16/03/2021

Wire

d = mil = $\frac{1}{1000}$ inch = $\frac{2.54\text{cm}}{1000}$

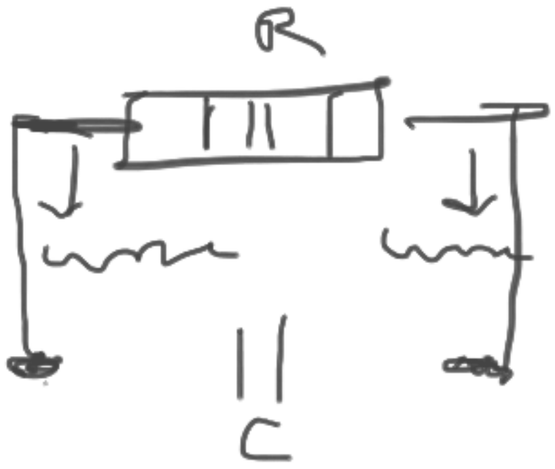
(diameter)

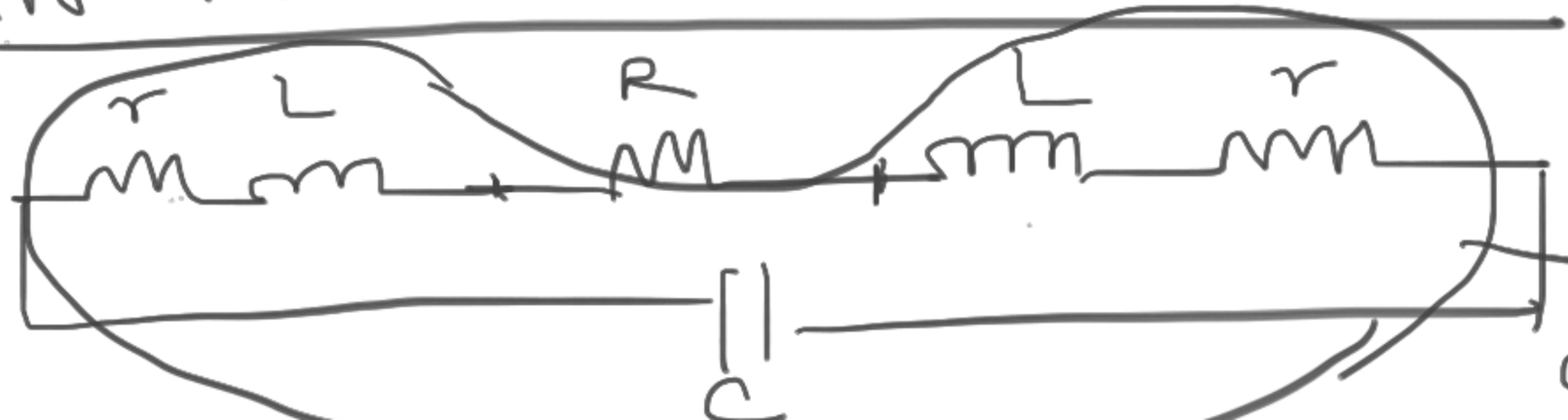
= 0.0254 mm

Resistor : GHz (10^9 Hz)

dc or low freq

Equivalent at ac or high freq





→ Parasitic or Stray elements

Impedance (Ω) : R, $j\omega L$, $\frac{1}{j\omega C}$

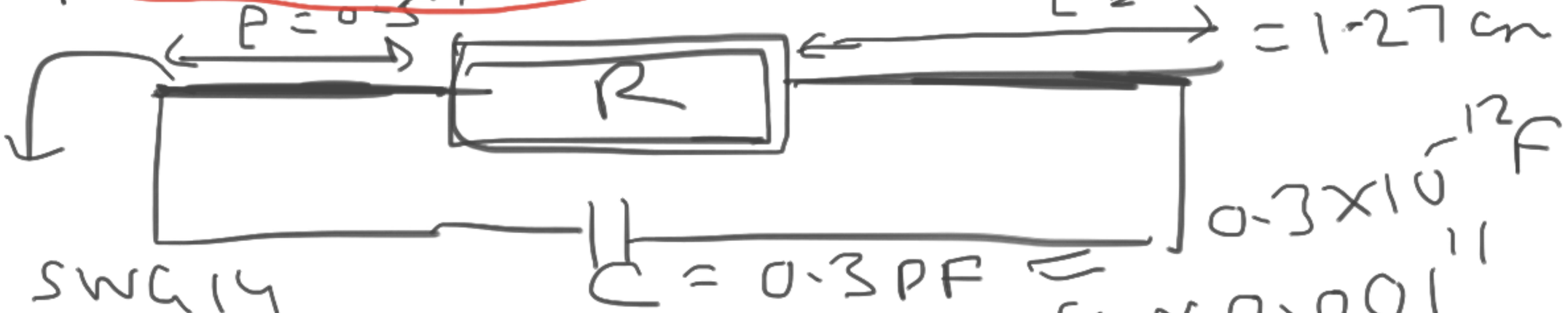
MFR (Metal Film Resistor) $\rightarrow \frac{1}{4}$ W $= 0.25$ W

Carbon Composite Resistor $= 0.5$ W

Ex

$f = 200$ MHz $= 200 \times 10^6$ Hz

$R = 10$K$\Omega = 10{,}000\ \Omega$



$d = $ SWG 14

$= 64$ mils $= 0.1628$ cm $= 64 \times 0.001$"

(1mil $= 0.254$ cm)

$C = 0.3$PF $= 0.3 \times 10^{-12}$F

Sol

$$L = 0.002\,\ell\left[2.3\log\left(\frac{4\ell}{d} - 0.75\right)\right] \mu H$$

no rate mege!

ℓ = length (cm)
d = dia (cm)

$$\therefore L = 0.002 \times 1.27\left[2.3\log\left(\frac{4 \times 1.27}{0.1628} - 0.75\right)\right] \mu H$$

$= 0.0087 \mu H$

$= 8.7 \times 10^{-9} H = \underline{8.7 \, nH}$

C (provided) = $\underline{0.3 \text{ pF}}$

L presents an eqn reactance at (inductive)

200 MHz :

$$X_L = j\omega L = j2\pi fL$$

$$= 2\pi \times 200\times10^{6} \times 8.7\times10^{-9}$$

$$X_L = j10.93\ \Omega$$

Cap C presents an eqn reactance at (capacitive)

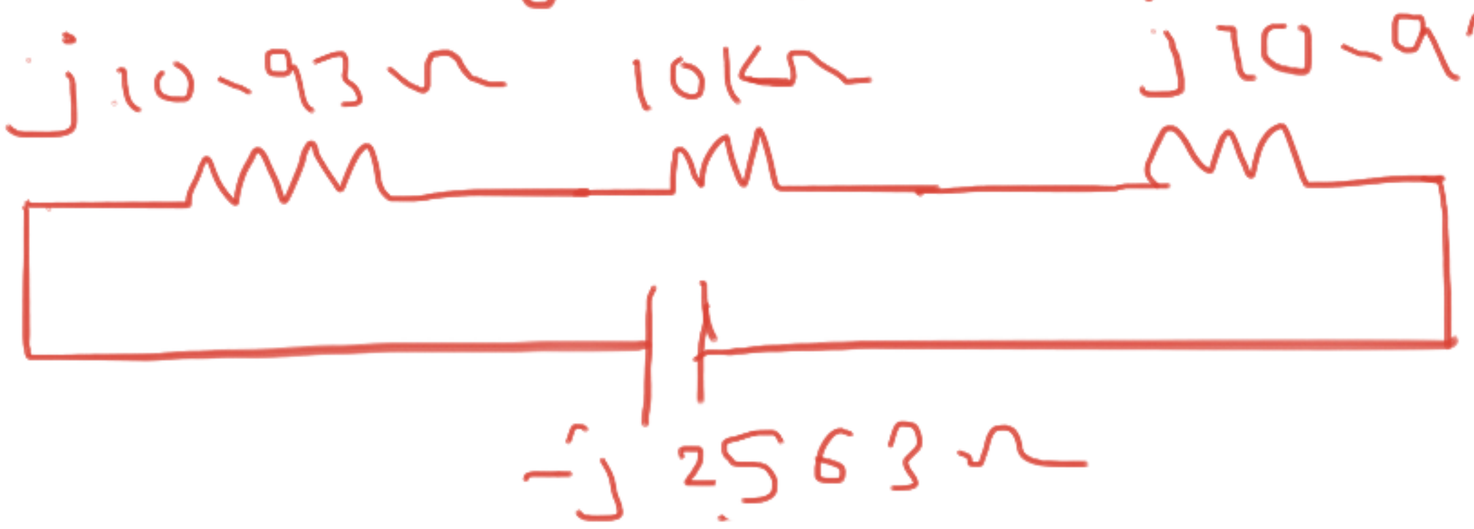
200 MHz :

$$X_C = \frac{-j}{\omega C}$$

$$X_C = \frac{1}{2\pi \times 200 \times 10^{6} \times 0.3\times10^{-12}}$$

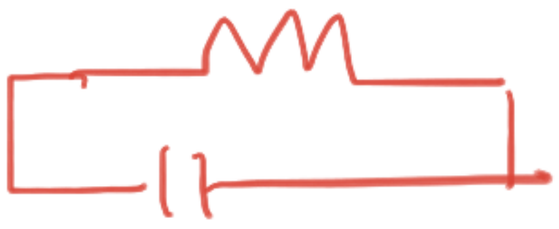
$$X_C = -j\,2563\ \Omega$$

∴ Eqn. ckt of R (= 10,000 Ω) at 200 MHz:



j10.93 Ω << 10 KΩ

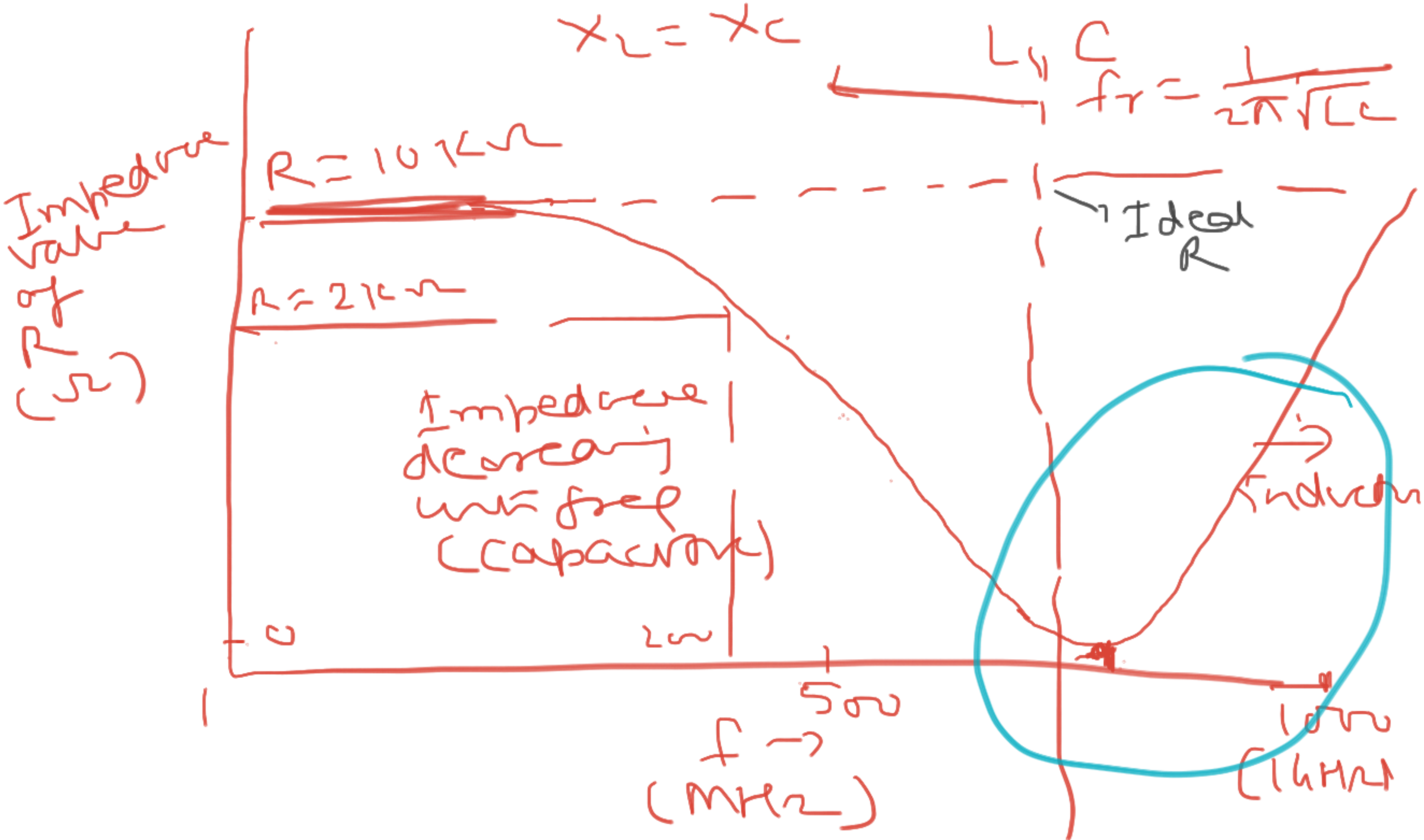
↳ neglected

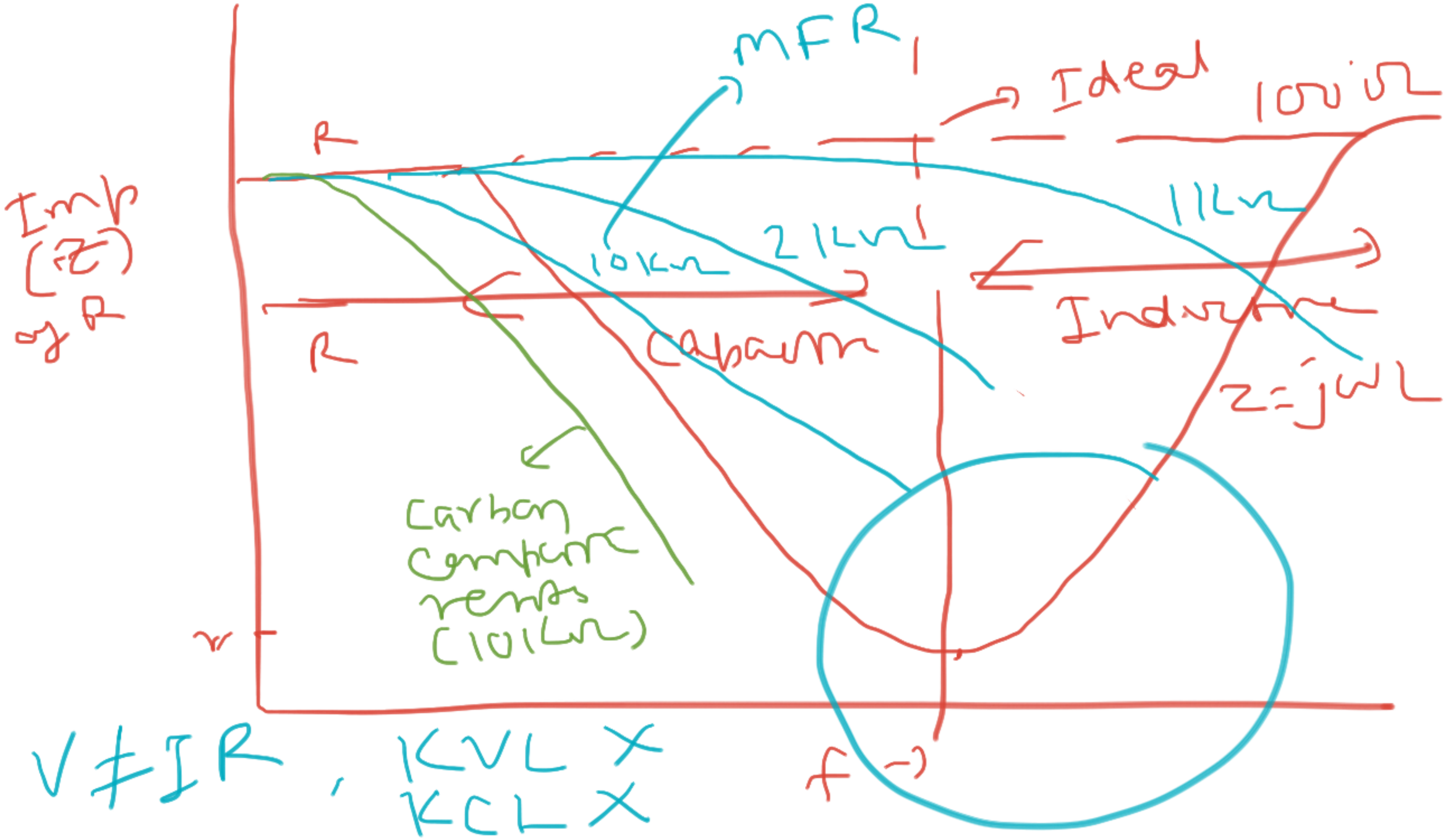


$$Z = \frac{RX_c}{\sqrt{R^2 + X_c^2}} = \frac{10K \times 2563}{\sqrt{(10k)^2 \quad (2563\ \Omega}}$$

$$Z = 1890\ \Omega$$

↳ 10K behaves like ~2KΩ resistor at 200 MHz


$X_L = X_C$
L || C
$f_r = \frac{1}{2\pi\sqrt{LC}}$
Impedance value of R (Ω)
R = 10 kΩ
R = 2 kΩ
Ideal R
Impedance decreasing with freq (capacitive)
Inductive
0
2ω
5ω
10ω
f → (MHz)
(1 kHz)


MFR
Ideal
R
Imp (Z) of R
10kΩ
2kΩ
1kΩ
R
Carbon
Carbon comp resis (10kΩ)
Z=jωL
f
V≠IR, KVL ✗
KCL ✗

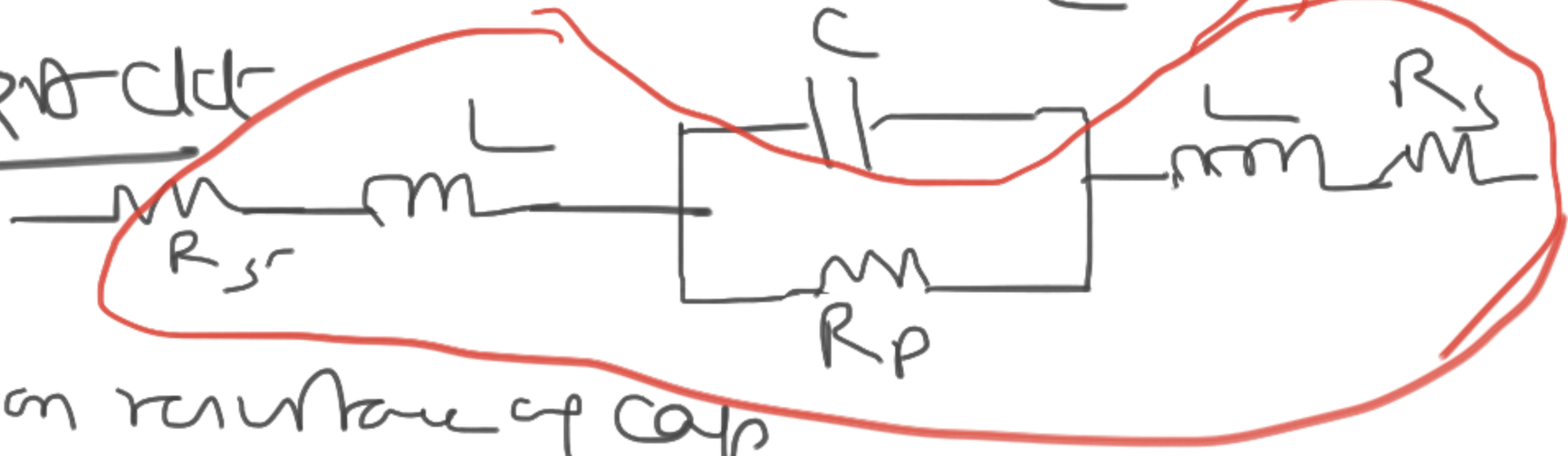
Capacitor : Dielectric constant

ϵ_r = 1.0005 (Vaccum)
= 1.01 (Air)
= 80 (water)

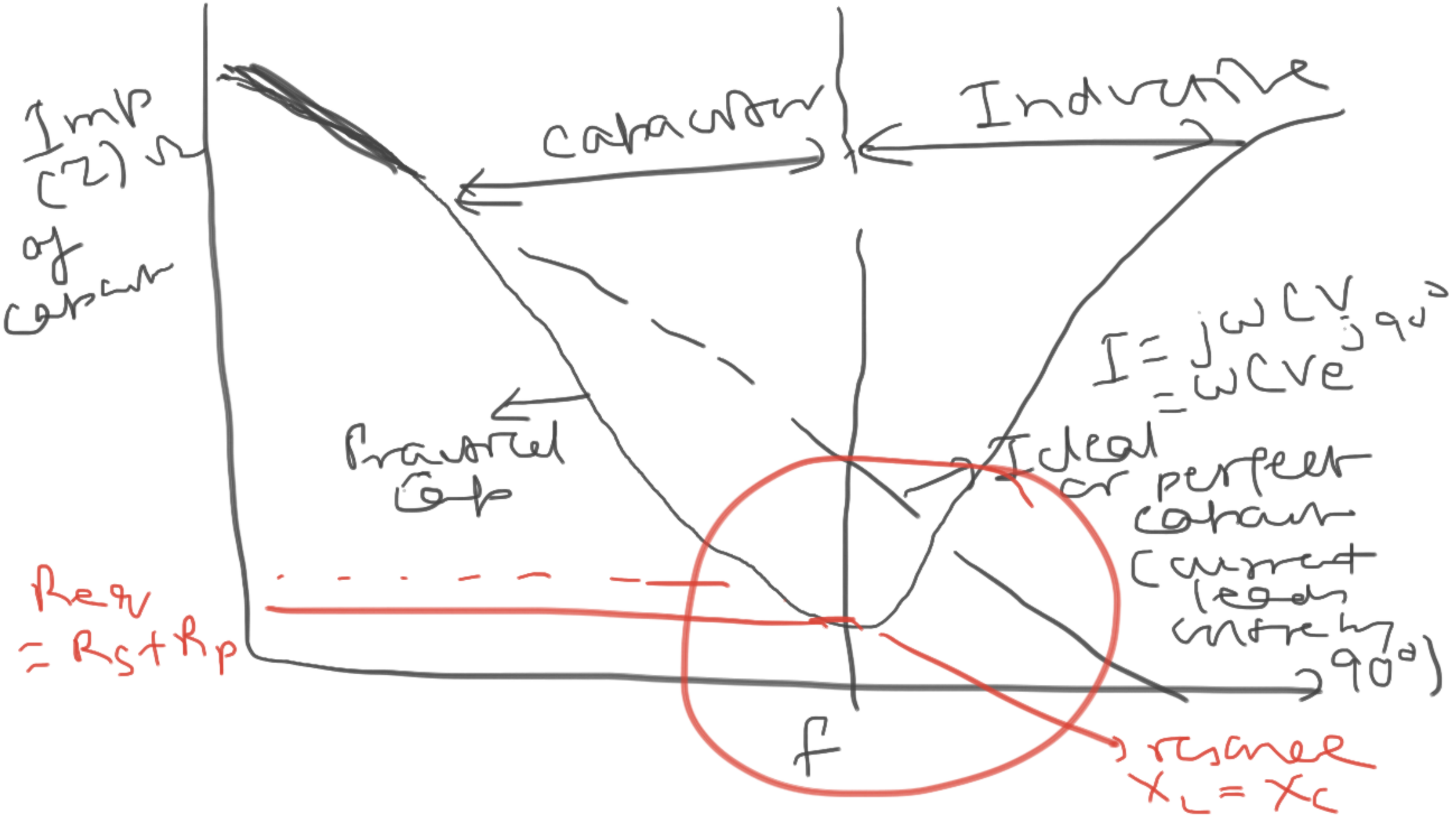
Charge retention capacity of medium

DC equivalent circuit of cap :

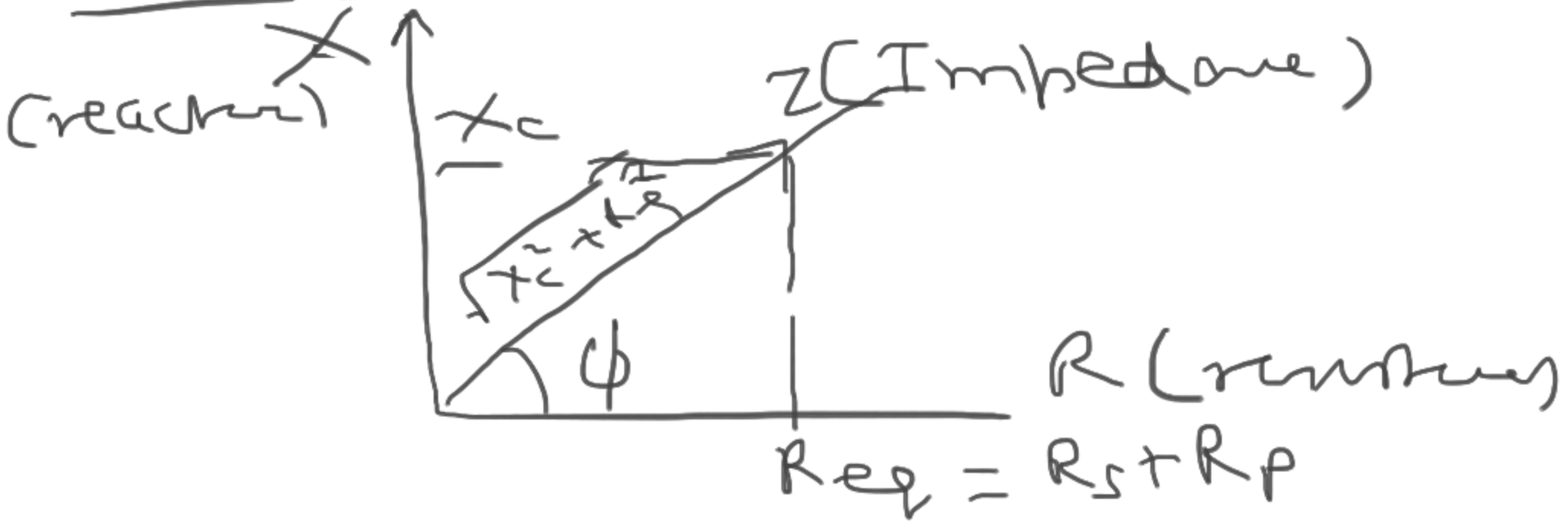
AC (RF) equivalent ckt



R_p = insulation resistance of cap


Imp (Z) of circuit
capacitive
Inductive
Parallel Comb
Ideal or perfect circuit (current leads voltage by 90°)
I = jωCV = ωCV e^{j90°}
Req = Rs + Rp
f
resonance
X_L = X_C

Power factor (PF) = $\cos\phi$



$$PF = \cos\phi = \frac{R_{eq}}{\sqrt{X_c^2 + R_{eq}^2}}$$

usually, $R_{eq} << X_c$, $X_c = \frac{1}{\omega C}$

$$\therefore PF \approx \frac{R_{eq}}{X_c}$$

ESR (equivalent series resistance)

↳ $R_{eq} = R_s + R_p$

Dissipation Factor (DF) → % of

↳ ratio of ac resistance to reactance of capacitor, $\Rightarrow DF = \frac{ESR}{X_c} \times 100\%$

$= \frac{R_{eq}}{X_c} \times 100\%$

Q-factor

$Q = \frac{X_c}{R_{eq}} = \frac{1}{\omega C R_{eq}}$

Loss tangent ($\tan\delta$)

↳ It is tangent of phase angle relationship between cap voltage & cap current

$$\tan\delta = \frac{\sigma}{\omega\epsilon}$$

σ = conductivity
ϵ = permittivity

$$\epsilon = \epsilon_r + j\epsilon_{imag}$$

↓

dielectric constant (real)

$$\tan\delta = \frac{-\epsilon_{imag}}{\epsilon_{real}}$$

$$Q = \frac{1}{\tan\delta}$$

For a reject (real) cap

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

$\Rightarrow$ PF $= 0$ $\left(= \frac{R_{eq}}{X_c}\right)$

$\Rightarrow$ Q $= \infty$ $\left(= \frac{X_c}{R_{eq}}\right)$

Photolithography

tanδ

PCB (FR-4) $\rightarrow$ $\epsilon_r = 4$

↳ Reinforced fabric

$FeCl_3$ (etchant)

Special PCBs → Dielectric substrate
(RT Duroid, Arlon, Taconic
FR-4 ⇒ tanδ = 0.0009 at 100 MHz
= 0.09 at 1 GHz

→ tanδ = 0.0009 at 1 GHz

apps of Coh
→ DC block
→ filter (L, C)
→ oscillator (L, C)