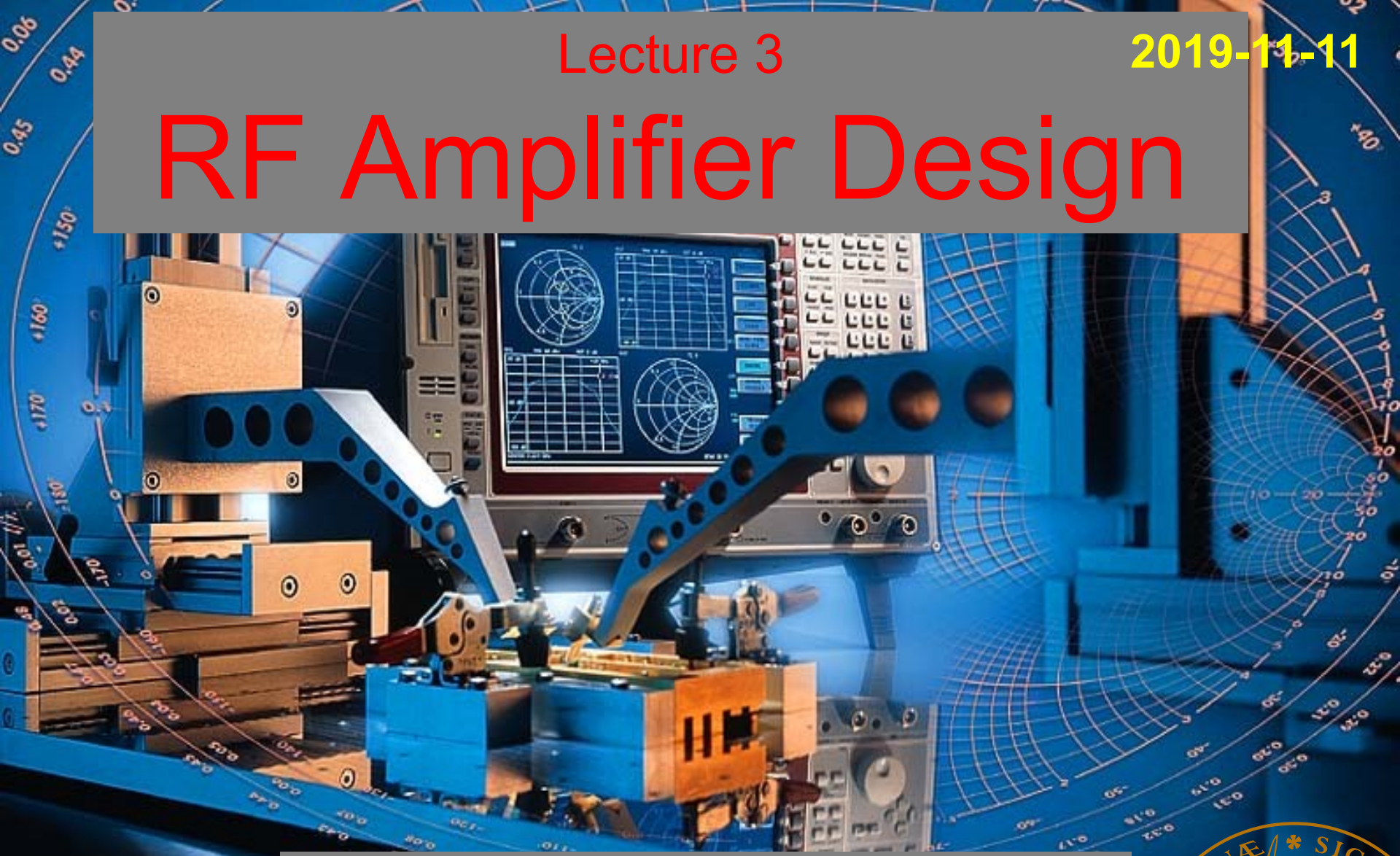
Lecture 3

2019-11-11

RF Amplifier Design



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Course Administration

- Register in LADOK (https://www.student.lu.se/)
  - Sign up (beforehand or on manual list)
  - Register
- LU Canvas > ETIN50 (https://canvas.education.lu.se/)
  - Course materials
  - Track lab progress
  - Hand in and grade reports

Schedule

- Lab Sessions
  - Only the morning slot of the labs will be offered due to the number of students this year

- This week: 1x Lecture, Handin 1 published, 2x Exercise, Lab 1
  - Hand-in assignment 1: “Input Impedance and Mismatch Loss” now published, due Fri, Nov 22, 23:59

  - Lab 1: ”Parallel Resonant Circuits”
    Thu, Nov 14, 8:00-12:00
  - Preparation tasks are compulsory to start labwork

  - 2x Exercises => make sure to have done lab prep. before and ask
  - Also, demo of ”deslib” toolbox for MATLAB on E3

Lecture 3

- The Smith Chart
  - Structure
    - Reflection Coefficient and Impedance
    - Scales
  - Applications
    - Reflection Coefficient and Electrical Length
    - Impedance and Admittance
    - Series Connection
    - Parallel Connection
    - Combined Z and Y Scales
    - Circuit Q
    - Standing-Wave Ratio

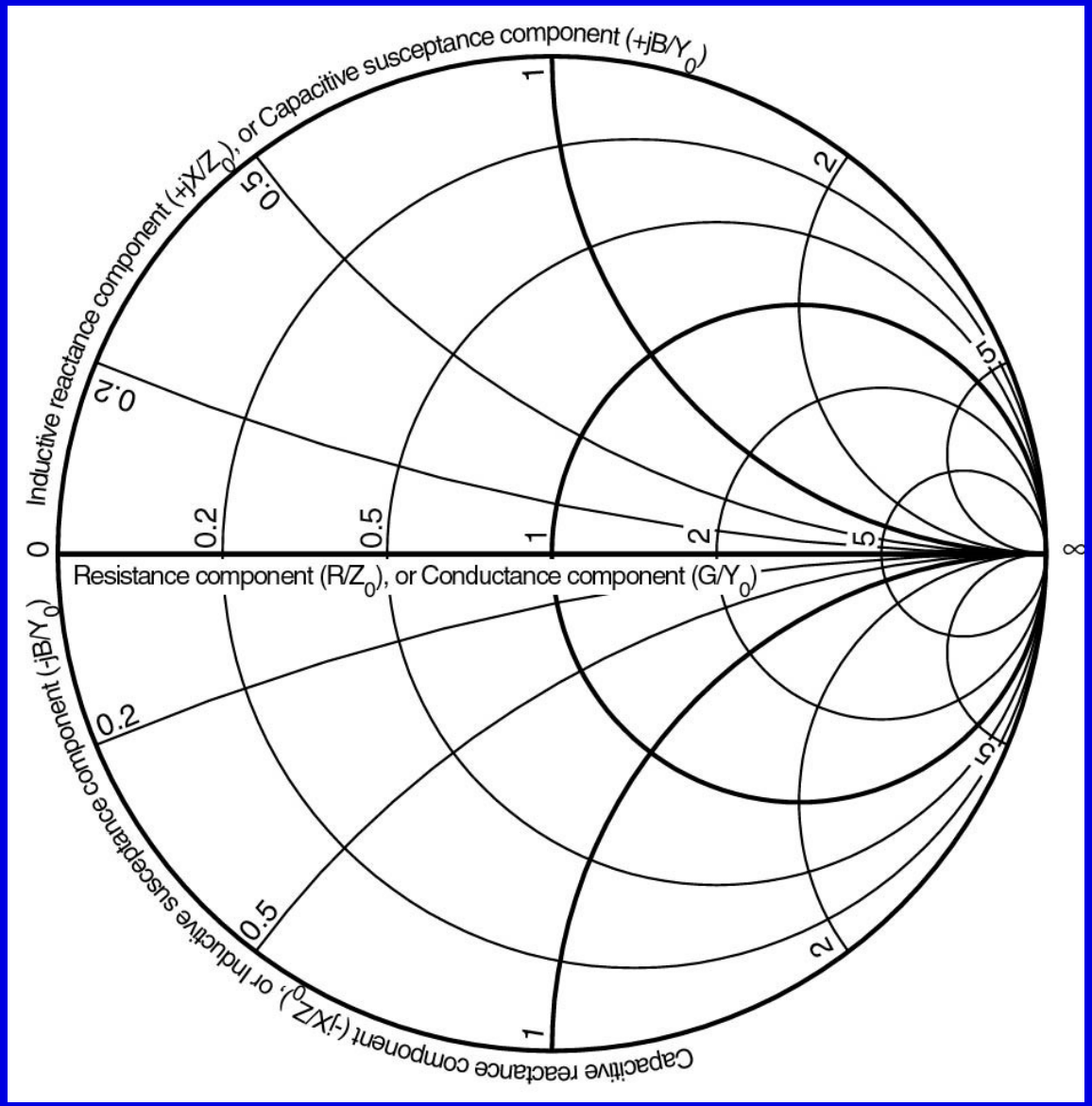
Reading Guide

- Chapter 4

The Smith Chart

The chart was invented by Phillip Smith in the early 1930-ties

Transform between the Γ– and Z–plane



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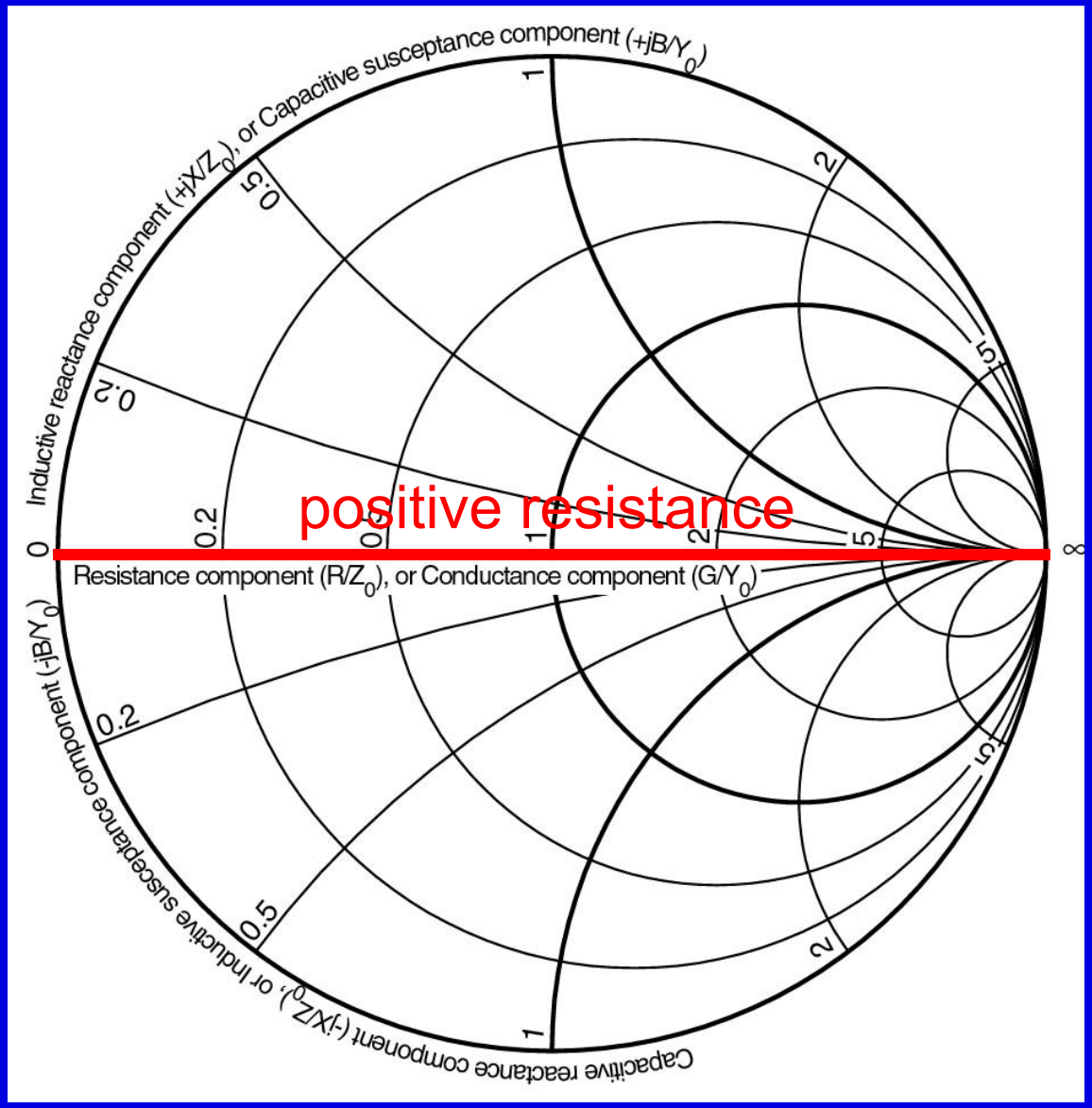

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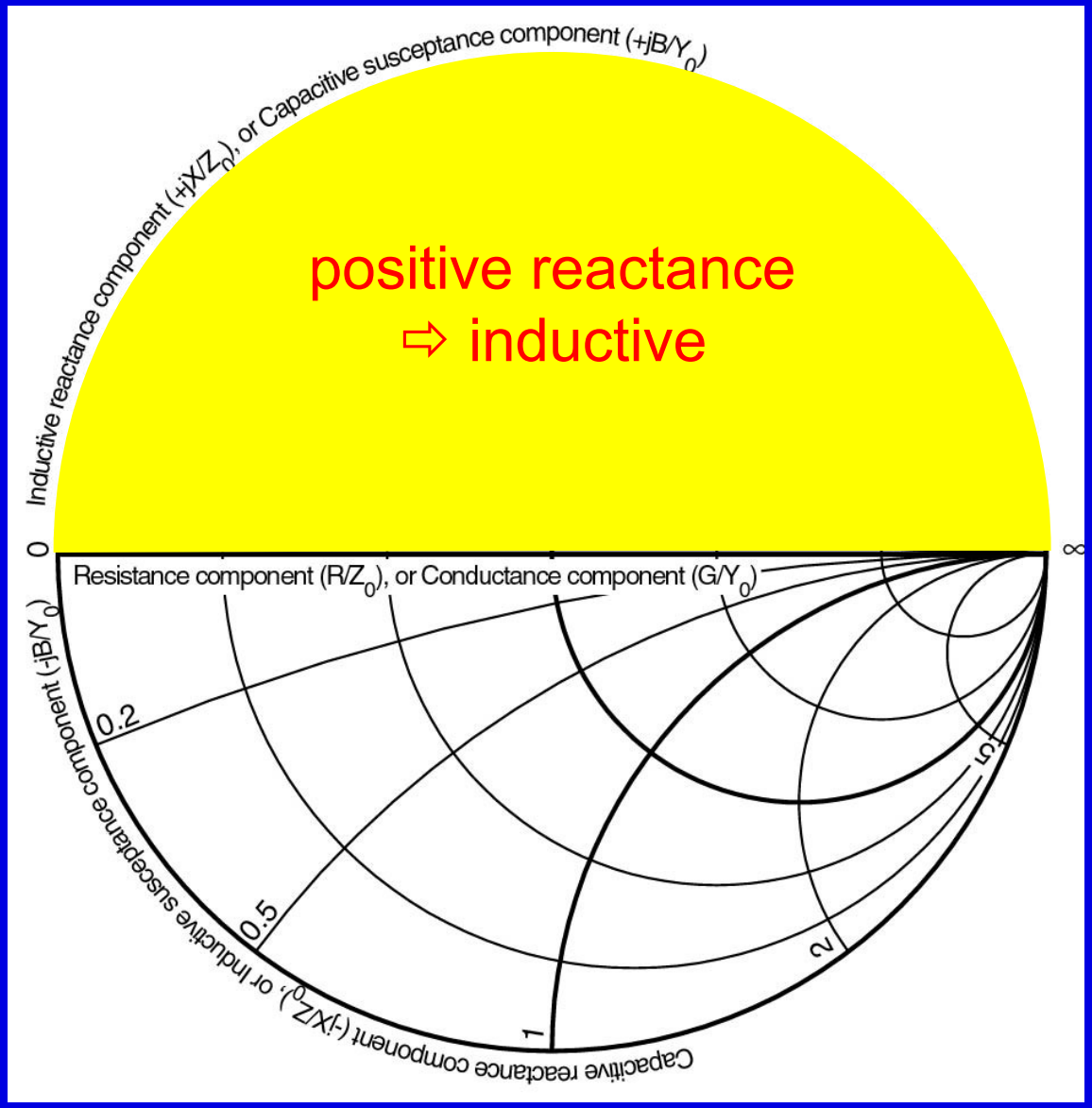

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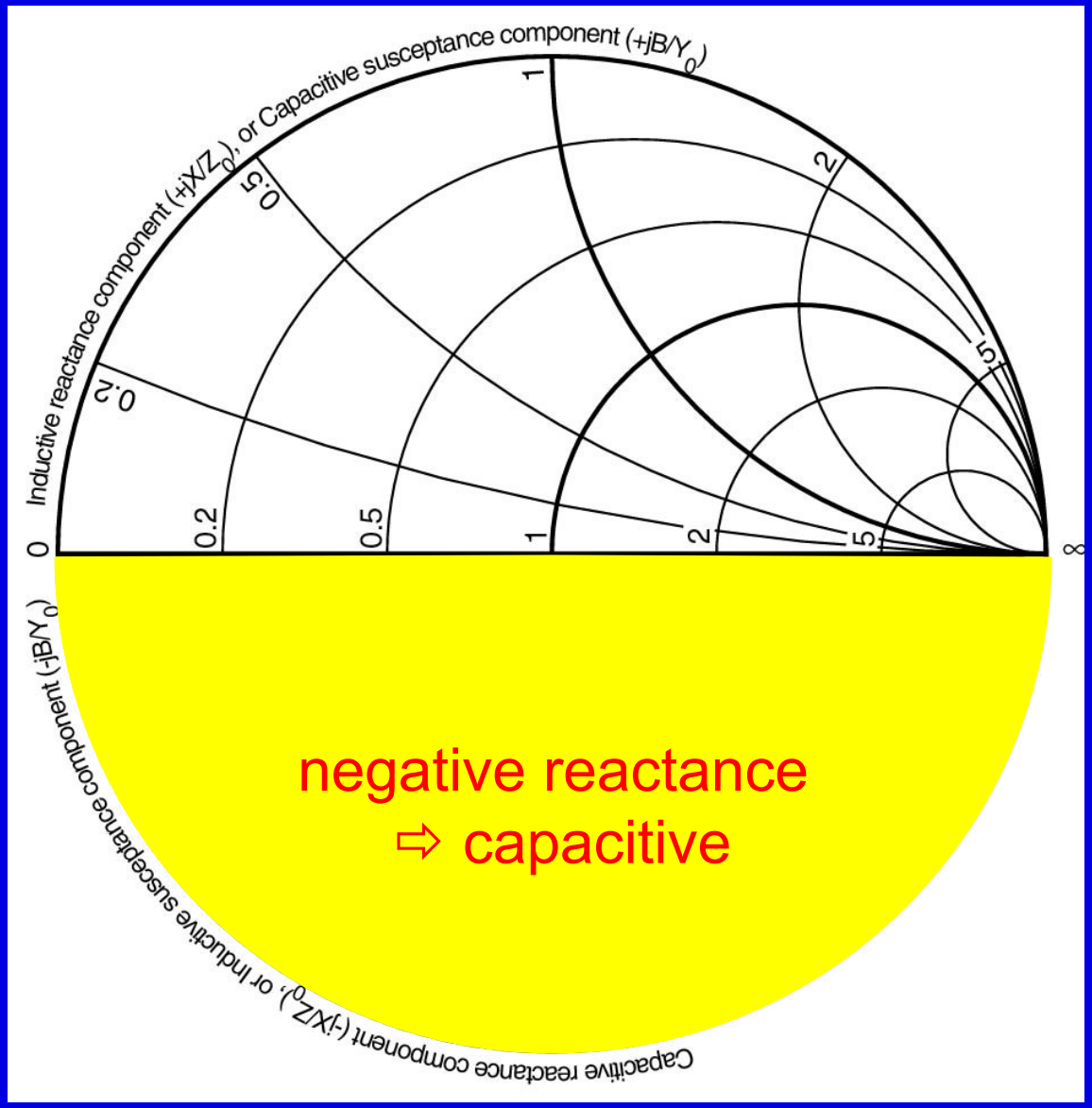


The Structure of the Smith Chart

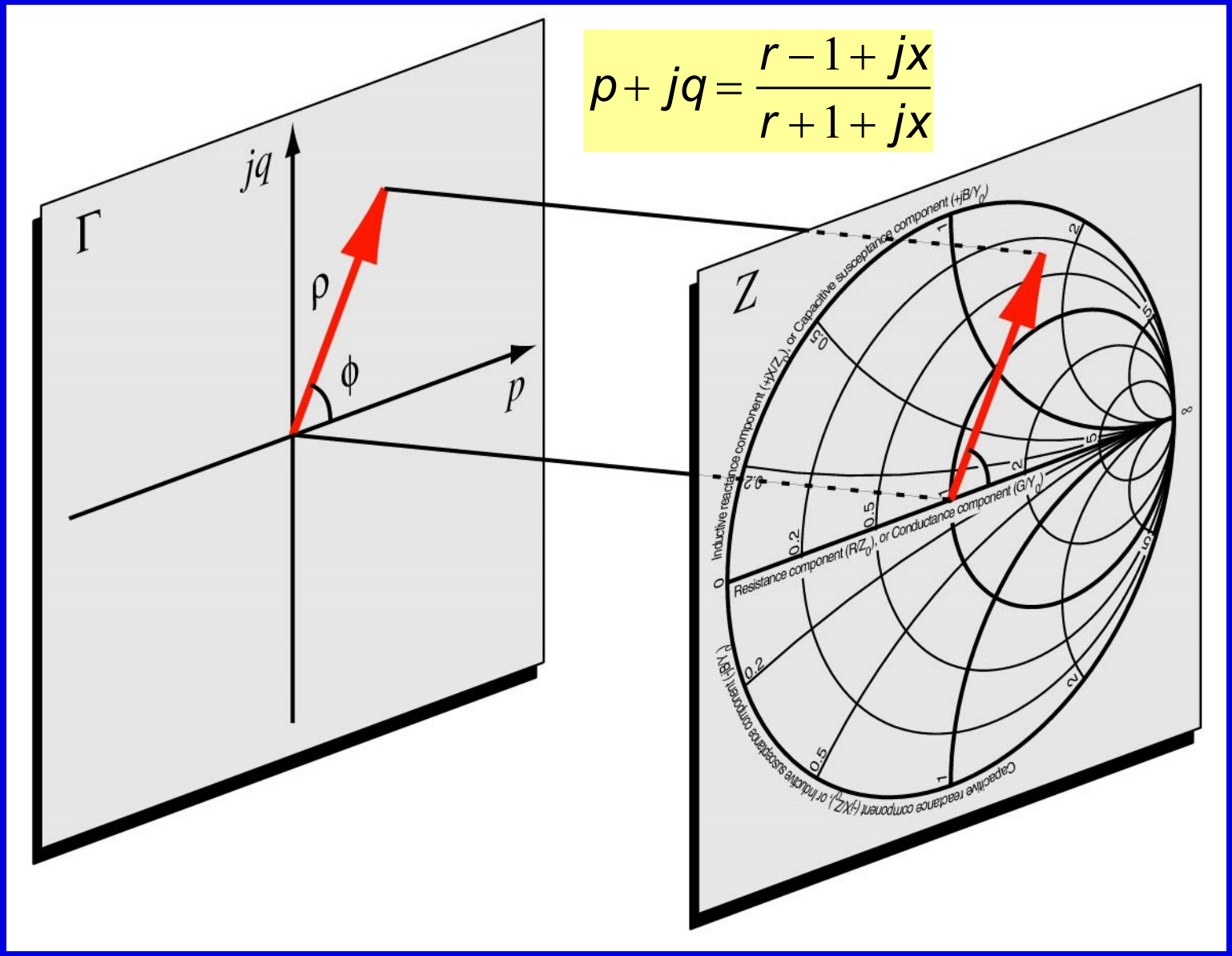
- Impedance $Z = R + jX$
- Reflection coefficient $\Gamma = \rho\angle\phi = \rho\exp(j\phi) = p + jq$
- Conversion: $\Gamma = \frac{z-1}{z+1}$ where $z = \frac{Z}{Z_0} = r + jx$ ⇨ $p + jq = \frac{r-1+jx}{r+1+jx}$

Coordinates in the Γ-plane

- split up the expression in
- real part: $\left(p - \frac{r}{r+1}\right)^2 + q^2 = \left(\frac{1}{r+1}\right)^2$ ⇨ circles at origin $\left(\frac{r}{r+1}, 0\right)$ and radius $\frac{1}{r+1}$
- Imaginary part: $\left(q - \frac{1}{x}\right)^2 + (1-p)^2 = \left(\frac{1}{x}\right)^2$ ⇨ circles at origin $\left(1, \frac{1}{x}\right)$ and radius $\frac{1}{x}$

Reflection Coefficient ⇨ Impedance

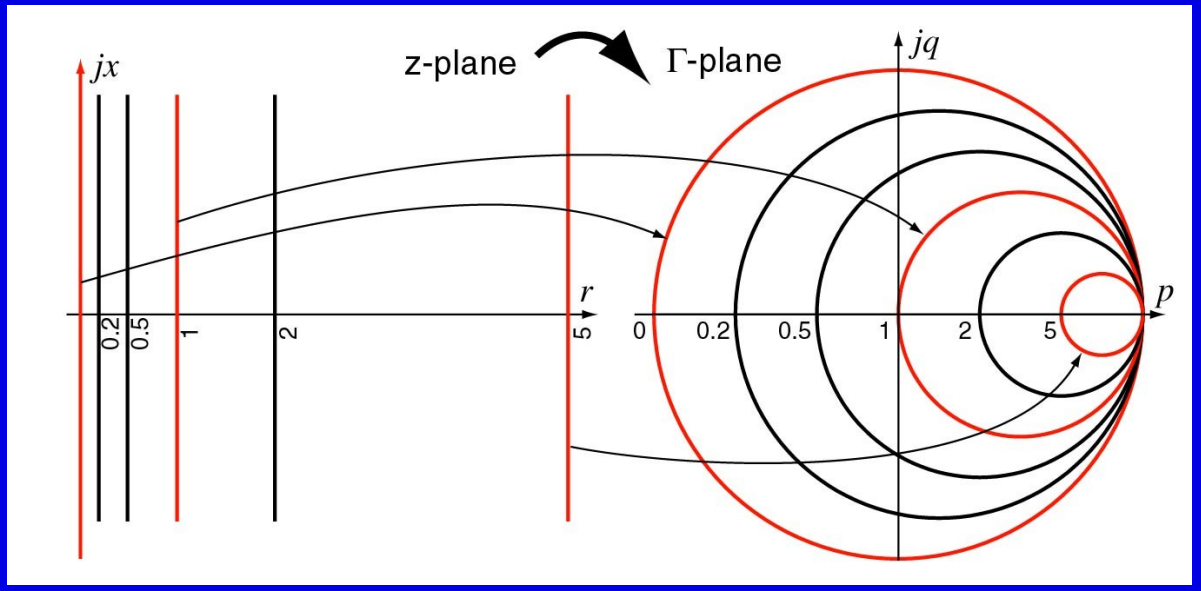
$$p + jq = \frac{r - 1 + jx}{r + 1 + jx}$$



The Smith Chart Circles

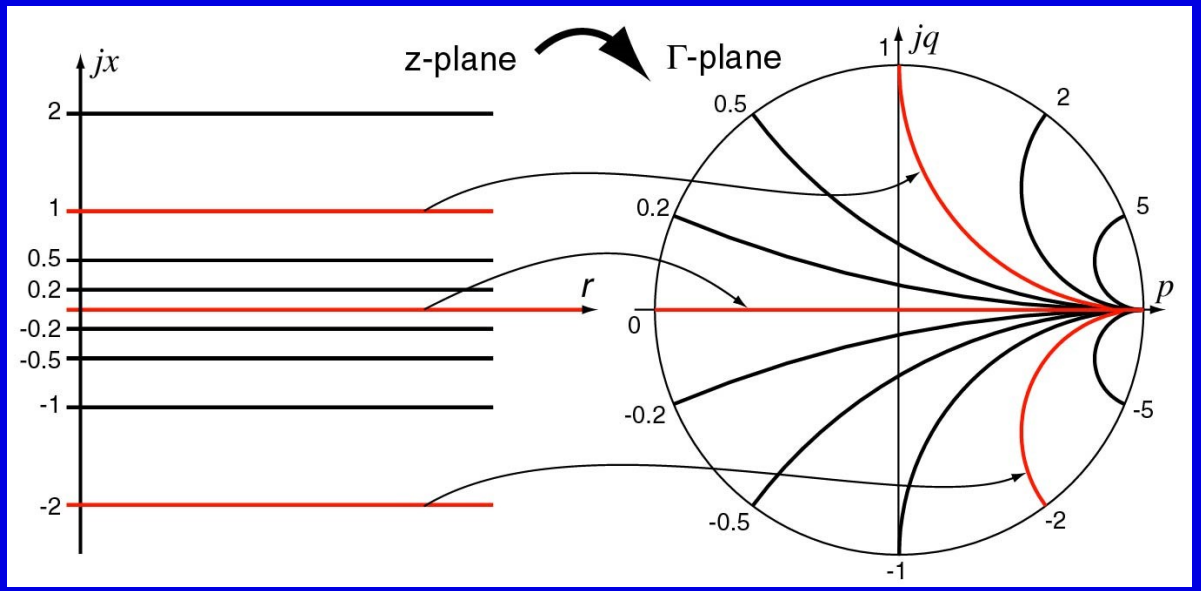
- Constant resistance lines ⇨ resistance circles

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



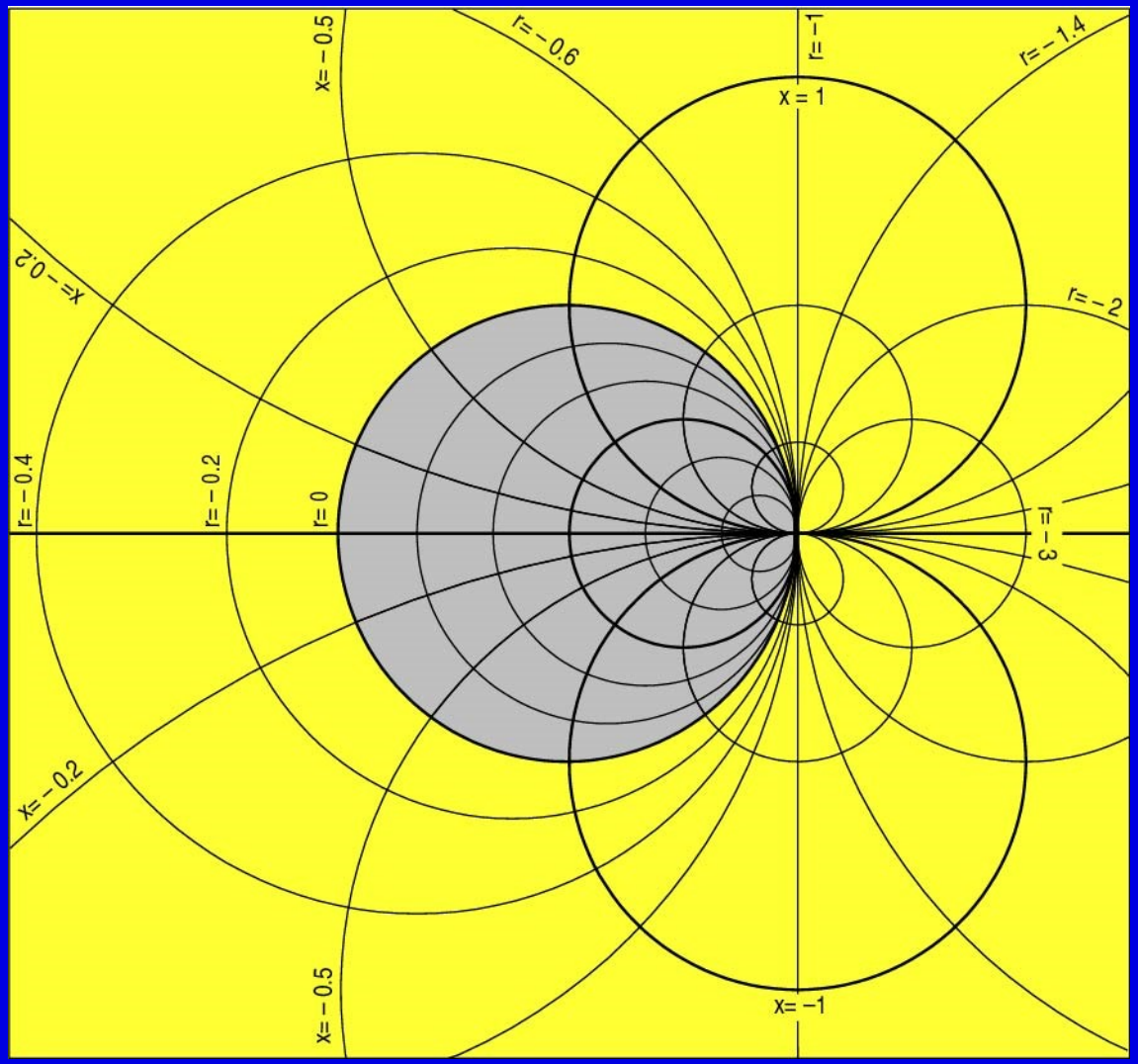
- Constant reactance lines ⇨ reactance circles

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

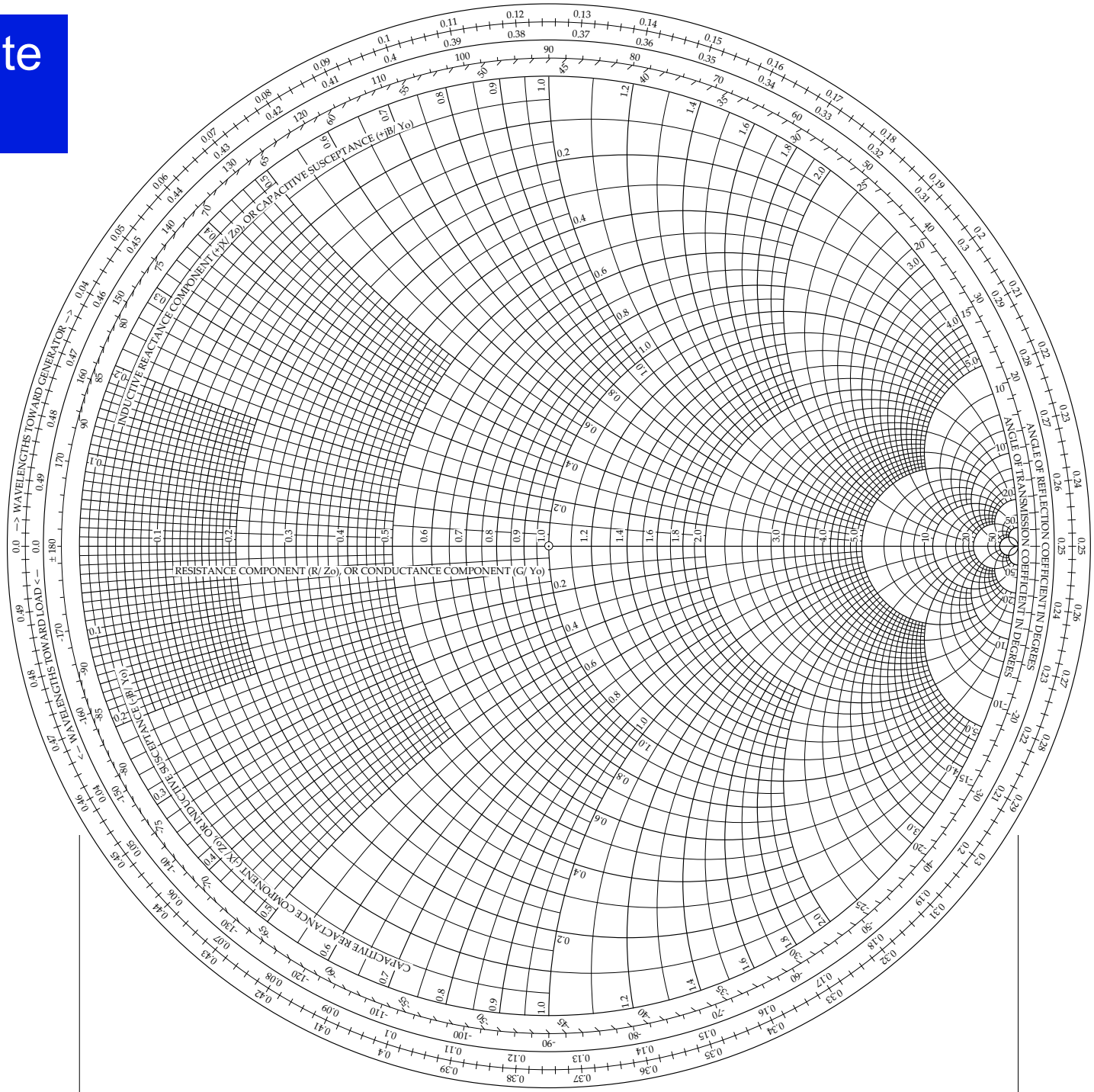


Negative Resistance

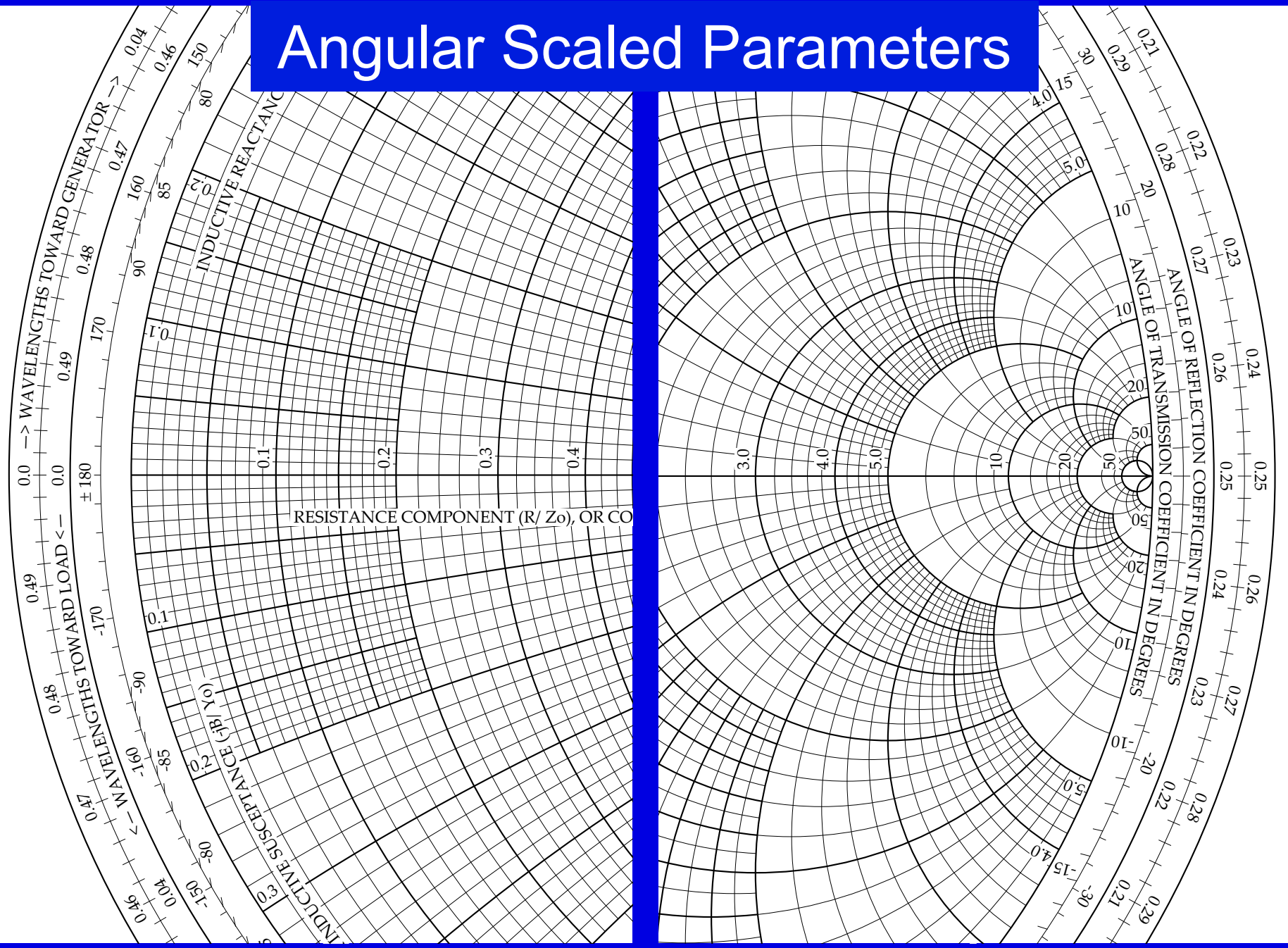
- Negative resistance is mapped outside Smith chart unit circle



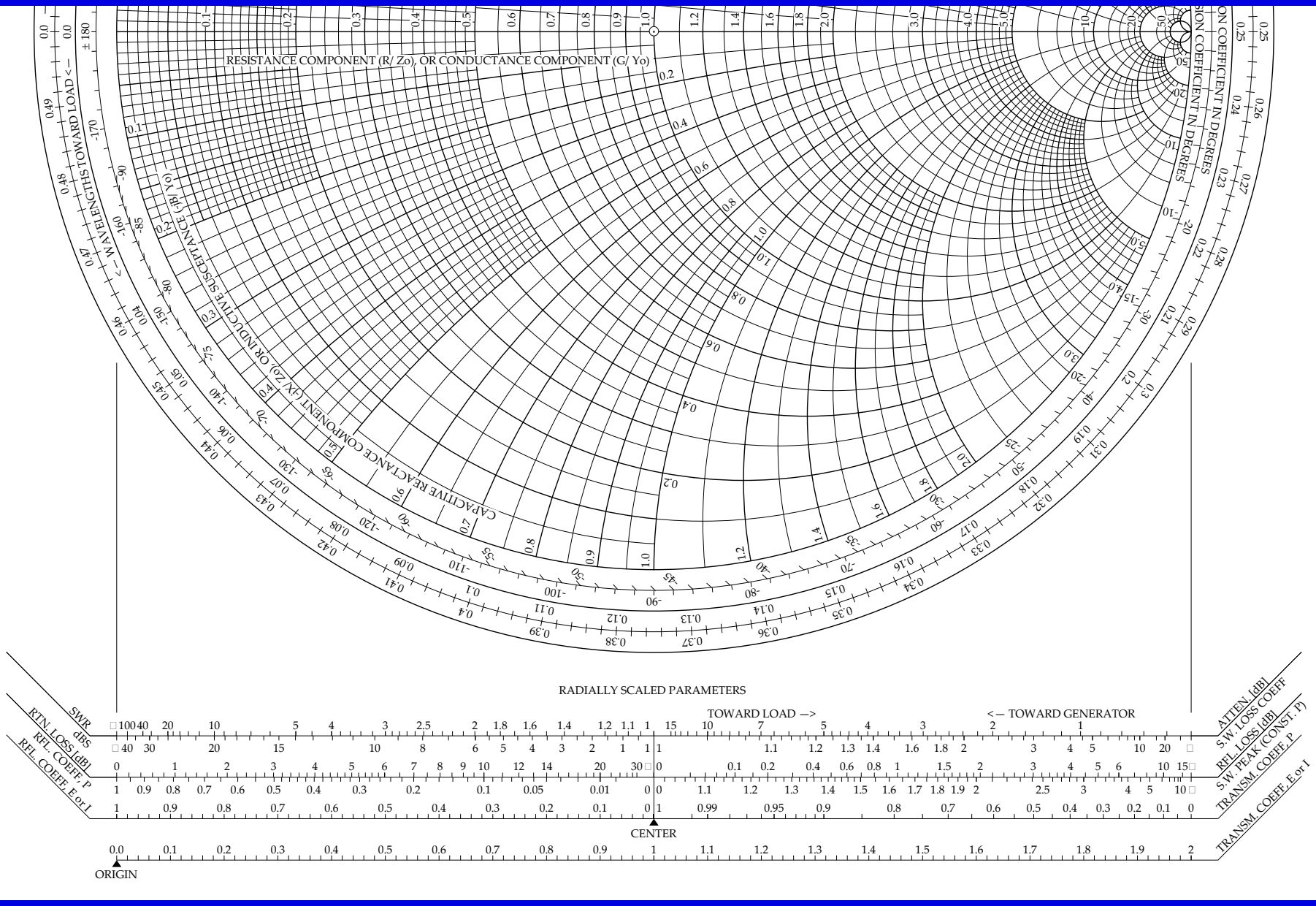
The Complete Smith Chart



Angular Scaled Parameters



Radially Scaled Parameters



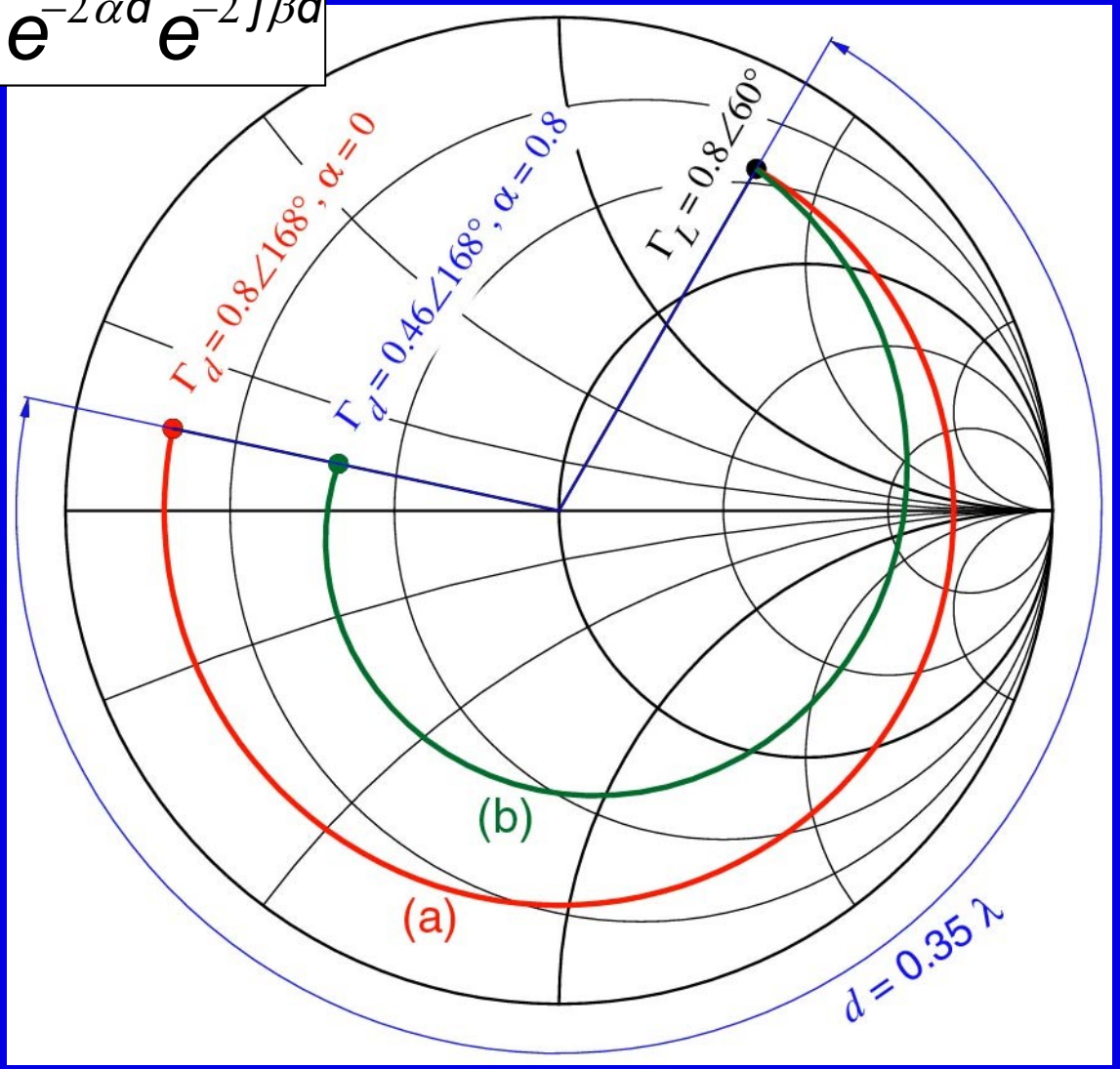
Reflection Coefficient and Electrical Length

$$\Gamma_d = \Gamma_L e^{-2\gamma d} = \Gamma_L e^{-2\alpha d} e^{-2j\beta d}$$

transmission through

a) a lossless line

b) a lossy line



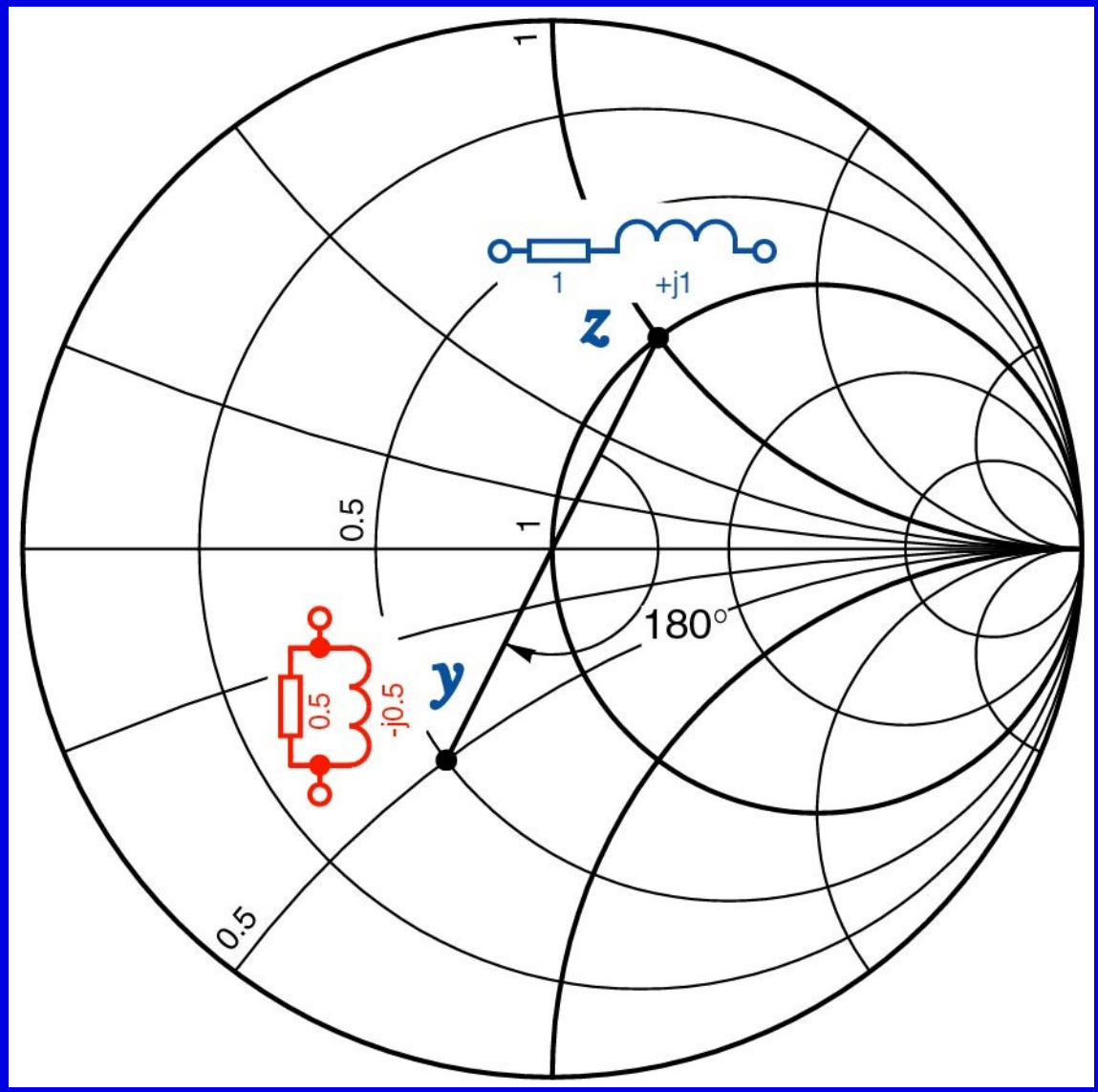
Conversion of Impedance ⇨ Admittance

$$z = \frac{1}{y}$$

$$\Gamma(y) = \frac{1/y - 1}{1/y + 1} =$$

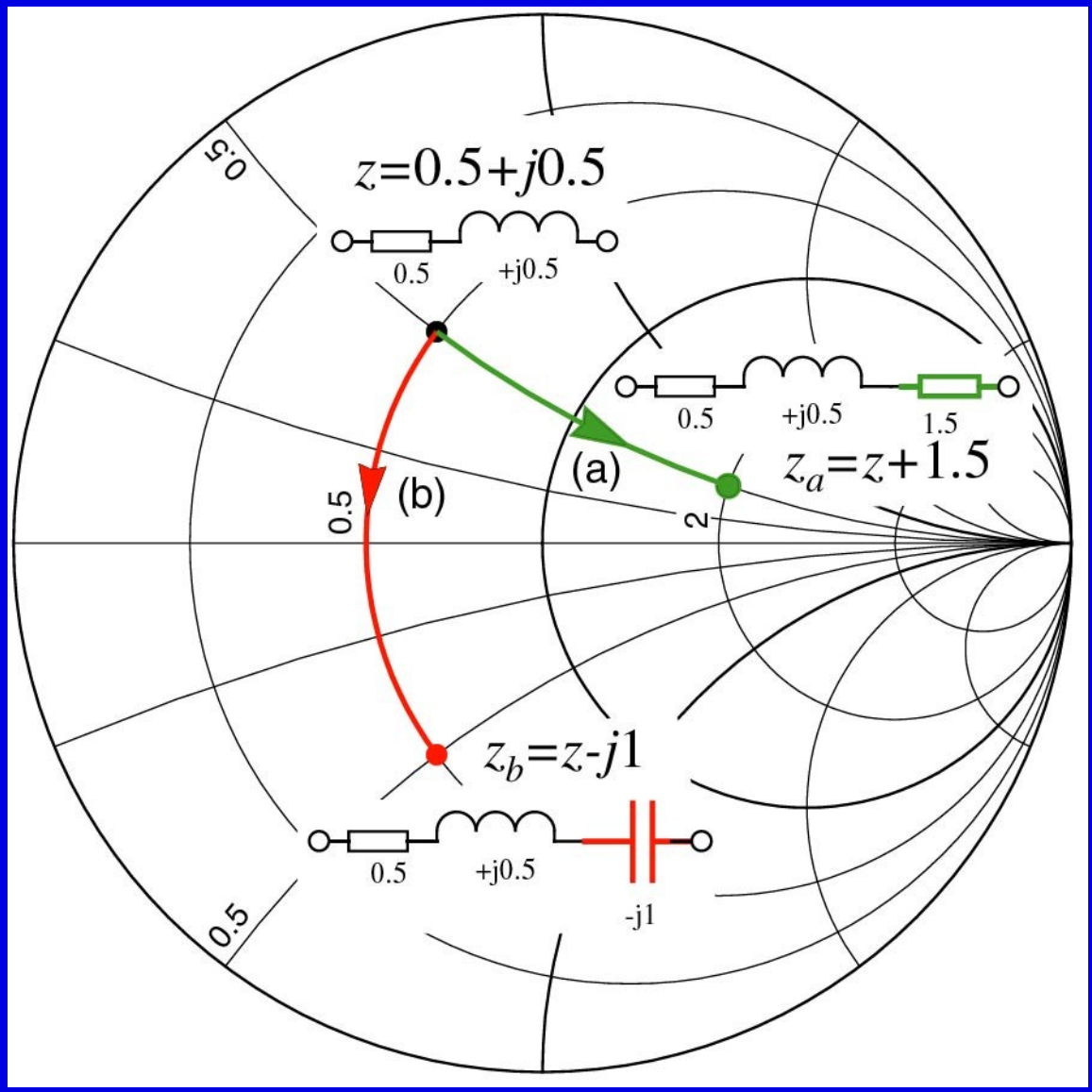
$$= -\frac{y-1}{y+1} =$$

$$= -\Gamma(z) = e^{j\pi}\Gamma(z)$$



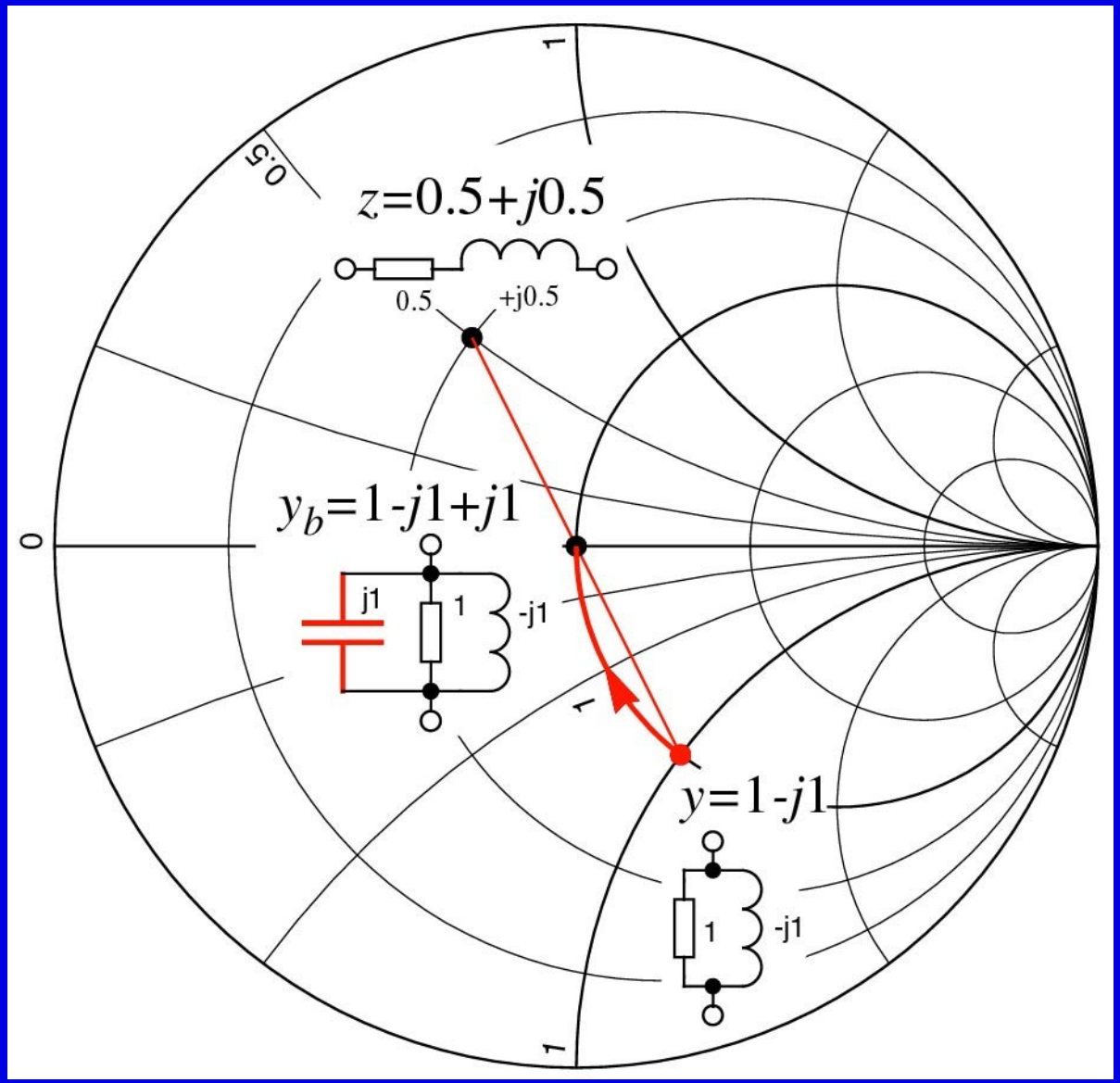
Series Connection

- Addition of resistance:
  - sliding at a constant reactance circle
- Addition of reactance:
  - sliding at a constant resistance circle



Parallel Connection

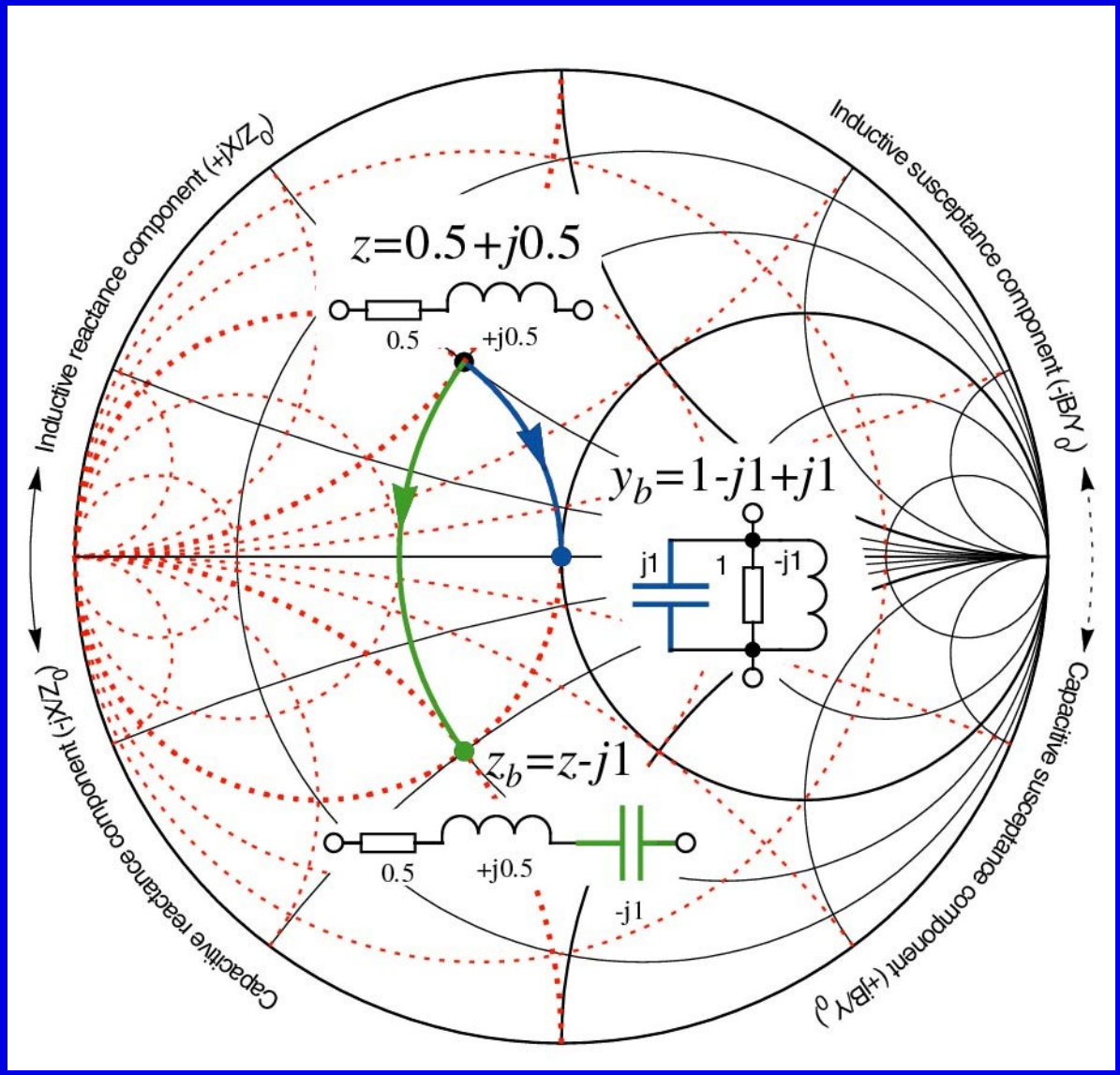
- Addition of susceptance:
  - motion at a constant conductance circle



The Inverted Smith Chart

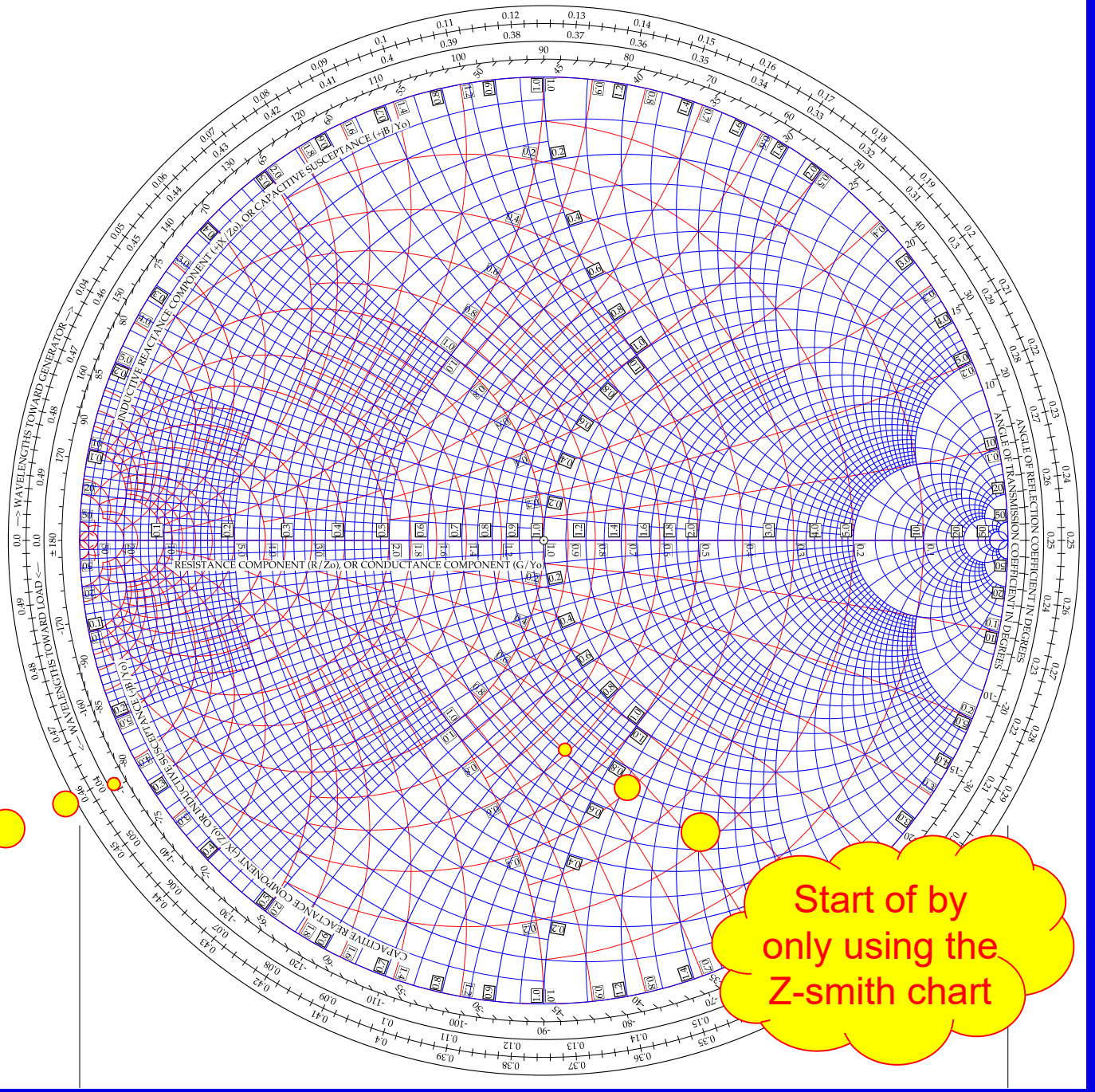
- The chart holds both Z- and Y scales
- The inverted Smith chart is used to read admittance

- Series connection of X:
  - slide along a constant resistance circle
- Parallel connection of X:
  - slide along a constant conductance circle



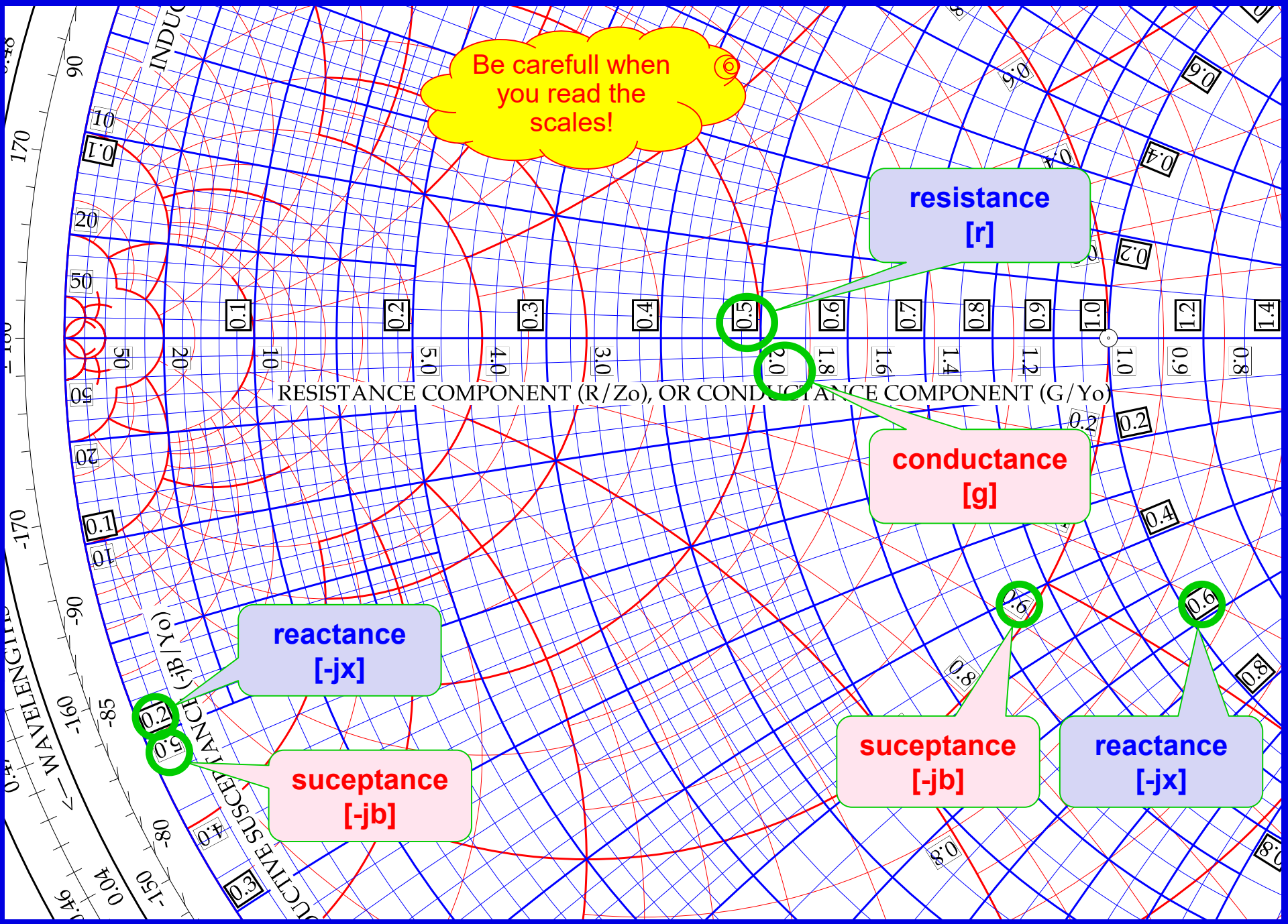
Combined Impedance and Admittance Chart

- The chart holds both Z- and Y-scales
- The inverted Smith chart is used to read admittance



Be carefull when you read the scales!

Start of by only using the Z-smith chart

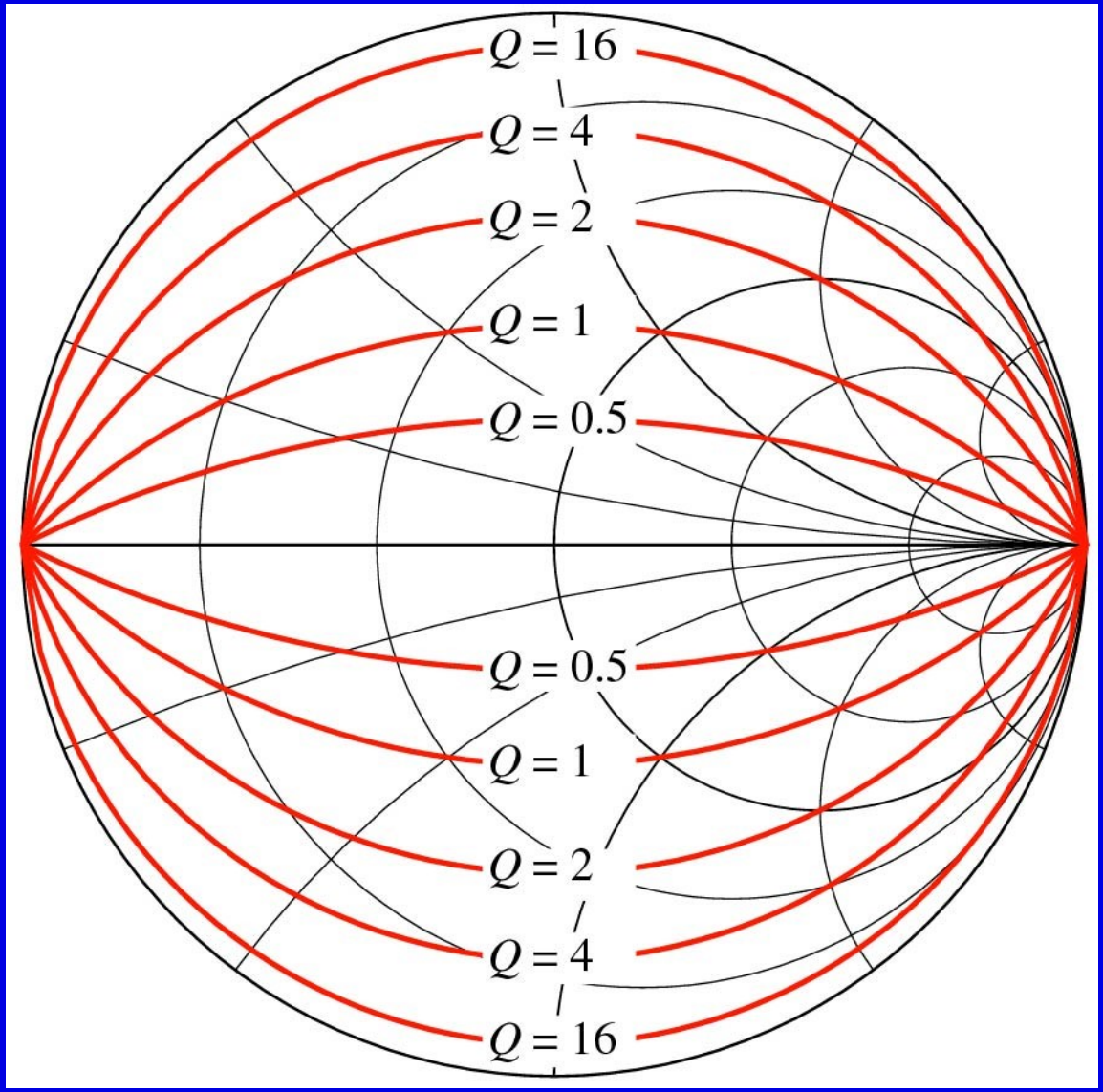

Be carefull when you read the scales!
resistance [r]
conductance [g]
reactance [-jx]
suceptance [-jb]
suceptance [-jb]
reactance [-jx]
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
WAVELENGTHS

(BREAK)

Circuit Q

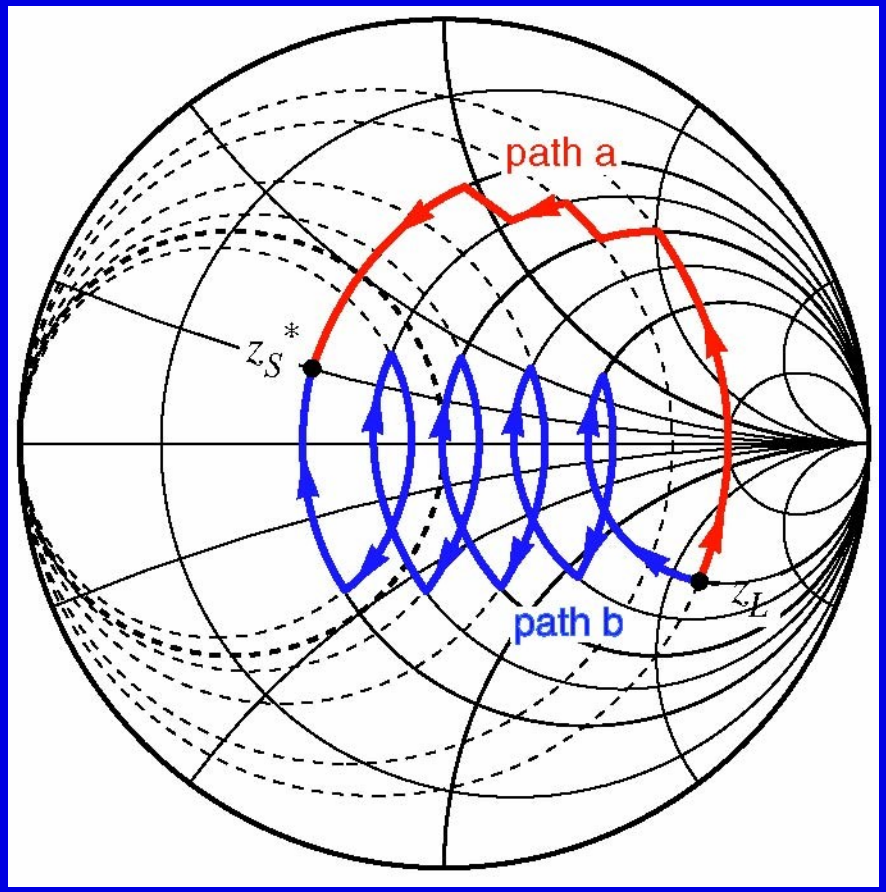
- If the Smith chart shows impedance, the circuit Q will be calculated as for a series connection:

$$Q = \frac{x}{r}$$

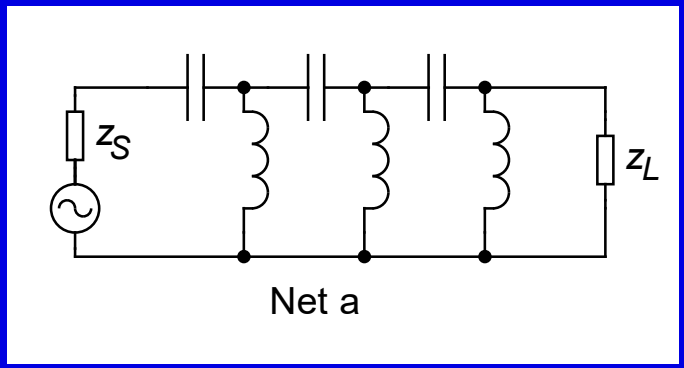


Matching Networks

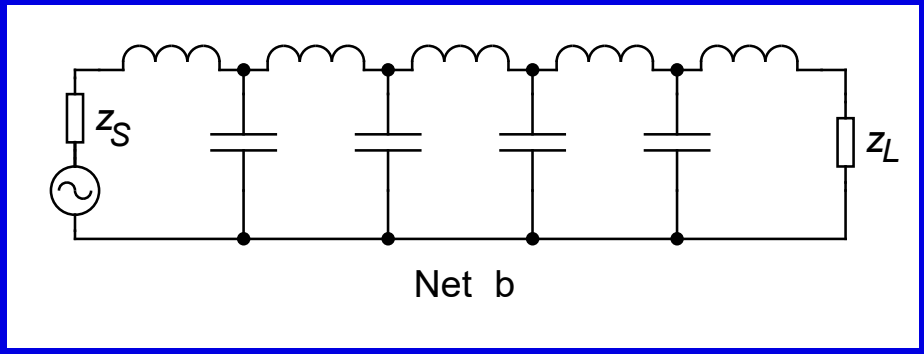
- By choosing a “path” in the Smith chart the circuit Q and the bandwidth of the network may be affected



High circuit Q = narrow bandwidth



Low circuit Q = wide bandwidth

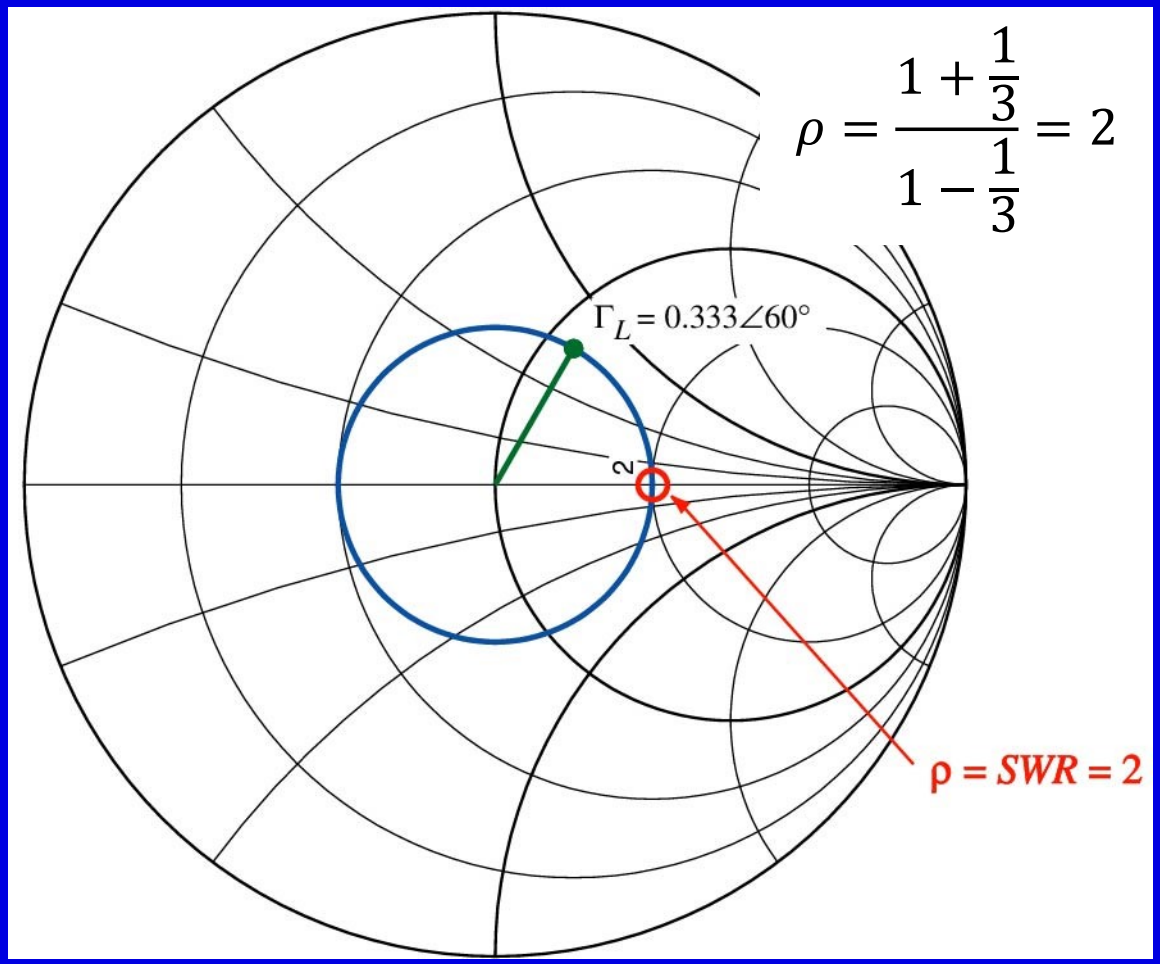


Reading the Standing-Wave Ratio

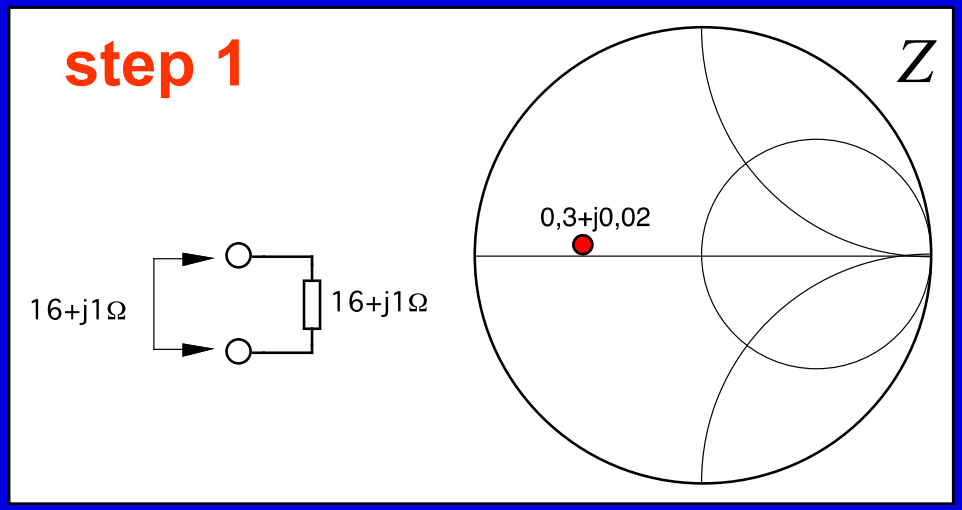
$$\rho = \mathrm{SWR} = \frac{|V_{max}|}{|V_{\min}|} = \frac{|I_{max}|}{|I_{\min}|} = \frac{1+|\Gamma|}{1-|\Gamma|}$$

$r \geq 1, x = 0:$

$$\rho = \frac{1+\Gamma}{1-\Gamma} = r$$

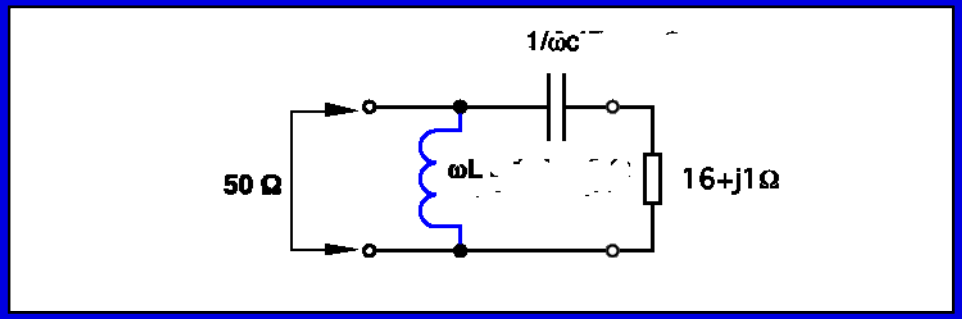


Experiment: Design a matching network by using the Smith chart and the VNA



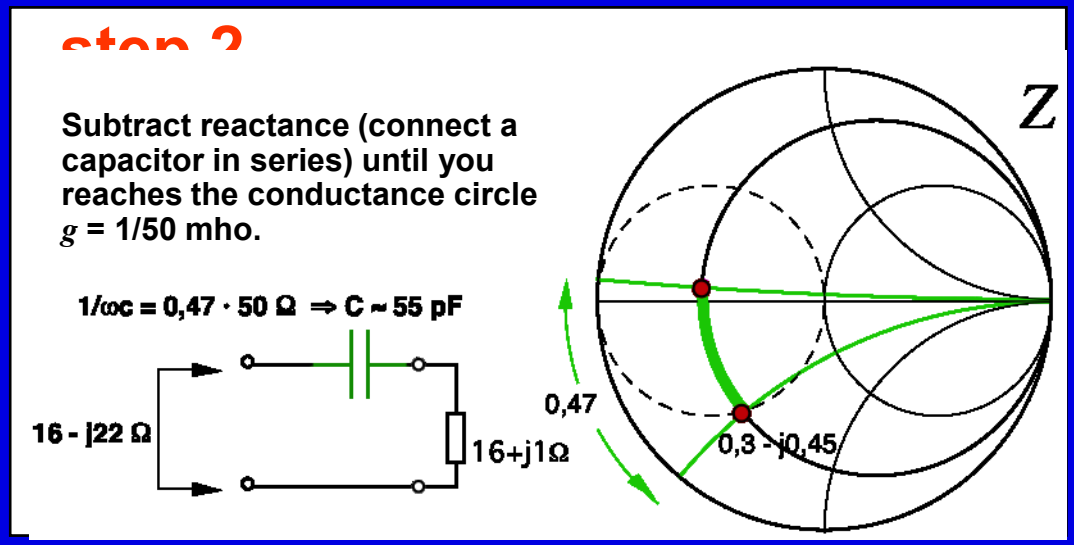
① Use the VNA to measure the load impedance

② Choose a network topology to match Z_L to 50Ω
(note: infinite options, but let's try a simple high pass L-topology)



Experiment: Design a matching network by using the Smith chart and the VNA

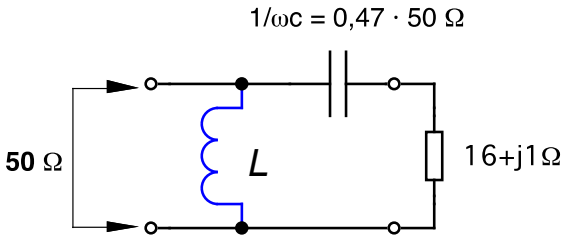
③ Determine the capacitance from the Smith Chart
④ Connect the capacitor
⑤ Verify the result by the VNA



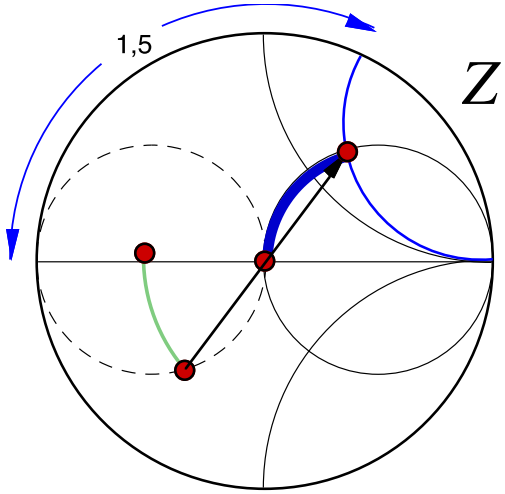
Experiment: Design a matching network by using the Smith chart and the VNA

step 3

Add susceptance (connect an inductor in parallel) until you end up in $Y = Y_0 = 1/50$ mho.



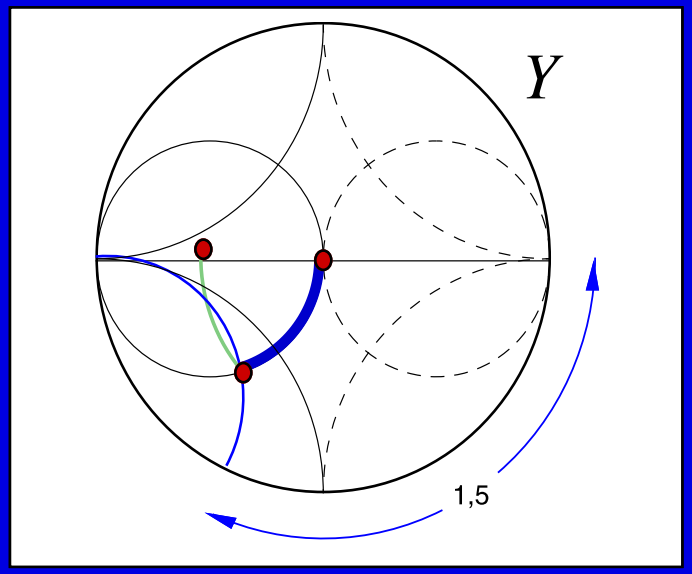
$$\frac{1}{\omega L} = bY_0 \Rightarrow L = 42 \text{ nH}$$



⑥ Determine the inductance from the Smith Chart
(you can use either the ordinary Z chart or the Y-Z chart)

⑦ Connect the inductor

⑧ Verify the result by the VNA



Practice Connections in the Smith Chart

- No gain, without pain (headache)