Attenuation & Phase constant.

$\gamma = \alpha + j\beta$ $\quad\alpha \to$ attenuation constt. $\quad\beta \to$ phase constt.

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

Squaring:

$$\alpha^2 - \beta^2 + 2j\alpha\beta = (R+j\omega L)(G+j\omega C)$$

$$\alpha^2 - \beta^2 + 2j\alpha\beta = RG - \omega^2 LC + j\omega(LG + RC)$$

comparing real & imaginary parts:

$$\alpha^2 - \beta^2 = RG - \omega^2 LC \quad - (1)$$

$$2\alpha\beta = \omega(LG + RC) \quad - (2)$$

magnitude of γ, $|\gamma| = \sqrt{\alpha^2+\beta^2}$

$$|\gamma| = \sqrt{\sqrt{R^2+(\omega L)^2}\sqrt{G^2+(\omega C)^2}}$$

$$= \sqrt{\alpha^2+\beta^2} = \sqrt{\sqrt{R^2+\omega^2L^2}\sqrt{G^2+\omega^2C^2}}$$

$$\Rightarrow \alpha^2+\beta^2 = \sqrt{R^2+\omega^2L^2}\sqrt{G^2+\omega^2C^2} \quad - (3)$$

Adding (1) and (3)

$$2\alpha^2 = \sqrt{(R^2+\omega^2L^2)(G^2+\omega^2C^2)} + RG - \omega^2 LC$$

$$\alpha = \sqrt{\frac{1}{2}\left\{\sqrt{(R^2+\omega^2L^2)(G^2+\omega^2C^2)} + RG - \omega^2 LC\right\}}$$

Subtracting (3) from (1)

$$2\beta^2 = \sqrt{(R^2+\omega^2L^2)(G^2+\omega^2C^2)} - (RG - \omega^2LC)$$

$$\beta = \sqrt{\frac{1}{2}\left\{\sqrt{(R^2+\omega^2L^2)(G^2+\omega^2C^2)} - (RG-\omega^2LC)\right.}$$

Distortions in Transmission Line

→ When the transmitted wave and the recieved wave at the load are NOT the exact same replica (copy) of each other, then we say the transmission line is having distortions.

→ The major causes of the distortion in a transmission line is the presence of multiple frequency components.

Major causes of distortions in transmission line:

(1) - characteristic impedance (Z_0) varying with frequency -

→ The characteristic impedance is a function of frequency and its changes with frequency.

→ When the transmission line is terminated with a ~~load~~ impedance, which does not change with the frequency and multiple frequency components, like the characteristic impedance, then it leads to distortion.

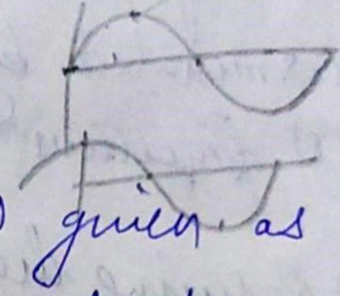
② Frequency distortion:

→ The attenuation constant, α, is the measure of attenuation in an electromagnetic wave travelling from source to the load.

→ α is a function of frequency. Thus multiple frequency terms will have attenuation to different levels.

→ Such a distortion is called frequency distortion.

③ Delay distortion:



→ The propagation velocity of a wave is given as

$$V = \omega/\beta \quad , \beta \rightarrow \text{phase constant.}$$

→ β is a function of frequency and changes rapidly with ~~frequ~~ change in frequency

→ Due to this, the velocity of the wave also changes with the frequency. and the transmitting ~~ease~~ time for all waves will NOT be the same.

Condition for minimum distortion

(I) Reducing change in Z_0 with the change in frequency.

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

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

$\frac{L}{R} \cdot \frac{C}{G}$

if $\frac{L}{R} = \frac{C}{G}$, then

$$Z_0 = \sqrt{\frac{R}{G}}$$

→ For $\frac{L}{R} = \frac{C}{G}$, the characteristic impedance is independent of frequency, and is completely resistive in nature

→ Thus for this case, the transmission line can be terminated by Z_0, and will reduce distortion at all frequencies

(II) Reducing change in attenuation constant with frequency

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

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

if $\frac{L}{R} = \frac{C}{G}$, then

$$\gamma = \sqrt{RG\left(\cancel{1} 1 + j\omega\frac{L}{R}\right)^2}$$

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

$$\gamma = \sqrt{RG} + j\omega L\sqrt{\frac{G}{R}}$$

$$\gamma = \sqrt{RG} + j\omega L\sqrt{\frac{C}{L}} \qquad \left[\frac{L}{R} = \frac{C}{G} \Rightarrow \frac{G}{R} = \frac{C}{L}\right]$$

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

also $\gamma = \alpha + j\beta$.

on comparing $\alpha = \sqrt{RG}$, $\beta = \omega\sqrt{LC}$

→ Here α, is independant of frequency, and so, change in attenuation of different wave having different frequencies will NOT occur.

③ Reducing distortion due to velocity varying with frequency.

$$V = \frac{\omega}{\beta}$$

→ Above we have derived that

$\beta = \omega\sqrt{LC}$ for the condition $\frac{L}{R} = \frac{C}{G}$

So velocity of wave, in this case

$$V = \frac{\omega}{\omega\sqrt{LC}} = \frac{1}{\sqrt{LC}}$$

→ Since ω, is independant of frequency, so all the the waves will travel with same speed and there will be no delay.