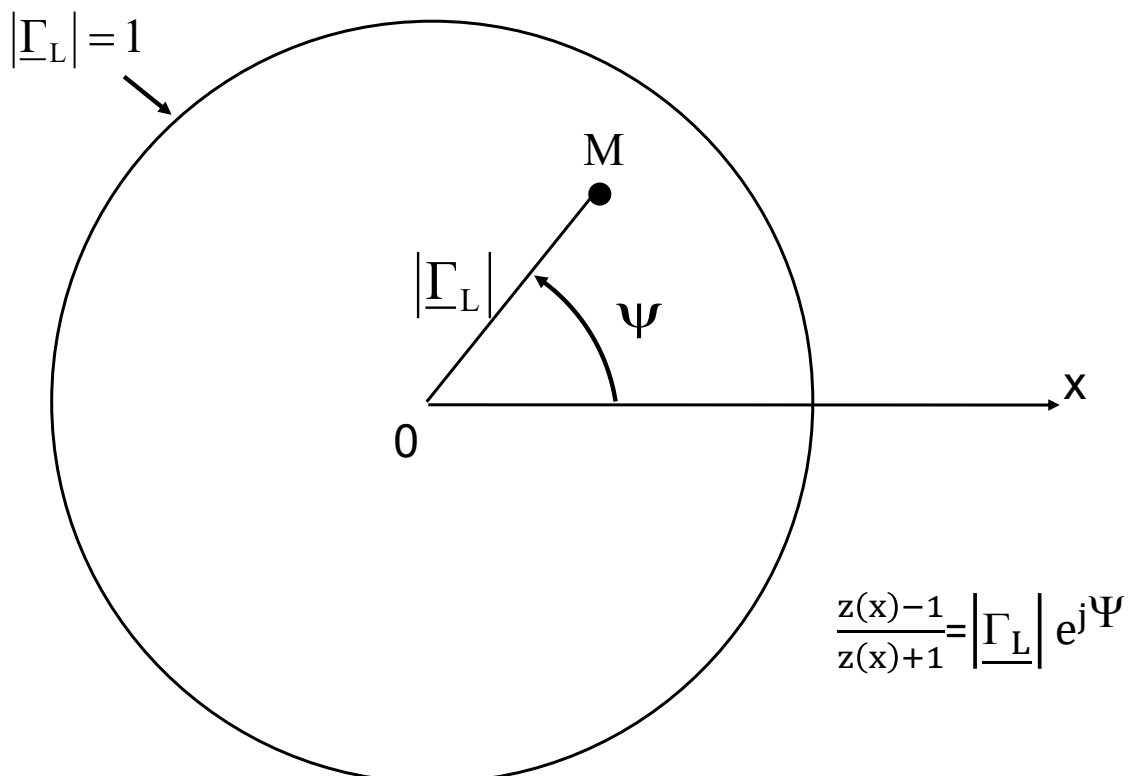
$$\underline{\Gamma}(x) = |\underline{\Gamma}_L| e^{j\Psi}$$

with

$$\Psi = \varphi - 2\beta x$$

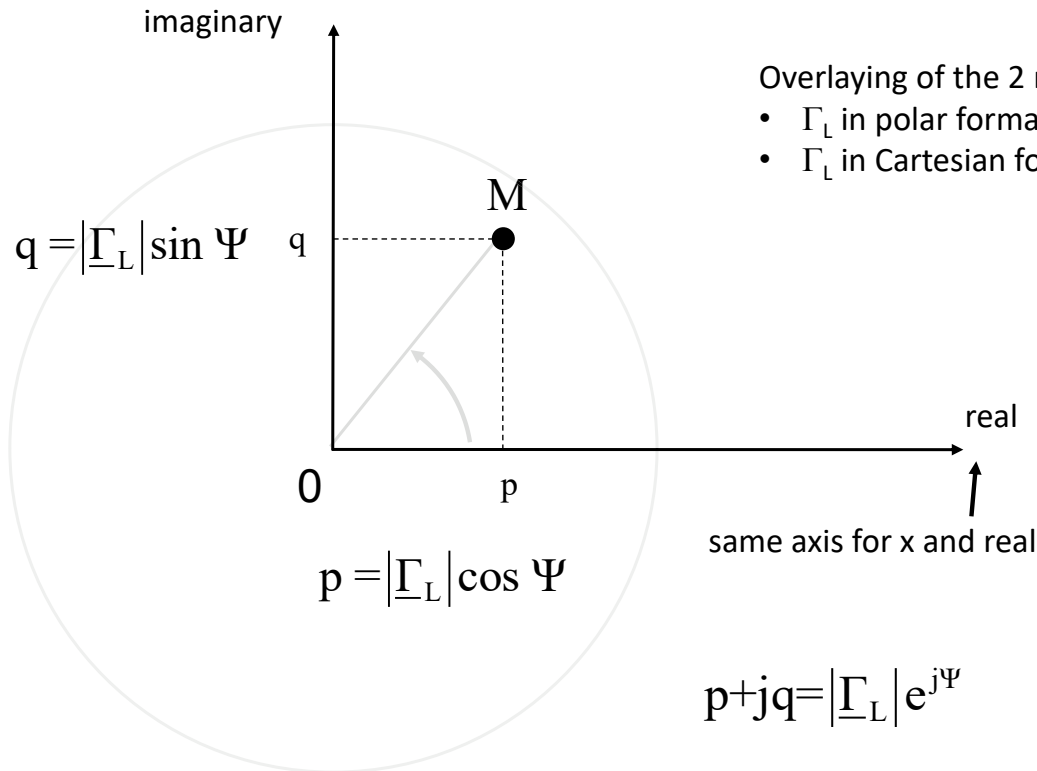
3. Smith Chart and impedance matching

5. Introduction, uses and principles



3. Smith Chart and impedance matching

6. Introduction, uses and principles



Overlaying of the 2 representations:

- Γ_L in polar format
- Γ_L in Cartesian format

3. Smith Chart and impedance matching

7. Introduction, uses and principles

Normalized impedance $z(x) = r_n + j x_n$

$$|\Gamma_L| e^{j\Psi} = p + j q = \frac{z(x)-1}{z(x)+1} \Rightarrow p + j q = \frac{(r_n-1)+j x_n}{(r_n+1)+j x_n} \quad (1)$$

If we know p and q, we can know r_n and x_n by equalizing the real and imaginary parts of the equation (1) :

at constant r_n

$$\left(p - \frac{r_n}{1+r_n} \right)^2 + q^2 = \left(\frac{1}{1+r_n} \right)^2 \Rightarrow$$

Center of the circle $(r_n/(1+r_n) , 0)$
 with radius $1/(1+r_n)$
 Circle centered on p axis
 All pass through a fixed point
 $p = 1 , q = 0$

Special cases: Circle $r_n = 0 \Rightarrow$ center $p = 0, q = 0$, circle of radius 1 (the largest)

Circle $r_n \rightarrow \infty \Rightarrow$ center $p = 1, q = 0$, circle of radius 0 (point)

3. Smith Chart and impedance matching

8. Introduction, uses and principles

at constant x_n

$$(p - 1)^2 + \left(q - \frac{1}{x_n}\right)^2 = \frac{1}{x_n^2}$$

\Rightarrow Circles center coordinates $(1, 1/x_n)$
and with radius $1/x_n$

Circle centered on $p=1$ axis // imaginary axis
All pass through a fixed point $p = 1, q = 0$

Special cases: Circle $x_n = 0 \Rightarrow$ center $p = 1, q = \infty$, circle with radius ∞
Real axis

Circle $x_n \rightarrow \infty \Rightarrow$ center $p = 1, q = 0$, circle with 0 (point)

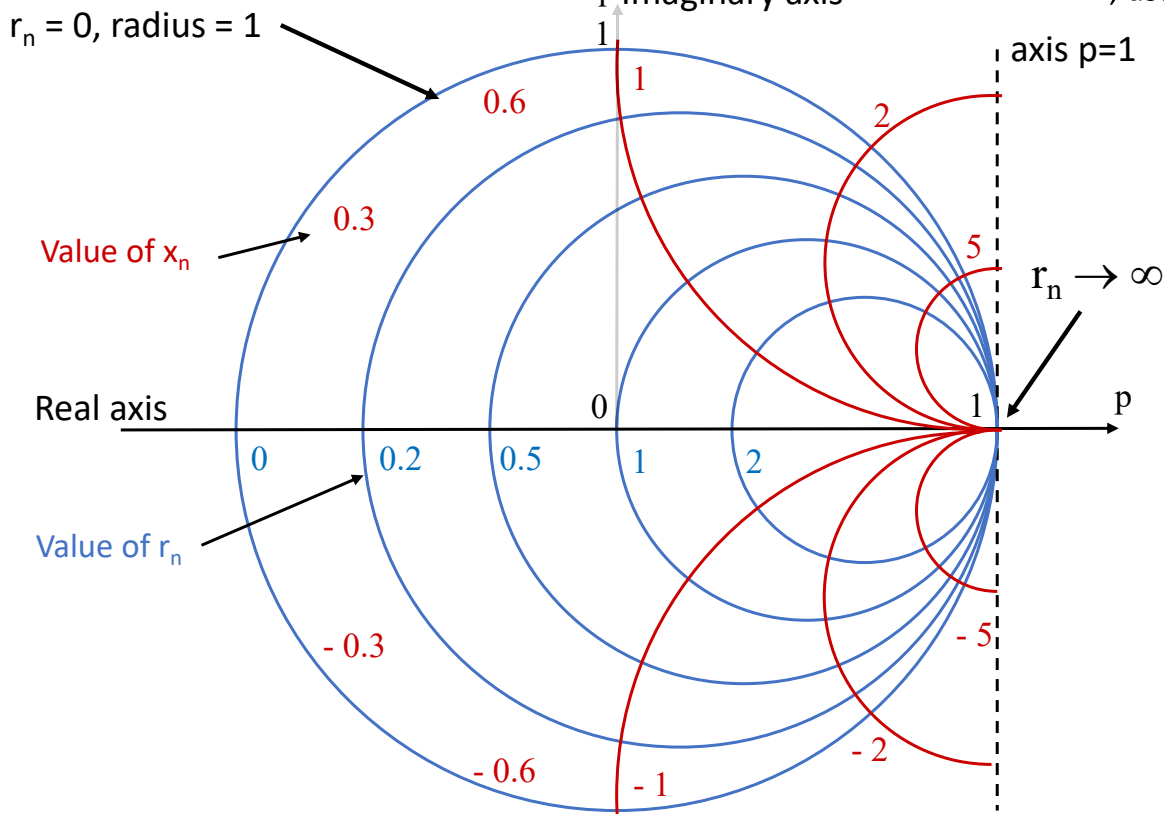
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3. Smith Chart and impedance matching

9. Introduction, uses and principles



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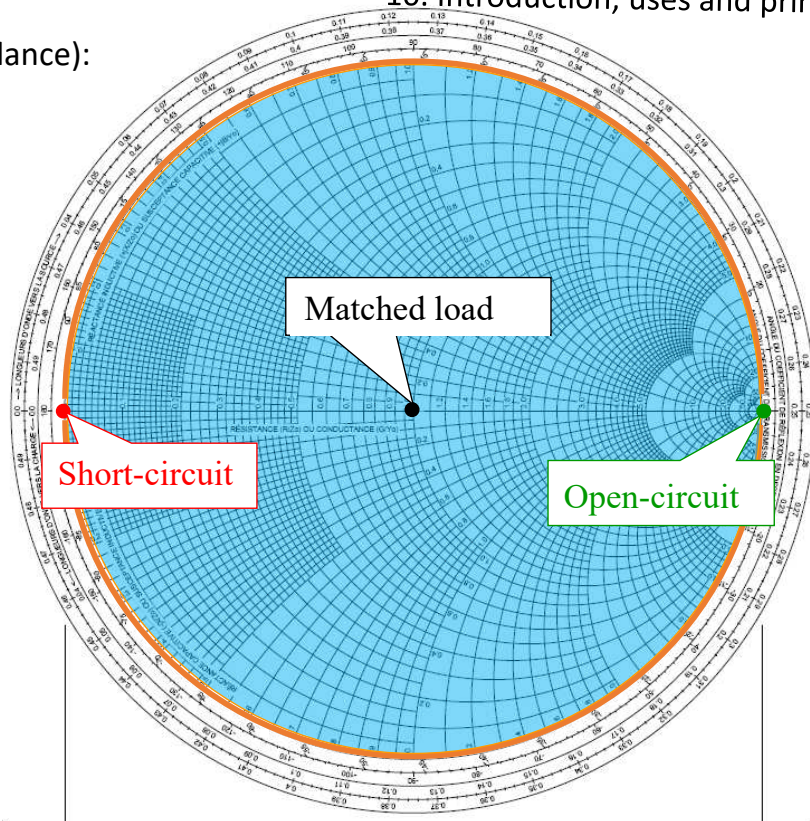
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3. Smith Chart and impedance matching

10. Introduction, uses and principles

Some loads on the Smith chart (z_n impedance):

- matched load
- Short-circuit
- Open circuit
- Short-circuit delay
- Location of all normalized loads

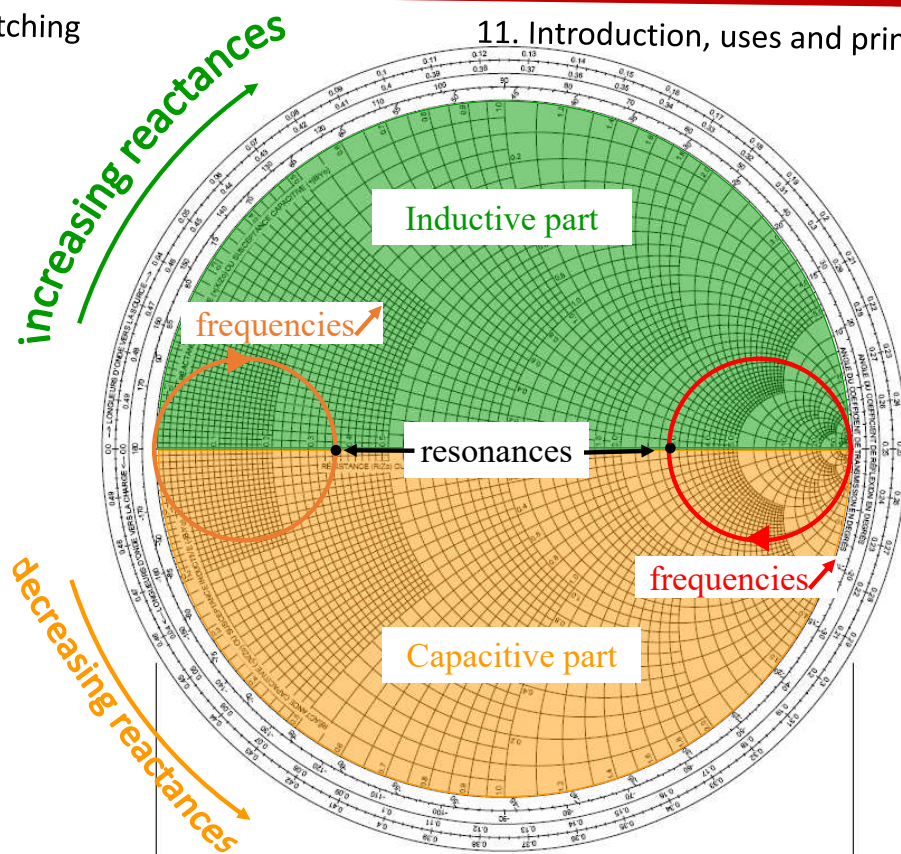


Quelques charges sur l'abaque de Smith

3. Smith Chart and impedance matching

11. Introduction, uses and principles

- capacitive load
- Inductive load
- Resonant circuit:
 - parallel
 - serial



3. Smith Chart and impedance matching

12. Introduction, uses and principles

If we know the impedance

⇒ Calculation of the reduced impedance

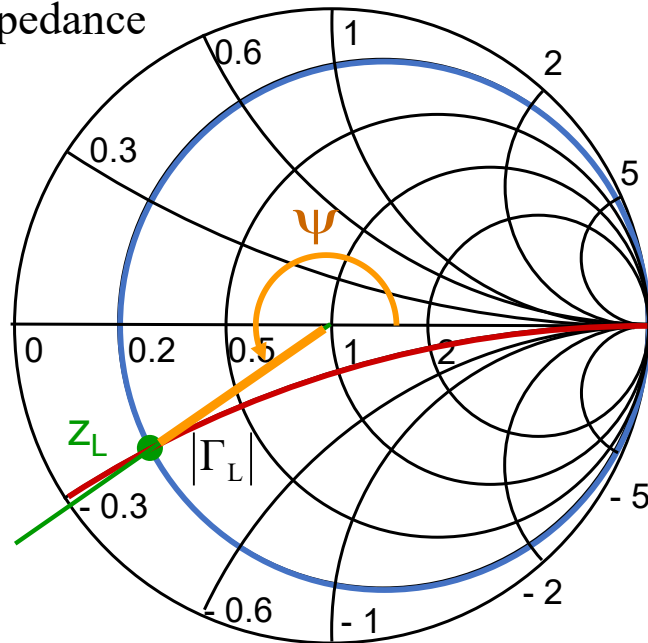
LLL

example : $Z_c = 50 \Omega$
et $Z_L = 10 - j15 \Omega$

Normalized impedance:

$$z_L = 0.2 - j0.3$$

Deduction of the reflection coefficient



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3. Smith Chart and impedance matching

13. Introduction, uses and principles

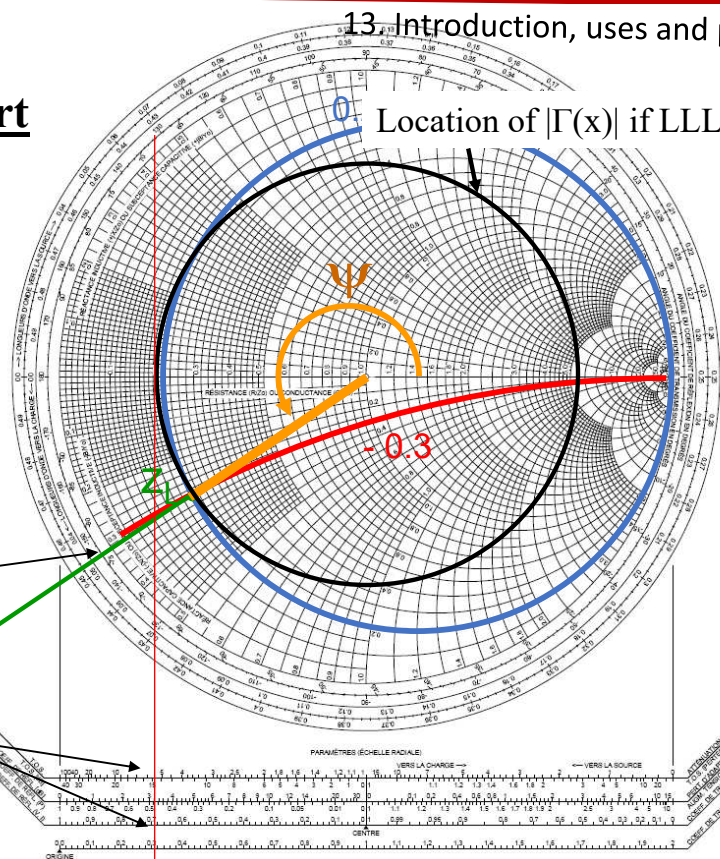
With the original Smith chart

$$z_L = 0.2 - j0.3$$

Deduction of the reflection coefficient

$$\underline{\Gamma}_L = 0.69 e^{-j146^\circ}$$

$$SWR = s = 5.5$$



Location of $|\Gamma(x)|$ if LLL

LLL

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3. Smith Chart and impedance matching

14. Introduction, uses and principles

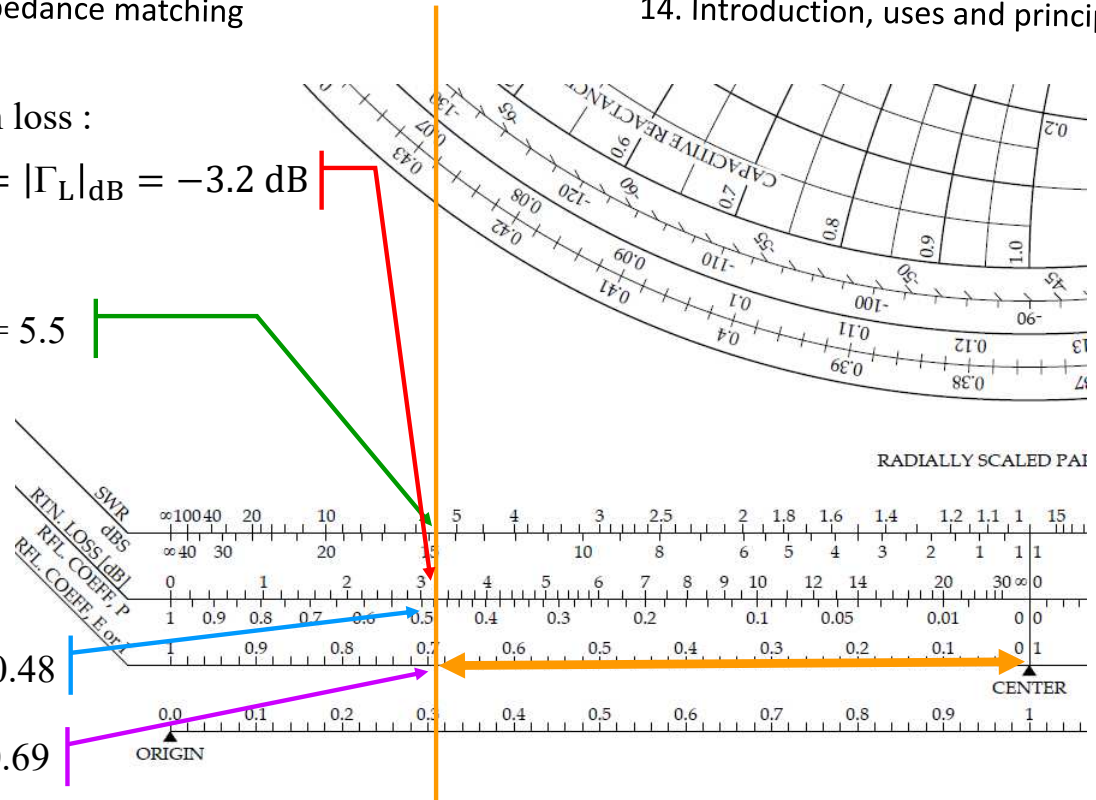
Return loss :

$$20 \cdot \log(|\Gamma_L|) = |\Gamma_L|_{dB} = -3.2 \text{ dB}$$

$$SWR = 5.5$$

$$|\Gamma_L|^2 = 0.48$$

$$|\Gamma_L| = 0.69$$



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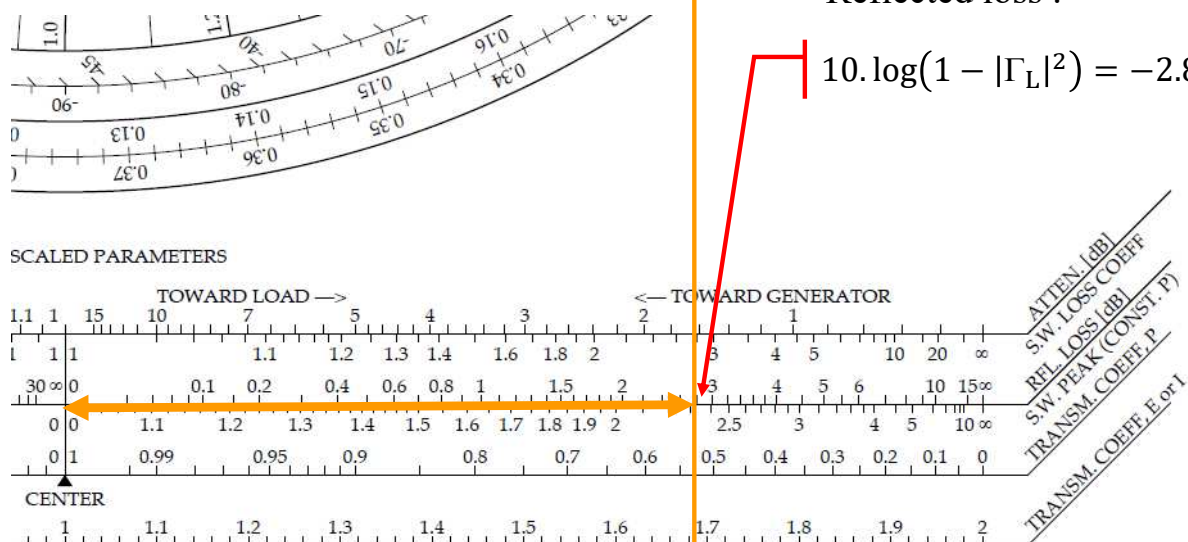
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3. Smith Chart and impedance matching

15. Introduction, uses and principles

Reflected loss :

$$10 \cdot \log(1 - |\Gamma_L|^2) = -2.8 \text{ dB}$$



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