Attenuators

In transmitter, strength (magnitude) of voltage or current is NOT required to be very low or very high. Very low signal strength ~~is~~ will not give good reception, whereas very high signal strength will cause distortion.

Low signal is increased by amplifiers whereas high signal strength can be reduced by attenuators.

An attenuator is an electronic device which reduces the strength (magnitude, power) of a signal, without affecting its waveform.

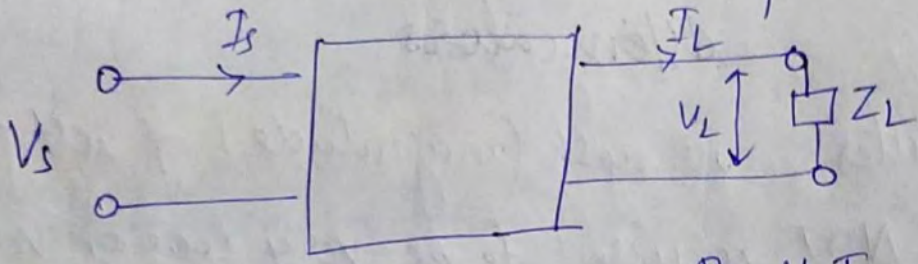
It is basically an amplifier of gain < 1.

An attenuator is normally a 4-terminal ~~device~~ resistive network, which is inserted between the source and the load.

Attenuation

→ Power loss in a n/w is called attenuation of the signal. Mathematically, it is the square root ration of source power (P_s) and the load power (P_L)

It is measured in decibel and nepers



$P_s = V_s I_s$ $\qquad$ $P_L = V_L I_L$

$$\text{Attenuation } (N) = \sqrt{\frac{P_s}{P_L}}$$

$$N = \sqrt{\frac{I_s^2 R}{I_L^2 R}} = \frac{I_s}{I_L} = \frac{V_s}{V_L}$$

① In decibels

$$\text{Attenuation (dB)} = 10 \log_{10}\left(\frac{P_s}{P_L}\right)$$

$$D = 10 \log_{10}\left(\frac{I_s^2 R}{I_L^2 R}\right)$$

$$= 20 \log_{10}\left(\frac{I_s}{I_L}\right) = 20 \log_{10}\left(\frac{V_s}{V_L}\right)$$

$$\boxed{D = 20 \log_{10}(N)} \text{ dB}$$

② In Nepers

$$\text{In Nepers} = \log_e (I_s / I_L) = \boxed{\log_e (N)} \text{ nepers}$$

$$= \frac{1}{2} \log_e (P_s / P_L)$$

Relation b/w decibels (dB) & nepers (N)

$$D = 20 \log_{10}(N)$$
$$= 20 \log_e(N) \times \log_{10}(e) \quad \text{(Log property)}$$
$$= 20 \times 0.434 \times \log_e(N)$$
$$= 8.686 \log_e(N)$$

attenuation in dB = 8.686 times attenuation in nepers

similarly
attenuation in nepers = 0.115 × attenuation in dB

Classification of attenuators

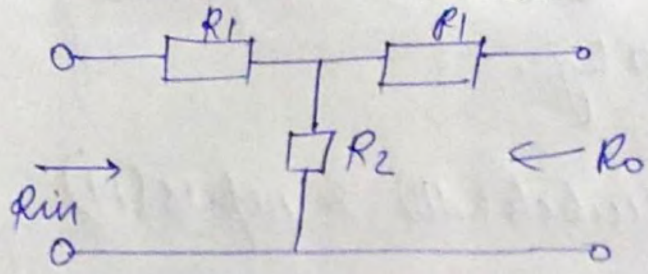
1) Symmetrical attenuators.

Symmetrical attenuators are resistive networks inserted b/w the source & the load having equal input and output ~~resistances~~ resistances.

a) - Symmetrical T attenuator.

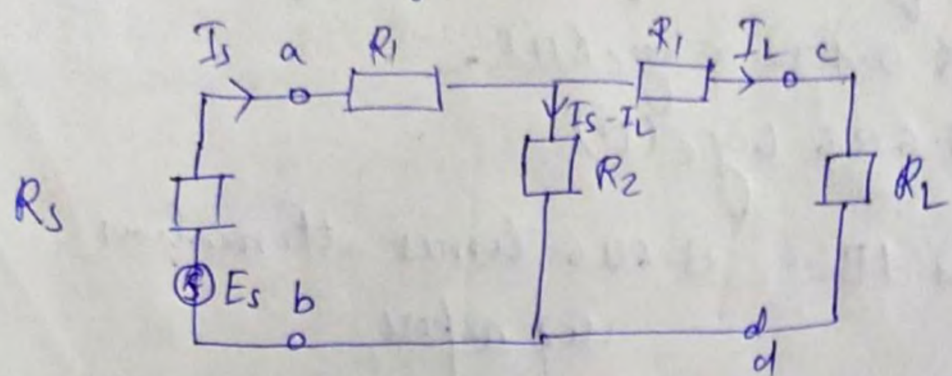
An attenuator whose shape looks like the english alphabet 'T'. is called T-type attenuator.

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



$R_{in} = R_0$

Symmetrical T- attenuator



~~sow~~ where $R_S = R_L = R_0$ (symmetrical)
let

$$\cancel{I_S R_1} + (I_S - I_L) R_2 = (R_1 + R_L) I_L$$

$$\Rightarrow I_S \times R_2 = (R_1 + R_2 + R_L) \times I_L$$

$$\frac{I_S}{I_L} = \frac{R_1 + R_2 + R_L}{R_2}$$

attenuation $N = \dfrac{I_S}{I_L} = \dfrac{R_1 + R_2 + R_L}{R_2}$ — (1)

$$\boxed{N = 1 + \frac{R_1 + R_L}{R_2}}$$

$$\Rightarrow \boxed{N - 1 = \frac{R_0 + R_1}{R_2}} \quad [R_S = R_L = R_0] \quad \text{— (2)}$$

Input impedance

$$R_{in} = R_1 + R_2 \,||\, (R_1 + R_0)$$

but $R_{in} = R_0$

$$\Rightarrow R_0 = R_1 + R_2 \,||\, (R_1 + R_0)$$

$$R_0 = R_1 + \frac{R_2(R_1+R_0)}{R_0+R_1+R_2} = R_1 + \frac{R_1+R_0}{\frac{R_1+R_2+R_0}{R_2}}$$

$$R_0 = R_1 + \frac{R_1+R_0}{N}$$

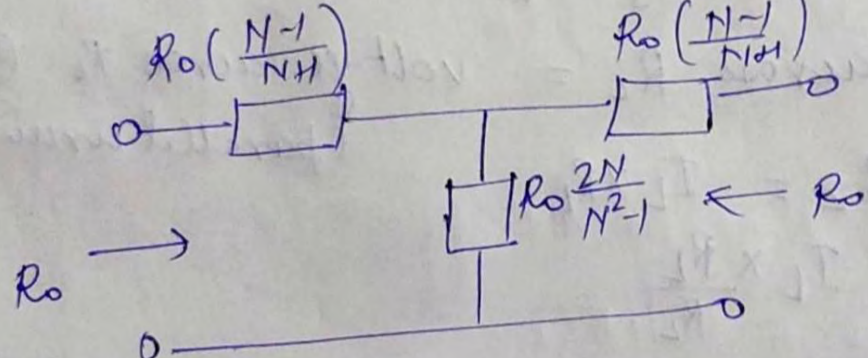
$$\Rightarrow \boxed{R_1 = R_0\left(\frac{N-1}{N+1}\right)}$$

Putting R_1 in (2)

$$N-1 = \frac{R_0 + R_0\left(\frac{N-1}{N+1}\right)}{R_2}$$

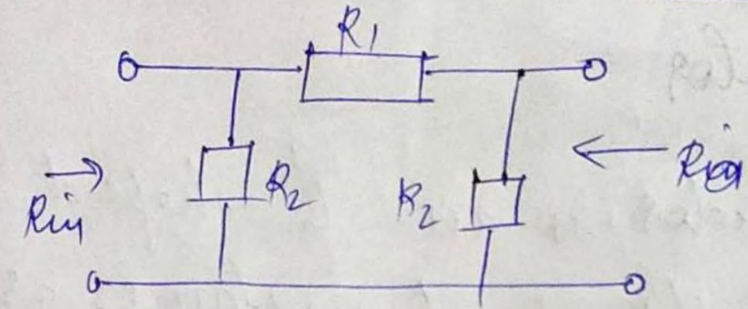
$$\boxed{R_2 = R_0 \frac{2N}{N^2-1}}$$

hence



Symmetrical π - network

An attenuator whose shape looks like 'π'. In this attenuator resistances in the <u>shunt arm</u> are equal and also the input resistance is equal to the output resistances.



$R_{in} = R_0$

Symmetrical π- ~~network~~ attenuator

$$R_1 = \frac{R_0 (N^2 - 1)}{2N}$$

$$R_2 = \left(\frac{N+1}{N-1}\right) R_0$$

Application of attenuators

① Resistive attenuators are used for impedance matching b/w circuits of ~~at~~ different resistive impedance

② Variable attenuator are used in laboratories for measurement of small values of current & voltages.

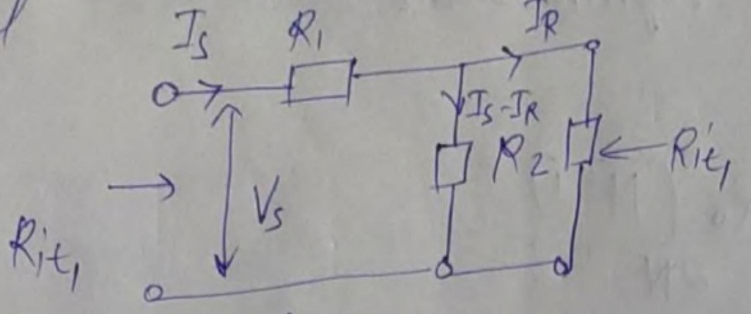
③ Resistive attenuators are used in high frequency signal transmission.

④ T & π-type attenuators are inserted in between source and load to avoid reflection of signal.

⑤ They are used in impedance matching.

L-type attenuator

An L-type attenuator is an 'L' shaped attenuator. The series and the shunt resistances are NOT equal, but the input and output resistances are equal



L-type

The ~~output~~ load resistance in this iterative impedance (R_{it_1})

$$R_2(I_S - I_R) = R_{it_1} \times I_R$$

$$N = \frac{I_S}{I_R} = \frac{R_{it_1} + R_2}{R_2}$$

$$N = 1 + \frac{R_{it}}{R_2} \Rightarrow \boxed{R_2 = \frac{R_{it_1}}{N-1}}$$

~~$V_S = I_S \times R_{it_1}$~~ Now from the figure

$$R_{it_1} = R_1 + R_2 \,||\, R_{it_1}$$

$$R_{it_1} = R_1 + \frac{R_2 \times R_{it_1}}{R_2 + R_{it_1}} \Rightarrow R_1 = R_{it_1}\left(1 - \frac{R_2}{R_2 + R_{it_1}}\right)$$

$$R_1 = \frac{R_{it_1} \times R_{it_1}}{R_2 + R_{it_1}} = \frac{R_{it_1}^2}{R_{it_1}\left(R_2/R_{it_1} + 1\right)} = \frac{R_{it_1}}{\left(\frac{1}{N-1} + 1\right)}$$

$$\boxed{R_1 = R_{it_1} \times \frac{N-1}{N}} \qquad R_{it_1}^2 =$$