09	03	202

CT 215 (Part -2) -Lecture- 1

Transmission Line Theory

-Sanjeev Gupta

$V \neq IR$

KVL, KCL } X

45%

wire, R, C, L behave at high frequency (RF or ac)?

RF (or ac or high freq) vs low freq (DC)

1) Presence of stray elements (parasitic or unwanted)
2) Skin effect
3) Radiation
4) Delay (transit time → minimize reflection)

↳ high freq → wavelength (λ)
↳ small

$$\lambda = \frac{c}{f}$$

BNC Connectors (British Navy Connectors)
↳ TNC = (Threaded Navy Connectors)

N, SMA, SMB, SMC

sub-miniature A screw
B ''
C ''

Gold plated

$V_A = V_0 \cos(\omega_0 t)$,

$\omega_0 = 2\pi f_0 t$

$$V_B = V_0 \cos[\omega_0 (t - \underline{\text{delay}})] \text{ volts}$$

Ex:- $f = 60\ Hz$

Length $l = 1\ m$

delay (time) $= \frac{\text{length}}{\text{speed}}$ → $1\ m$, $3 \times 10^8\ m/sec$

$\omega t_{delay} = 2\pi f t_{delay} = 0.000012$

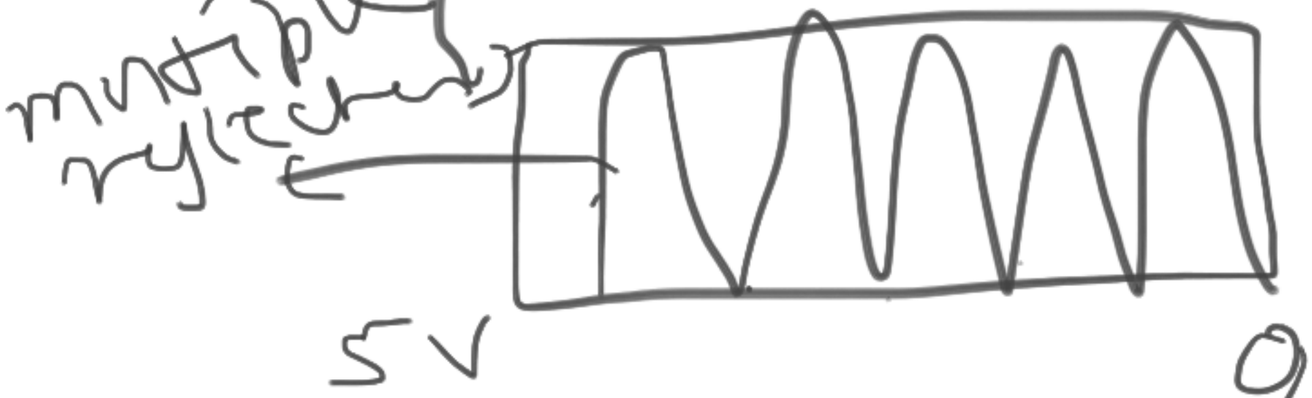
$V_B \cong V_A = V_0 \cos \omega_0 t$

$f = 1\,GHz = 1 \times 10^9\ Hz$

$\omega t_{delay} = 20.94$ radians

$= 6.67$ cycles

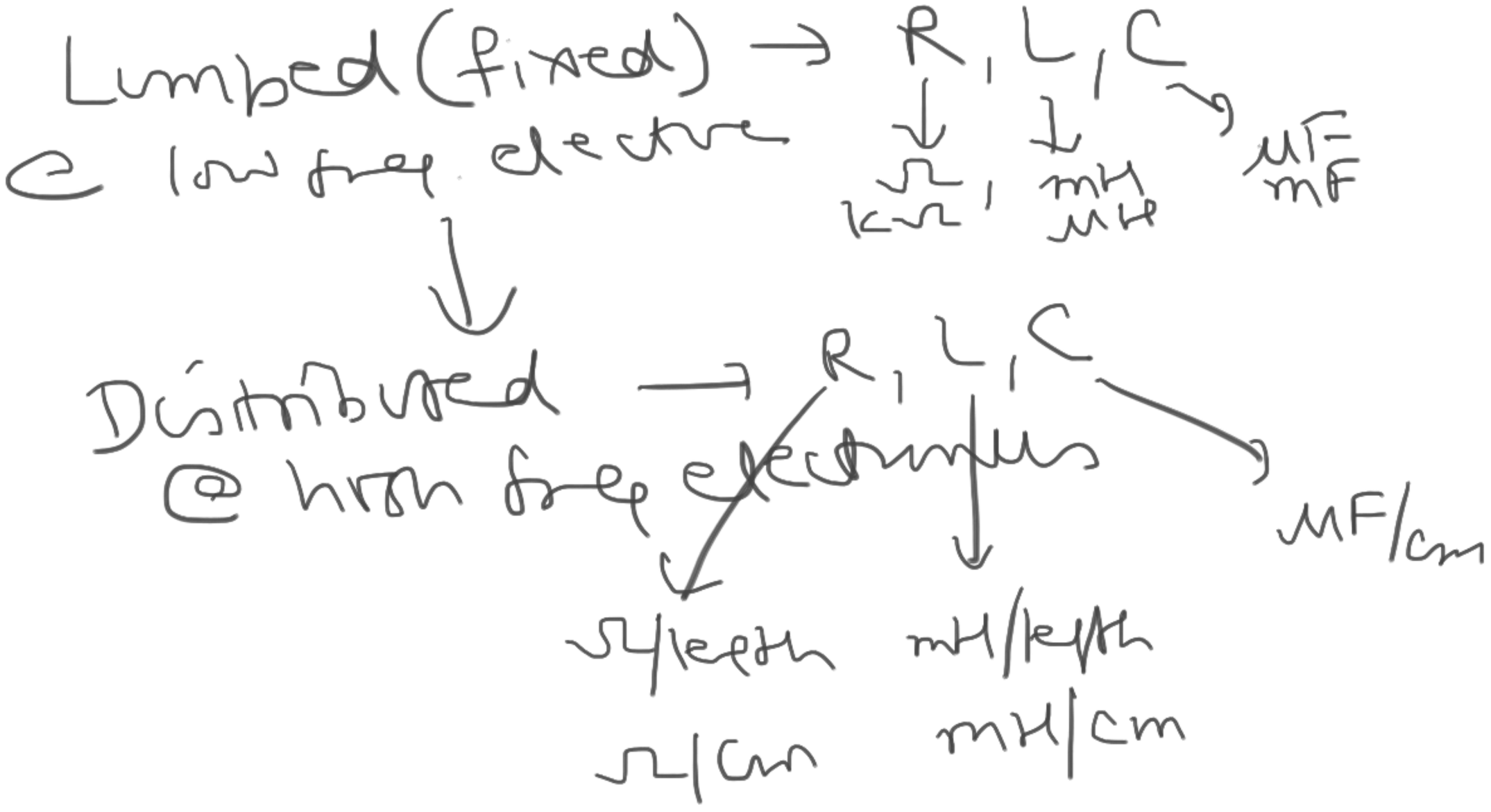
$180^\circ = 2\pi$ rad $=$ 1 cycle



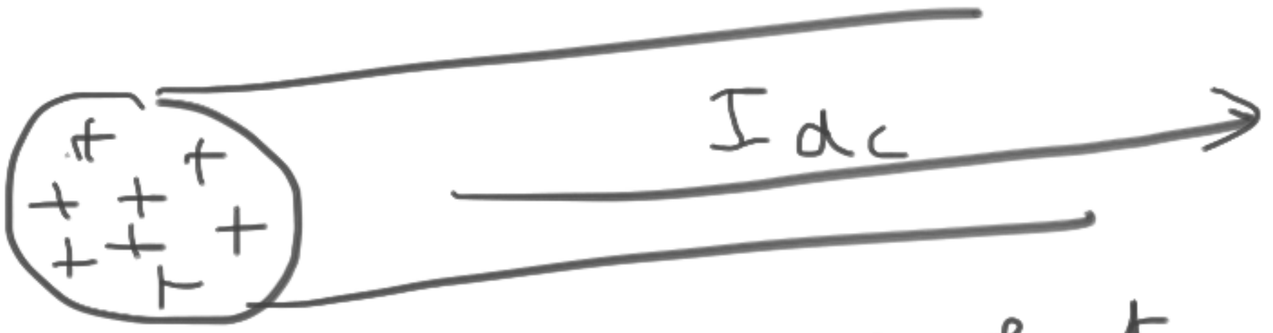
$V_B = 0.49 V_A$

2.5 V

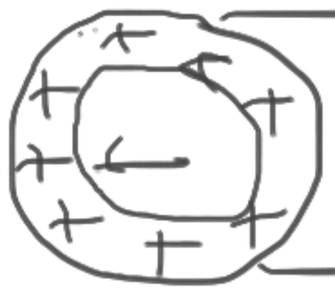
transit time effect (delay)


Lumped (fixed) → R, L, C
@ low freq electric
Distributed → R, L, C
@ high freq electronics
Ω/length
Ω/cm
mH/length
mH/cm
MF/cm

Skin effect : wire



at low freq or dc current, entire cross-section of conductor (wire) is used to pass low freq (or dc) current

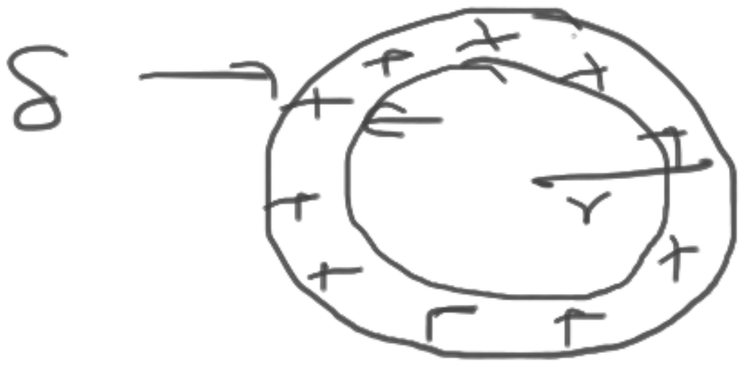


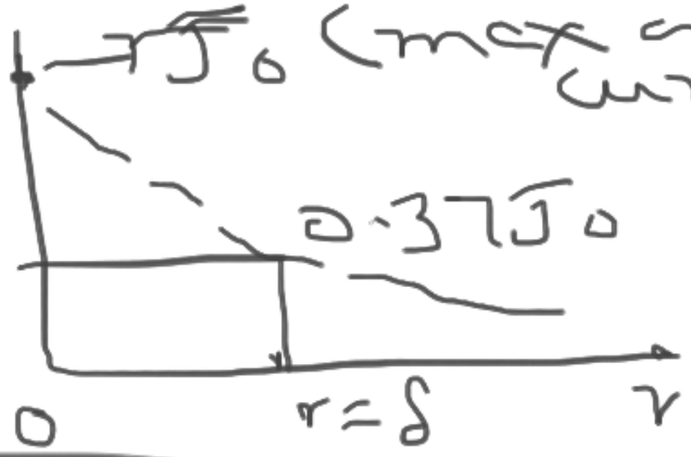
$\delta \rightarrow$ $\longrightarrow I_{ac}$ (high freq or ac current)

at high freq or ac, only a portion from skin of conductor is used to pass the current

δ (Skin depth) = Depth of penetration

where signal amplitude is $1/e$ or 36.8% of its surface (max) amplitude. (≈ 37%)





$$\delta = \sqrt{\frac{2}{\omega \mu \sigma}} = \frac{1}{\sqrt{\pi f \mu \sigma}}$$

[∵ $\omega = 2\pi f$)

μ = permeability

σ = conductivity

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

Ex - copper wire

$\delta = 60\,Hz$

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

$\sigma = 5.8 \times 10^{7}\ S/m$

Siemens, or ohm^{-1} or mho

$f = 60\,Hz$

$$\delta = \frac{1}{\sqrt{\pi f \mu \sigma}} = 0.85\,cm$$

$f = 10^{6}\,Hz\,(1\,MHz)$

$\delta = 0.007\,cm$

Presence of Stray elements

→ parasitic

→ Between conductors of circuit

→ " components " "

→ " " & ground

Wire : Eqn ckt of wire at AC or high freq

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

r

→ because of material

→ inductive reactance (ohms)

at low freq

X_L = negligible

≈ 0

$r = 0$

AWG (American wire Gauge)
↓
SWG (Standard wire Gauge)

AWG 50 ⇒ d (diameter) = 1 mil

AWG / SWG

SWG
44 = 2 mils
36 = 4 mils
32 = 8 mils
26 = 16 mils
20 = 32 mils
14 = 64 mils

1 mil
= 1/1000 inch
= 0.0254 mm

(1 inch = 25.4mm)