1.2 WAVEFORM DISTORTION

In an ideal transmission line of a signal through the transmission line when the input signal or the sending end signal is not the same at the receiving end.

Then the signal is said to be distorted.

The distortion is to be classified into,

i. Frequency Distortion
ii. Phase Distortion

i. FREQUENCY DISTORTION:

The attenuation constant (α) is a function of frequency.

The signal transmitted along the line will be attenuated to the different extent.

For example, a voice signal consists of many frequencies will be transmitted along the transmission line and all the frequencies will not be attenuated equally along the transmission line.

Hence the received signal is not the exact replica of the input signal at the sending end. Such a distortion is called as frequency distortion.

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

ii. PHASE DISTORTION

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

We know that,

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

The phase distortion is also depends on frequency.

Thus the velocity of propagation v also varies with frequency. So some of the signal reach the receiving end very fast while some waves will be delayed then the others will not have same transmission time.

Thus the receiving end signal is not the exact replica of the sending end signal. This kind of distortion is called as phase distortion or delayed distortion.

THE DISTORTION LESS LINE:

The distortion less line does not distort the signal phase, but does introduce a signal loss line they are not super conductors. This is known as Heaviside distortion.

Already we know that,

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

The value must be made independent of frequency by making LG+ RC = 0

Derive the condition for a distortion less line,

Z = R+jωL

Y = G+jωC

γ = α+jβ

$\gamma = \sqrt{ZY}$

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

$\gamma = \sqrt{RG + j\omega RC + \ j\omega RC - \ \omega^2 LG}$

$\gamma = \sqrt{RG - \ \omega^2 LC + j\omega(RC + \ LG)}$ ………(1)

To make a frequency independent; in the imaginary part LG+ RC = 0

Sub this condition in eqn (1),

$\gamma = \sqrt{RG - \ \omega^2 LC + j\omega(0)}$

$\gamma = \sqrt{RG - \ \omega^2 LC}$

$(-1 = j^2)$

Sub in above value,

$\gamma = \sqrt{RG + \ j^2 \omega^2 LC}$

$\gamma = \sqrt{RG} + \sqrt{j^2 \omega^2 LC}$

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

α+jβ = $\sqrt{RG} + j\omega\sqrt{LC}$

α = $\sqrt{RG}$

β = $\omega\sqrt{LC}$

Where the phase velocity,

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

$v_p = \frac{\omega}{\omega\sqrt{LC}}$

$\boldsymbol{v_p = \frac{1}{\sqrt{LC}}}$

CHARACTERISTIC IMPEDANCE OF DISTORTION LESS LINE:

$Z_o = R_o + jX_o = \sqrt{\frac{Z}{Y}}$

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

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

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

LG = RC

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

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

$Z_o = \sqrt{\frac{R}{G}} = \sqrt{\frac{L}{C}}$

Therefore the distortion less line must satisfy the conditions

i. LG = RC
ii. α = $\sqrt{RG}$
iii. β = $\omega\sqrt{LC}$
iv. $v_p = \frac{1}{\sqrt{LC}}$

v. $Z_o = \sqrt{\frac{R}{G}} = \sqrt{\frac{L}{C}}$

vi. $\alpha = \sqrt{G}$

TELEPHONE CABLE:

We know, propagation constant,

$\gamma = \sqrt{ZY}$

Z = R+jωL

Y = G+jωC

γ = α+jβ

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

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

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

If there is no attenuation,

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

$\alpha + j\beta = \sqrt{LC\left(\frac{R}{L} + j\omega\right)\left(\frac{R}{L} + j\omega\right)}$

$\alpha + j\beta = \sqrt{LC\left(\frac{R}{L} + j\omega\right)^2}$

$\alpha + j\beta = \sqrt{LC}\left(\frac{R}{L} + j\omega\right)$

$\alpha + j\beta = \frac{R}{L}\sqrt{LC} + j\omega\sqrt{LC}$

$\alpha + j\beta = \sqrt{LC}\left(\frac{R}{L} + j\omega\right)$

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

(or)

Separate the real and imaginary terms,

$\alpha = \frac{R}{L}\sqrt{LC}$ (or) $\frac{G}{C}\sqrt{LC}$

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

We know that,

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

$v_p = \frac{\omega}{\omega\sqrt{LC}}$

$v_p = \frac{1}{\sqrt{LC}}$

CHARACTERISTIC IMPEDANCE:

$Z_o = \sqrt{\frac{Z}{Y}}$

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

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

For distortionless line,

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

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

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

LOADING AND DIFFERENT METHODS OF LOADING:

A distortion less transmission line must satisfy the condition LG = RC therefore

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

The attenuation of a transmission line is given by,

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

It is observed that α depends on four primary constants in addition to the frequency(L, C, R, G)

DIFFERENT LOADING METHODS

There are two loading methods

i. Inductance Loading
ii. Capacitance Loading

Capacitance loading techniques increases the impedance and attenuation

Inductance loading is mostly used in transmission lines.

The types of inductance loading methods are,

i. Lumped Loading
ii. Continuous Loading (or) Uniform Loading

i. <u>LUMPED LOADING:</u>

In this method, lumped inductors or loading coils are placed in series along the transmission lines at suitable intervals. Hence, it is called lumped loading. It will increase the total effective inductance.

The cut-off frequency is given by,

$$f_c = \frac{1}{\pi\sqrt{L_c C\, d}}$$

$$f_c \propto \frac{1}{\sqrt{LC}}$$

L_c – inductance of the loading coil and cable per km.

C – Capacitance per km

d – Spacing between the coils

ii. <u>CONTINUOUS LOADING:</u>

In this method, wing the cable with a high permeability material. The inductors use perm-alloy or molybdenum. In Fig 1.2.1 the coil is wound of the largest gauge of content with small size and each winging is divided into two equal parts.

In a uniformly loaded cables, assume

i) G = 0
ii) Wavelength is large

Loading coils are placed into steel pots.

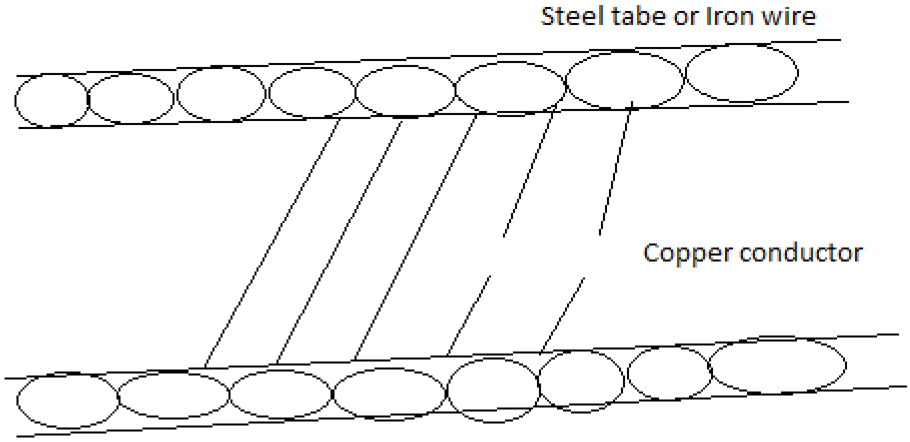

Fig: 1.2.1 Continuous loading coils