07/04/2021

RF behaviour of capacitor

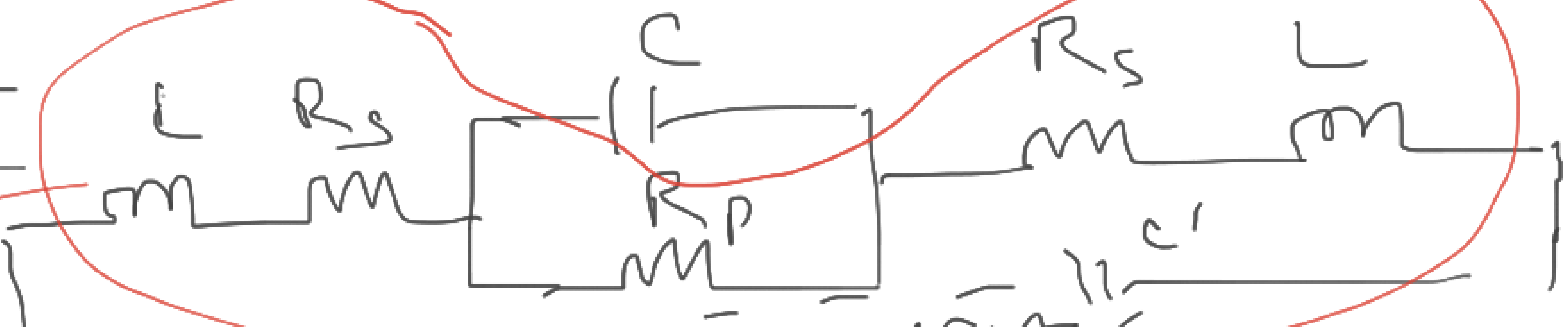
Dielectric constant (ϵ_r) → Electric permittivity

↓ complex $\epsilon_r = \epsilon_r' + j\epsilon_r''$

→ measure of charge retention capacity of medium

DC eqv ckt

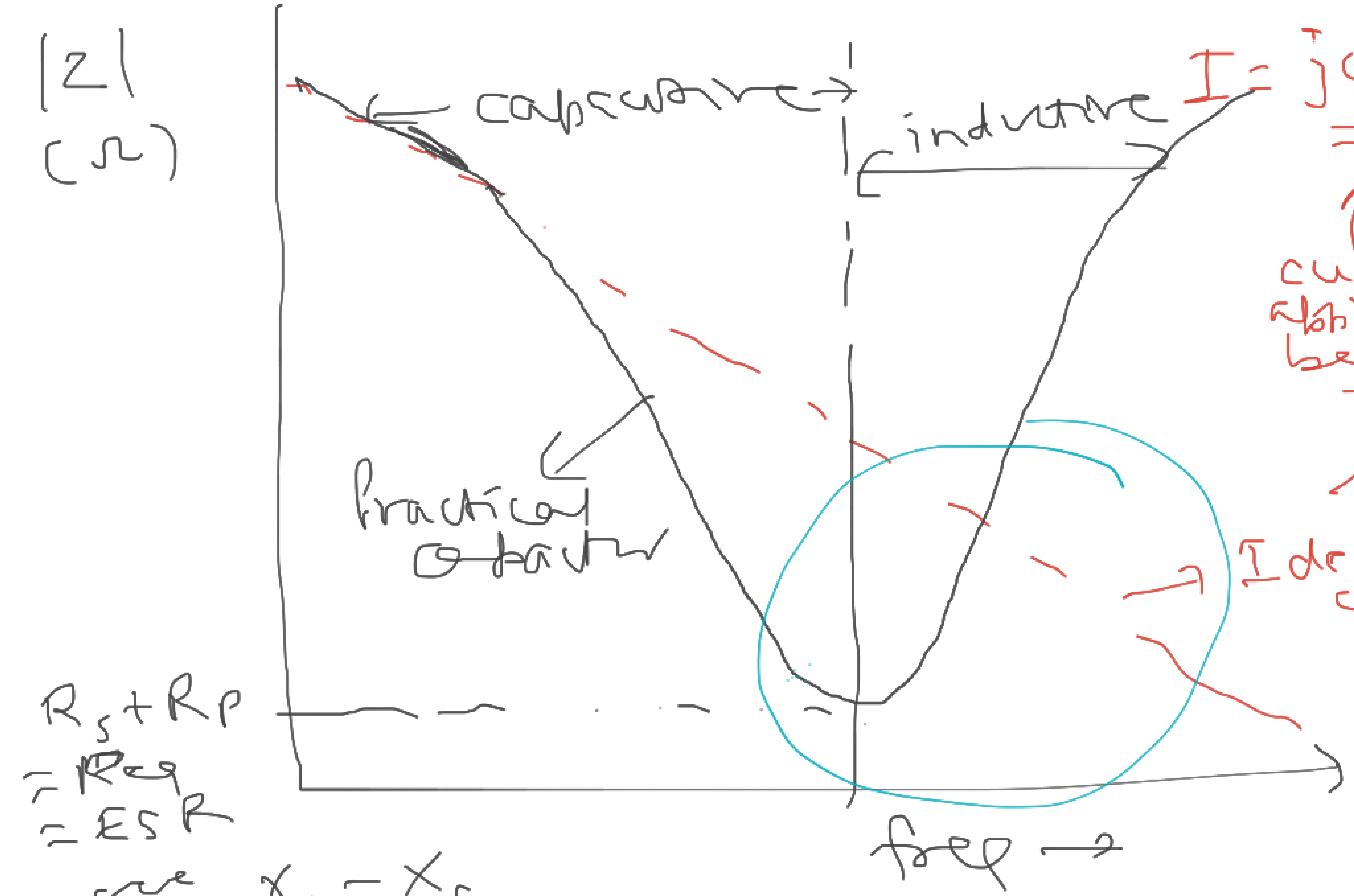
AC Eqv ckt



Parasitic or stray elements

R_p = insulation resistance of capacitor

R_s = series resistance & L = inductance of lead



$I = j\omega C V$
$= \omega C V e^{j90}$

current leads applied voltage by exactly 90°

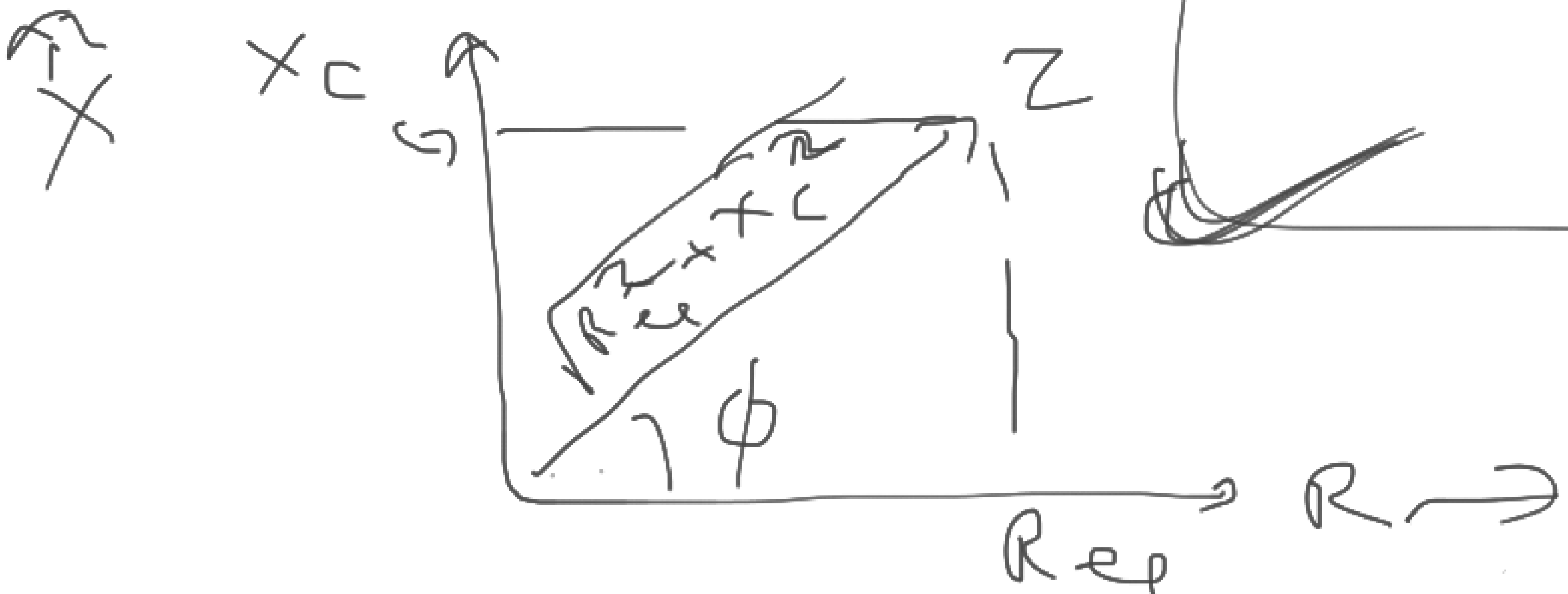
Ideal (or perfect) cap $= \frac{1}{j\omega C}$
$= \frac{1}{j2\pi f C}$

CIVIL

resonance $X_L = X_C$

$j\omega L = \frac{1}{j\omega C} \Rightarrow f = \frac{1}{2\pi\sqrt{LC}}$

(i) Power factor (PF) $= \cos\phi = \dfrac{R_{eq}}{\sqrt{R_{eq}^2 + X_C^2}}$



$X_C = \dfrac{1}{j\omega C}\ \Omega$

Usually, $R_{eq} \ll X_C$, R_{eq} (or ESR)

approximate $\boxed{PF \simeq \cos\phi \approx \dfrac{R_{eq}}{X_C}}$

(ii) R_{eq} or ESR $= R_s + R_p =$ ac resistance of capacitor

(equivalent resistance) (effective series resistance)

(iii) Dissipation Factor (DF) : ratio of ac resistance to reactance of capacitor

$$\boxed{DF = \frac{R_{ep}}{X_C} \times 100\%}$$

(iv) Quality factor (Q) $= \frac{X_C}{R_{ep}} = \frac{1}{\omega C R_{ep}}$

$\approx \frac{1}{PF} \approx \frac{1}{DF}$

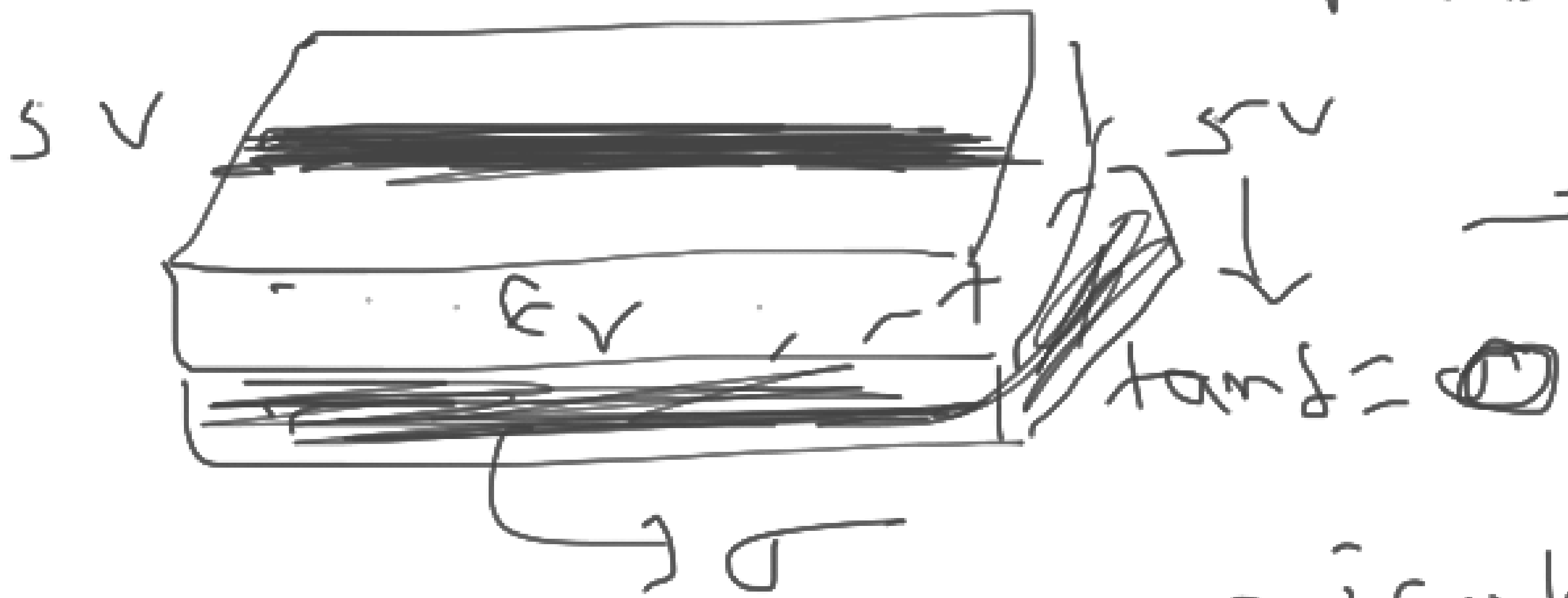
(v) Loss tangent ($\tan\delta$) → here $\delta \neq$ skin depth

$$\tan\delta = \frac{-\epsilon_r''}{\epsilon_r'}$$

$$\left(\epsilon_r = \epsilon_{r_{real}} + \epsilon_{r_{img}} = \epsilon_r' + \epsilon_r''\right)$$

$$\boxed{\tan\delta = \frac{\sigma}{\omega\epsilon}} \neq \frac{\sigma + \omega\epsilon''}{\omega\epsilon'} = \frac{1}{Q_{dielectric}}$$

σ = conductivity



→ PCB (capacitor)

→ $FeCl_3$ (Etchant)
↓
etch metal
↓
eat away

→ isopropyl alcohol (cleaner)

PCB = FR4 → ($\epsilon_r = 4$)

at 1GHz

Reinforced fabric

$\tan\delta = 0.0001$ at 10 kHz

$= 0.001$ at 100 kHz

$= 0.01$ at 1000 kHz (1 MHz)

$= 0.1$ at 1 GHz

very loss at 1 GHz

Several PCBs → Dielectric substrate

$\tan\delta = 0.0001$ at 1 GHz

(very low loss at 1 GHz)

- RT Duroid
- Arlon
- Taconic

Dielectric substrate

$\tan\delta \approx 0.0001$ at 1 GHz

For a perfect capacitor

R_{eq} (or ESR) $= 0$

PF $= 0$

DF $= 0\%$

$Q = \infty$

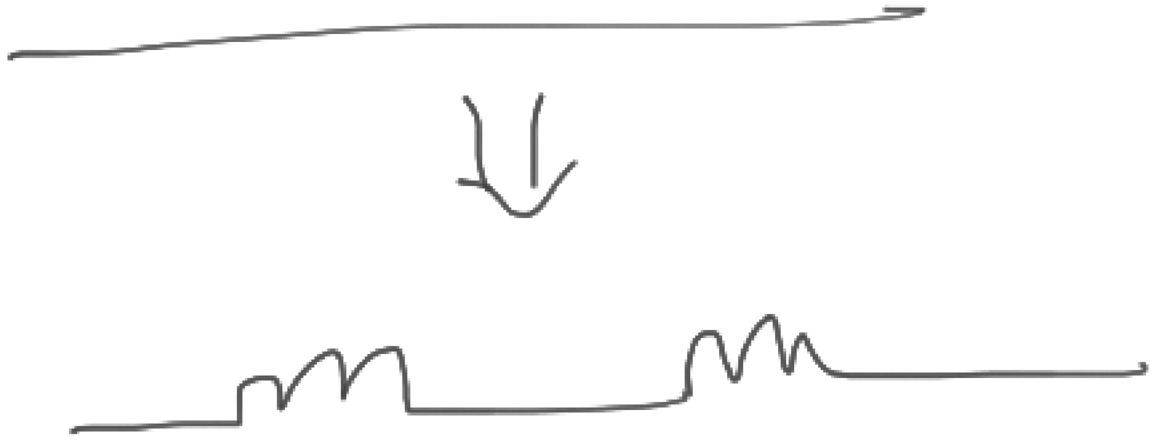
$\tan\delta \approx 0$

Applications of Cap

→ Resonator
- filter
→ DC block

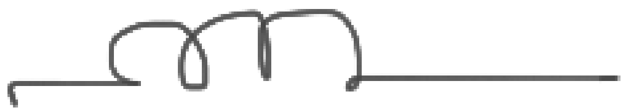
RF behaviour of Inductor (L)

wire

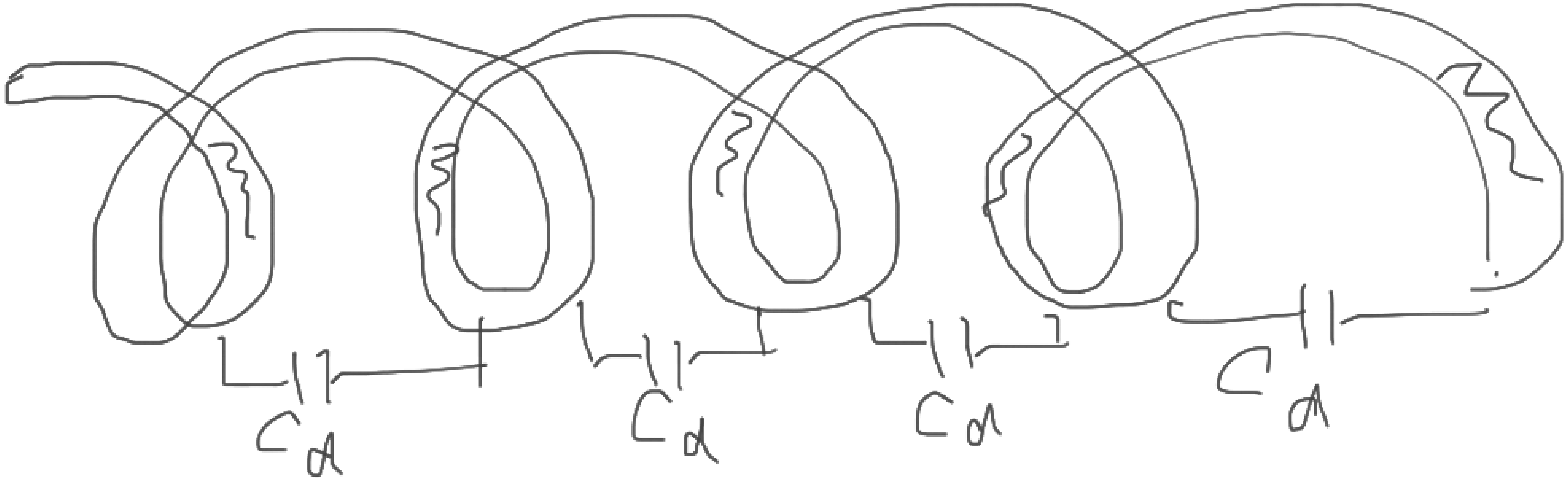


a wire that is coiled (or wounded) in such a manner so as to increase magnetic flux linkage between turns of coil

DC: eqv ckt of L



AC (or RF) eqn ckt of inductor

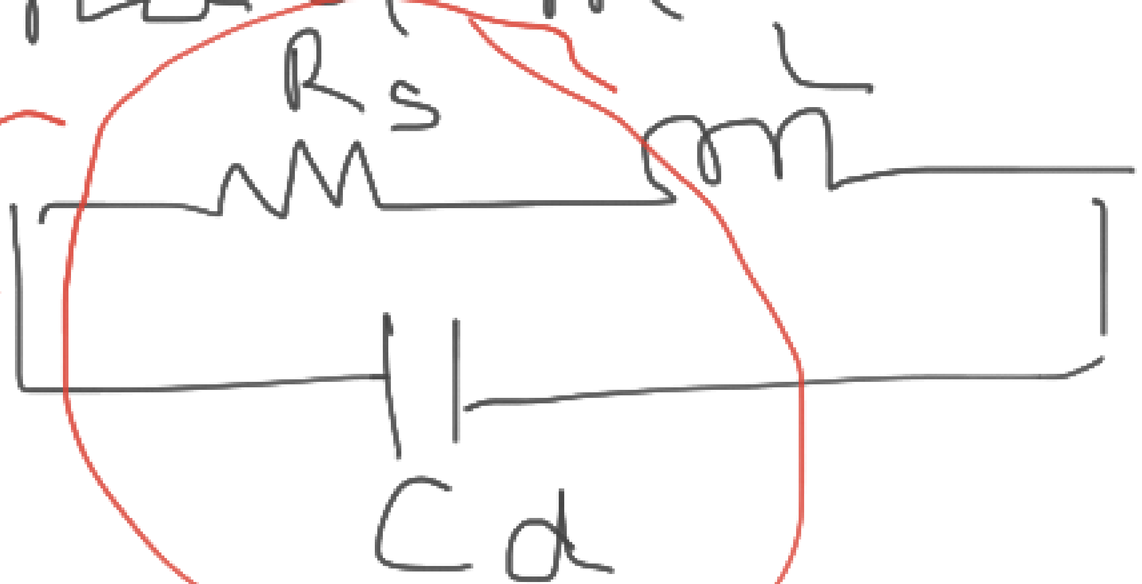


C_d = distribution cap

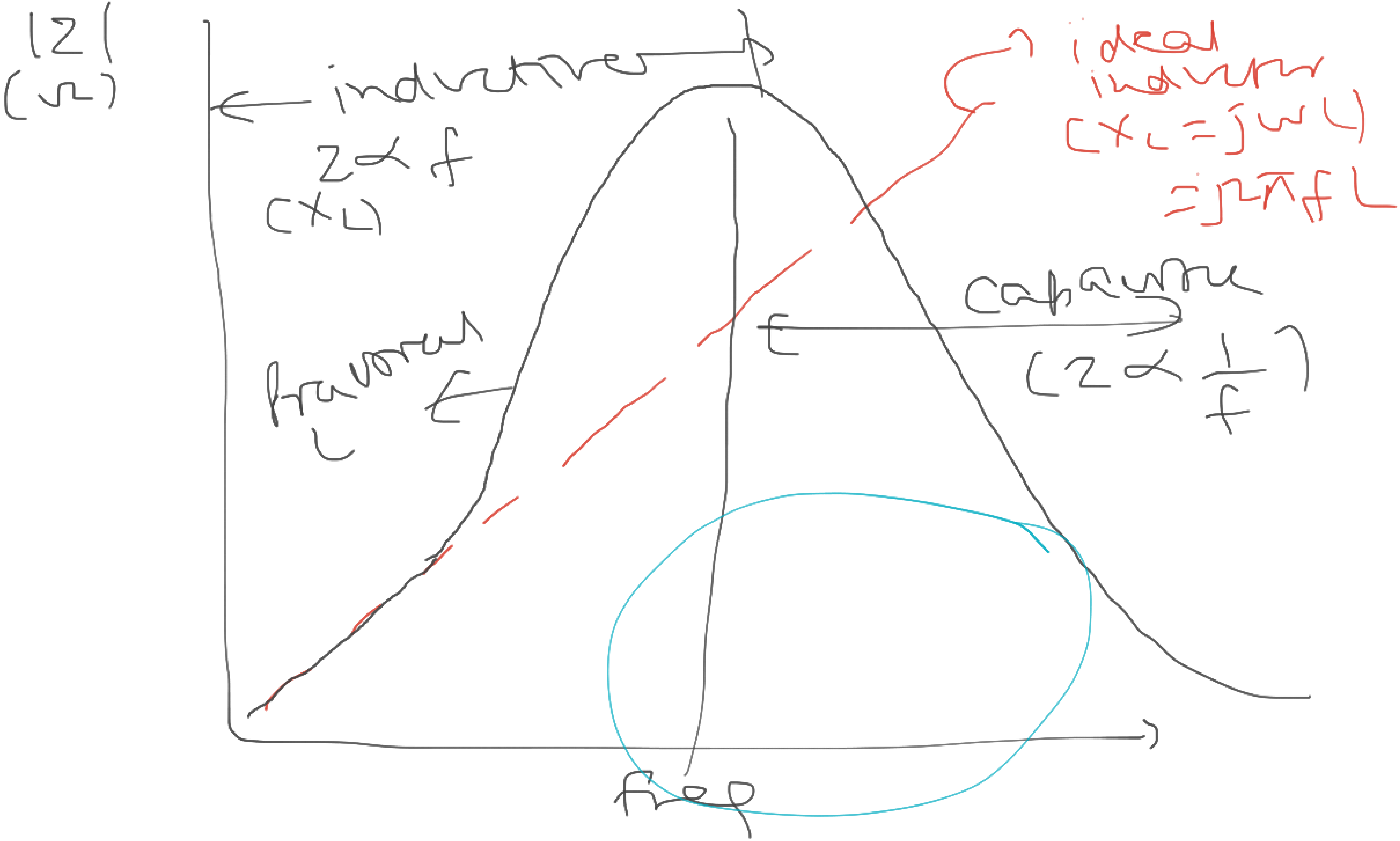
L =

R = resistance of material of wire

Parasitic or stray elements



L, C
↳ reactance


|Z| (Ω)
inductive
Z ∝ f
(X_L)
ideal inductor
(X_L = jωL
= j2πfL
capacitive
(Z ∝ 1/f)
ferrous
L
freq

For a perfect inductor

$R_s = 0$

$$Q = \frac{X_L}{R_s} = \frac{\omega L}{R_s} = \frac{2\pi f L}{R_s} = \infty$$

To increase Q of inductor

(i) use a larger diameter of wire
$\rightarrow$ area (A) is larger $\rightarrow R = \frac{\rho l}{A}$ = smaller

(ii) spread the windings apart
$\rightarrow$ d will increase (distance) between winds $\Rightarrow C = \frac{\epsilon A}{d}$ = smaller

(iii) increase L by increasing permeability of magnetic flux linkage $\rightarrow$ ferrite rod

Applications of inductor

Resonant ckt

Filter

Phase shifter (ϕ) $\quad V\angle 0^\circ \rightarrow \boxed{\phi} \rightarrow V\angle \phi^\circ$

Delay network (Δt)

RF choke (blocks the RF or ac)

Bias Tee (Bias T)