Unit : 04

Attenuator.....

Date :- 15/01/25

» Attenuator :-

Attenuation is define as loss of power in a transmission line or an electrical network. Attenuation is expressed as either in Neper (N). or decibel (dB) notation.

Attenuator are either of fixed value or adjustable value types. Generally fixed attenuator provide constant attenuation are called as pads.

In communication various elements are used in the system while transmitting AC power from sending point to receiving point then the system introduce losses of power at various points.

I/p → [4 terminal Network] → O/p

Let input and output power be P_1 and P_2 respectively. The network introduced between generator and load may provide loss or gain in power. Let the ratio of input power to output power i.e P_1/P_2 be M.

If M is greater than unity then network introduce loss. If M is less than unity then the network introduce gain.

If n number of n/w connected in cascade then overall ratio obtained by multiplying individual power ratio of network. Let M_1 to $M(n-1)$ be individual input power to O/P power for $(n-1)$ network respectively then.

$$\frac{P_1}{P_n} = \frac{P_1}{P_2} \times \frac{P_2}{P_3} \times \frac{P_3}{P_4} \times \ldots\ldots \times \frac{P_{(n-1)}}{P_n}$$

$$M = M_1 \times M_2 \times M_3 \times \ldots\ldots \times M(n-1).$$

This complex calculation to made simple expressed the equation in logarithmic scale. This enables addition of power ratio in the logarithmic scale instead of multiplication. The logarithmic unit employed as 'BELL'.

$$\boxed{\text{Power ratio in bell} = \log_{10}\left(\frac{P_1}{P_2}\right)}$$

BELL unit is too large therefore small unit called decibel is introduced.

$$\boxed{1 \text{ bell} = 10 \text{ decibel.}}$$

Power ratio expressed in decibel.

$$\boxed{D = \log_{10}\left(\frac{P_1}{P_2}\right)}$$

If $\frac{P_1}{P_2} > 1$ then D will be positive which indicates power loss.

$\frac{P_1}{P_2} < 1$ the D will be negative which indicates power gain.

→ The power ratio can be expressed as decibel.

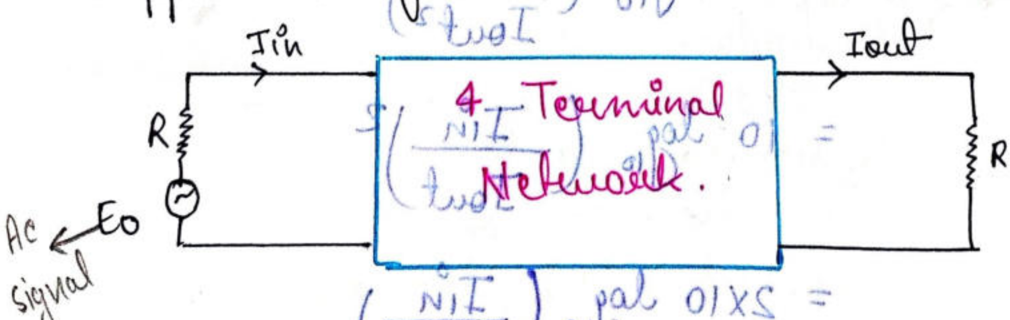
$$D = 10 \log_{10} \left(\frac{P_1}{P_2}\right)$$

$$\frac{D}{10} = \log_{10} \left(\frac{P_1}{P_2}\right)$$

$$\boxed{\text{Antilog} \frac{D}{10} = \frac{P_1}{P_2}}$$

usually power ratio are expressed in decibel but it is possible to expressed voltage and current ratio in decibel. If the resistive components of generator and load impedence are equal. similarly neper is usually used to expressed current ratio but it is possible to express power ratio in neper if the resistive component of generator and load impedence are equal.

→ Suppose a four network:-



Day:- Friday Date:- 17/01/25

→ If Power entering a Pin and that leaving a network is Pout than the attenuation is decibel is defined as

$$\text{Attenuation (dB)} = 10 \log_{10}\left(\frac{P_{in}}{P_{out}}\right)$$

→ If the current entering a network is Iin and that leaving the network is Iout. Then the attenuation in Neper defined as.

$$\text{Attenuation (Neper)} = \ln\left(\frac{I_{in}}{I_{out}}\right)$$

→ Condition of equal resistive we can write

$$\text{Attenuation} = 10 \log_{10}\left(\frac{P_{in}}{P_{out}}\right)$$

$$= 10 \log_{10}\left(\frac{I_{in}^2 \cancel{R}}{I_{out}^2 \cancel{R}}\right)$$

$$= 10 \log_{10}\left(\frac{I_{in}^2}{I_{out}^2}\right)$$

$$= 10 \log_{10}\left(\frac{I_{in}}{I_{out}}\right)^2$$

$$= 2 \times 10 \log_{10}\left(\frac{I_{in}}{I_{out}}\right)$$

$$= 20 \log_{10}\left(\frac{I_{in}}{I_{out}}\right)$$

$$\boxed{\frac{\text{Attenuation}}{dB} = 20 \log_{10}\left(\frac{E_{in}}{E_{out}}\right)}$$

$$\underset{(\text{Neper})}{\text{Attenuation}} = \ln\left(\frac{I_{in}}{I_{out}}\right)$$

$$= \ln\left(\frac{E_{in}}{E_{out}}\right)$$

$$= \frac{1}{2} \ln\left(\frac{P_{in}}{P_{out}}\right)$$

Definition of Neper and Decibel :-

i) Neper (N) :- The Neper (N) is similar to the decibel (dB). It is unitless and is used to express ratios. The Neper uses the natural logarithm and invented by 'John Napier'.

$$dB = 20 \log (a/b)$$

$$N = \ln (a/b)$$

$$\frac{dB}{N} = \frac{20 \log (a/b)}{\ln (a/b)}$$

$$= \frac{20}{\ln(10)} = 8.685.$$

Note = $\ln (x) = \log (x) \times \ln (10)$.

* Attenuation (dB) = 8.685 x attenuation (N).

* Attenuation (N) = 0.1151 x attenuation (dB).

ii) Decibel (DB) :- The decibel is a logarithmic unit of measurement that express the magnitude of a physical quantity relative to a specified or implied reference level.

» Classification of Attenuator :-

Attenuator are basically classified as fixed and variable attenuator. Fixed attenuator are some times called Pads. These pads are Symmetrical or Asymmetrical network.

- The Symmetrical attenuator are either T, π lattice or bridged-T network.
- Asymmetrical network are generally L-network.

Attenuator

- Fixed
  - → Symmetrical attenuator.
  - → Asymmetrical attenuator.
- Variable
  - → Ladders.

→ Variable attenuators are ladder types and continously variable type network.

An example of a ladder type attenuator is a signal generator where input and output voltage or current ratio are to be reduced in known ratio.

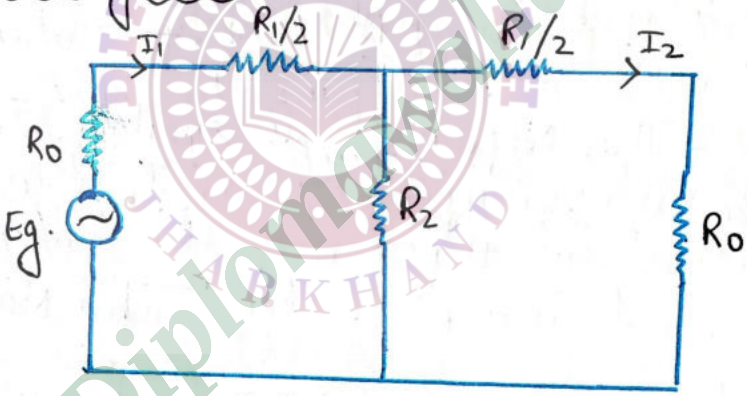
Date:- 27/01/25 Day:- Monday

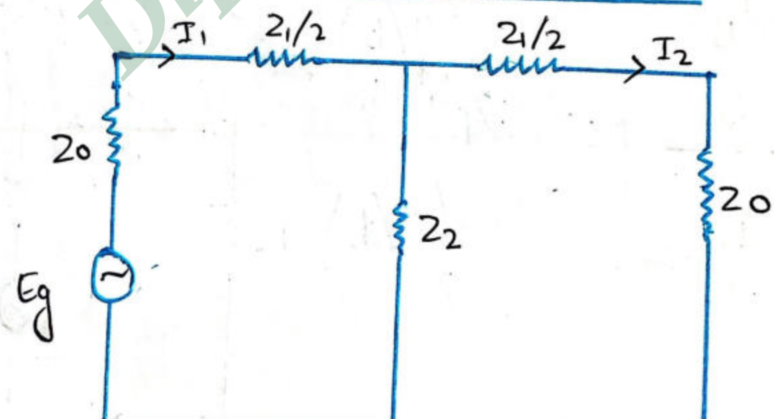
» Symmetrical T- Attenuator:-

In attenuator whose shapes looks like the english alphabet "T" is called T-type attenuator.

→ In this attenuator the resistance in the series are equal and also the total input resistance (R_{in}) and output resistance (R_o) are also equal.

* Circuit Diagram:-





$Z_o \longrightarrow R_o$

$\frac{Z_1}{2} \longrightarrow \frac{R_1}{2}$

$Z_2 \longrightarrow R_2$

$\gamma = \alpha + \cancel{j\beta}$

$\gamma = \alpha.$

$$\boxed{N = \frac{I_1}{I_2}}$$

R_0 = Characteristics Resistance. or design Impedence.

$R_1 = (R_0, N)$

$R_2 = (R_0, N)$

→ In symmetrical T-Network, (formulas,)

$$\boxed{\frac{Z_1}{2} = Z_0 \tanh\frac{\gamma}{2}}$$

$$\boxed{Z_2 = \frac{Z_0}{\sinh\gamma}}$$

→ Hyperbolic = h

$$\boxed{\frac{R_1}{2} = R_0 \tanh\frac{\alpha}{2}}$$

$$\boxed{R_2 = \frac{R_0}{\sinh\alpha}}$$

Note:-
$e^{\alpha} = N = \frac{I_1}{I_2}$.

* $\frac{R_1}{2} = R_0\left[\frac{e^{\alpha/2} - e^{-\alpha/2}}{e^{\alpha/2} + e^{-\alpha/2}}\right]$

$= R_0\left[\frac{e^{\alpha/2} - \frac{1}{e^{\alpha/2}}}{e^{\alpha/2} + \frac{1}{e^{\alpha/2}}}\right]$

$= R_0\left[\frac{e^{\alpha} - 1}{e^{\alpha} + 1}\right]$

$$\boxed{\frac{R_1}{2} = R_0\left[\frac{N-1}{N+1}\right]} \quad \text{—(1)}$$

* $R_2 = \frac{R_0}{\sinh\alpha} = \frac{R_0}{\left(\frac{e^{\alpha} - e^{\alpha}}{2}\right)}$

$= \frac{R_0}{\frac{e^{\alpha} - e^{1/\alpha}}{2}} = \frac{2R_0}{e^{\alpha} - e^{1/\alpha}}$

$$= \frac{2R_0}{N - \frac{1}{N}}$$

$$= \frac{2R_0}{\frac{N^2-1}{N}}$$

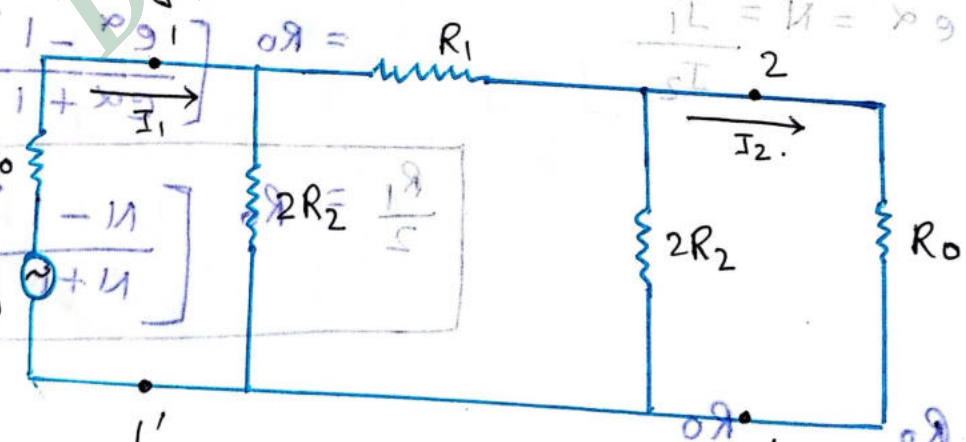
$$\boxed{R_2 = R_0\left(\frac{2N}{N^2-1}\right)} \quad \text{—— (ii)}$$

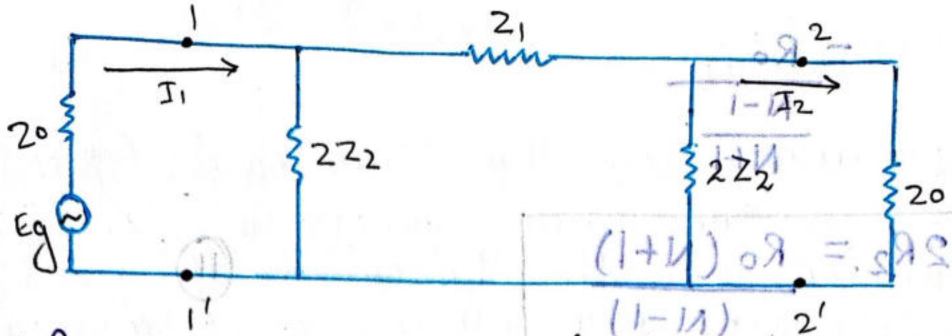
→ Eqn (i) and (ii) are design eqn in symmetrical T-attenuator.

» Symmetrical π - attenuator :-

An attenuator whose shapes look like π is called π- type attenuator. In this attenuator resistance in the shunt are equal and also the input resistance is equal to the output resistance.

* Circuit Diagram :-





$Z_0 \rightarrow R_0$

$Z_1 \rightarrow R_1$

$2Z_2 \rightarrow 2R_2$

$\gamma = \alpha + \cancel{j\beta}$

$\gamma = \alpha.$

→ In Symmetrical π - Network :-

$$\boxed{Z_1 = Z_0 \sinh \gamma}$$

$$\boxed{2Z_2 = \frac{Z_0}{\tanh \gamma/2}}$$

$$\boxed{R_1 = R_0 \sinh \alpha}$$

$$\boxed{2R_2 = \frac{R_0}{\tanh \alpha/2}}$$

→ $\underline{R_1} = R_0 \left[\frac{e^{\alpha} - e^{-\alpha}}{2}\right]$

$$= R_0 \left[\frac{N - \frac{1}{N}}{2}\right]$$

$$= R_0 \left[\frac{\frac{N^2-1}{N}}{2}\right]$$

$$\boxed{R_1 = R_0 \left[\frac{N^2-1}{2N}\right]} \quad \text{———} \quad (1)$$

→ $\underline{2R_2} = \frac{R_0}{\tanh \frac{\alpha}{2}}$

$$= \frac{R_0}{\frac{e^{\alpha/2} - e^{-\alpha/2}}{e^{\alpha/2} + e^{-\alpha/2}}}$$

$$= \frac{R_0}{\frac{e^{\alpha} - 1}{e^{\alpha} + 1}}$$

$$= \frac{R_o}{\frac{N-1}{N+1}}$$

$$\boxed{2R_2 = \frac{R_o(N+1)}{(N-1)}} \quad \text{———} \quad (II)$$

→ Eqn (I) and (II) are design eqn in symmetrical π-Network.