$$P_y(f) = |H(f)|^2 \lim_{T\to\infty} \frac{1}{T} |X_T(f)|^2$$

or, simply

$$P_y(f) = |H(f)|^2 P_x(f)$$

Hence the power transfer function of the network will be

$$G_h(f) = \frac{P_y(f)}{P_x(f)} = |H(f)|^2$$

Show
Example 2-14: RC LOW-PASS Filter (page 81)

## Distortionless Transmission

In communication systems distortionles channel is often desired. This implies that the channel output is just proportional to a delayed version of the input.

$$y(t) = A\ x(t - T_d)$$

where, $A$ is a gain and $T_d$ is the delay.

Taking FT of both sides :

$$Y(f) = A\ X(f) e^{-j2\pi f T_d}$$

Thus, for distortionless transmission, we require that the transfer function be:

$$H(f)=\frac{Y(f)}{X(f)}=Ae^{-j2\pi fT_d}$$

Therefore for NO distortion two of the following requirements must be satisfied.

1. The amplitude response is flat

$$|H(f)|=cons\tan t=A$$

2. The phase response is a linear function of frequency. That is

$$\theta(f)=\angle H(f)=-2\pi fT_d$$

*Note*:
When the first condition is satisfied, it is said that there is no amplitude distortion.

When the second condition is satisfied there is no phase distortion.

For DISTORTIONLESS transmission both conditions must be satisfied.

The second requirement is often specified in an equivalent way using the time delay, which is defined as:

$$T_d(f)=-\frac{1}{2\pi f}\theta(f)=-\frac{1}{2\pi f}\angle H(f)$$

Show
Example 2-15: Distortion Caused By A Filter (pages 83-84)

Assignment # 1

2-49 (a)(b) , 2-54 , 2-69 , 2-75, 2-82

## Band Limited Signals And Noise

Signal and noise waveforms are referred to as band-limited only if their spectra is finite in a certain frequency band.

If a signal is bandlimited then the "Sampling Theorem" may be applied to process the signal.

In the next couple of sections we will examine properties of bandlimited signals, sampling and dimensionality theorem.

Bandlimited Waveforms:
A waveform $w(t)$ is absolutely band-limited to $B$ Hz if:

$$W(f) = F[w(t)] = 0 \qquad for \quad |f| \geq B$$

A waveform $w(t)$ is absolutely *time limited* if

$$w(t) = 0 \qquad \text{for} \qquad |t| > T$$

*Theorem*: An absolutely band-limited waveform can not be absolutely time limited and vice versa.

Show
as example a rectangular pulse and its spectrum

Sampling Theorem:
Sampling theorem is one of the most useful theorems since it applies to digital communications. It is simply an other application of orthogonal series expansion.

*Theorem*: Any physical waveform may be represented over the interval $-\infty < t < \infty$ by:

$$w(t) = \sum_{n=-\infty}^{\infty} a_n \frac{\sin\left\{\pi f_s\left[t - \left(n/f_s\right)\right]\right\}}{\pi f_s\left[t - \left(n/f_s\right)\right]} \tag{1}$$

where;

$$a_n = f_s \int_{-\infty}^{\infty} w(t) \frac{\sin\left\{\pi f_s\left[t - \left(n/f_s\right)\right]\right\}}{\pi f_s\left[t - \left(n/f_s\right)\right]} dt$$

Also if $w(t)$ is band-limited to $B$ Hz and $f_s >= 2B$ then equation (1) is the sampling function representation where,

$$a_n = w(n/f_s) = w(nT_s) \tag{2}$$

This implies that when $f_s >= 2B$ then the orthogonal series coefficients are simply the values of the waveform that are obtained when the waveform is sampled every ($T_s$ seconds).

For us to represent any signal $w(t)$ using equation (1) supported by (2)

$$\frac{\sin\left\{\pi f_s\left[t-\left(n/f_s\right)\right]\right\}}{\pi f_s\left[t-\left(n/f_s\right)\right]}$$ needs to be an orthogonal function

i.e.

$$\varphi_n(t)=\frac{\sin\left\{\pi f_s\left[t-\left(n/f_s\right)\right]\right\}}{\pi f_s\left[t-\left(n/f_s\right)\right]} \tag{3}$$

If we can show that $\varphi_n(t)$ forms a set of orthogonal functions then the series representation holds for all.

What we need to show is that $\varphi_n(t)$ satisfy the following:

$$\int_{-\infty}^{\infty}\varphi_n(t)\varphi_m^*(t)dt = K_n\delta_{nm}$$