ECE343 Spring 2025

Objective 3.56: Smith Charts & Impedance Matching



UNITED STATES
AIR FORCE
ACADEMY

Lesson	Topics	Reading	Notes
1	Course Overview & Introduction	Ch.1	LO 1.1-1.2
Chapter 2: Electric and Magnetic Fields			
2	Fields, Parameters, Field Quantities	Ch. 2	LO 2.1-2.2
Chapter 3: Transmission Lines			
3	Lumped Element Model	3.1-3.4	LO 3.1
4	Telegrapher's Equations	3.5-3.6	LO 3.1
5	Characteristic Impedance & Wave Propagation	3.7-3.9	LO 3.2
6	Coaxial, Reflection Coefficient, VSWR	3.10,3.12-3.14	LO 3.2-3.3
7	Terminated Transmission Lines	3.15,3.17-3.19	LO 3.4
8	Impedance Matching	3.21-3.23	LO 3.4
9	Impedance Matching	3.21-3.23	LO 3.4
10	Smith Charts	Supplemental	LO 3.5
11	Smith Charts	Supplemental	LO 3.5
12	Smith Charts	Supplemental	LO 3.5
13	Smith Charts	Supplemental	LO 3.5
14	Transients	Supplemental	LO 3.6
15	Reflection/Transmission Coefficient Lab	Lab Packet	LO 3.7
Chapter 4: Vector Analysis			
16	Vector & Coordinate System Review	Ch. 4	LO 4.1-4.4 **GR 1 due**
Chapter 5: Electrostatics			
17	Coulomb's Law	5.1-5.3	LO 5.1
18	Surface and Volume Charge	5.4	LO 5.1
19	Gauss' Law (Integral Form)	5.5-5.6	LO 5.2
20	Gauss' Law (Differential Form)	5.7-5.8	LO 5.2
21	Electric Potential	5.9-5.10, 5.15	LO 5.3

Ch 3 Learning Objectives

3.1 I can describe the origin of the transmission line equation, understand the method of developing a solution, and interpret the solution.

3.2 I can explain the physical meaning of and calculate the following quantities: propagation constant, phase constant, attenuation constant, characteristic impedance, VSWR, reflection coefficient, and transmission coefficient.

3.3 I can use the transmission line equation to calculate the voltage/current at an arbitrary point on a specified transmission line.

3.4 I can use the transmission line equation to match a load to a source using a length of transmission line.

3.5 I can identify the various quantities represented on the Smith Chart.

3.6 I can use a Smith Chart to design a matching network for a given source and load, using series components, parallel components, shorted stubs, and open stubs.

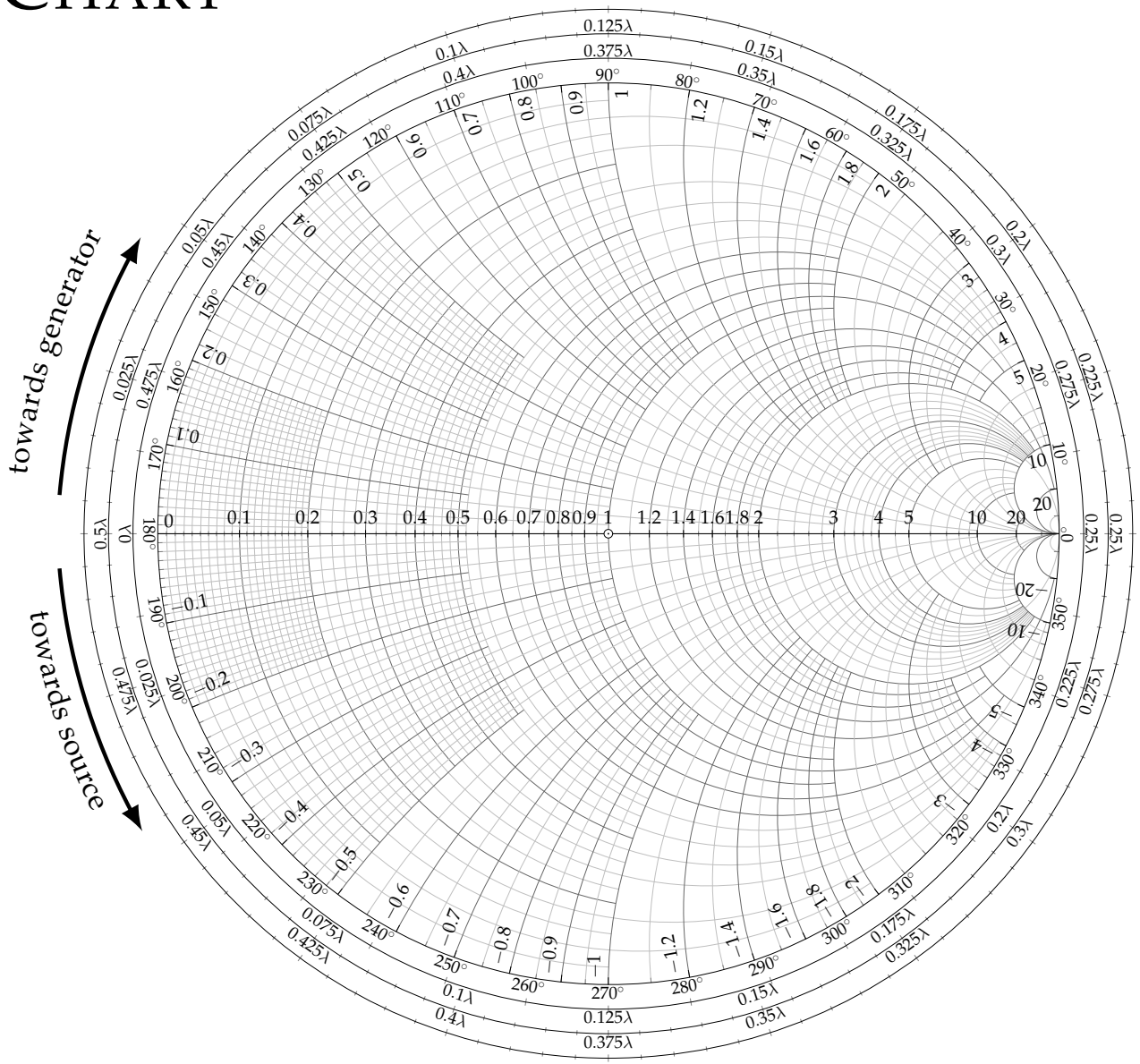
3.7 I can plot the transient response of a load connected to a source through a transmission line.

3.8 I can measure the reflection coefficient across a range of frequencies and interpret the measurement using a network analyzer.

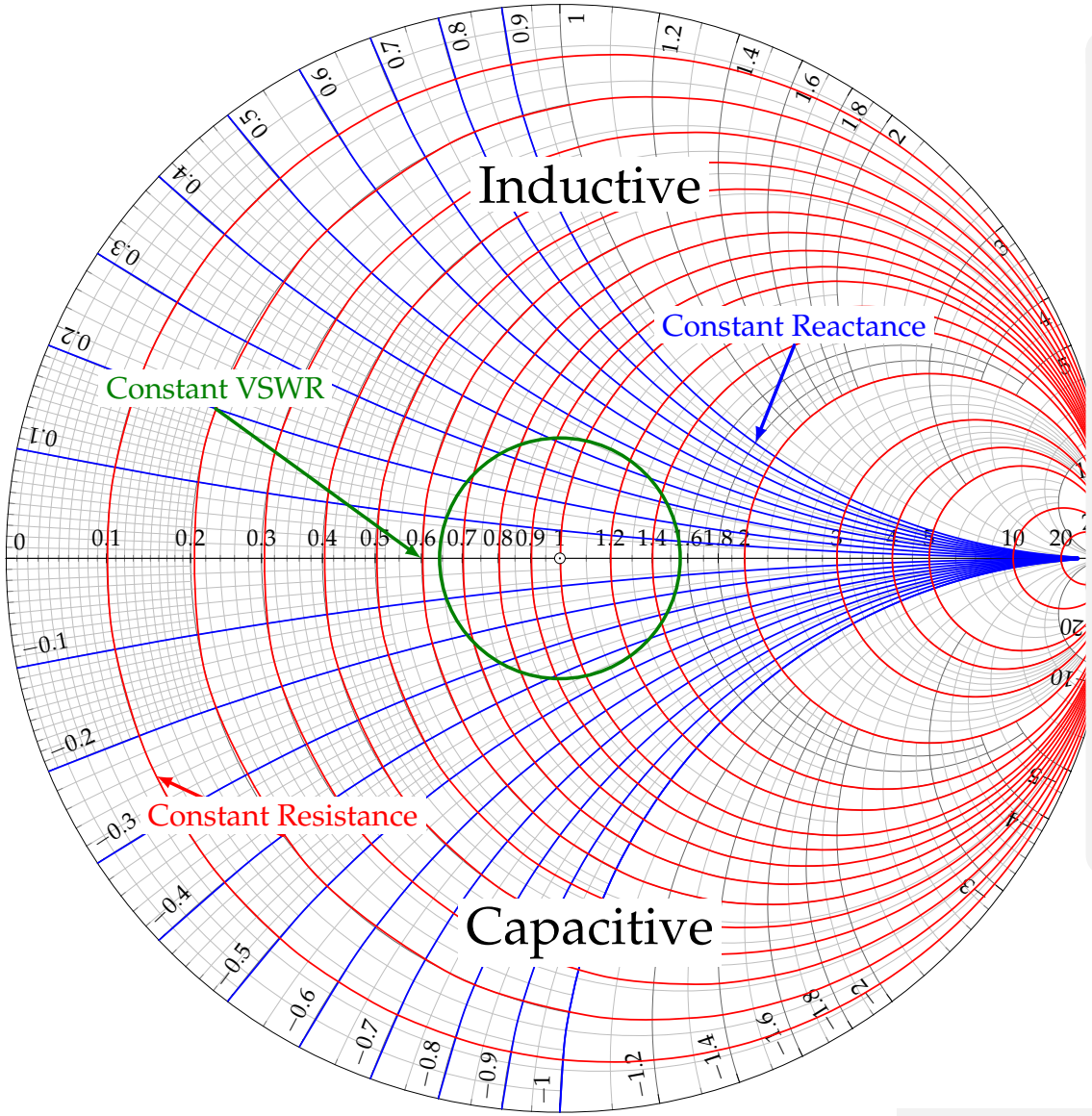
Smith Charts: History

- Developed in 1939 by Phillip H. Smith
- Used to solve a variety of tx line and waveguide problems
- Measure/evaluate complex reflection/transmission on a tx line
- Measure/evaluate VSWR
- Measure/evalute impedance along a tx line
- Evaluate IO transfer functions

Smith Chart



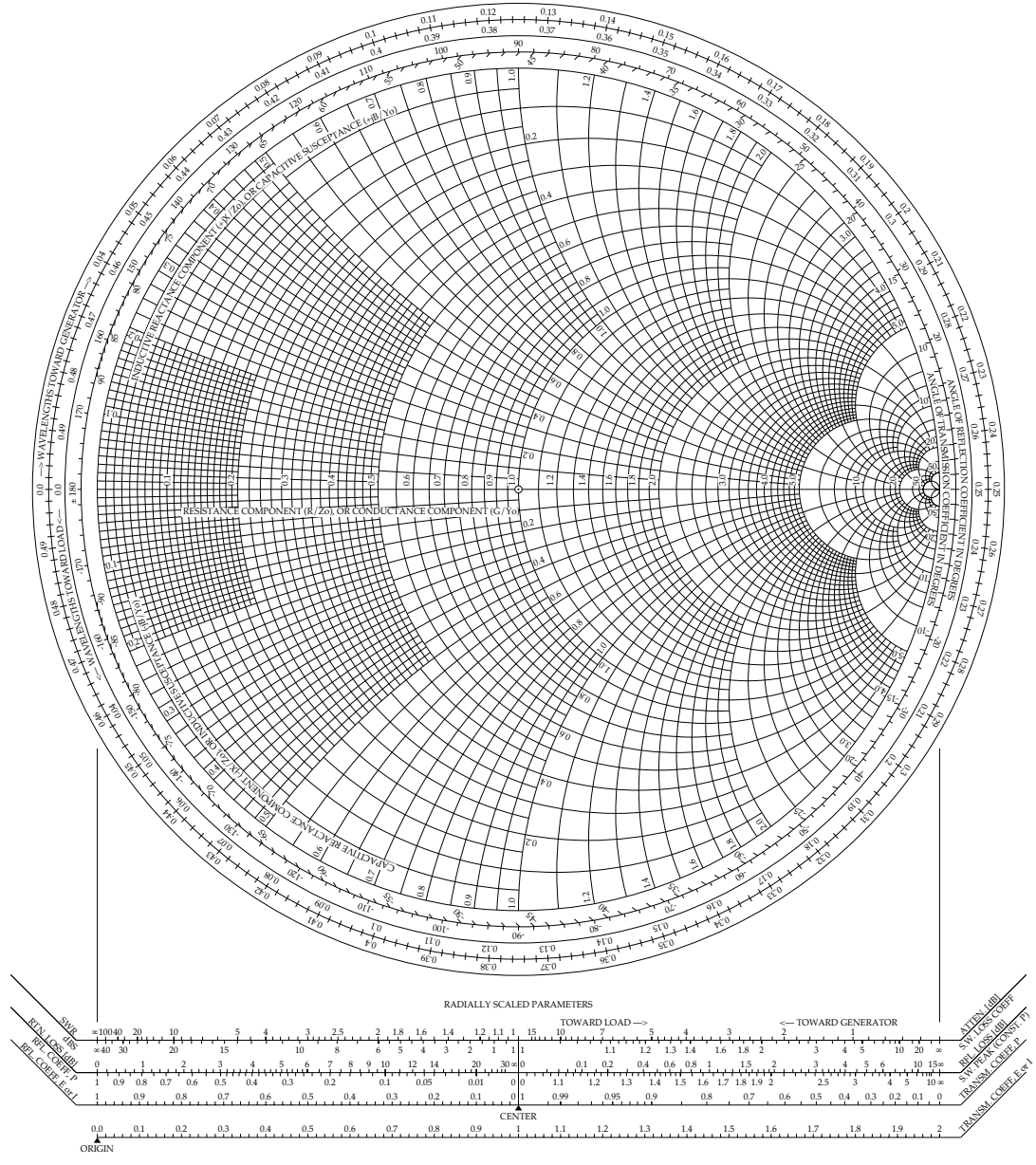
Smith Charts: Measurements

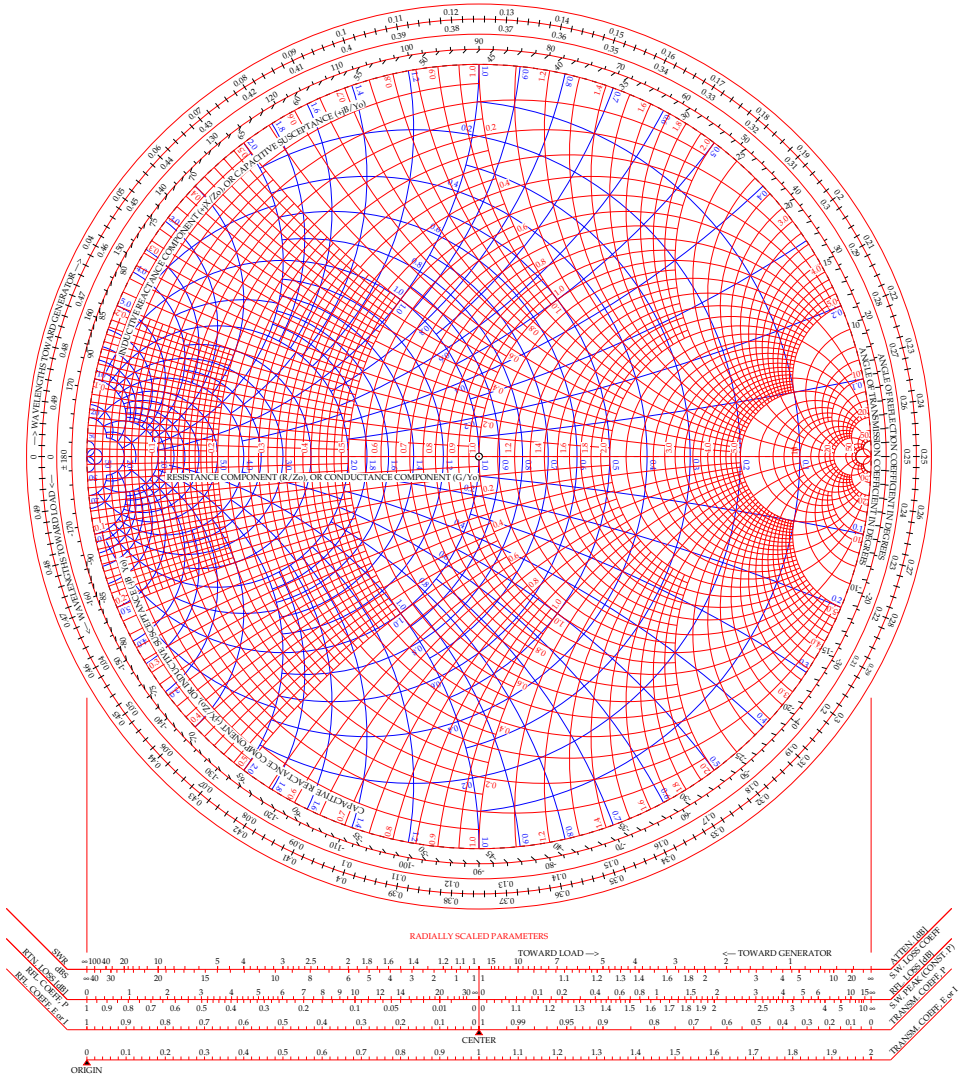


- Plot complex impedances
- Use circles of constant R & X
- Measure Γ_L
- Magnitude and Phase
-

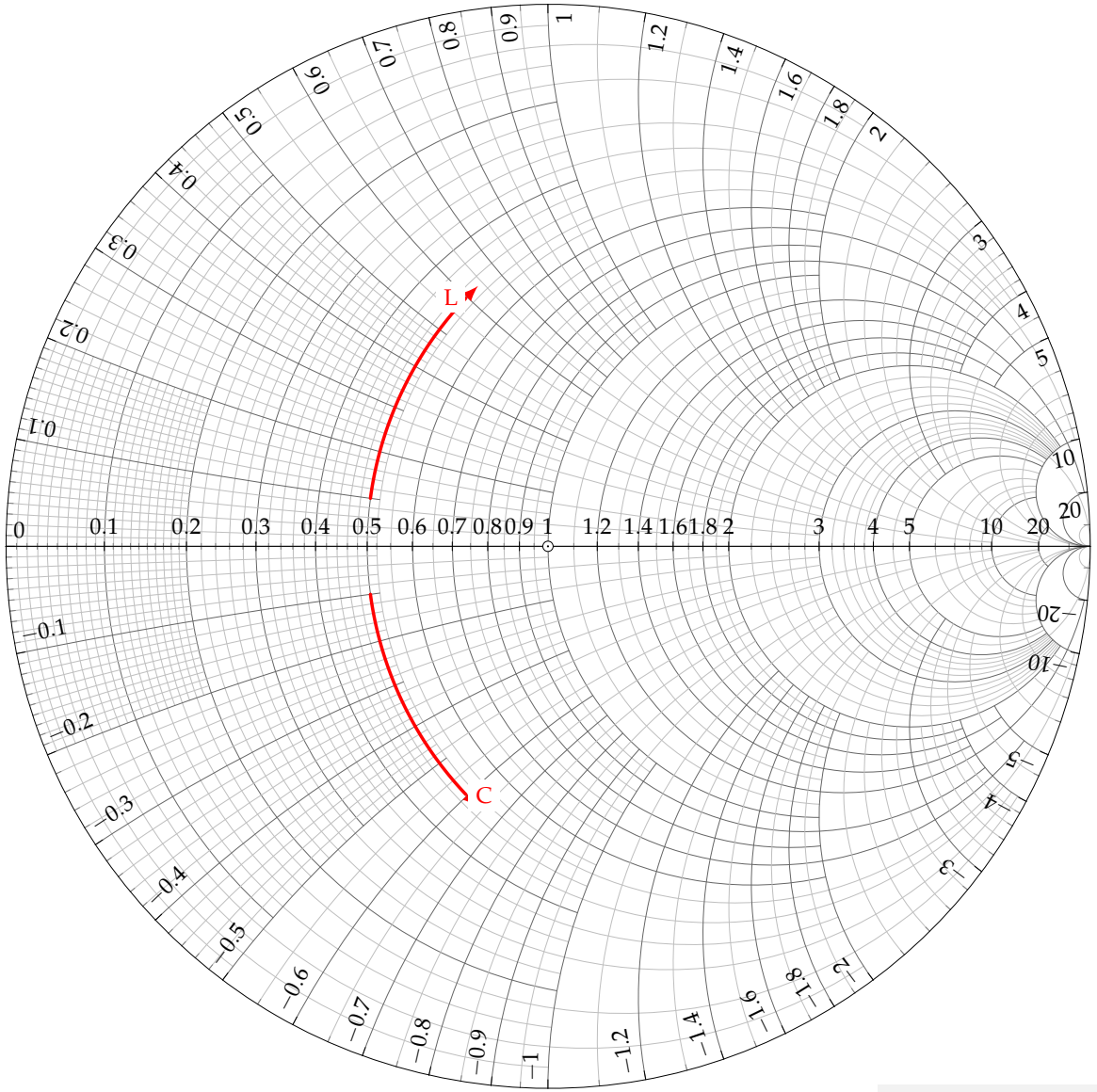
The Complete Smith Chart

Black Magic Design




RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
INDUCTIVE REACTANCE COMPONENT (jX/Zo), OR SUSCEPTANCE (+jB/Yo)
CAPACITIVE REACTANCE COMPONENT (-jX/Zo), OR SUSCEPTANCE (-jB/Yo)
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
ANGLE OF TRANSMISSION COEFFICIENT IN DEGREES
WAVELENGTHS TOWARD GENERATOR
WAVELENGTHS TOWARD LOAD
RADIALLY SCALED PARAMETERS
TOWARD LOAD —>
<— TOWARD GENERATOR
SWR
ATTN. LOSS (dB)
REFL. COEFF. ρ
REFL. COEFF. E or I
ATTEN. (dB)
S.W.R. LOSS COEFF.
REFL. LOSS (dB)
S.W.R. CONST. (?)
TRANSM. COEFF. P
TRANSM. COEFF. E or I
CENTER
ORIGIN

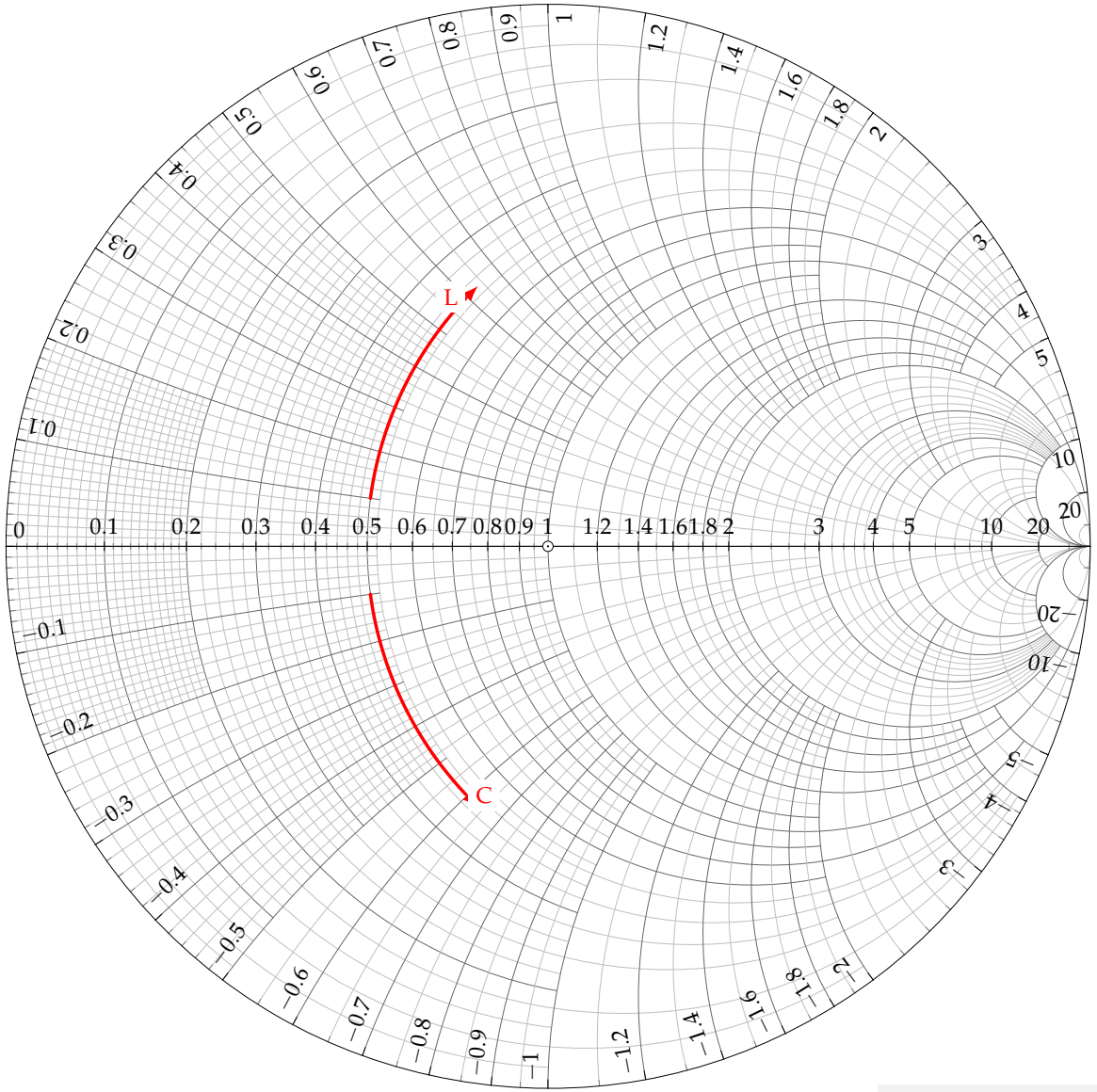
Smith Charts: Components



Series

- Series _____ move _____ along lines of constant resistance
- Series _____ move _____ along lines of constant resistance

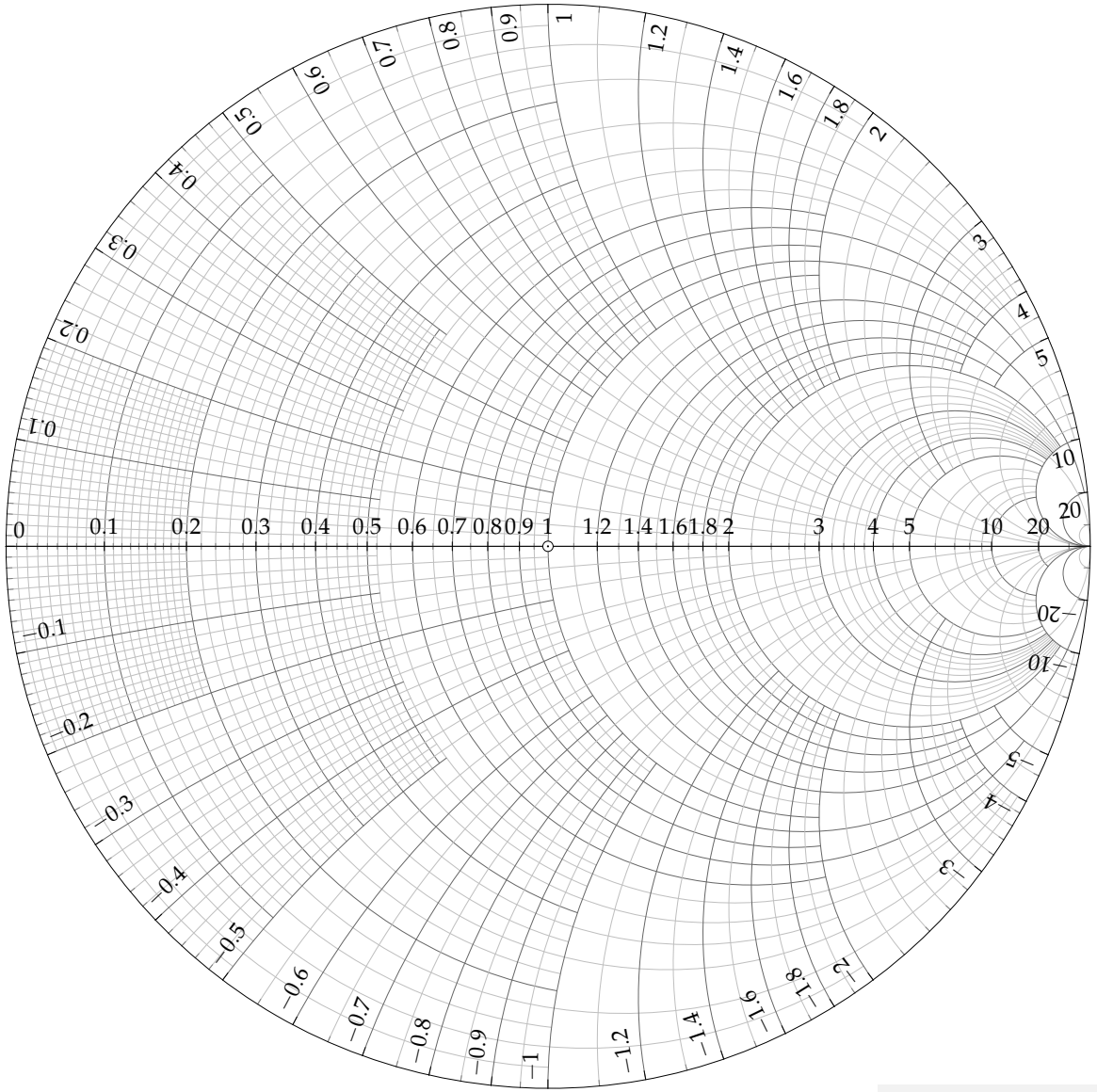
Smith Charts: Components



Parallel

- Parallel _____ move _____ along lines of constant conductance
- Parallel _____ move _____ along lines of constant conductance

Smith Charts: Plotting Impedances

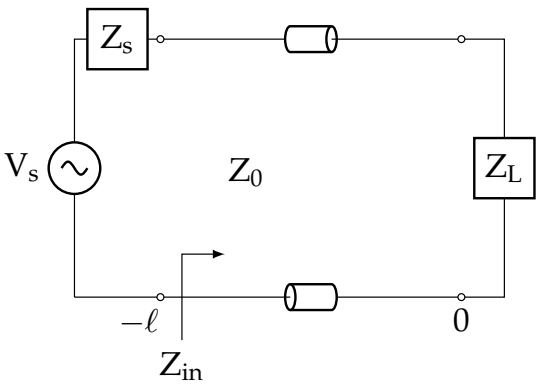


Plot these

- $Z_L = 2 - j1.4$ $\longrightarrow$ (C or L?)
- $Z_L = 1.5 + j0.5$ $\longrightarrow$ (C or L?)
- $Z_L = 75 + j60\Omega$ with $Z_0 = 50\Omega$
- Short circuit
- Open circuit

Impedance Matching: General Process

Match the combined load (Z_L and TX line) to Z_s.



Process

1. Normalize impedances to Z_0
2. Find reflection coefficient (Γ_L)
3. Holding the _____ of Γ_L constant, find the input impedance $z_{in} =$ _____

$$\implies |\Gamma_L| = \frac{z_{in} - 1}{z_{in} + 1}$$

4. Determine capacitance or inductance from X.

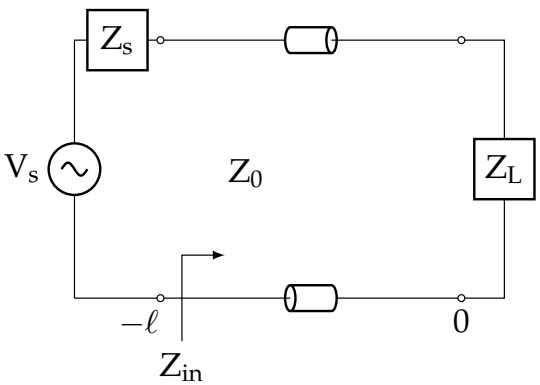
$$\implies Z_C = \frac{1}{j\omega C} \text{ or } Z_L = j\omega L$$

5. Find the length of TX line to make:

$$\implies z_{in} = 1 + jX = \frac{z_L + j\tan(\beta\ell)}{1 + jz_L\tan(\beta\ell)}$$

Impedance Matching: Smith Chart Process

Match the combined load (Z_L and TX line) to Z_s.



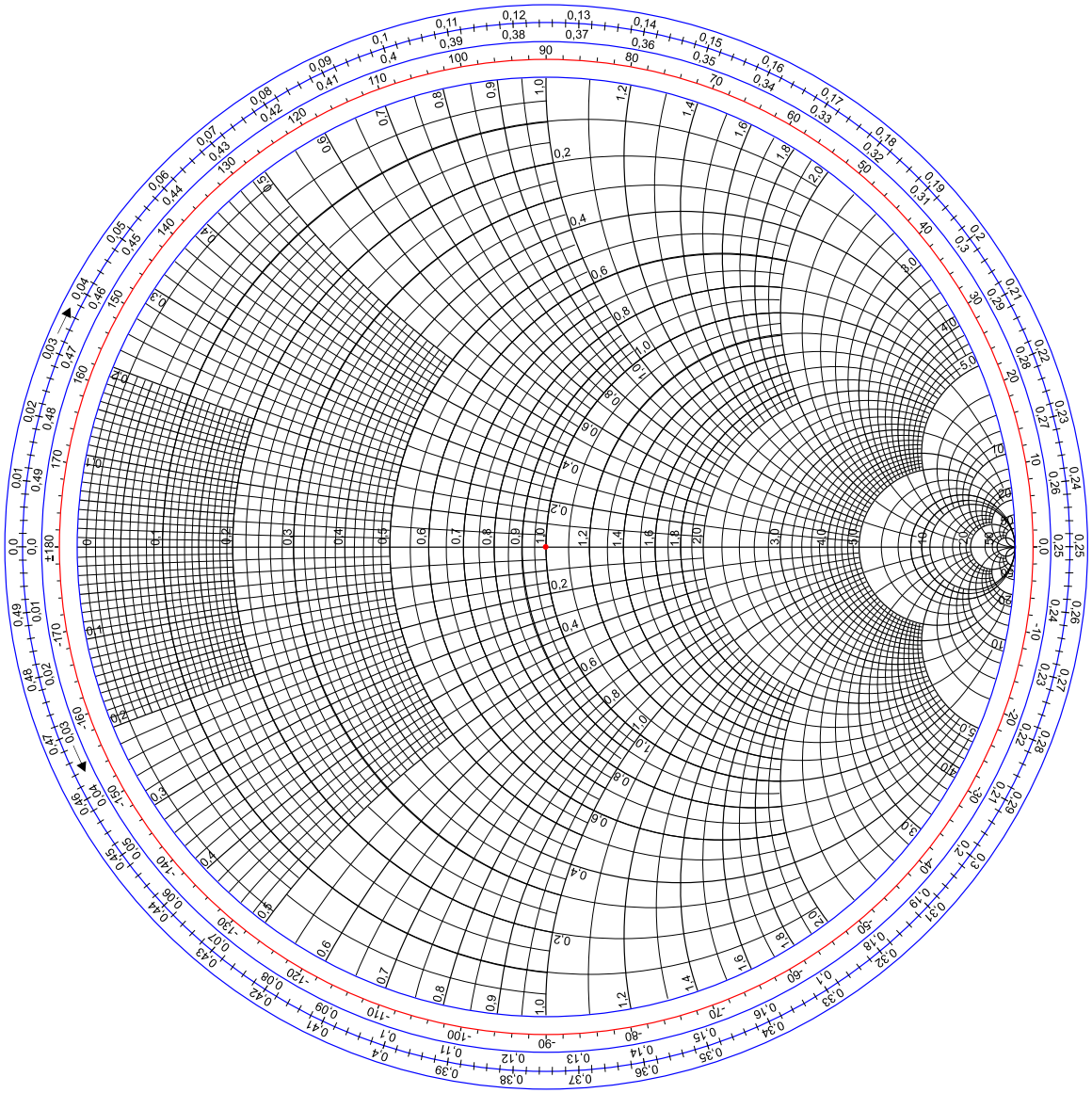
Process

1. Normalize impedances to Z_0
2. Draw _____
3. Rotate towards _____ on circle until intersection with _____
4. Read _____
5. Determine capacitance or inductance from X.

$$\implies Z_C = \frac{1}{j\omega C} \text{ or } Z_L = j\omega L$$

6. Measure TX line length (ℓ) from _____

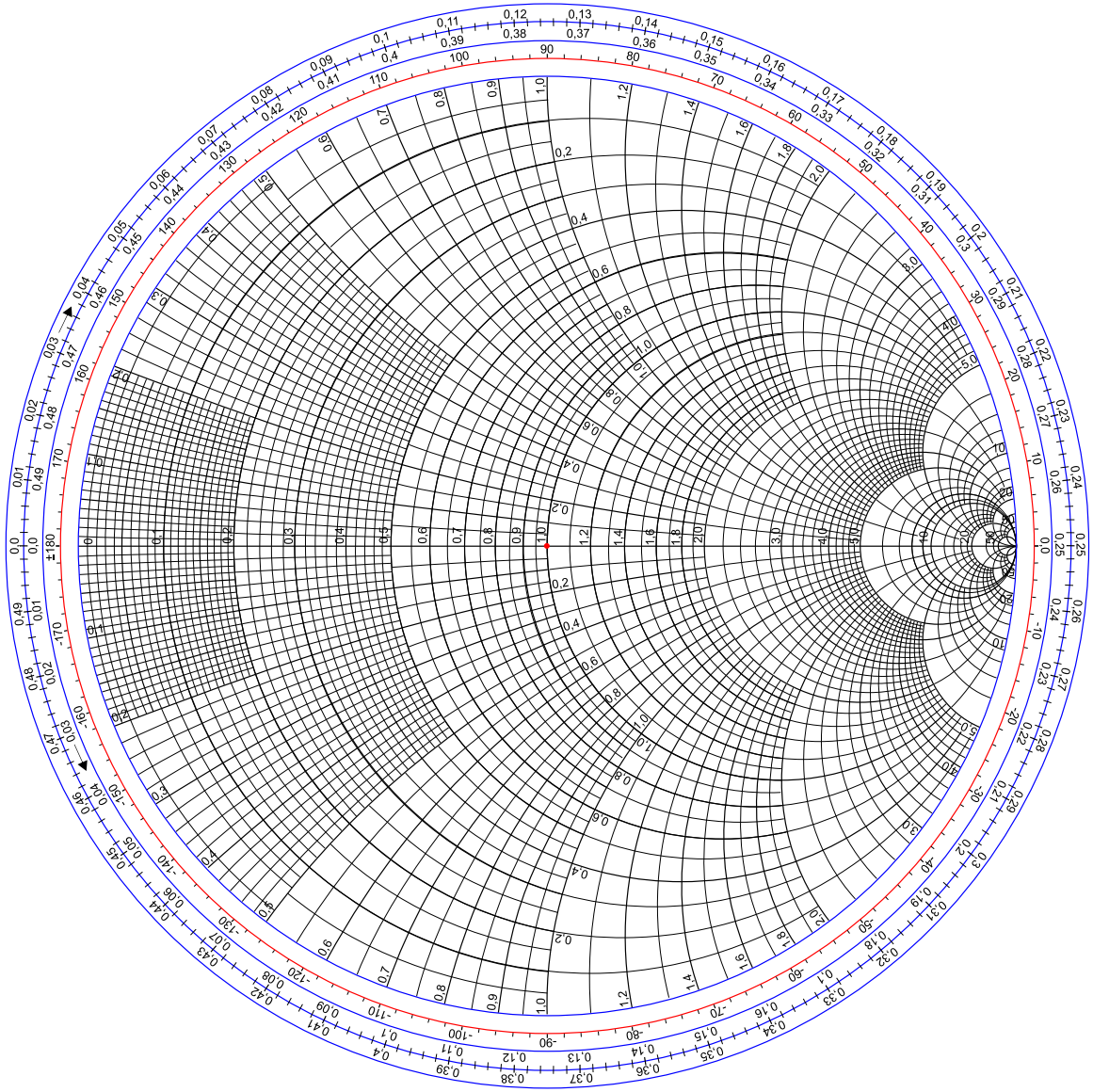
Impedance Matching Example



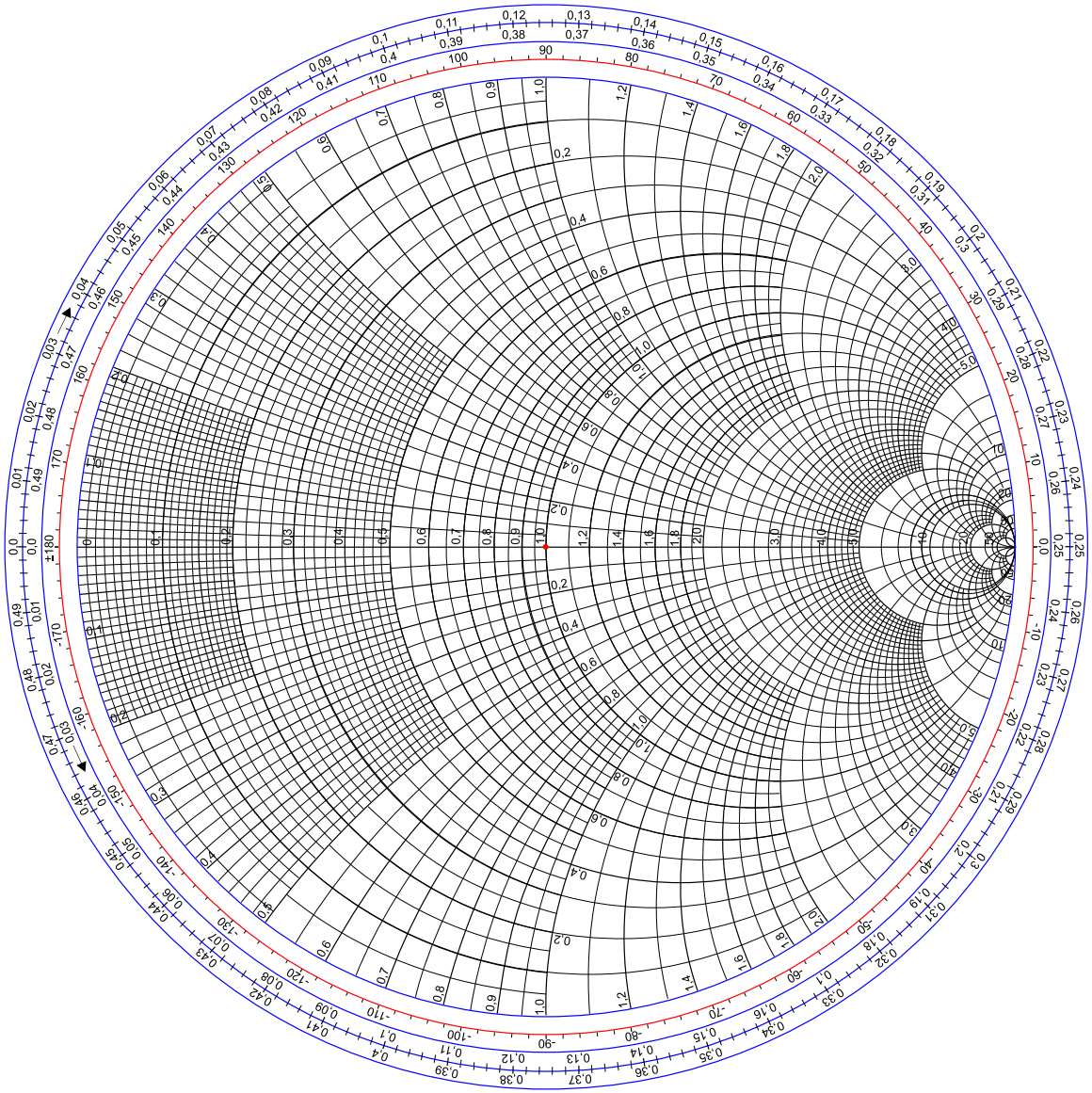
Previous Example

- Match Z_s=50Ω to Z_L=33.9+j17.9Ω
- Z_0 = 50Ω
- _____
- _____
- _____
- _____
- _____

Impedance Matching Example



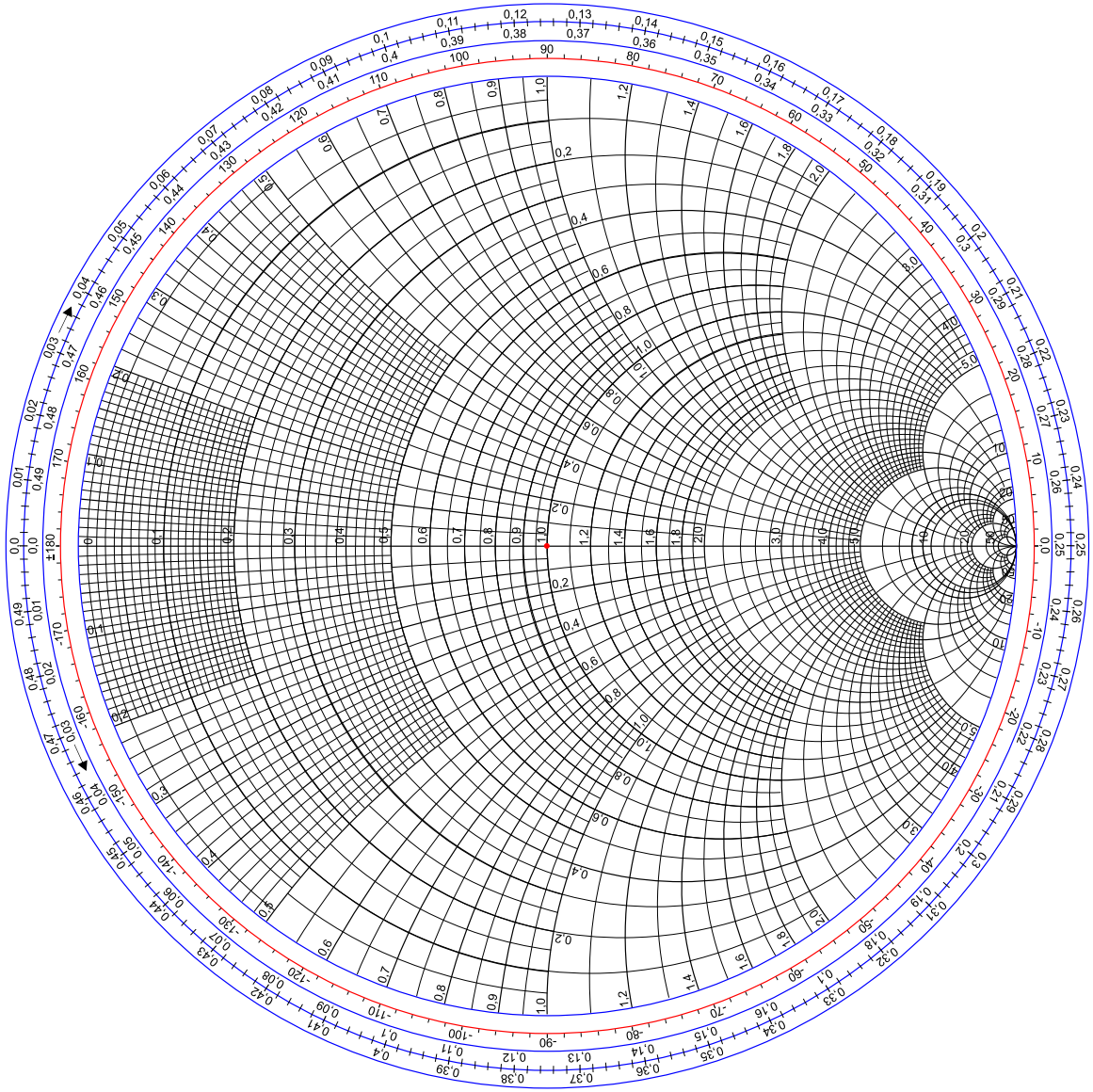
Impedance Matching: Your Turn



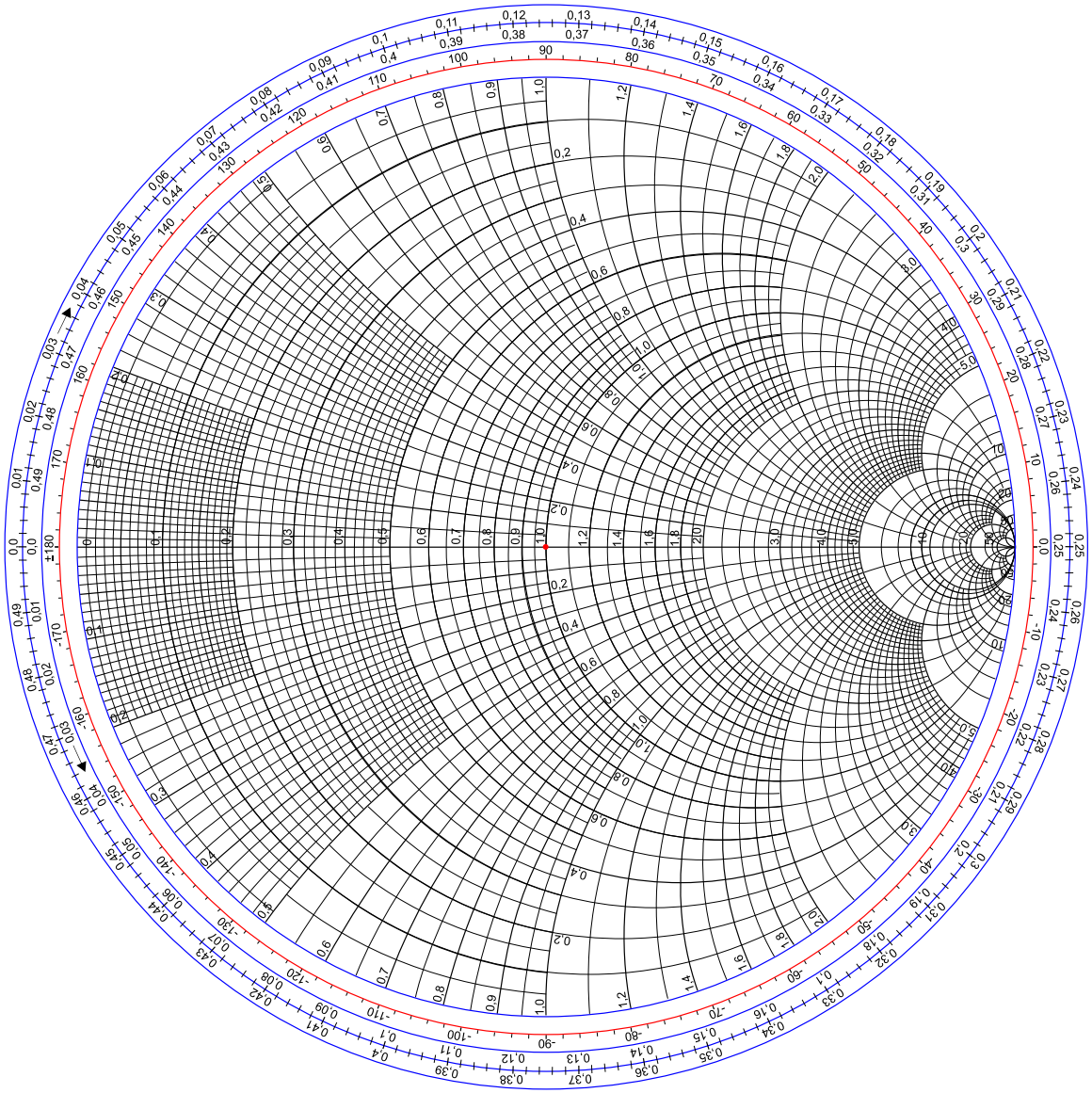
Example 2

- Match Z_s=50Ω to Z_L=30-j120Ω
- Z_0 = 75Ω
- _____
- _____
- _____
- _____
- _____

Impedance Matching: Your Turn



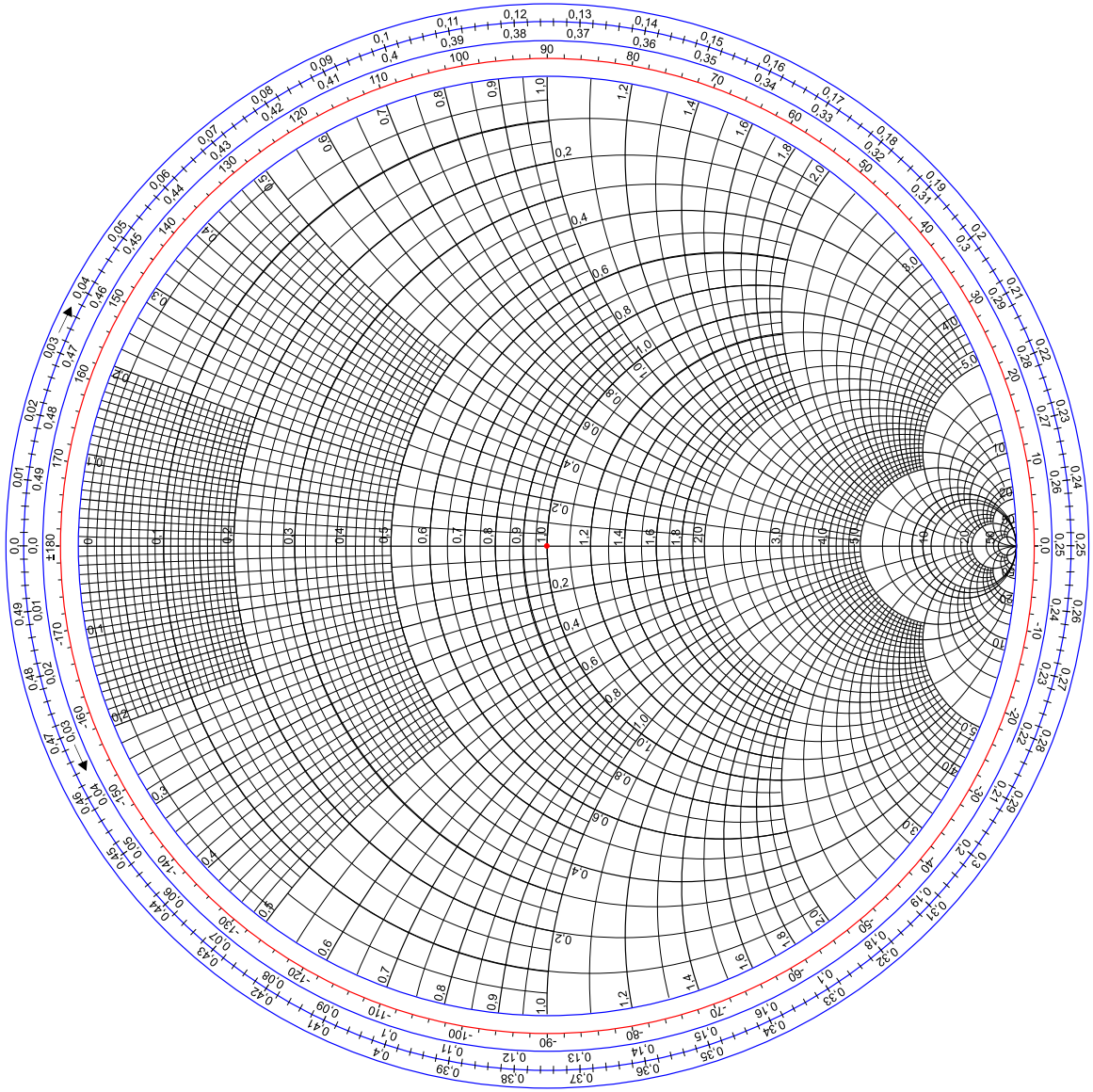
Impedance Matching: Parallel Component



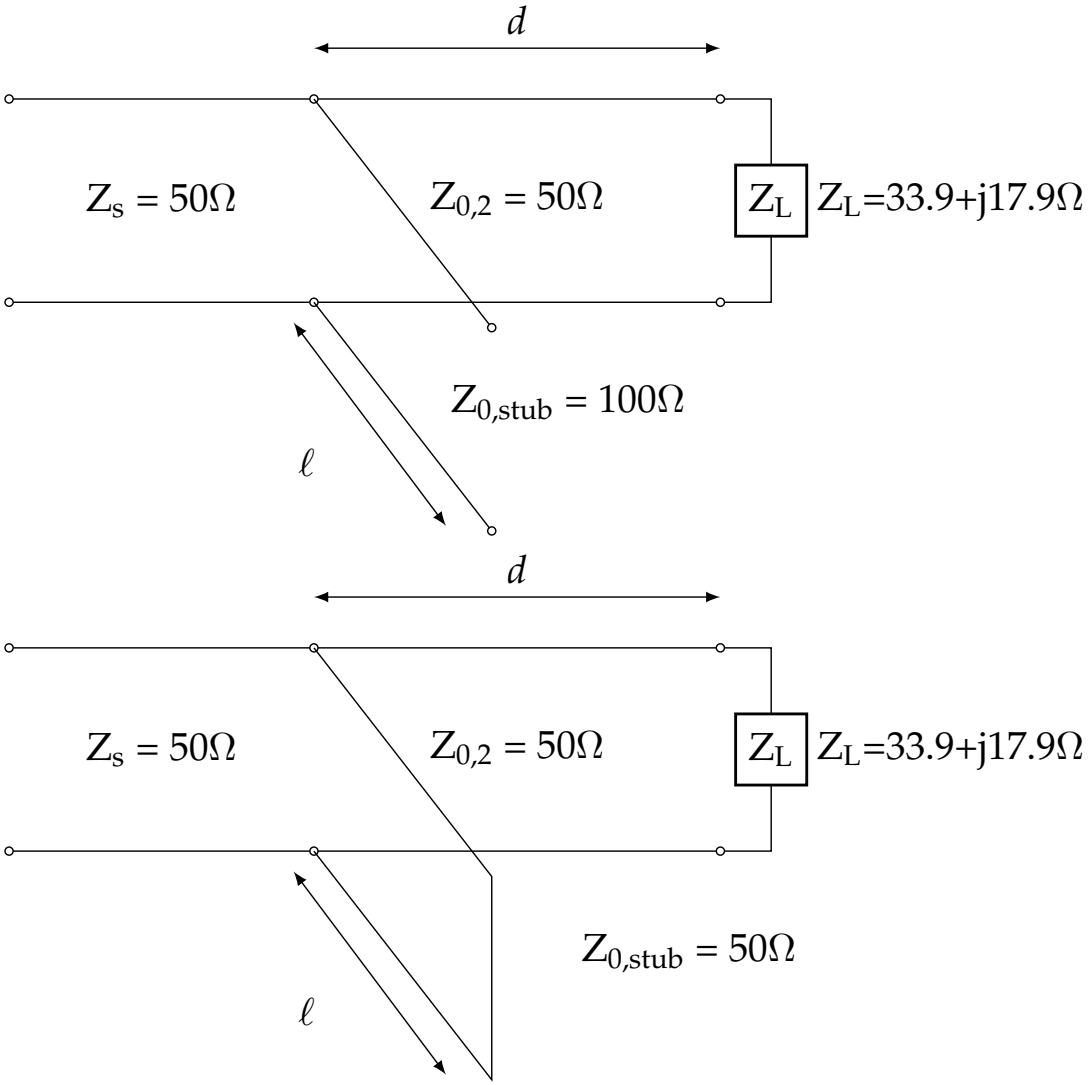
Previous Example

- Use a parallel component
- _____
- _____
- _____
- _____
- _____
- _____

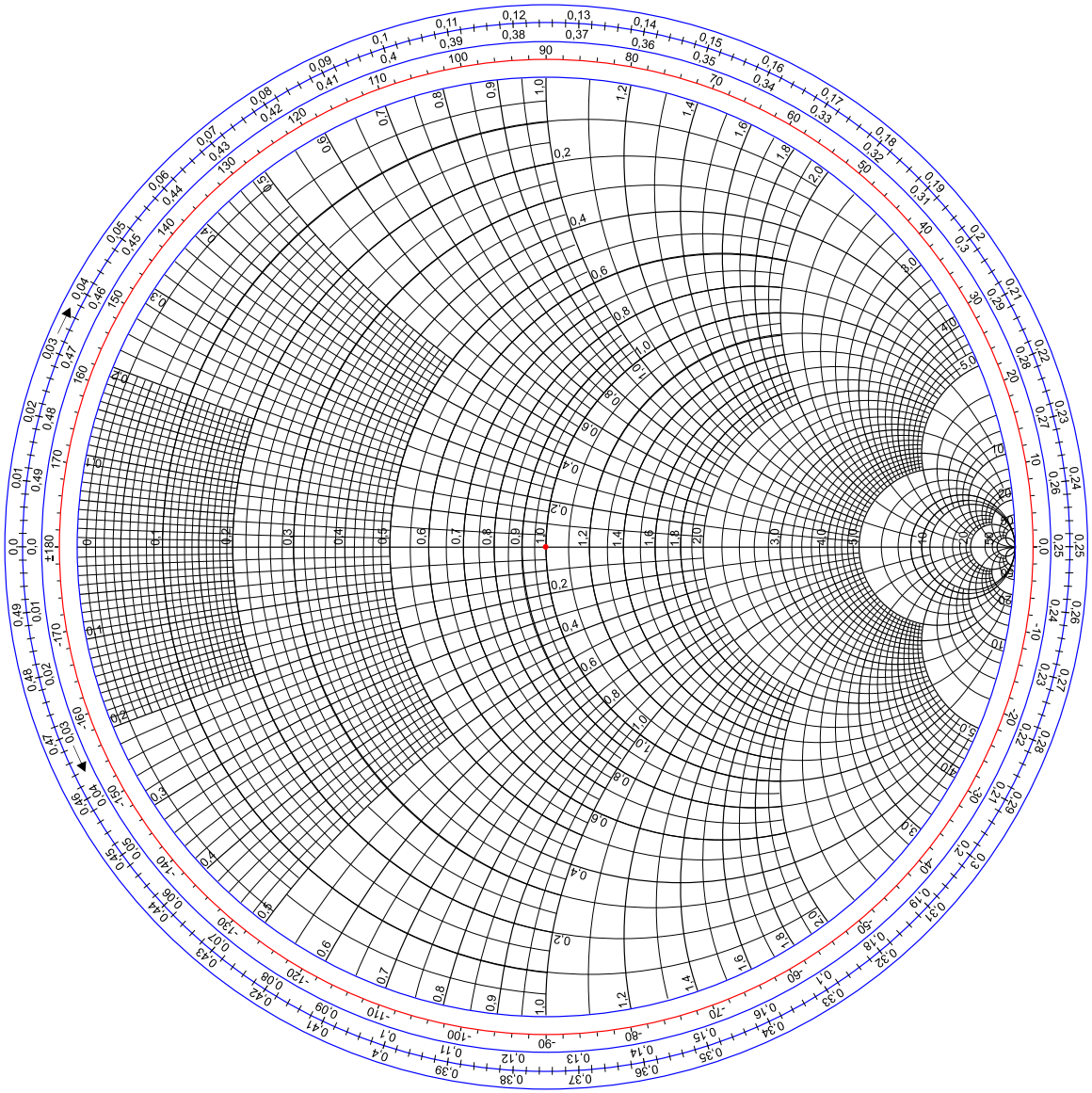
Impedance Matching: Parallel Component



Impedance Matching: TX Line Stubs



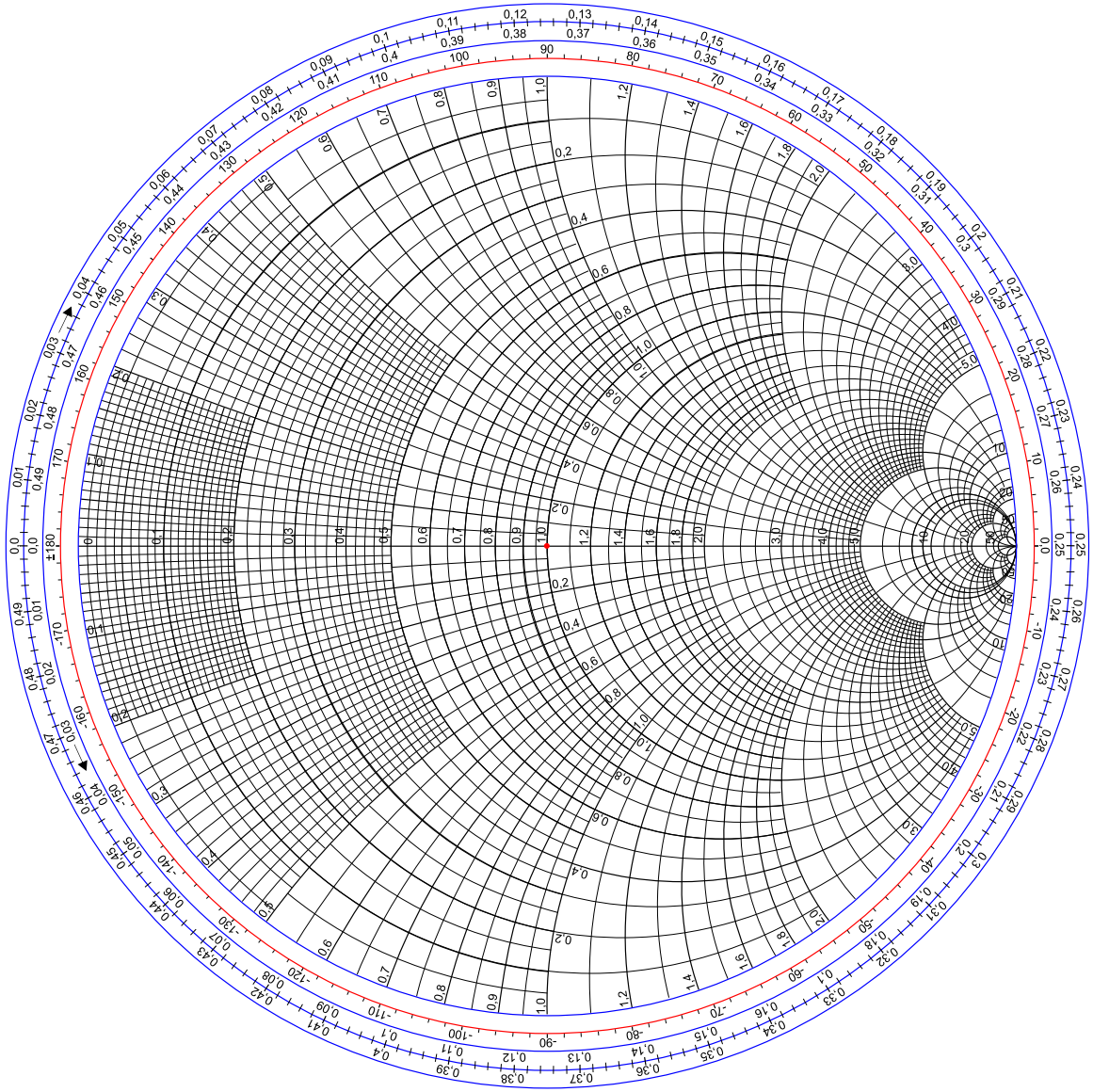
Impedance Matching: Stubs



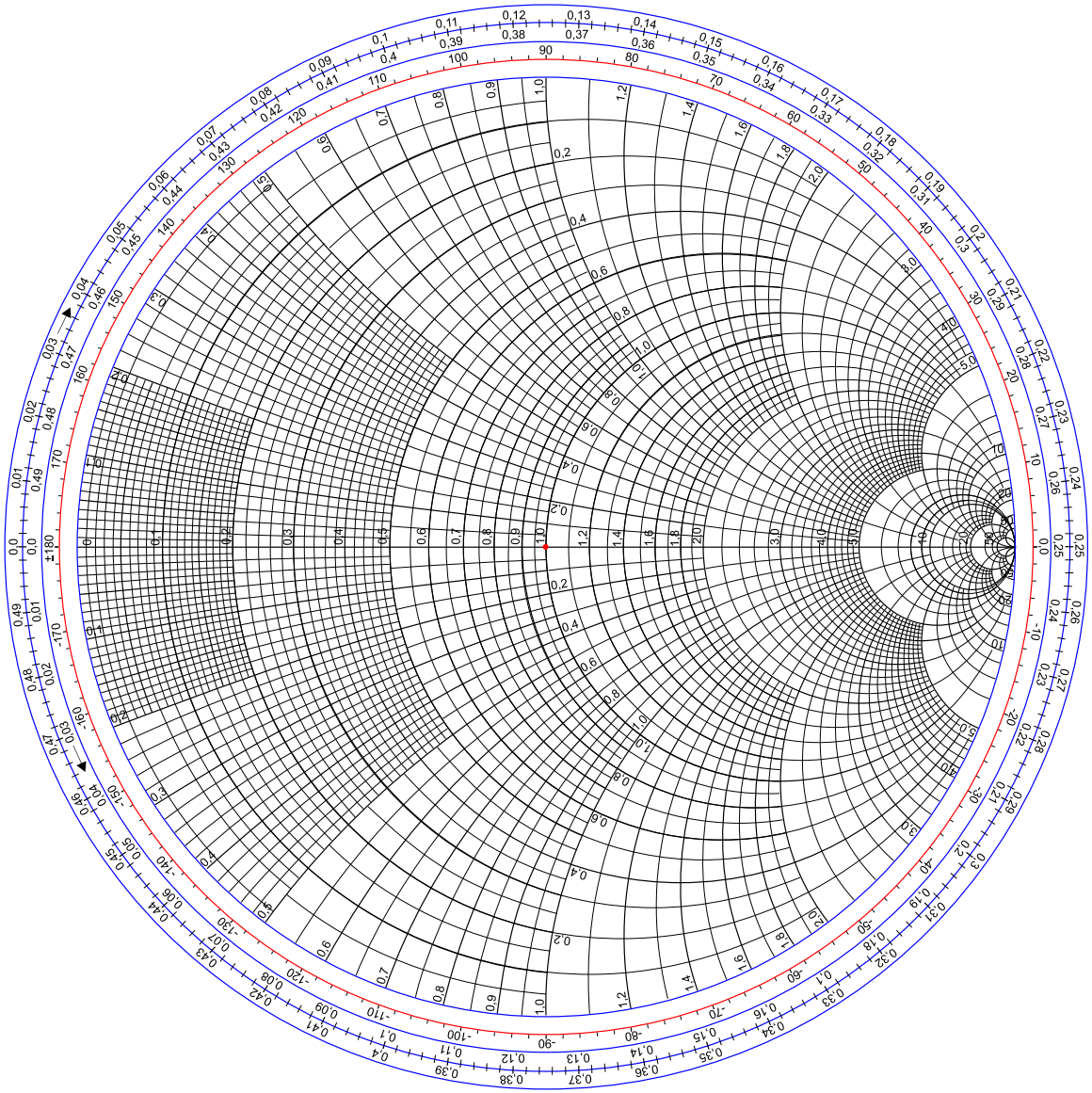
Previous Example

- Match Z_s=50Ω to Z_L=33.9+j17.9Ω
- _____
- _____
- _____
- _____
- _____
- _____

Impedance Matching: Parallel Component



Impedance Matching: Stubs - Your Turn



Example 2

- Match Z_s=50Ω to Z_L=33.9+j17.9Ω
- _____
- _____
- _____
- _____
- _____
- _____

Impedance Matching: Parallel Component

