POWER TRANSMISSION:

CIRCUITS:

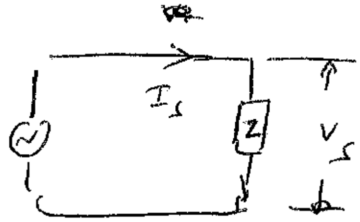


FIG. 1

THE MEAN POWER DISSIPATED IN AN IMPEDANCE, Z IS

$$\langle P \rangle = \frac{1}{2} \mathrm{Re}\{V_s I_s^*\} \longrightarrow (1)$$

WHERE V_s IS THE VOLTAGE ACROSS Z & I_s IS THE CURRENT THROUGH Z, IN THE PHASOR NOTATION. {IF YOU ARE NOT FAMILIAR WITH (1), USE

$$v = \mathrm{Re}\{V_s e^{j\omega t}\} = V_p \cos(\omega t + \theta_v)$$

$$i = \mathrm{Re}\{I_s e^{j\omega t}\} = I_p \cos(\omega t + \theta_i)$$

$$p = v\, i$$

$$= V_p I_p \cos(\omega t + \theta_v) \cos(\omega t + \theta_i)$$

PERIOD

$$\langle p \rangle = \frac{1}{T} \int_0^T V_p I_p \cos(\omega t + \theta_v) \cos(\omega t + \theta_i)\, dt$$

$$= \frac{1}{2} \mathrm{Re}\{V_s I_s^*\} \longrightarrow \text{PROVE [illegible]}$$

TRANSMISSION LINES

WE USE EQ. (1) TO EXPRESS POWER AT ANY POINT IN THE TRANSMISSION LINE.

$$\langle P(z) \rangle = \frac{1}{2} Re\{V_s(z) I_s^*(z)\}$$

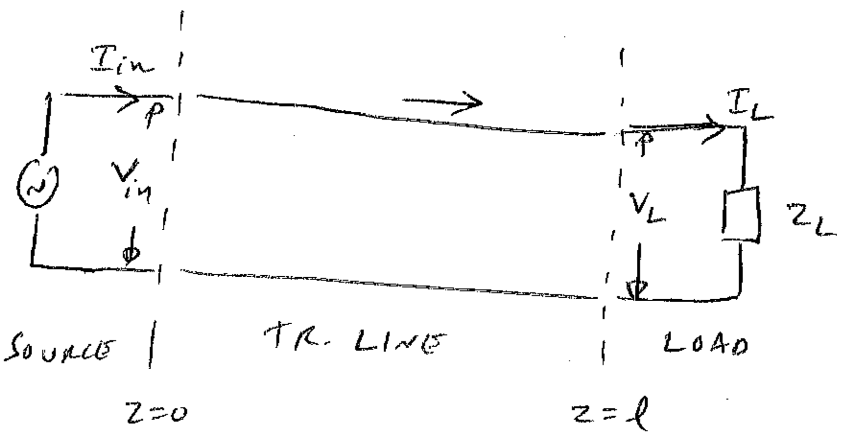


FIG. 2

AT THE SOURCE, $z=0$, $\langle P(z) \rangle = \cancel{P(0)} = P_{in}$

$$V_s(0) = V_{in}$$

$$I_s(0) = I_{in}$$

$$\therefore P_{in} = \frac{1}{2} Re\{V_{in} I_n^*\}$$

AT THE LOAD, $z=\ell$, $\langle P(z=\ell) \rangle = P_L$

$$V_s(\ell) = V_L$$

$$I_s(\ell) = I_L$$

$$\therefore P_L = \frac{1}{2} Re\{V_L I_L^*\}$$

LET US ASSUME THAT THE CHARACTERISTIC IMPEDANCE, Z_0 IS EQUAL TO Z_L SO THAT THERE IS NO REFLECTION. IN THIS CASE, THERE IS ONLY FORWARD PROPAGATING WAVE

$$V_s(z) = V_0^+ e^{-\gamma z} = V_0^+ e^{-(\alpha + j\beta z)}$$

$$I_s(z) = I_0^+ e^{-\gamma z} = \frac{V_0^+}{Z_0} e^{-\gamma z}$$

$$\gamma = (\alpha + j\beta)$$

AT $z = 0$, $V_s(0) = V_{in} = V_0^+ e^0 = V_0^+$

$$I_s(0) = I_{in} = I_0^+ e^0 = \frac{V_0^+}{Z_0}$$

$$\langle P(0) \rangle = P_{in} = \frac{1}{2} Re\left\{ \frac{V_0^+ (V_0^+)^*}{Z_0^*} \right\}$$

LET $Z_0 = |Z_0| e^{j\theta_0}$

$$\therefore \quad P_{in} = \frac{1}{2} Re\left\{ \frac{|V_0^+|^2}{|Z_0|} \cdot e^{+j\theta_0} \right\}$$

$$= \frac{|V_0^+|^2}{2|Z_0|} \cdot \cos\theta_0 \quad \rightarrow (2)$$

AT ANY z,

$$\langle P(z) \rangle = \frac{1}{2} Re\{ V_s(z) I_s^*(z) \}$$

$$= \frac{1}{2} Re\left\{ V_0^+ \frac{(V_0^+)^*}{Z_0^*} \cdot e^{-2\alpha z} \right\}$$

$$= P_{in} \cdot e^{-2\alpha z} \quad \longrightarrow (3)$$

POWER LOSS IN dB ~~[illegible]~~ UNITS IS EXPRESSED AS

$$\text{POWER LOSS (dB)} = -10 \log_{10}\left[\frac{\langle P(z)\rangle}{\langle P(0)\rangle}\right] \longrightarrow (4)$$

NOTE: $P(z) < P(0)$ & HENCE, $\log_{10}[P(z)/P(0)]$ IS NEGATIVE. TYPICALLY, WE LIKE TO EXPRESS THE LOSS OF POWER DUE TO PROPAGATION FROM 0 to z AS POSITIVE. SO, $-$VE SIGN IS ~~NE~~ INTRODUCED IN (4).

USING (3) IN (4), WE FIND

$$\text{POWER LOSS (dB)} = -10 \log_{10}\left(\frac{P_{in}\, e^{-2\alpha z}}{P_{in}}\right)$$

$$= -10 \frac{\log_e(e^{-2\alpha z})}{\log_e 10}$$

-4.342

$$\boxed{\text{POWER LOSS (dB)} = 8.69\,\alpha z} \longrightarrow (5)$$

LOSS RATING IS ~~EXP~~ THE POWER LOSS in dB PER UNIT LENGTH, i.e.

$$\boxed{\text{LOSS RATING (dB/m)} = \frac{\text{POWER loss (dB)}}{z} = 8.69\,\alpha} \longrightarrow (6)$$

NOTE: α SHOULD IN THE UNIT OF Np/m or m^{-1}.

(5)

$$\langle P(z) \rangle = \frac{1}{2} \operatorname{Re}\left\{ V_s(z)\, I_s^*(z) \right\}$$

$$= \frac{1}{2} \operatorname{Re}\left\{ V_s(z) \frac{V_s^*(z)}{Z_0^*} \right\} = \frac{|V_s(z)|^2}{2} \operatorname{Re}\left\{\frac{1}{Z_0^*}\right\}$$

$$P_{in} = \frac{1}{2} \operatorname{Re}\left\{ V_s(0) \frac{V_s^*(0)}{Z_0^*} \right\} = \frac{|V_s(0)|^2}{2} \operatorname{Re}\left\{\frac{1}{Z_0^*}\right\}$$

$\therefore$ (4) CAN BE WRITTEN AS

$$\text{POWER LOSS (dB)} = -10 \log_{10} \frac{|V_s(z)|^2}{|V_s(0)|^2}$$

$$\boxed{\text{POWER LOSS (dB)} = -20 \log_{10} \frac{|V_s(z)|}{|V_s(0)|}}$$

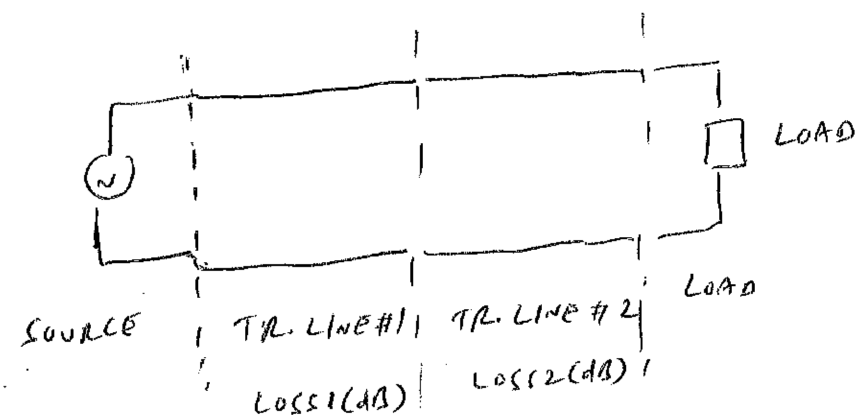
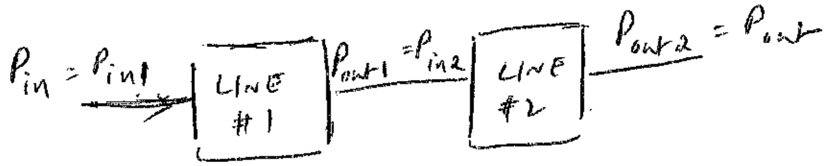


FIG. 8



$$\text{LOSS 1 (dB)} = -10 \log_{10}\left(\frac{P_{out1}}{P_{in1}}\right)$$

$$\text{LOSS 2 (dB)} = -10 \log_{10}\left(\frac{P_{out2}}{P_{in2}}\right) =$$

$$\text{Total loss (dB)} = -10\log_{10}\left(\frac{P_{out}}{P_{in}}\right) = -10\log_{10}\left(\frac{P_{out2}}{P_{in1}}\right)$$

$$= -10\log_{10}\left(\frac{P_{out2}}{P_{in2}}\;\frac{P_{in2}}{P_{in1}}\right)$$

$$= -10\left[\log_{10}\left(\frac{P_{out2}}{P_{in2}}\right) + \log_{10}\left(\frac{P_{out1}}{P_{in1}}\right)\right]$$

$$\boxed{\text{TOTAL LOSS(dB)} = \text{LOSS1(dB)} + \text{LOSS2(dB)}}$$

THE ADVANTAGE OF DECIBEL UNIT IS THAT LOSSES/GAINS IN THE SYSTEM CAN BE ADDED/SUBTRACTED. IN CONTRAST, IF WE USE $e^{-\alpha z}$ to MODEL LOSS, MULTIPLICATIONS WILL BE REQUIRED.

EXAMPLE: TR. LINE#1 SHOWN IN FIG. 3 HAS AN ATTENUATION COEFFICIENT OF 0.01 NP/m & ~~LINE #2~~ IT IS 20 m long. LINE # 2 IS RATED AT 0.1 dB/m & IS 15 m long. THE JOINT IS NOT WELL DONE & THE CONNECTION LOSS IS 2 dB. FIND THE TOTAL LOSS.

$$\langle P(z)\rangle = P_{in}\, e^{-2\alpha z}$$

FROM (5), POWER LOSS1 (dB) $= 8.69\,\alpha z$

$$= 8.69 \times 0.01 \times 20 \text{ dB}$$

$$= 1.738 \text{ dB}$$

$$\text{POWER loss 2 (dB)} = 0.1 \frac{dB}{m} \times 15\,m$$

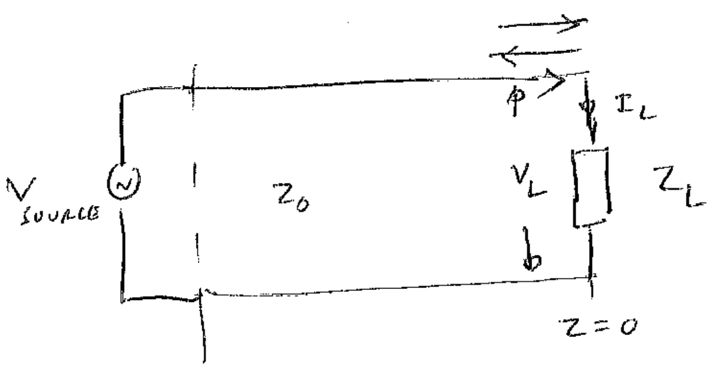
$$= 1.5\,dB$$

$$\text{TOTAL LOSS (dB)} = \text{loss 1 (dB)} + \text{loss 2 (dB)} + \text{connection loss (dB)}$$

$$= 1.738 + 1.5 + 2\,dB$$

$$= 5.238\,dB$$

POWER REFLECTION



THE REFLECTION COEFFICIEN IS DEFINED AS (SEE NOTES ON WAVE REFLECTION)

$$\Gamma = \frac{\text{AMPLITUDE OF THE } \cancel{\text{FORWARD}} \text{ BACKWARD WAVE AT LOAD}}{\text{AMPLITUDE OF THE FORWARD WAVE AT LOAD}}$$

$$= \frac{V_0^-}{V_0^+}$$

THE AVERAGE POWER OF THE $+\xrightarrow{}$ FORWARD WAVE AT LOAD

$$= \langle p^+(z) \rangle = \frac{1}{2} Re\{ V_0^+ (I_0^+)^* \}$$

$$= \frac{1}{2} Re\left\{ V_0^+ \left(\frac{V_0^+}{Z_0}\right)^* \right\}$$

$$= \frac{1}{2} |V_0^+|^2 Re\left\{ \frac{1}{Z_0^*} \right\}$$

THE AVERAGE POWER OF THE $-$ REFLECTED WAVE @ LOAD

$$= \langle p^-(z) \rangle = \frac{1}{2} Re\{ V_0^- (I_0^-)^* \}$$

$$\frac{V_0^-}{I_0^-} = -Z_0$$

$$\therefore \quad \langle p^-(z) \rangle = -\frac{1}{2} |V_0^-|^2 Re\left\{ \frac{1}{Z_0^*} \right\}$$

$-$VE SIGN INDICATES THE POWER IS DIRECTED IN $-z$ DIRECTION. SINCE WE ARE INTERESTED ONLY IN THE MAGNITUDE OF POWER, WE WILL OMIT THE SIGN.

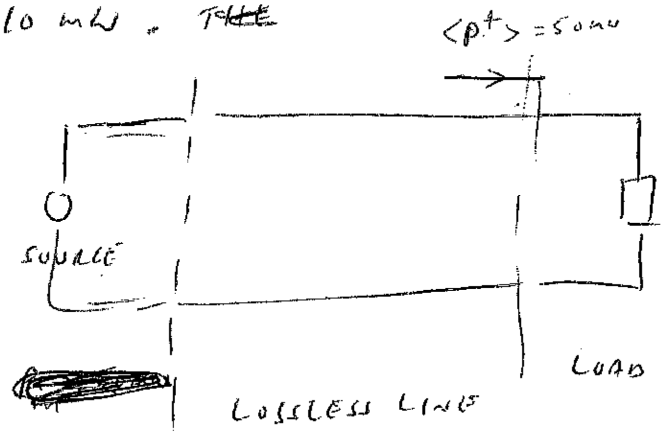
THE FRACTION OF INCIDENT POWER THAT IS REFLECTED IS

$$\frac{|\langle p^-(z) \rangle|}{|\langle p^+(z) \rangle|} = \frac{\cancel{1/2} |V_0^-|^2 \cancel{Re\{1/Z_0^*\}}}{\cancel{\frac{1}{2}} |V_0^+|^2 \cancel{Re\{1/Z_0^*\}}} \therefore \frac{|V_0^-|^2}{|V_0^+|^2} = |\Gamma|^2$$

THE FRACTION OF THE INCIDENT POWER THAT IS TRANSMITTED INTO THE LOAD (OR DISSIPATED BY IT) IS

$$\frac{\langle p_t(z)\rangle}{\langle p^+(z)\rangle} = \frac{|\langle p^+\rangle| - |\langle p^-\rangle|}{|\langle p^+\rangle|} = 1 - |\Gamma|^2$$

FOR EXAMPLE, SUPPOSE THE INCIDENT POWER ON A LOSSLESS TRANSMISSION LINE IS 50 mW & THE REFLECTED POWER IS 10 mW. ~~THE~~



THE FRACTION OF THE INCIDENT POWER THAT IS REFLECTED is $10/50 = 0.2$.

$$\therefore \quad |\Gamma|^2 = 0.2.$$

THE POWER DISSIPATED BY THE LOAD IS $50 - 10 = 40$ mW.

THE FRACTION OF THE INCIDENT POWER THAT IS TRANSMITTED (OR DISSIPATED BY THE LOAD) IS

$$1 - |\Gamma|^2 = 0.8.$$