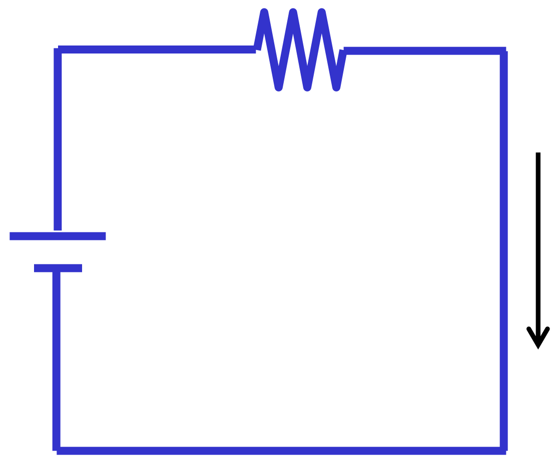
Impedance Basic Theory & Measurement Parameters

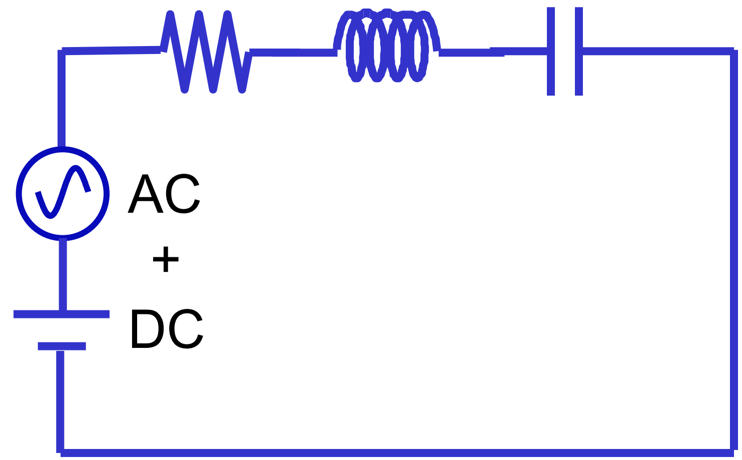
Agenda

♣ **After completing this course, you will be able to:**

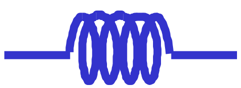
- ► Define impedance
- ► Define quality and dissipation factors
- ► Explain parasitics and draw equivalent circuits
- ► List and describe four component dependency factors
- ► Difference of various Impedance (Z , Z_L , Z_0)

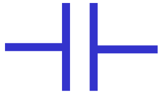
Definition of Impedance





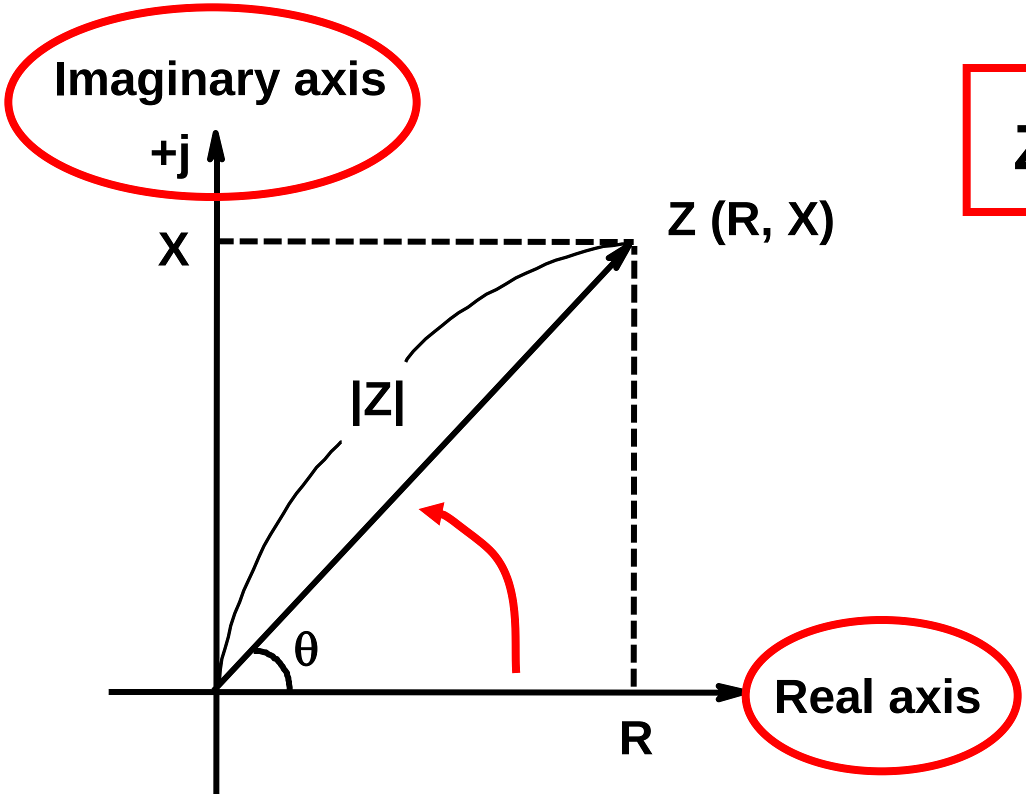
 $\Rightarrow$ R

 $\Rightarrow$ $X_L = \omega L = 2\pi f L$

 $\Rightarrow$ $X_C = \dfrac{1}{\omega C} = \dfrac{1}{2\pi f C}$

Definition of Impedance

Z : Total opposition a device or circuit offers to the flow of AC



$$Z = R + jX = |Z| \angle \theta$$

$$|Z| = \sqrt{R^2 + X^2}$$

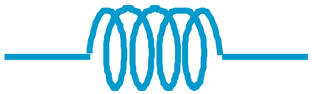
$$\theta = \tan^{-1}(X/R)$$

$$R = |Z| \cos \theta$$

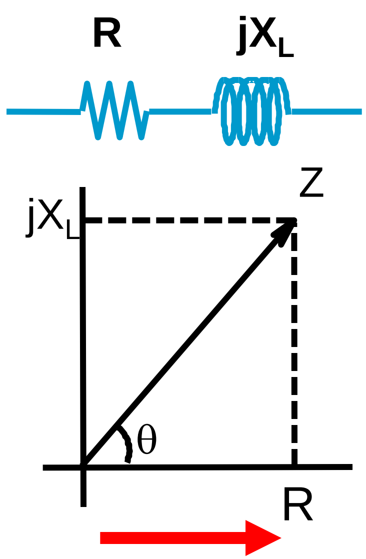
$$X = |Z| \sin \theta$$

Impedance plane

L (Inductance)



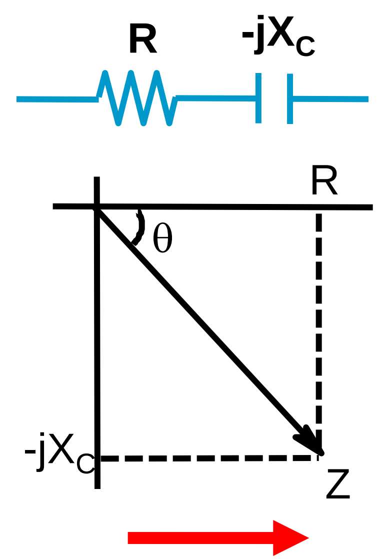
$+jX_L \Rightarrow +j2\pi fL$



(a) Inductive vector on impedance plane

C (Capacitance)

$-jX_C \Rightarrow \dfrac{-j}{2\pi fC}$



(b) Capacitive vector on impedance plane

Impedance plane

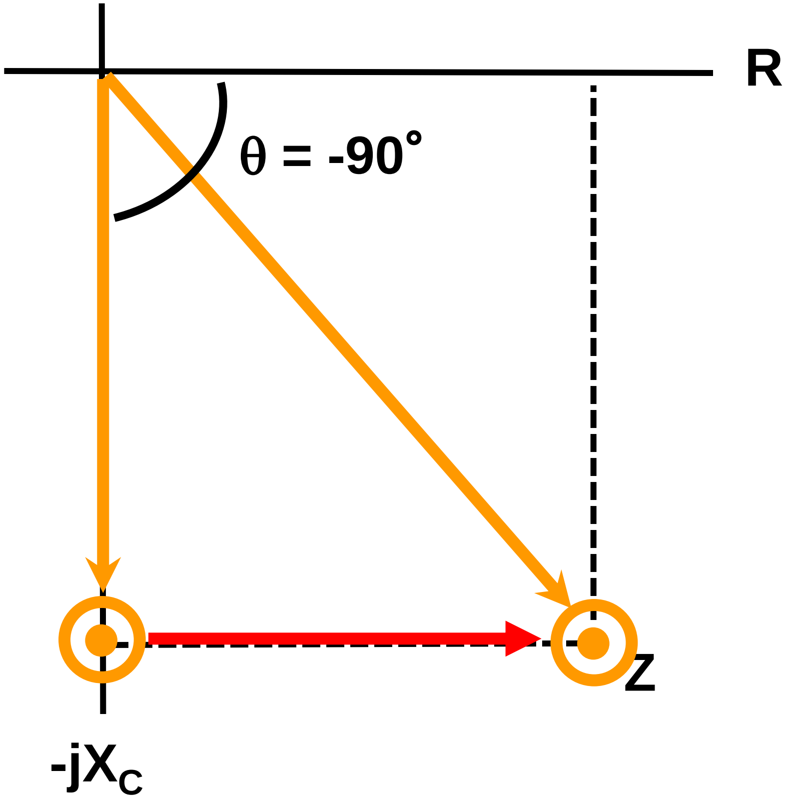
♣ **Ideal Case**

$- jX_C \Rightarrow \dfrac{-j}{2\pi fC}$

♣ **Real Case**

$$|Z| = \sqrt{R^2 + X^2}$$

$$\theta = \tan^{-1}(X/R)$$



Agenda

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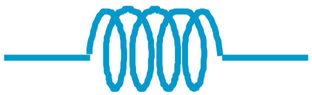
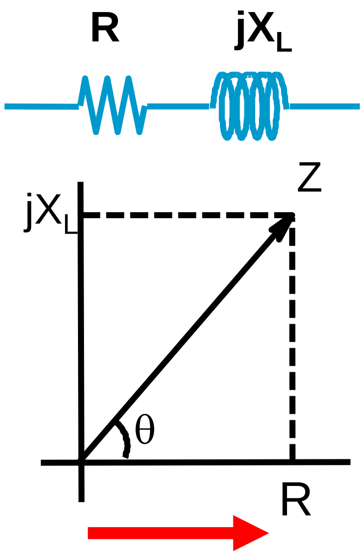
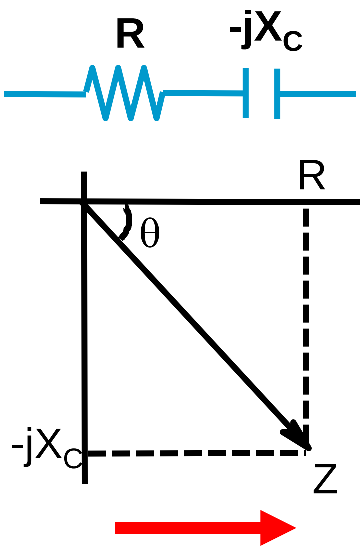
Quality and Dissipation Factor



L (Inductance)

C (Capacitance)





Q = quality factor

$$= \frac{X_L}{R} = \frac{-X_C}{R}$$

D = dissipation factor $= \frac{1}{Q}$

Impedance plane

♣ **Resistance : R**

♣ **Reactance : X**

♣ **Impedance : IZI**

♣ **Phase : θ**

♣ **Quality : Q**

♣ **Dissipation : D**

L C R

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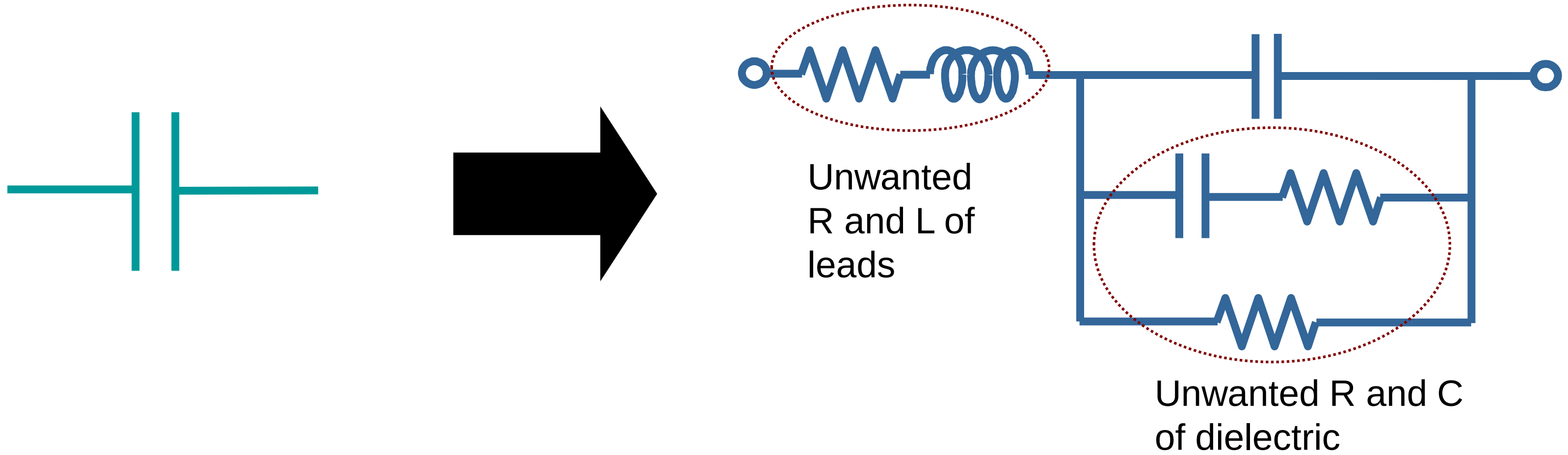
Parasitic

- **No real components are purely resistive or reactive**
  - Every component is a combination of R, C and L elements
  - The unwanted elements are called **parasitics**



Capacitor Equivalent Circuit

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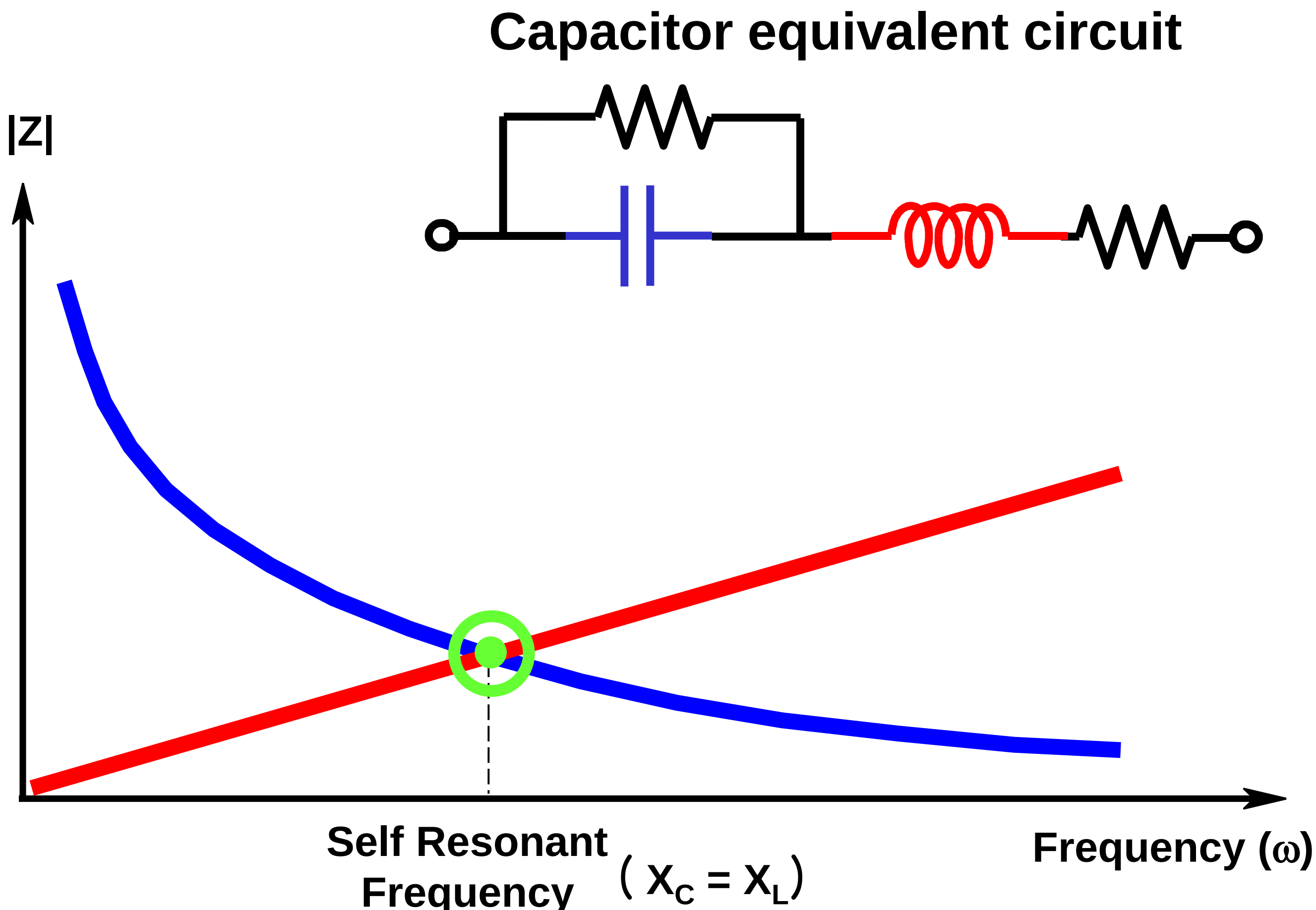
Component Dependency Factors

- **Measurement conditions that determine the measured impedance value**
- **Effects depend on component materials and manufacturing processes**
- **Four major factors:**
  - Test signal frequency
  - Test signal level
  - DC voltage and current bias
  - Environment

Component Dependency Factors

① |Z| vs. Test Signal Frequency

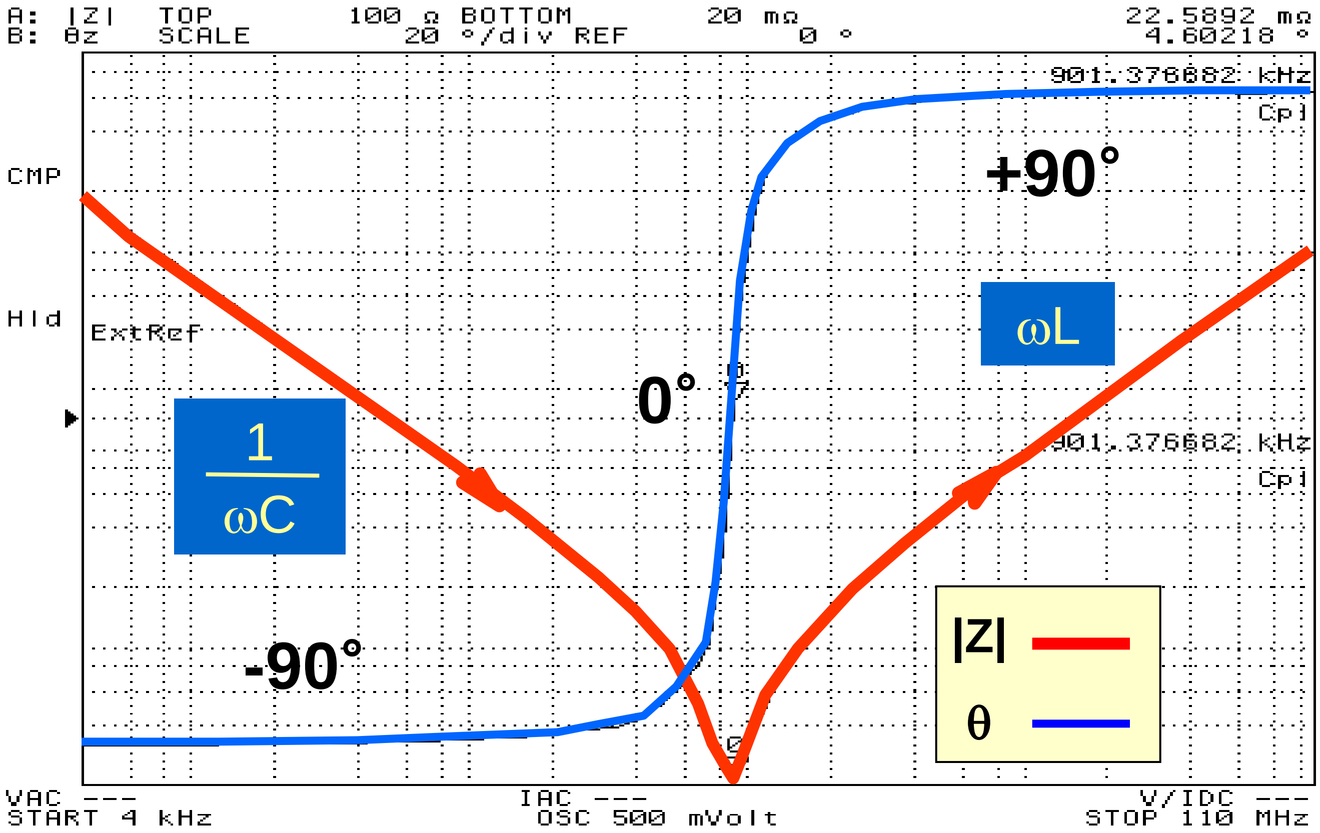
$$Z = R + jX = R + \left(j2\pi fL + \frac{-j}{2\pi fC} \right)$$



Component Dependency Factors

① IZI vs. Test Signal Frequency

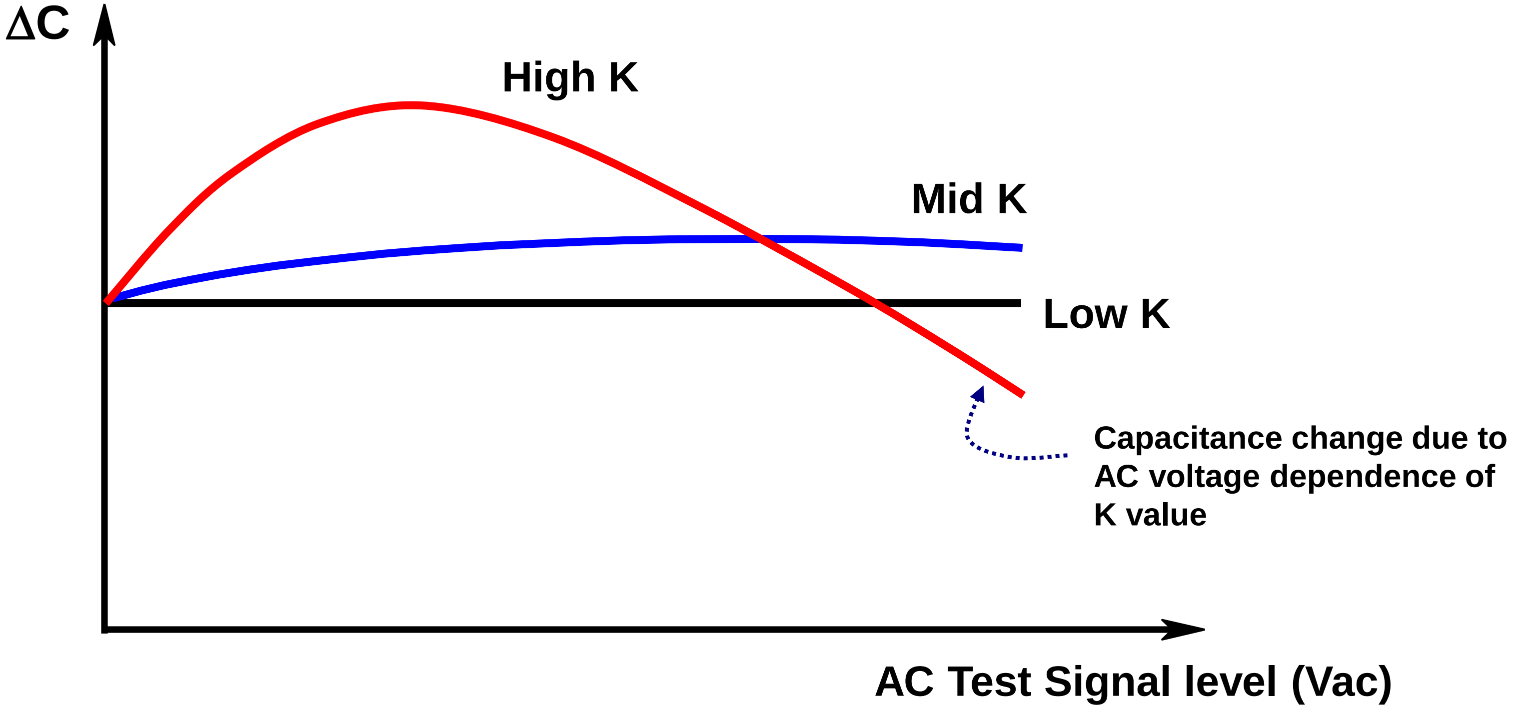
Example Capacitor Resonance



Component Dependency Factors

② C vs. Test Signal Level

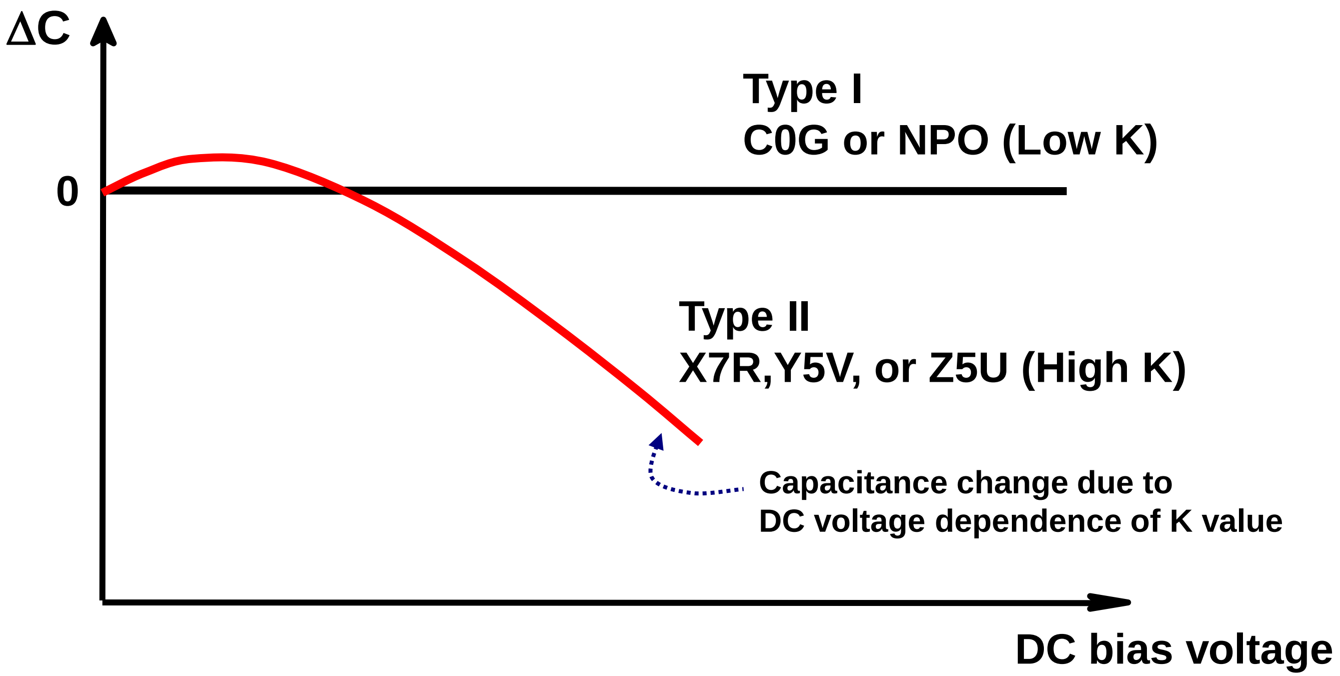
- **AC voltage dependency of ceramic SMD capacitors for various values of dielectric constant (K)**



Component Dependency Factors

③ C vs. DC Voltage Bias

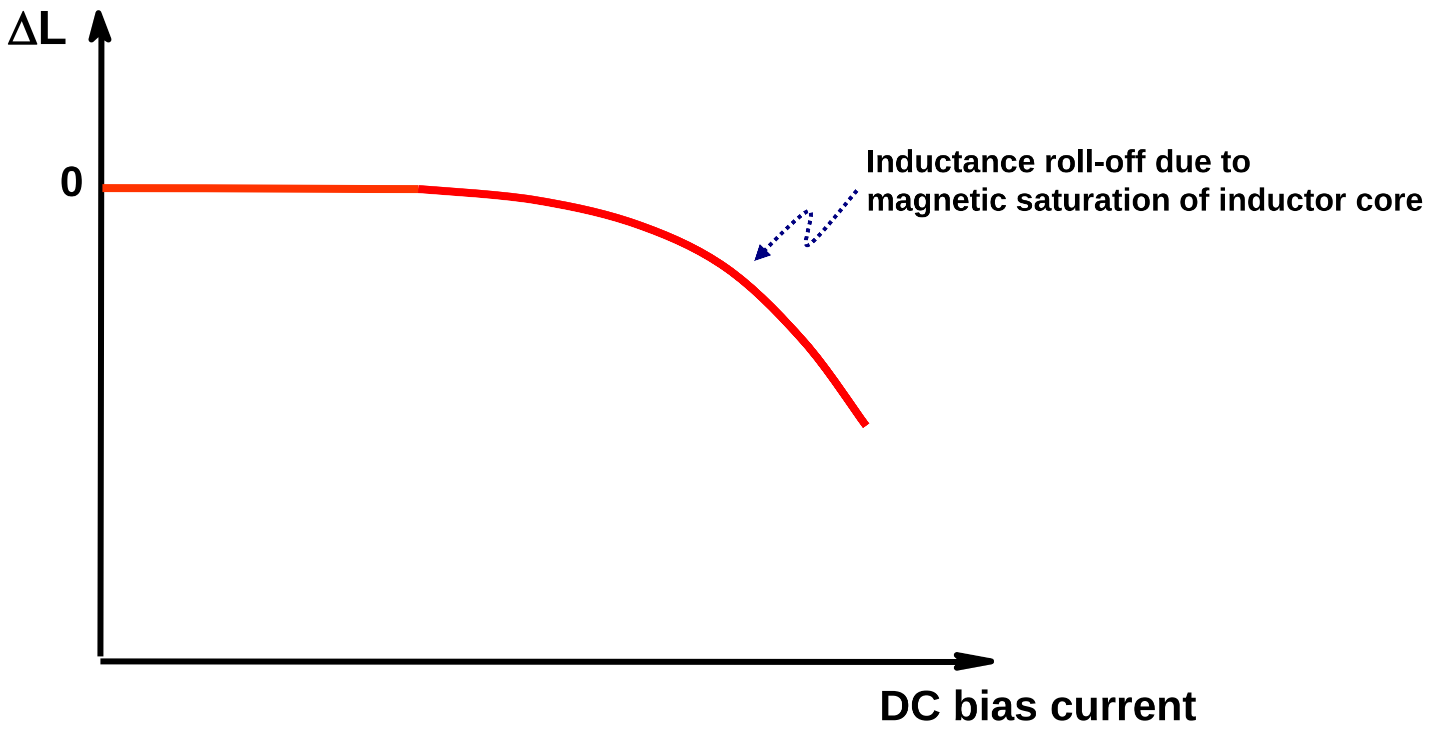
- **DC bias voltage dependency of type I and II SMD capacitors**



Component Dependency Factors

④ L vs. DC Current Bias

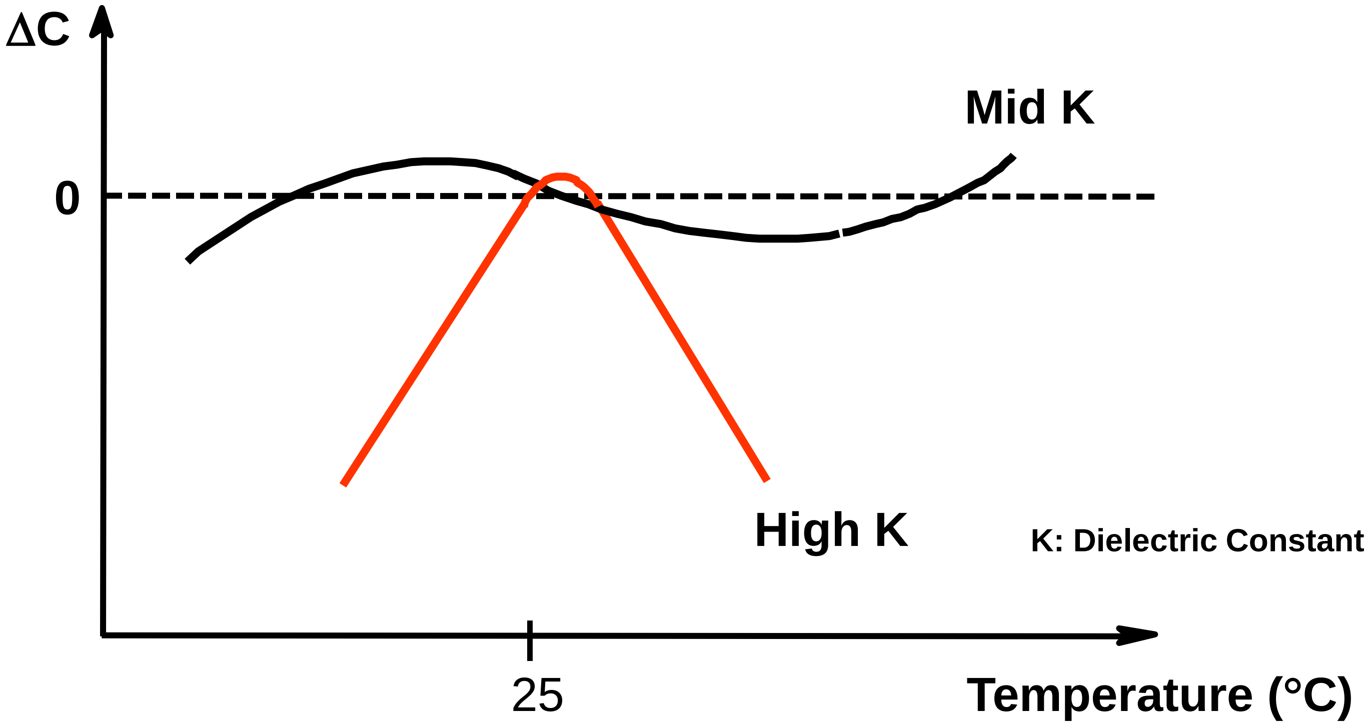
- **DC bias current dependency of cored inductors**



Component Dependency Factors

⑤ C vs. Temperature

- **Temperature dependency of ceramic capacitors for different K values**



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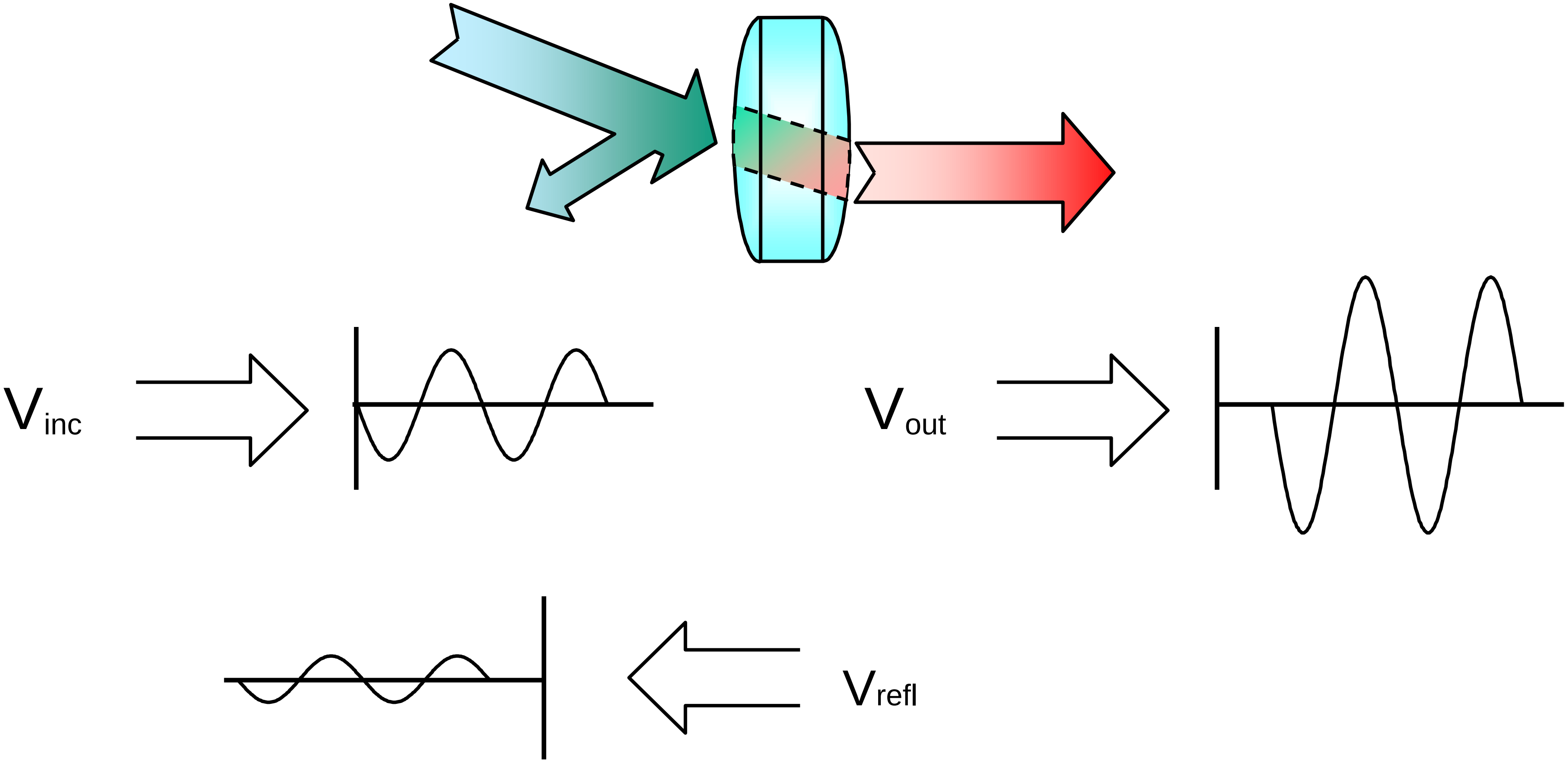
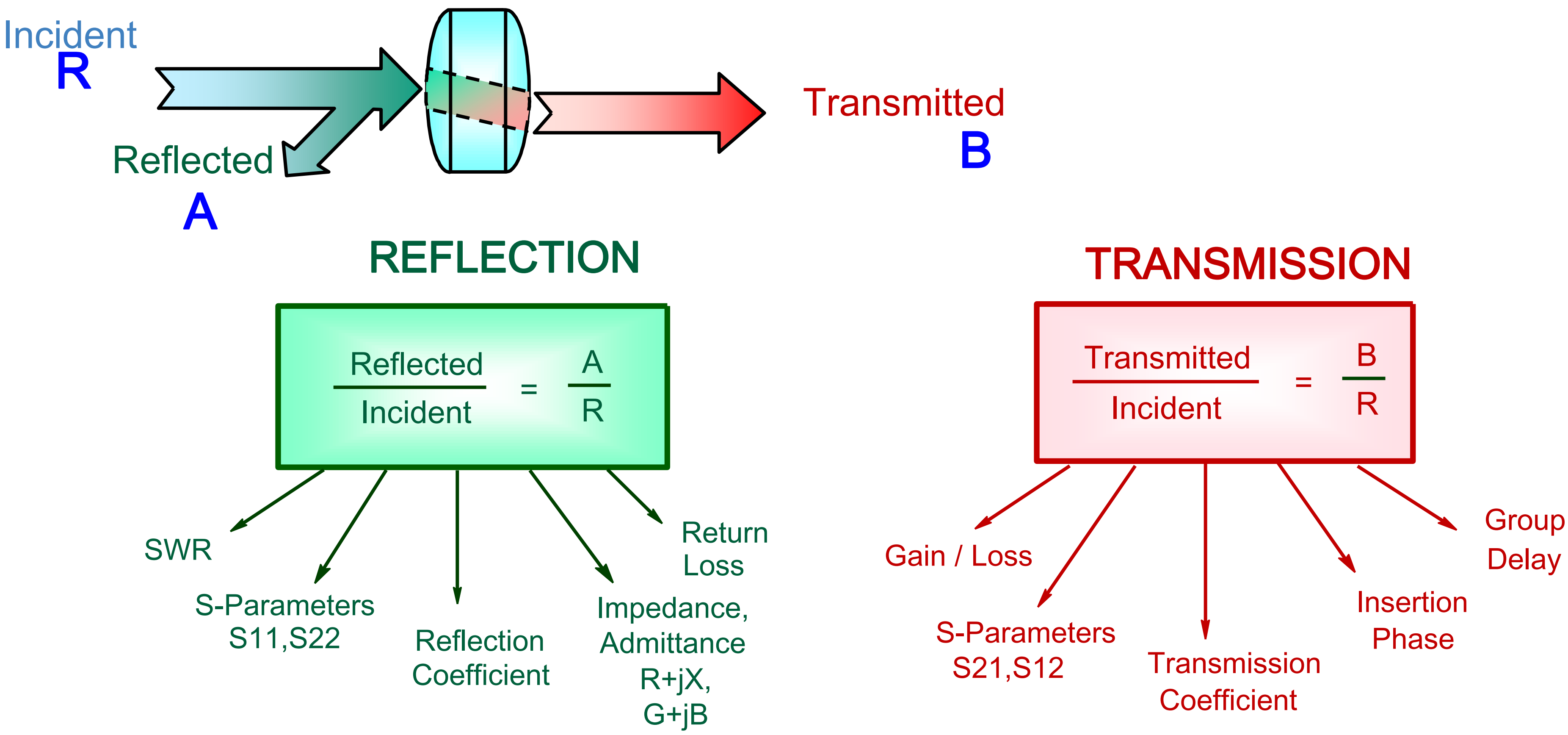
Impedance Theory of Network Analysis

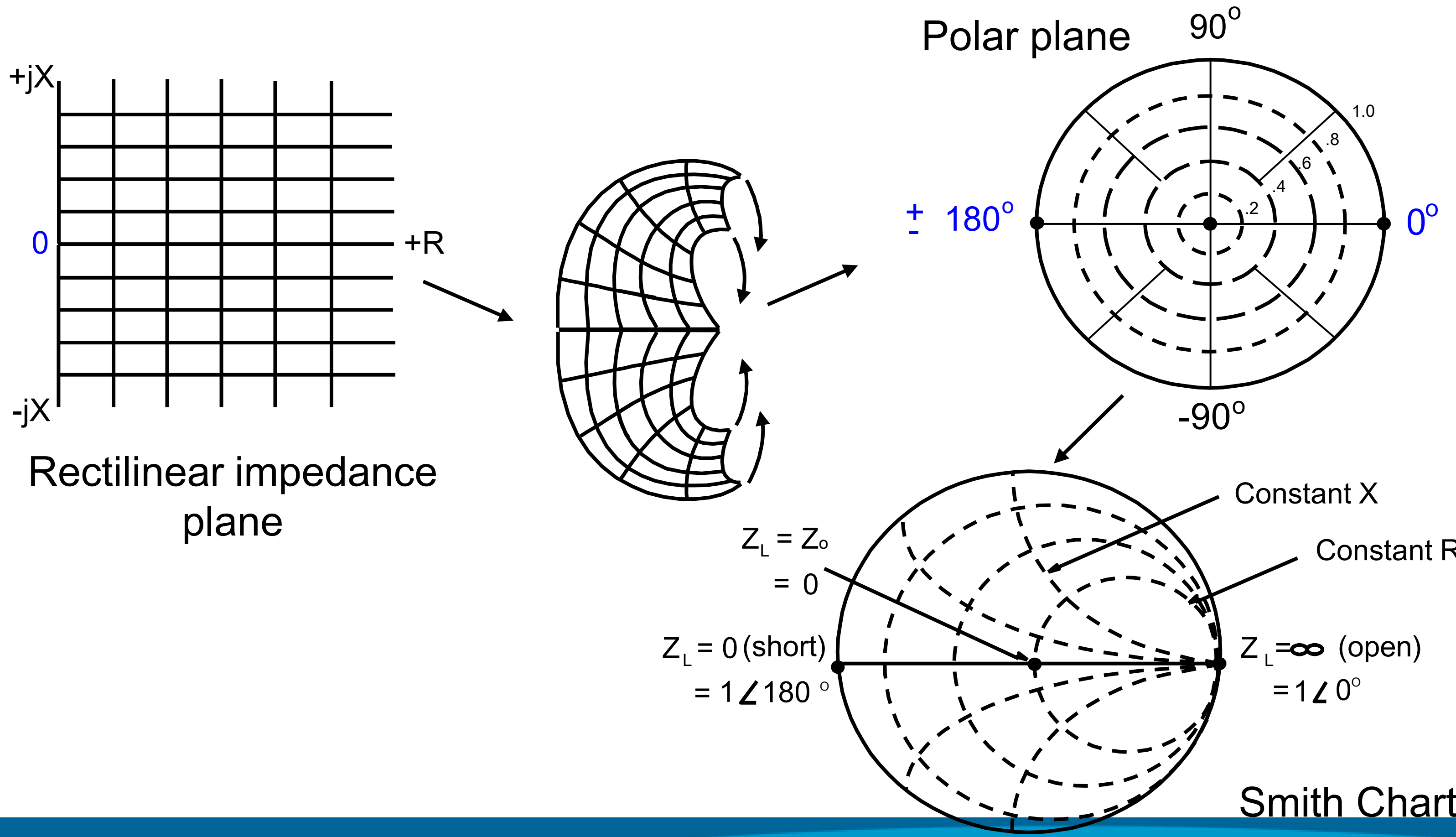


Impedance Theory of Network Analysis



Smith Chart Review

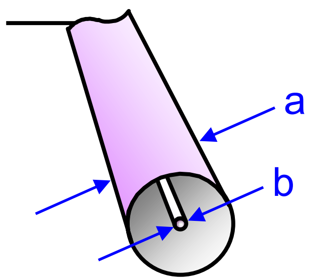
$$Z = R + jX$$



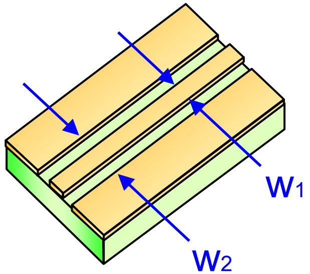
Characteristic Impedance of Transmission line

Reflection Coefficient

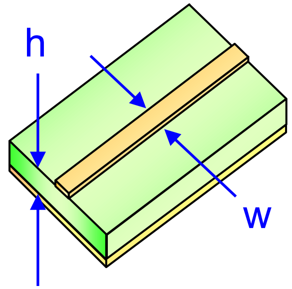
$$\Gamma = \frac{V_{reflected}}{V_{incident}} = \rho \angle \Phi = \frac{Z_L - Z_O}{Z_L + Z_O}$$



Coaxial

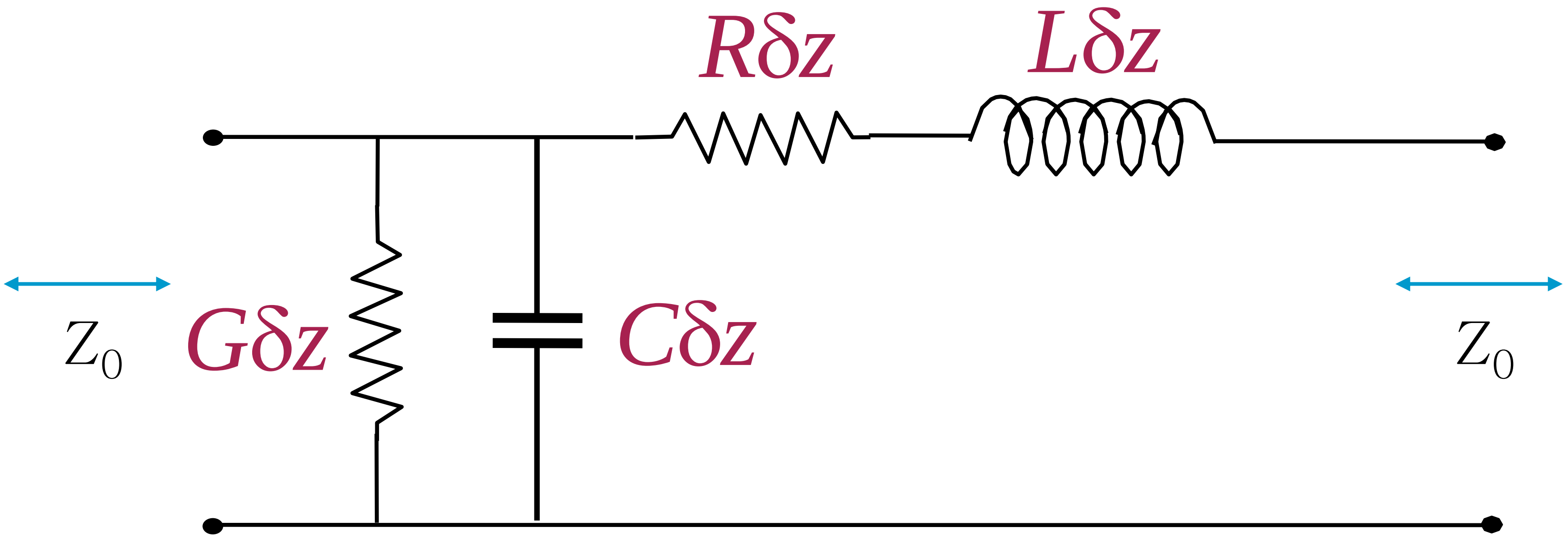


Coplanar



Microstrip

Characteristic Impedance of Transmission line



LCR meter & Impedance Analyzers

E4980A LCR Meter (20 Hz ~ 2 MHz)

4285A LCR Meter (75 kHz ~ 30 MHz)

4263B LCR Meter (100 Hz ~ 100 kHz)

E4981A Capacitance Meter (120 Hz , 1 kHz , 1 MHz)

High Resistance Meter (10E3 Ω ~ 1.6X10E16 Ω)

E4982A LCR Meter (1 MHz ~ 3 GHz)

LCR meter & Impedance Analyzers

4294A Impedance Analyzer
(40 Hz ~ 110 MHz)

E4991A Impedance Analyzer
(1 MHz ~ 3 GHz)

QUESTION !!!