$\boxed{26/03/2021}$

RF electronics – 3 challenges

1) Presence of stray elements / parasitic elements

2) Skin effect

3) Radiation

Radiation

Antenna size $\propto \lambda$

Length of FM antenna = 75 cm

FM = 88 – 108 MHz

100 MHz $\Rightarrow \lambda = \dfrac{3\times10^{10}\text{ cm/}}{100\times10^{6}}$

= 300 cm

$\dfrac{300}{4} = 75\text{ cm} = \dfrac{\lambda}{4}$

very low freqs

BNC connector — British Navy Connector / Buoyant

Al/steel

TNC (Threaded Navy Connector)

GHz

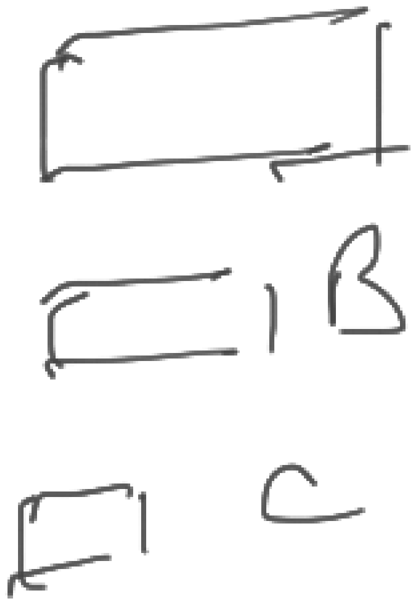
N-type connector

[illegible]

SMA - Sub-miniature 'A' B series C

SMB - ''

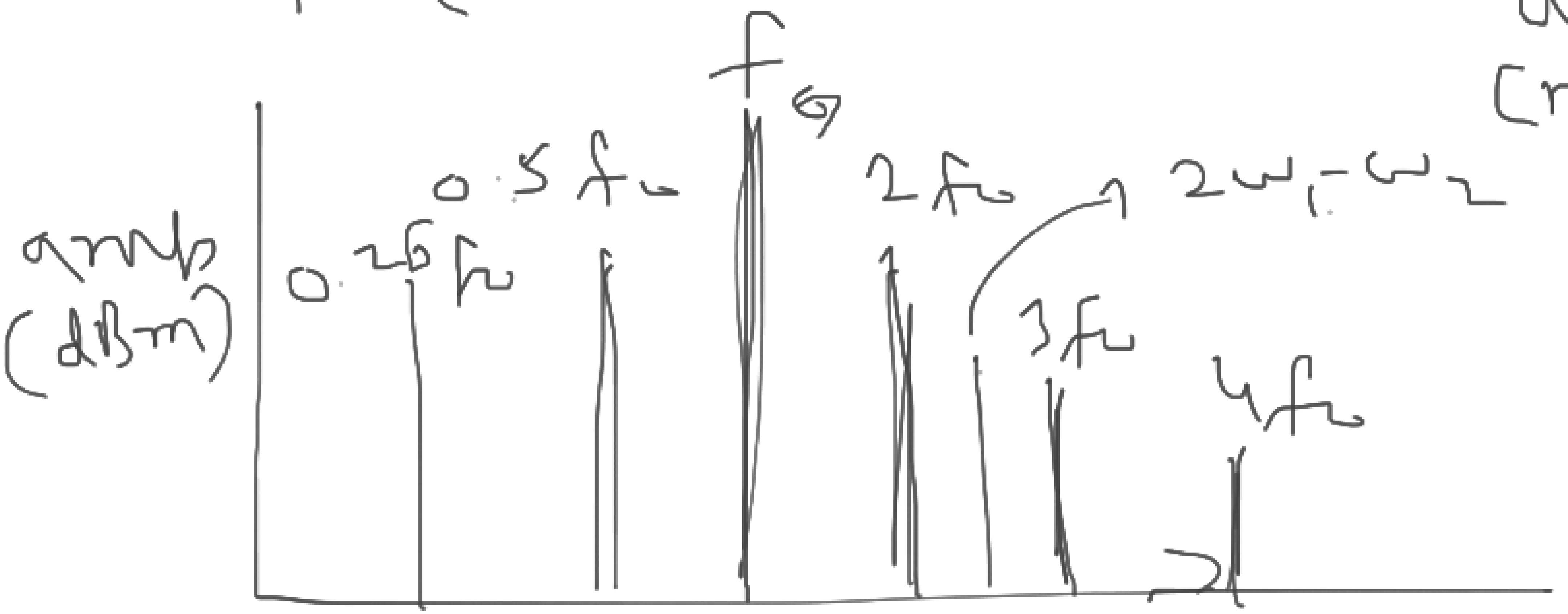
SMC - ''



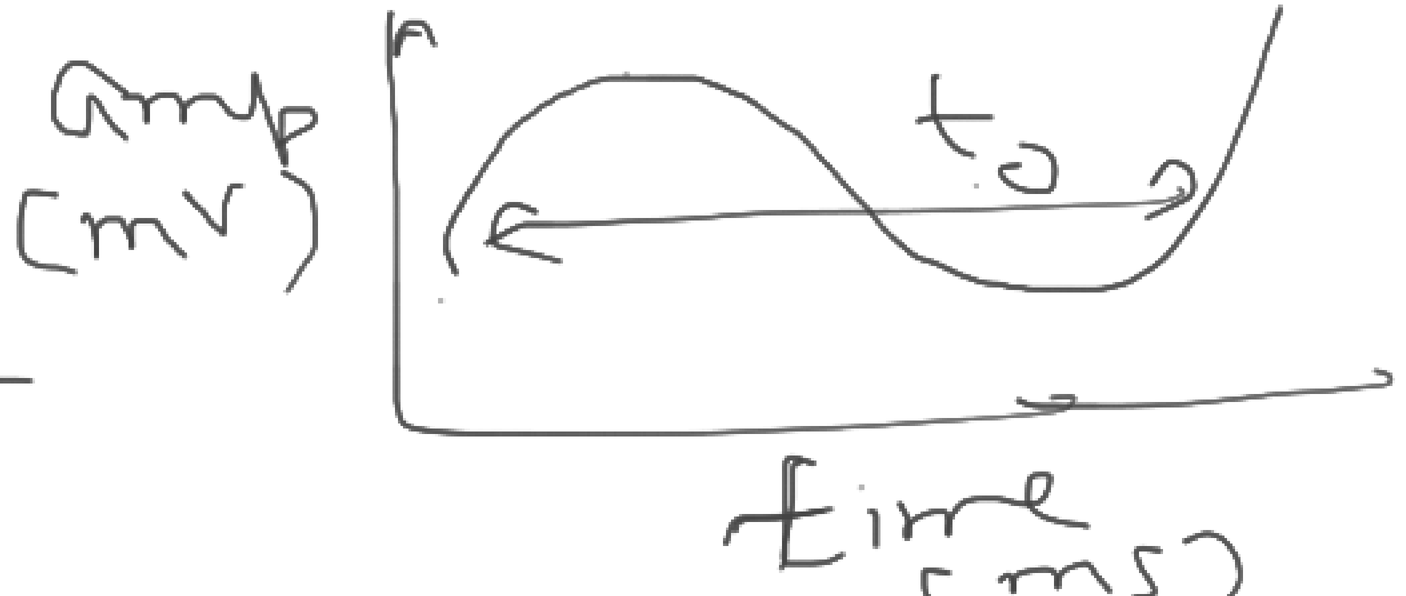
Gold plated

Spectrum Analyzer Vs Oscilloscope

freq domain



time domain



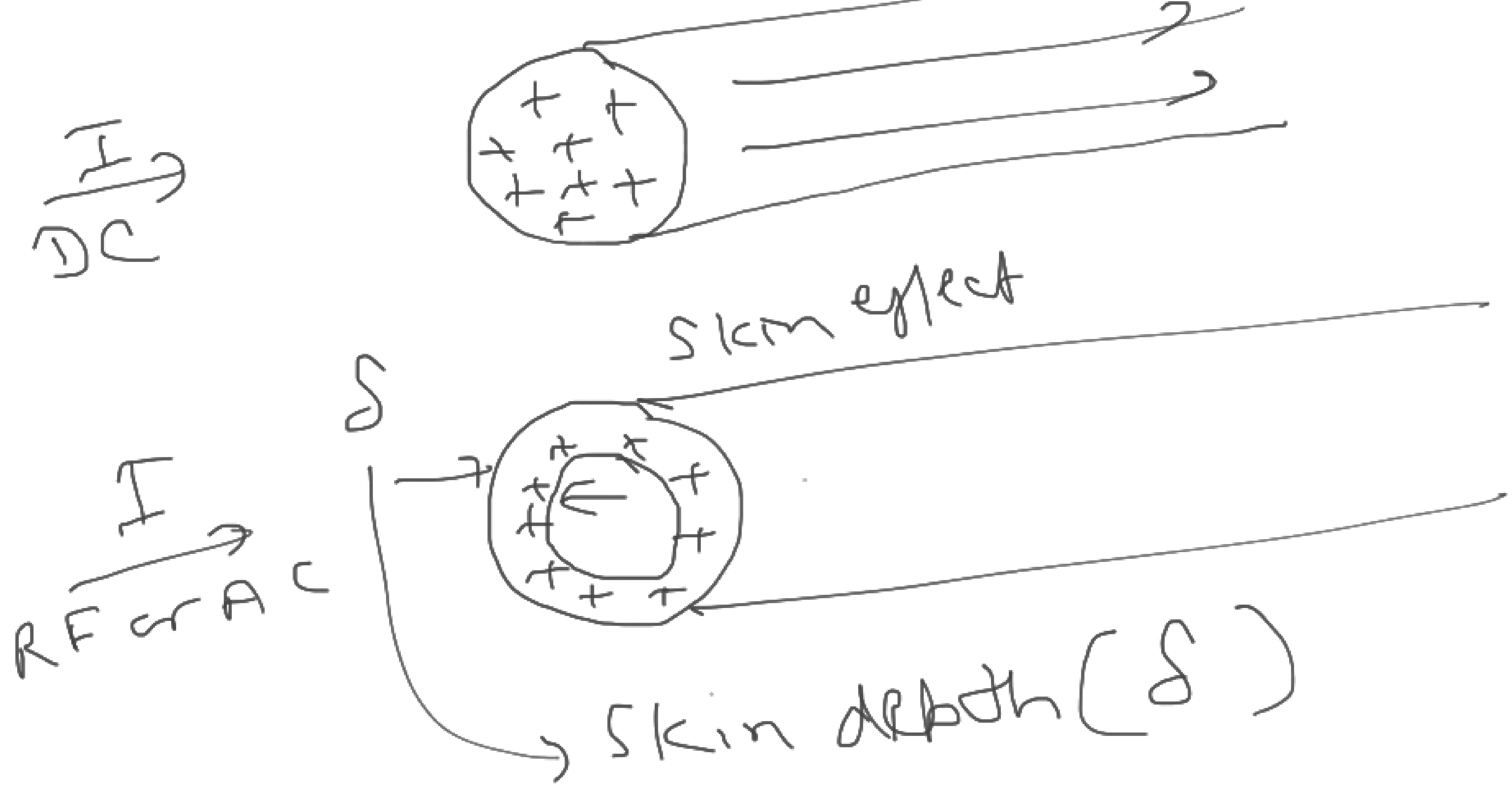
$f_0 = 1/t_0$

→ VNA (Vector Network Analyzer) → TDR (Time Domain Reflectometry)

→ Agilent (Keysight) → ADS (Adv. Design Simulator)

↳ HFSS

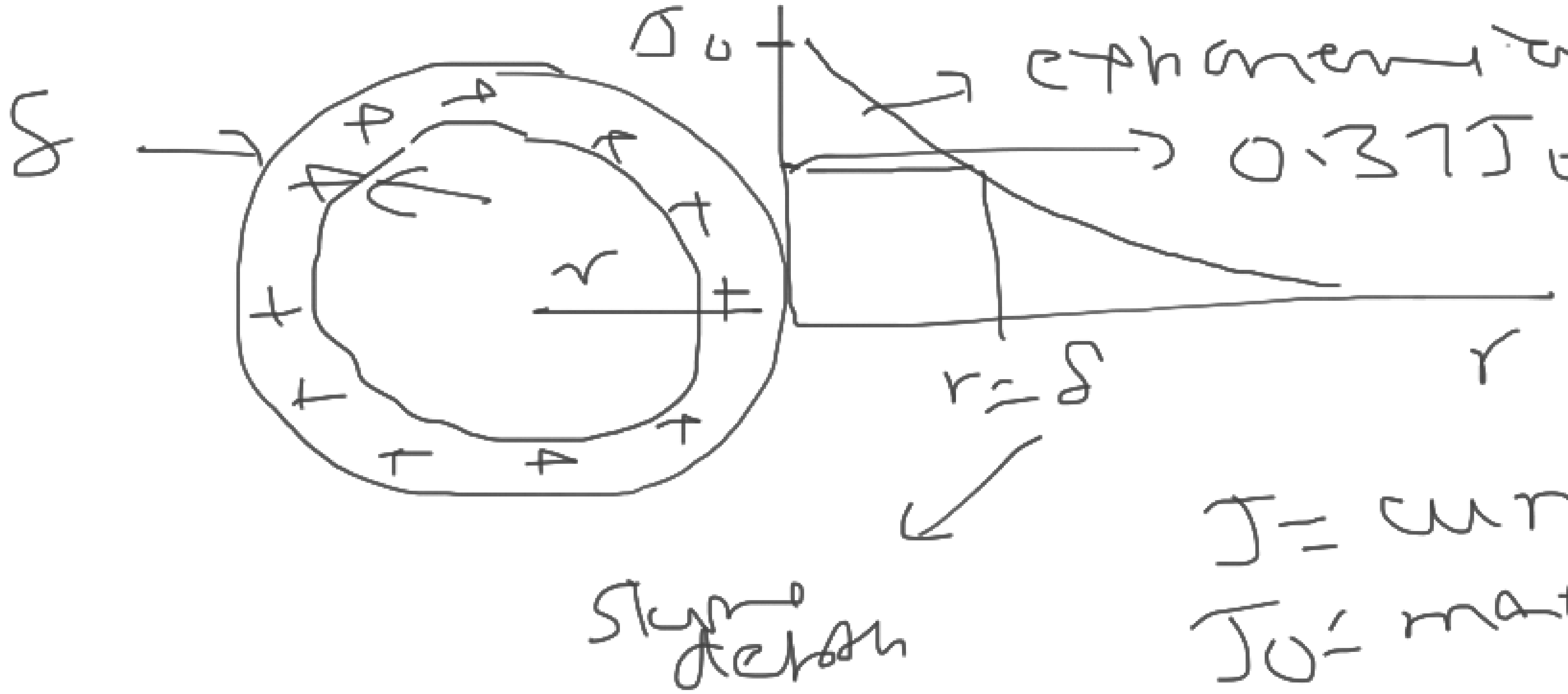
Skin Effect :



<u>Skin effect</u> :- Higher freq or AC current tends to flow only on the skin (or periphery) of the conductor; & not at centre i.e., not entire cross-section of conductor is used to pass the current (as in DC or low freq)

<u>Skin depth</u> :- It is defined as depth of penetration of the current where current amp (density) falls to $1/e$ of its max surface amplitude (J_0); falls off exponentially

or 36.8% of its max. value



→ exponentially decreases

→ $0.37 J_0$ (36.8% of J_0)

J = current density $= \frac{I}{A}$

J_0 = max " " (@ surface)

Skin depth

$$\boxed{\delta = \sqrt{\frac{2}{\omega \mu \sigma}} = \sqrt{\frac{1}{\pi f \mu \sigma}}} \quad (\omega = 2\pi f)$$

f = freq, σ = conductivity

μ = permeability

<u>Ex:</u> copper wire → skin depth at
(i) 60 Hz (ii) 1 MHz

For Cu, $\sigma = 5.8 \times 10^{7}$ S/m
↳ siemens or mho or ohm^{-1}

$\mu = 4\pi \times 10^{-7}$ H/m

(i) At $f = 60$ Hz, $\delta = \sqrt{\frac{1}{\pi f \mu \sigma}} = 0.85$ cm

(ii) At $f = 1$ MHz $= 10^{6}$ Hz, $\delta = 0.007$ cm

$\delta \propto \frac{1}{\sqrt{f}}$ $\delta \propto \frac{1}{\sqrt{\sigma}}$

Presence of stray elements (or parasitic) / RF behaviour of R, L, C, wire

wire :- Equivalent ckt of wire at RF frequency (high)

↓

inductive reactance

(Ω) $X_L = j\omega L = j2\pi f L$

at low freq, $f \approx 0 \Rightarrow X_L = 0$

high (RF), X_L can't be neglected

American Wire Gauge (AWG)

↓

Standard " " (SWG)

$\rightarrow$ diameter of wr

$\frac{S}{A}$WG

50	$\Rightarrow$	$d = 1$ mil
44	$\Rightarrow$	$d = 2$ "
36	$\Rightarrow$	$d = 4$ "
32	$\Rightarrow$	8 "
26	——	16 "
20	——	32 "
14	——	64 "

$1 \text{ mil} = \frac{1}{1000} \text{ inch}$

$= \frac{2.54}{1000} \text{ cm}$

$= \frac{25.4}{1000} \text{ mm}$

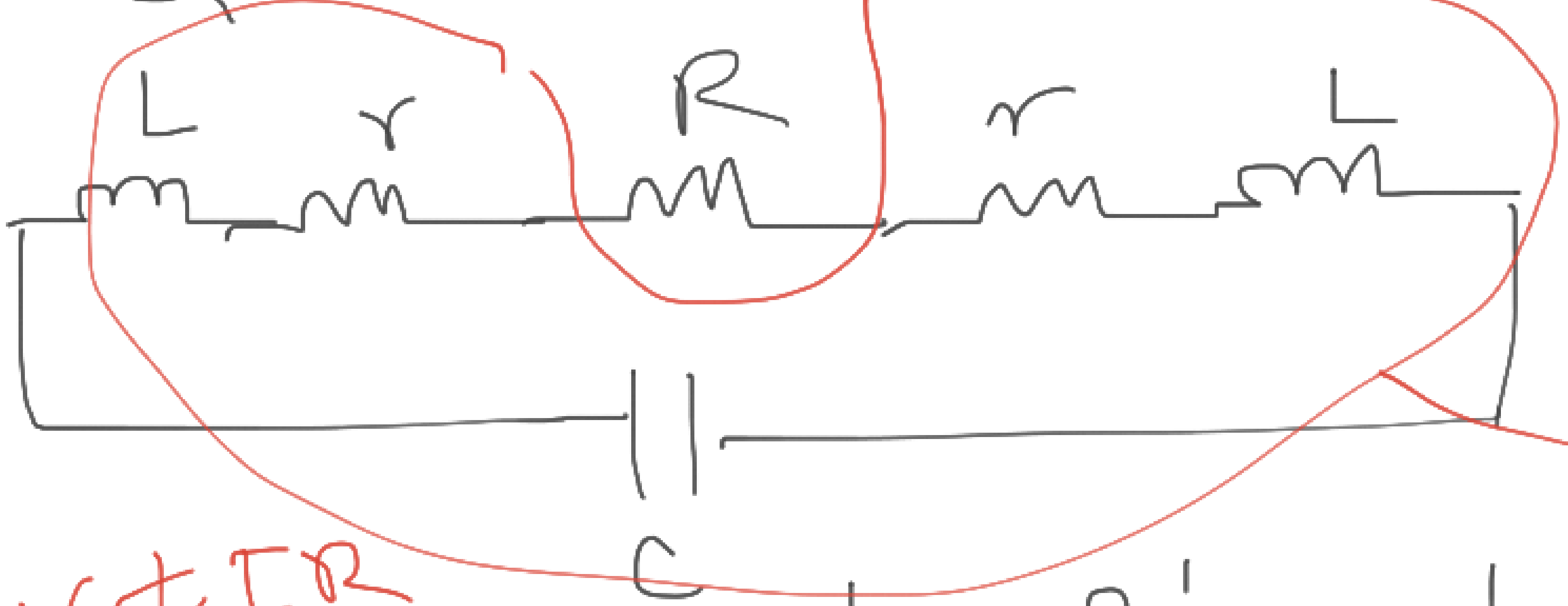
$$\boxed{\begin{aligned} 1 \text{ mil} &= 0.0254 \text{ mm} \\ &= 0.254 \text{ cm} \end{aligned}}$$

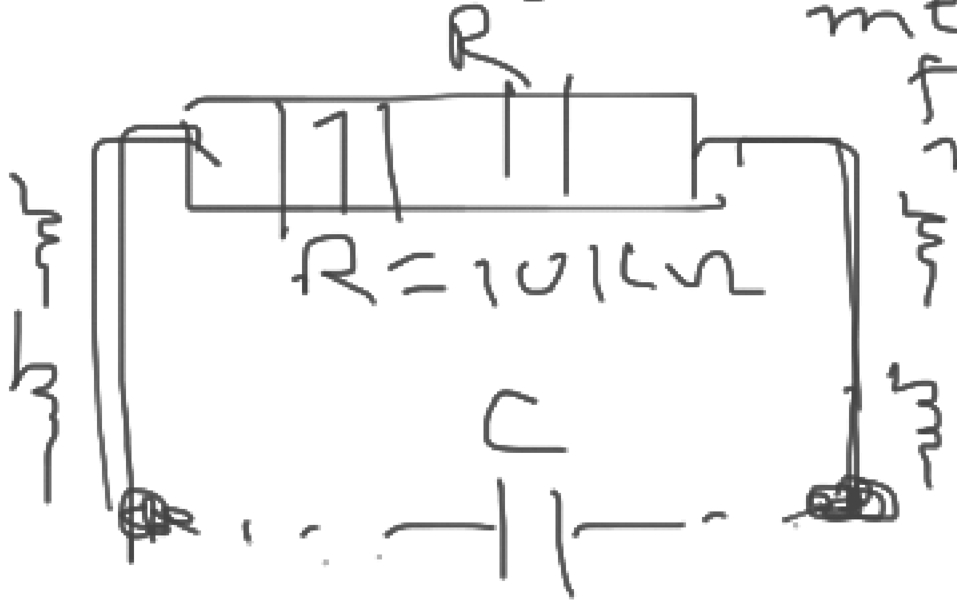
RF behaviour of resistor (R)

Eqv ckt of resistor at low or DC freqs

Eqv ckt of resistor at RF freqs (MFR)

metal film resistor





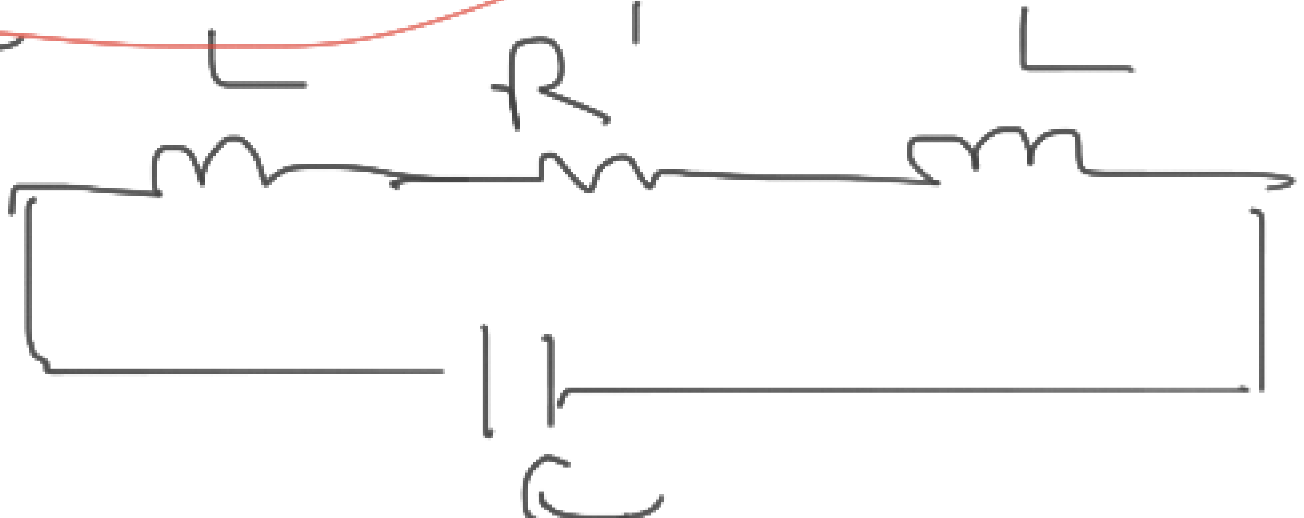
→ Parasitic elements

X_L and X_C

$= j\omega L$ $\quad = \frac{1}{j\omega C}$

$V \neq IR$

↳ $f_0 = \frac{1}{2\pi\sqrt{LC}}$



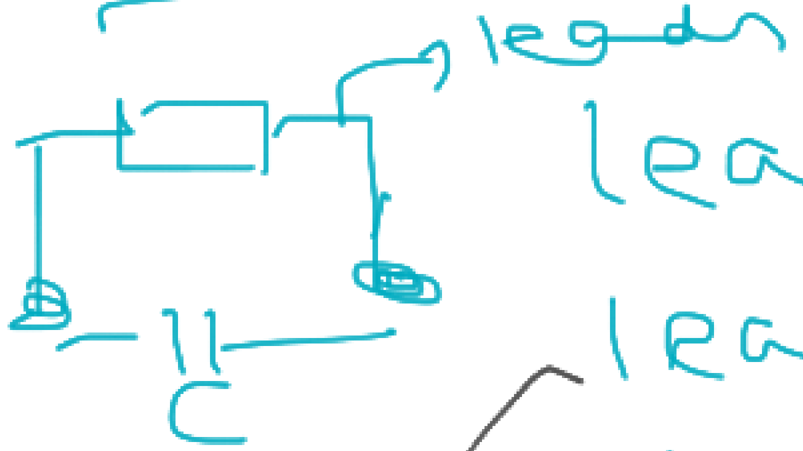
$R \rightarrow Z$ (impedance

$$X_L = X_C$$

$$j\omega L = \frac{1}{j\omega C}$$

$$\omega_r = \frac{1}{\sqrt{LC}} \Rightarrow f_r = \frac{1}{2\pi\sqrt{LC}}$$

<u>Example:</u> $10\,k\Omega$ (MFR) $\longrightarrow f = 200\,MHz$



lead length $= 0.5'' = 1.27\,cm$

lead diameter $=$ SWG 14

stray capacitance $C = 0.3\,pF = 0.3 \times 10^{-12}\,F$

(provided by manufacturer)

$d =$ SWG 14 $= 64$ mils
$= 64 \times 0.254\,cm$
$= 0.1628\,cm$

Soln: $L, C \rightarrow X_L$ & X_C , $\omega = 2\pi f$

$X_L = j\omega L$, $X_C = \frac{1}{j\omega C}$, $f = 10^6$ Hz

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

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

ℓ = length (in cm)

d = dia (in cm)

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

$= 0.0087\ \mu H$

$= 8.7$ nH $\quad (8.7 \times 10^{-9}$ nH$)$

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

$$= j2\pi \times \underbrace{200 \times 10^6}_{f} \times \underbrace{8.7 \times 10^{-9}}_{L}$$

$$X_L = j10.98\ \Omega$$

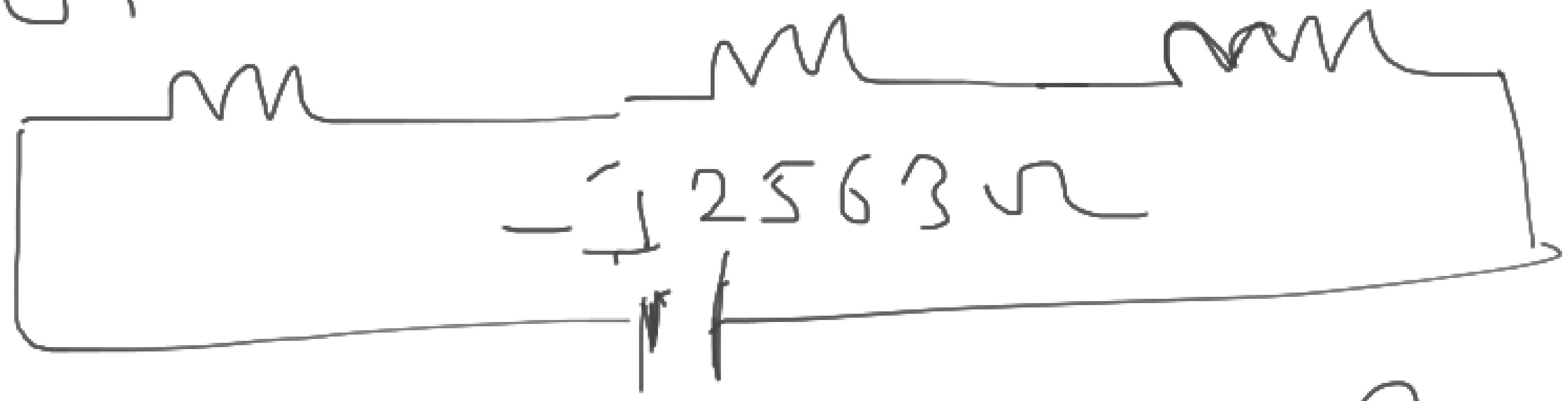
$$X_C = \frac{1}{j\omega C} = \frac{-j}{\omega C} = \frac{-j}{2\pi \times 200 \times 10^6 \times 0.3 \times 10^{-12}}$$

$$X_C = -j2653\ \Omega$$

$X_L = +ve$

$X_C = -ve$

Eqv ckt of R of 10KΩ at 200 MHz



(amount of r of wire = 0)

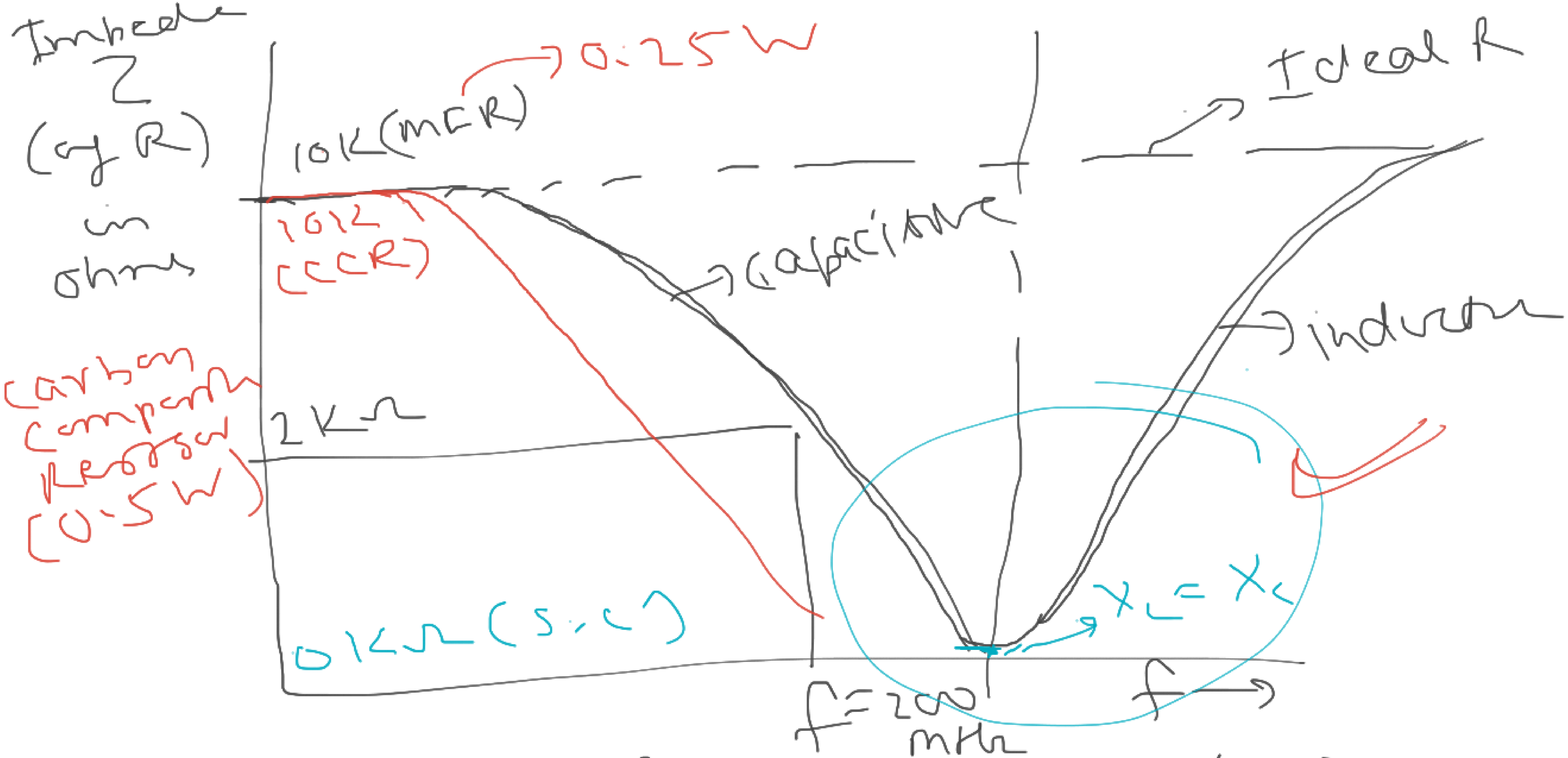
10.93Ω << 10KΩ ($X_L << R$)

10K will behave like 2K at 200 MHz

$$\Rightarrow Z = \frac{R X_c}{\sqrt{R^2 + X_c^2}}$$

$$= \frac{10{,}000 \times 2563}{\sqrt{(10{,}000)^2 + (2563)^2}}$$

$$\Rightarrow \boxed{Z = 1890\ \Omega}$$



Z decreases with f → capacitive $\left(\frac{1}{j\omega C}\right)$

Z increases with f → inductive $(j\omega L)$