Transmission Line Types

Lossy Tx Line

$$\gamma = \alpha + j\beta = \sqrt{(R+j\omega L)(G+j\omega C)}$$

$$= \sqrt{(RG - \omega^2 LC) + j\omega(LG+RC)}$$

$$Z_0 = \sqrt{\frac{R+j\omega L}{G+j\omega C}} = R_0 + j X_0$$

Lossless Tx Line ($R = G = 0$)

* conductors are perfect and
* dielectric medium separates conductors

$\longrightarrow Z_0 \to \infty$

$$\gamma = \alpha + j\beta = \sqrt{(0+j\omega L)(0+j\omega C)}$$

$$= \sqrt{j^2\omega^2 LC}$$

$$= j\omega\sqrt{LC}$$

$$\alpha = 0 \quad \text{and} \quad \beta = \omega\sqrt{LC}$$

$$u = \frac{\omega}{\beta} = \frac{\omega}{\omega\sqrt{LC}} = \frac{1}{\sqrt{LC}} = f\lambda$$

$$Z_0 = \sqrt{\frac{0+j\omega L}{0+j\omega C}} = \sqrt{\frac{L}{C}} = R_0$$

Distortionless Tx Line $\left(R/L = G/C\right)$

Lossy Line → α → frequency dependant

→ phase velocity of each frequency component → frequency dependant

↓

distortion

Distortionless Line → α → frequency independant

and

β → linearly depends on the frequency

$$\gamma = \sqrt{(R+j\omega L)(G+j\omega C)}$$

$$= \sqrt{RG\left(1+j\omega\frac{L}{R}\right)\left(1+j\omega\frac{C}{G}\right)}$$

$$= \sqrt{RG\left(1+j\omega\frac{C}{G}\right)\left(1+j\omega\frac{C}{G}\right)}$$

$$= \sqrt{RG}\left(1+j\omega\frac{C}{G}\right)$$

$$\alpha + j\beta = \sqrt{RG} + j\omega \sqrt{RG} \cdot \frac{C}{G}$$

$$= \sqrt{RG} + j\omega \sqrt{\frac{R}{G}} \cdot C$$

$$= \sqrt{RG} + j\omega \sqrt{\frac{1}{C}} \cdot C$$

$$= \sqrt{RG} + j\omega \sqrt{LC}$$

α (not frequency dependant) $\qquad \beta$

$$Z_0 = \sqrt{\frac{R}{G} \frac{(1 + j\omega L/R)}{(1 + j\omega C/G)}} = \sqrt{\frac{R}{G}} = \sqrt{\frac{L}{C}} = R_0$$

case	$\gamma = \alpha + j\beta$	$Z_0 = R_0 + jX_0$
Lossy	$\sqrt{(R+j\omega L)(G+j\omega C)}$	$\sqrt{\frac{R+j\omega L}{G+j\omega C}}$
Lossless	$0 + j\omega\sqrt{LC}$	$\sqrt{\frac{L}{C}} + j0$
Distortionless	$\sqrt{RC} + j\omega\sqrt{LC}$	$\sqrt{\frac{L}{C}} + j0$

Example

A distortionless tx line operates at 100 MHz has $Z_0 = 60\Omega$, $\alpha = 20$ mNp/m, $u = 0.6c$. Determine the parameters R, L, G, C and λ.

Here $c = 3 \times 10^8$ m/s,

$$\alpha = \sqrt{RG} = \sqrt{R \cdot \frac{RC}{L}} = R\sqrt{\frac{C}{L}}$$

$$Z_0 = \sqrt{\frac{L}{C}}$$

$$\alpha = \frac{R}{Z_0}$$

$$R = \alpha . Z_0 = \left(20 \times 10^{-3}\right) \times 60 = \underline{1.2\ \Omega/m}$$

$$\frac{\omega}{\beta} = u = \frac{1}{\sqrt{LC}} \rightarrow L = \frac{Z_0}{u} = \frac{60}{0.6 \times (3 \times 10^8)} = \underline{333\ nH/m}$$

$$G = \frac{\alpha^2}{R} = \frac{\left(20 \times 10^{-3}\right)^2}{1.2} = \underline{333\ \mu\ /m}$$

$$u = \frac{1}{\sqrt{LC}} \rightarrow u \cdot \sqrt{\frac{L}{C}} = \frac{1}{C} \rightarrow u Z_0 = \frac{1}{C}$$

$$C = \frac{1}{0.6 \times (3 \times 10^8) \times 60} = \underline{92.59\ pF/m}$$

$$\lambda = \frac{u}{f} = \frac{0.6 \times (3 \times 10^8)}{100 \times 10^6} = \underline{1.8\ m}$$