Attenuators

Attenuator is a two port resistive network. It is used to reduce the signal level when used between a generator and load. Attenuators may be symmetrical or asymmetrical. They may provide fixed or variable attenuation. A fixed attenuator is also called a pad. The attenuation is measured in decibels (dB) or nepers.

$$\text{Attenuation in dB} = 10 \log_{10} \frac{P_1}{P_2}$$

$$= 20 \log_{10} \frac{V_1}{V_2}$$

$$= 20 \log_{10} \frac{I_1}{I_2}$$

There are 4 types of attenuators.

(i) T = type attenuator
(ii) π = type attenuator
(iii) Lattice type attenuator
(iv) Bridged T = type attenuator

T–type attenuator

Figure 1 show a symmetrical T = attenuator. Each series arm is assumed to have a resistance of R_1 Ω while the resistance of shunt arms equals R_B Ω.

Applying KVL to the network,

$$R_2(I_1 - I_2) = I_2(R_1 + R_0)$$

$$I_2(R_2 + R_1 + R_0) = I_1R_2$$

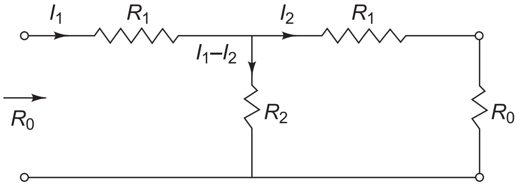

Fig. 1

$$\frac{I_1}{I_2} = \frac{R_2 + R_1 + R_0}{R_2} = N \qquad \text{(i)}$$

Characteristic impedance is R_0 when it is attenuated in a load of R_0

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

Substituting Eq. (i),

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

$$NR_0 = NR_1 + R_0 + R_0$$

$$R_0(N - 1) = R_1(N + 1)$$

$$R_1 = \frac{R_0(N - 1)}{N + 1} \qquad \text{(ii)}$$

From Eq. (ii)

$$NR_2 = R_2 + R_1 + R_0$$

$$(N - 1)\, R_2 = R_1 + R_0$$

Substituting Eq. (ii),

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

$$(N - 1)\, R_2 = \frac{2NR_0}{N + 1}$$

$$R_2 = \frac{2NR_0}{N^2 - 1}$$

π-Type Attenuator

Figure 2 show a symmetrical π attenuator. The series and shunt elements of this attenuator can be specified in terms of characteristic impedance and propagation constant.

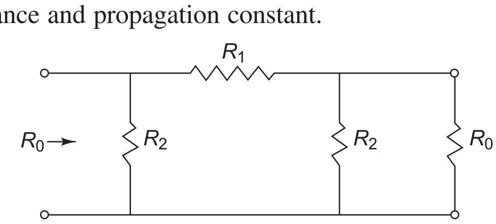

Fig. 2

For resistive network $z_0 = R_0$ and $\gamma = \alpha$

$$R_1 = R_0 \sinh \alpha$$

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

$$R_1 = R_0 \, \frac{e^{\alpha} - e^{-\alpha}}{2}$$

$$e^{\gamma} = \frac{I_1}{I_2} = N$$

$$R_1 = R_0 \; \frac{N - \dfrac{1}{N}}{2} = R_0 \; \frac{N^2 - 1}{2N}$$

Similarly

$$\tanh \frac{\gamma}{2} = \frac{e^{\gamma/2} - e^{-\gamma/2}}{e^{\gamma/2} + e^{-\gamma/2}}$$

$$= \frac{e^{\gamma} - 1}{e^{\gamma} + 1}$$

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

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

Lattice Attenuator

Figure 3 shows a lattice attenuator. The elements of lattice attenuator can be specified in terms of characteristic impedance and propagation constant.

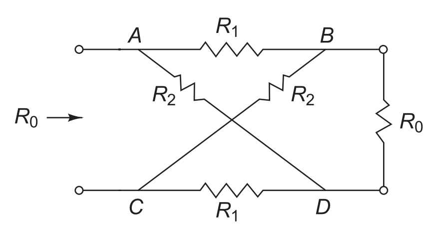

Fig. 3

We know that

$$z_0 = \sqrt{z_{SC}\, z_{OC}}$$

Redrawing the lattice network,

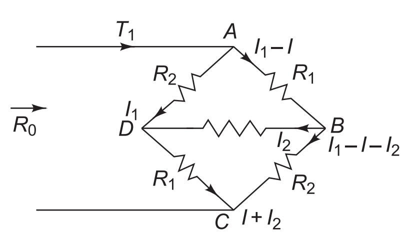

Fig. 4

$$z_{SC} = \frac{2R_1R_2}{R_1 + R_2}$$

$$z_{OC} = \frac{R_1 + R_2}{2}$$

$$z_0 = R_0 = \sqrt{z_{SC}\,z_{OC}}$$

$$= \sqrt{\left(\frac{2R_1R_2}{R_1 + R_2}\right)\left(\frac{R_1 + R_2}{2}\right)}$$

$$= \sqrt{R_1R_2}$$

Applying KVL to the network,

$$I_1R_0 = (I_1 - I)\, R_1 + I_2R_0 + (I + I_2)R_1$$

$$I_1R_0 = R_1(I_1 + I_2) + I_2R_0$$

$$I_1(R_0 - R_1) = I_2(R_1 + R_0)$$

$$\frac{I_1}{I_2} = \frac{R_1 + R_0}{R_0 - R_1} = \frac{1 + \dfrac{R_1}{R_0}}{\dfrac{R_1}{1 - R_0}}$$

$$N = e^{\alpha} = \frac{I_1}{I_2} = \frac{1 + \dfrac{R_1}{R_0}}{1 - \dfrac{R_1}{R_0}}$$

$$e^{\alpha} = \frac{1 + \sqrt{R_1/R_0}}{1 - \sqrt{R_1/R_2}}$$

$$\alpha = \log\left[\frac{1 + \sqrt{R_1/R_2}}{1 - \sqrt{R_1/R_2}}\right]$$

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

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

Similarly

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