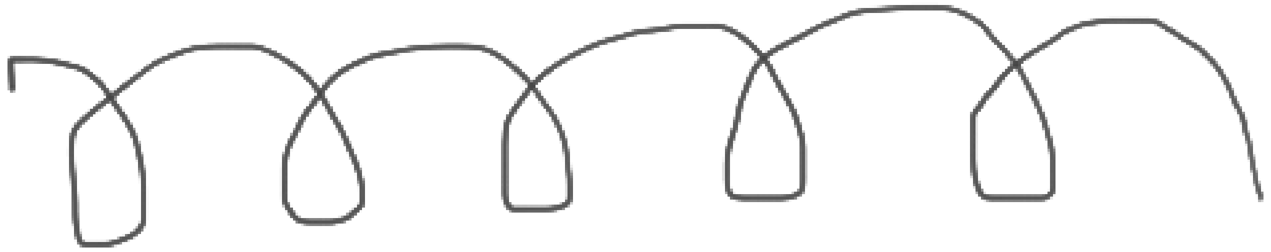
18/03/2021

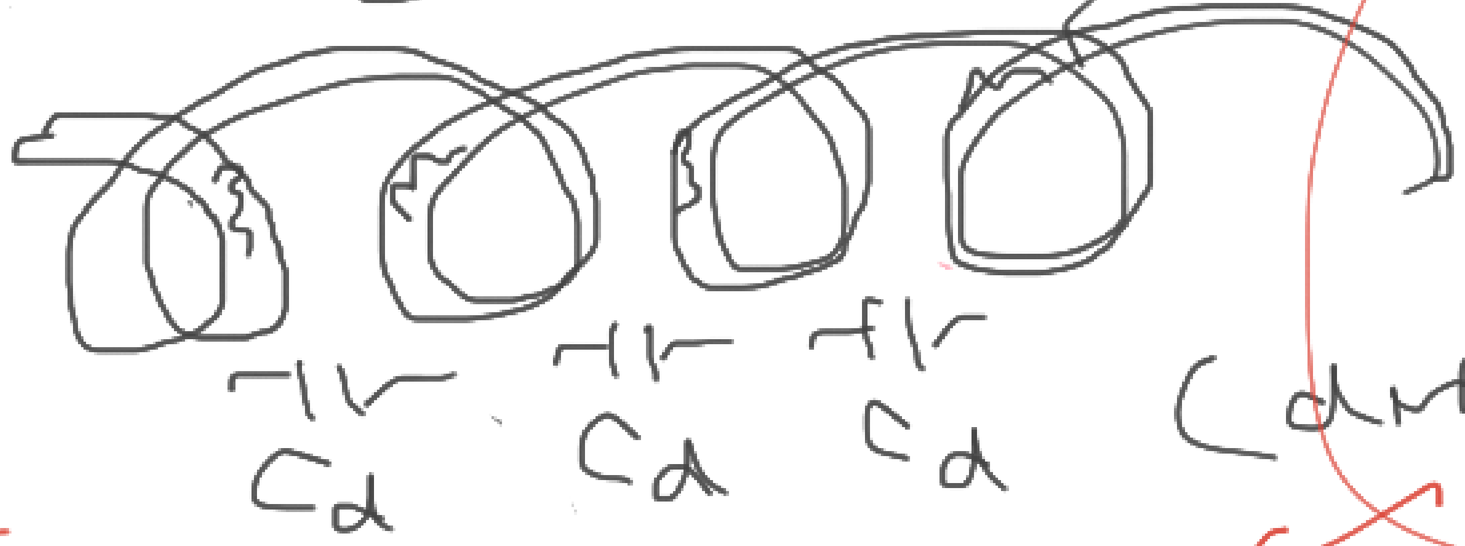
Inductor

→ 



coiled to increase the magnetic flux linkage

L

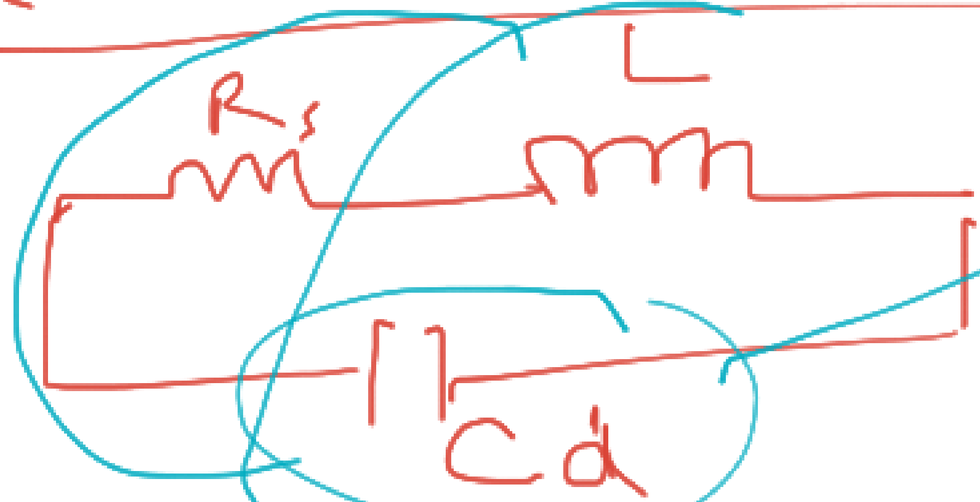


→ resistance (R)

(distributed capacitance) (C)

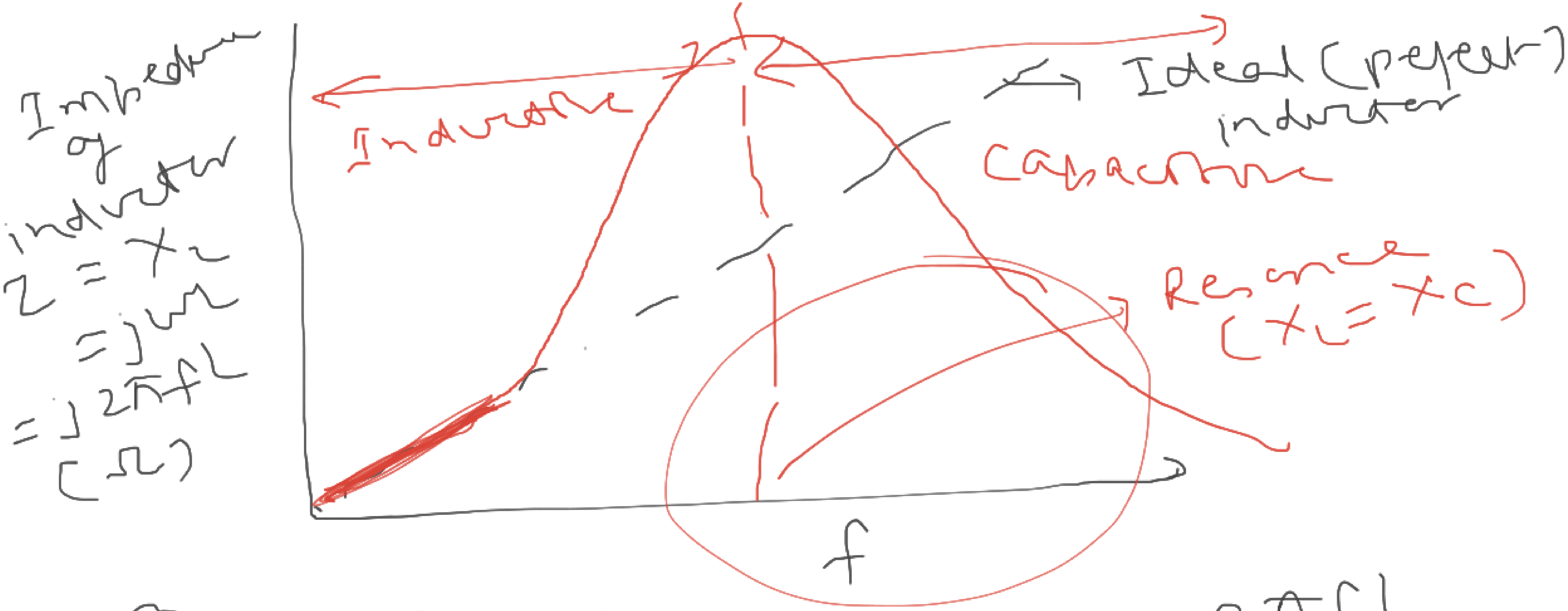
Stray elements
parameters

Eqvt ckt of inductor at ac (or RF or high freq)



L, C → resonance

Rs - series resistance



Quality factor

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

For a perfect inductor, $R_S = 0$

$$\Rightarrow Q = \infty$$

To increase Q of L

→ use a larger diameter

⇒ resistance decreases [$R = \frac{\rho l}{A}$]

↳ Area

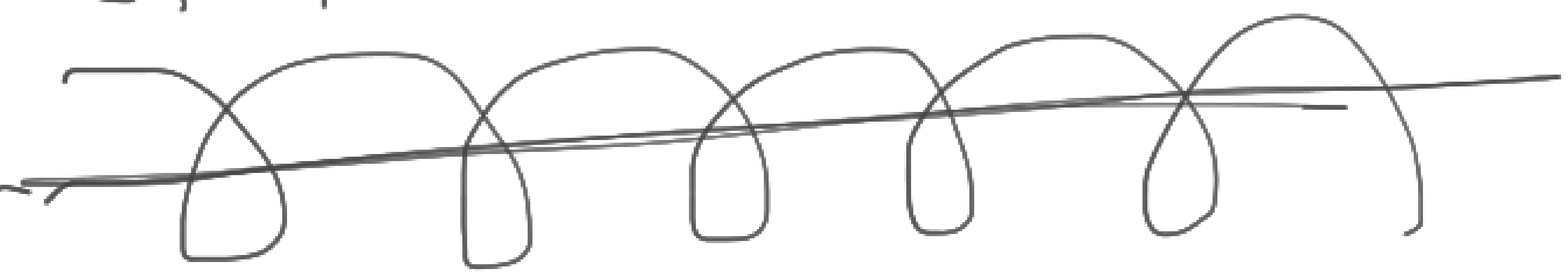
⇒ Q increases

→ Spread the windings apart (d)

⇒ C_d decreases [$C = \frac{\epsilon A}{d}$]

⇒ Q increases

→ increase the permeability of magnetic flux linkage by using a ferrite rod between the core → Q increases



ferrite rod

Applications of L

→ LC filter

→ oscillator ($f = \frac{1}{2\pi\sqrt{LC}}$)

→ delay (phase change)

5 mV → $\boxed{\times 10}$ → 50 mV

$5\,mV \angle 0^\circ$ → $50\,mV \angle 30^\circ$

L → delay

↳ phase change

→ RF choke

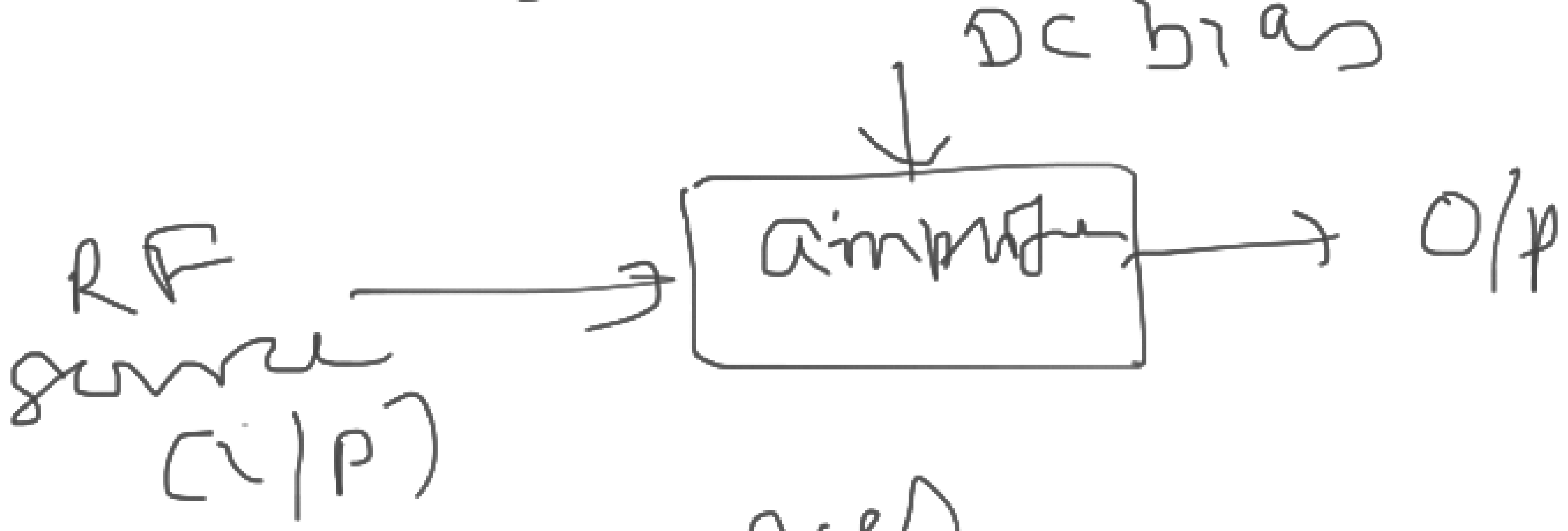
(allows dc to pass through)

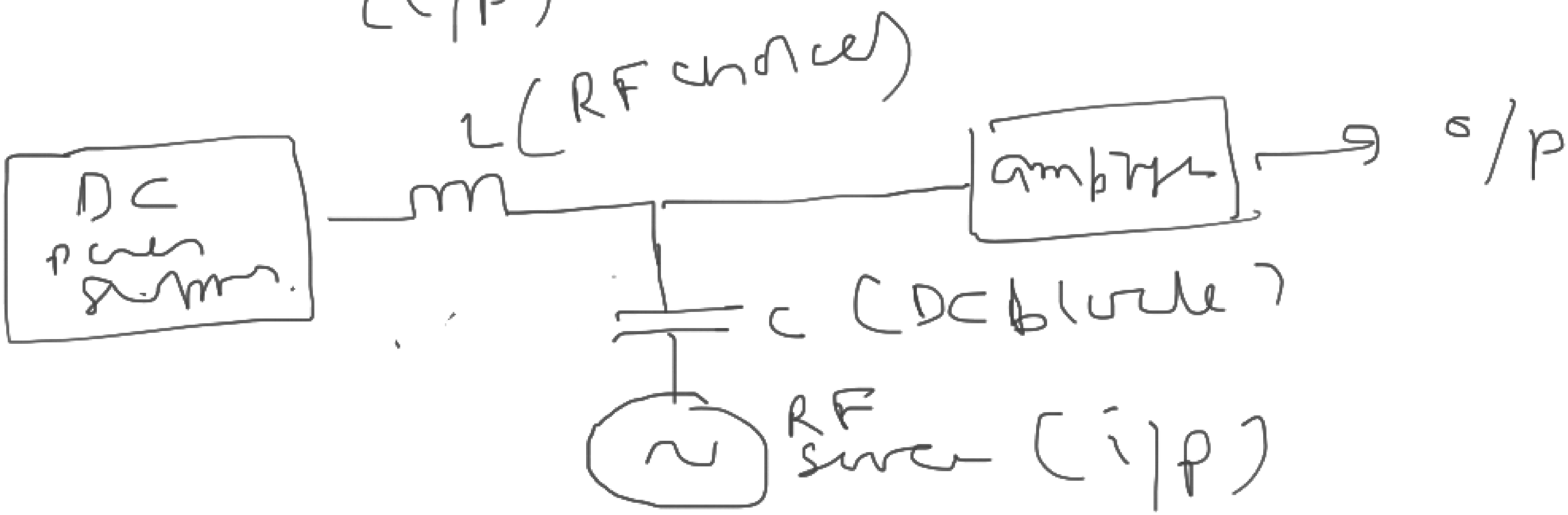
doesn't allow RF or ac to pass through

Bias Tee (T)

DC power supply (low freq or zero freq)

RF generator (high freq) —

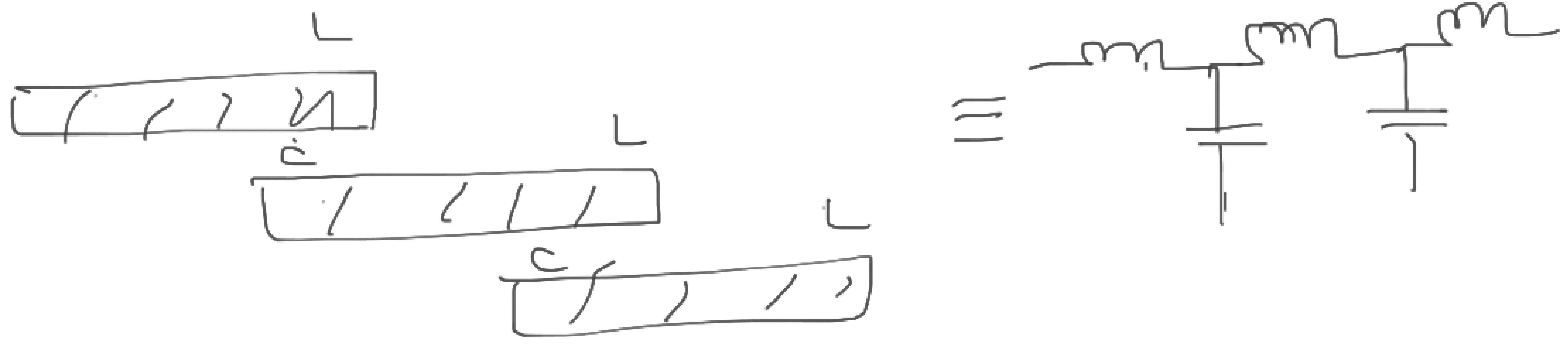


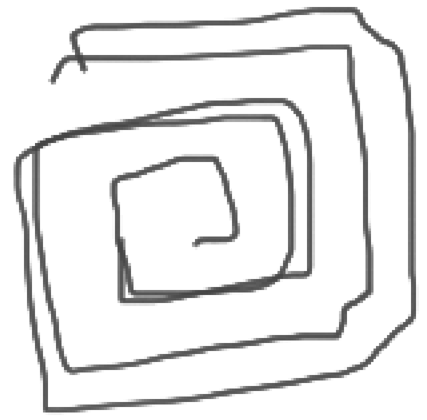


Chip resistors (no leads)

Size code	L (mils)	W (mils)
0402	40	20
0603	60	30
0805	80	50
1206	120	60
1218	120	180

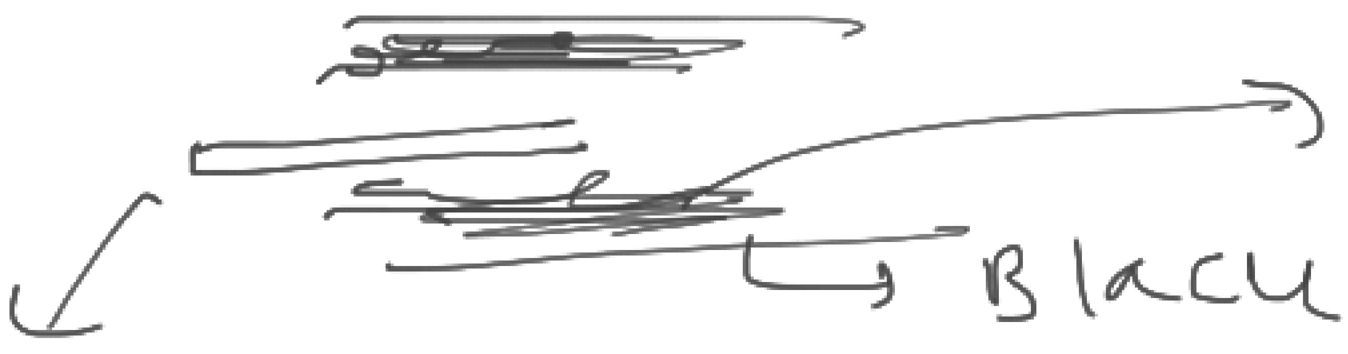
L, C (printed form)





wire
R
C
L

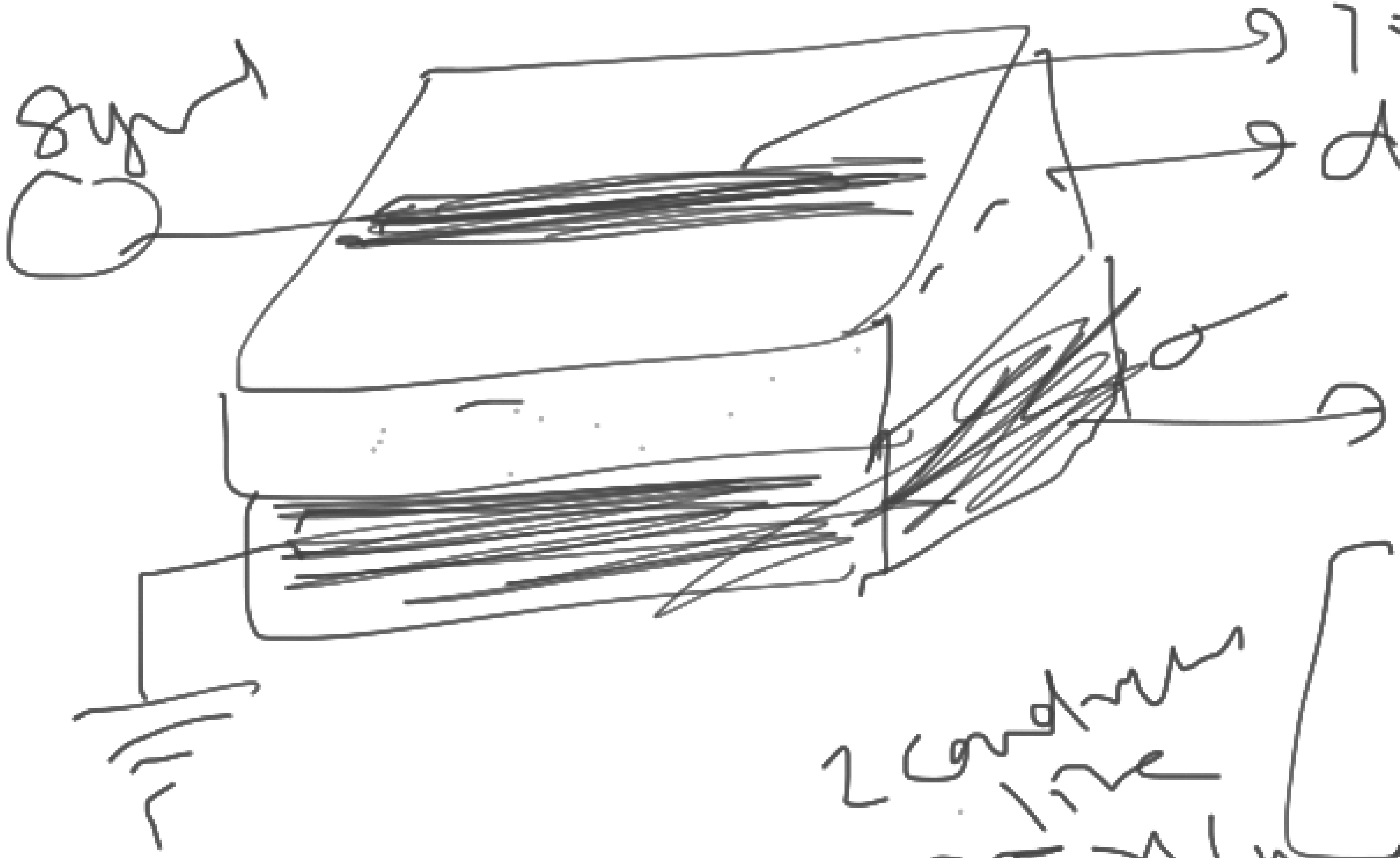
Transmission Line



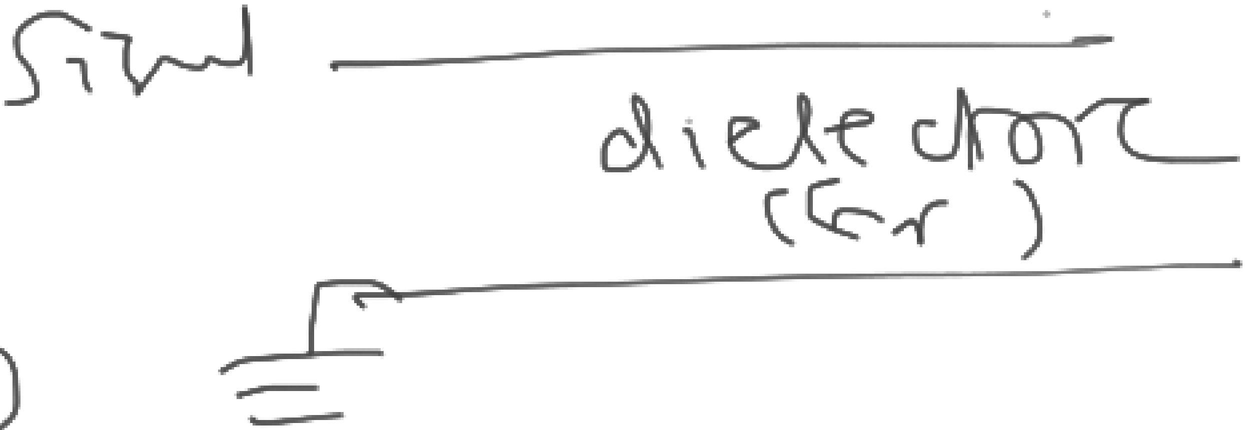
(coaxial or coax cable)

2 conductor line (wire - single conductor)

PCB

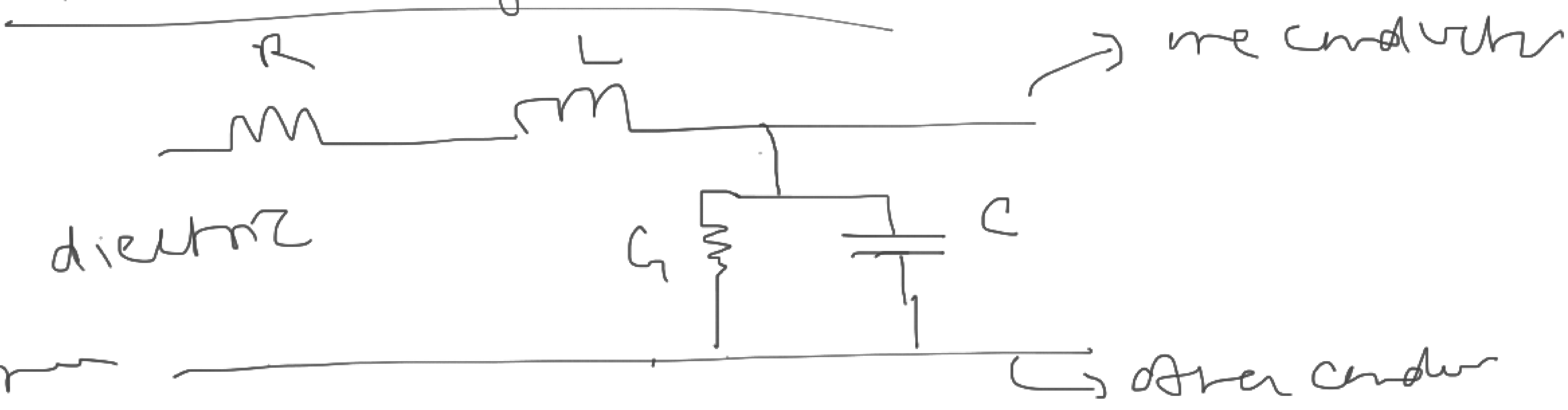


2 conductor line



2 conductor line (T line)

Eqvt circuit of TX line



R → due to resistance of conductor

L → represents magnetic flux generated by current on TX line

C → capacitance due to dielectric between two conductor

G → represents coupling currents between two conductors because dielectric has some conductivity (leakage current)
(conductance)

R, L, G, C (not lumped or fixed values)

ohm, H → mhos or ohm^{-1} or siemense (S)

F

$G \neq \frac{1}{R}$

Distributed R, L, G, C

$\frac{ohm}{length}$ (cm)

$\frac{mH}{length}$

$\frac{siemens}{length}$

$\frac{F}{length}$

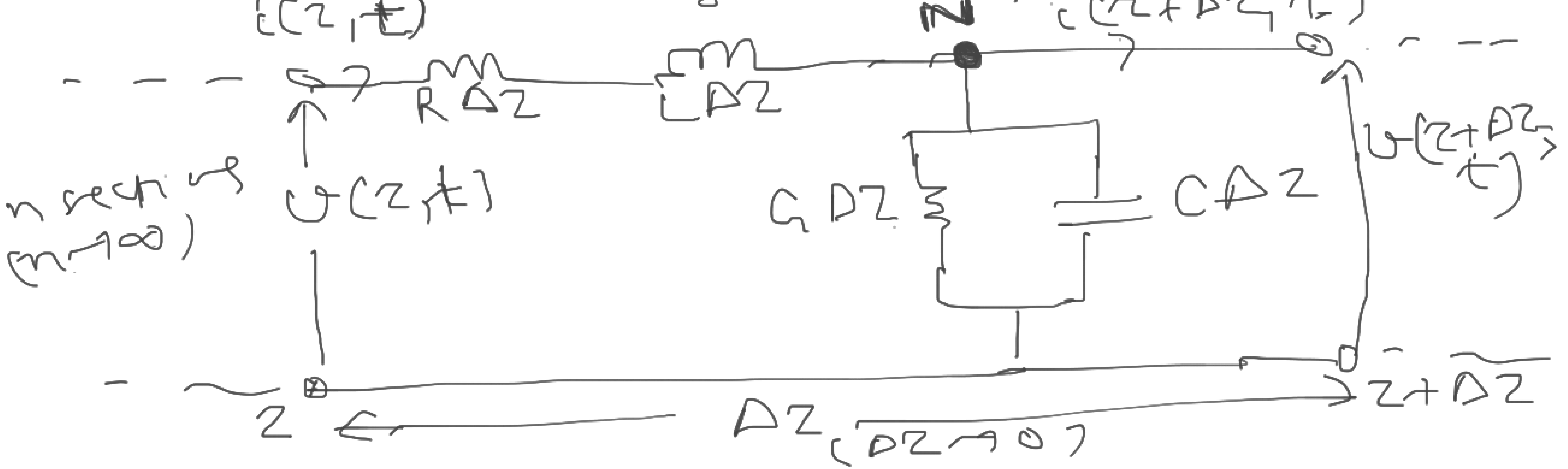
$V \neq IR$ ✗

KVL ✗

KCL ✗

Analysis of Transmission (TX) line

We divide TX line of length l into no. of small sections ($l = \Delta Z$), $\Delta Z \to 0$
$(n \to \infty)$ infinitesimally length



$R \to \dfrac{\text{ohm}}{\text{length}}$ (dimension)

$R\Delta Z = \dfrac{\text{ohm}}{\cancel{\text{length}}}\ \cancel{\text{length}} = \text{fixed})$

instantaneous (t)

Applying KVL (loop eqn)
↳ sum of voltages in a loop = 0

$$v(z,t) - R\,\Delta z \cdot i(z,t) - L\,\Delta z \cdot \frac{\partial i}{\partial t}(z,t) = v(z+\Delta z, t),$$

where $v(z,t)$ = instantaneous voltage at z
$v(z+\Delta z, t)$ = " " " $(z+\Delta z)$

Rearrange & dividing by Δz & combining v terms, we get

$$-\left[\frac{v(z+\Delta z,t) - v(z,t)}{\Delta z}\right] = R\,i(z,t) + L\frac{\partial i}{\partial t}(z,t)$$

In limit $\Delta z \to 0$
(difference goes to differential),
we have

$$\boxed{-\frac{\partial v(z,t)}{\partial z} = R\, i(z,t) + L\frac{\partial i(z,t)}{\partial t}}$$

(1)

Similarly, applying KCL to node N
↳ sum of currents into a node = 0

$$i(z,t) - G\Delta z \cdot v(z+\Delta z,t) - C\Delta z \cdot \frac{\partial v(z+\Delta z,t)}{\partial t}$$

$$= i(z+\Delta z,t)$$

Rearranging & dividing by Δz & combining i terms, we set & limit $\Delta z \to 0$, we get

$$\boxed{-\frac{\partial i(z,t)}{\partial z} = G\,v(z,t) + C\frac{\partial v(z,t)}{\partial t}} \quad (2)$$

(1) & (2) general TX line eqns

(or Telegrapher's eqns)

For harmonic time dependence, use of phasors simplifies transmission line eqns to ordinary differential eqns.

For a cosine reference, we write

$$v(z,t) = \text{Re}\left[V(z)e^{j\omega t}\right] \quad \text{--- (3)}$$

$$\& \quad i(z,t) = \text{Re}\left[I(z)e^{j\omega t}\right] \quad \text{--- (4)}$$

Substituting (3) & (4) in (1) & (2), we get ordinary differential eqns

$$\boxed{-\frac{dV(z)}{dz} = (R+j\omega L)\,I(z)} \quad \text{--- (5)}$$

$$\boxed{-\frac{dI(z)}{dz} = (G+j\omega C)\cdot V(z)} \quad \text{--- (6)}$$

Eqns (5) & (6) are time harmonic transmission line eqns.

In these eqns, V & I are coupled

Eqns (5) & (6) → $V(z)$, $I(z)$ = ?

$\therefore$?

Taking $\frac{d}{dz}$ of one eqn (say, (6)) & substitute into another eqn ((5))

$$(6) \Rightarrow \frac{d^2 I(z)}{dz^2} = (G + j\omega C) \cdot \frac{dV(z)}{dz}$$

→ next lecture