APPENDIX

MULTIPLEXING

In the modulation system like AM, PM and FM discussed so far, we have translated the baseband signal to a high frequency in the spectrum and then transmitted them by continuous use of the transmission channels.

Suppose we have many signals of specific frequencies f_m then by using the above technique, we require separate transmitters to transmit different message signals, with a frequency separation of atleast 2 f_m Hz between the carriers of respective transmitters. As the number of signals to be transmitted increases, it becomes impractical to use separate transmitters for each message. In such cases, we go in for a method called Multiplexing.

Multiplexing is actually defined as the process of transmitting several message signals simultaneously, over a single channel. There are two types of multiplexing technique.

Frequency Division Multiplexing : This is the technique of separating the signals in frequency

Time Division Multiplexing : This is the technique of separating the signals in time.

Frequency Division Multiplexing

In this method, each message of frequency f_m is translated into different frequency spectrum using base carriers. Then they are all combined using adder circuit and are used to modulate a common carrier using AM.

At the receiver, a broad – band receiver receives this signal and passes it on to a base band receiver, which receives the signals corresponding to the base band frequency.

If the signals to be transmitted simultaneously are $e_{m1}(t)$, $e_{m2}(t)$, $e_{m3}(t)$, $e_{m4}(t)$ and base band carrier frequencies are f_1, f_2, f_3 and f_4 then the modulated base band carrier at the adder input are,

$$e_1(t) = E_1\ [1 + e_{m1}(t)]\ \text{Cos}\ \omega_1 t]$$

$$e_2(t) = E_1\ [1 + e_{m2}(t)]\ \text{Cos}\ \omega_2 t]$$

$$e_3(t) = E_1\ [1 + e_{m3}(t)]\ \text{Cos}\ \omega_3 t]$$

$$e_4(t) = E_1\ [1 + e_{m4}(t)]\ \text{Cos}\ \omega_4 t]$$

These signals are combined together at the adder and form a common modulating signal for the AM transmitter.

$e_m = e_1(t) + e_2(t) + e_3(t) + e_4(t)$ + (modulated wave) and with a carrier frequency f_C. The transmitter output is

$$e = E_C \{1 + e_a(e_1(t) + e_2(t) + e_3(t) + e_4(t)\} \cos \omega_c t.$$

Thus the transmitted wave contains all the original signal and have,

Bandwidth = $2\,(f_{m1} + f_{m2} + f_{m3} + f_{m4})$.

Where $f_{m1}, f_{m2}, f_{m3}, f_{m4}$ are the highest modulation frequencies in the signal. At the receiver, these signals are separated and passed to respective channels.

To transmit a number of signals over the same channel, signals must be kept apart, so that they do not interfere with each other, and thus each can be separated at the receiving end. This is achieved by using 'guard bands' between different message signals in the frequency spectrum, as shown in the fig. 1.

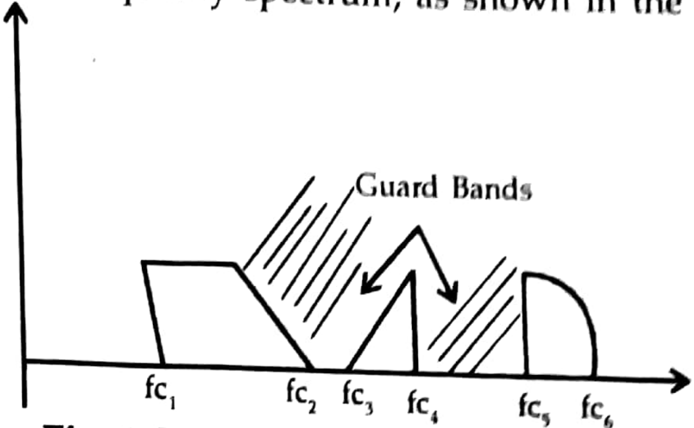

Fig. 1 Spectrum of multiplexed signal

The operation of FDM system can be understood, with reference to the figure 2. Each signal input is passed through a low pass filter, which is designed to remove high frequency components that do not contribute much towards signal representation, but are capable of disturbing other message signals that share the common channel. The filtered signals are applied to modulators which shift the frequency ranges of the signals so as to occupy mutually exclusive frequency intervals. For modulation, we mostly use SSB technique which approximately requires a band width of 4 KHz. The band pass filters following the modulators are used to restrict the band of each modulated wave to its prescribed range. The resulting band pass filter outputs are next combined in parallel to form the input to the common channel.

At the receiving terminal, a bank of bank-pass filters with their inputs connected in parallel, is used to separate the message signals on a frequency spectrum. Finally the original message signals are recovered using individual demodulators. The FDM shown in figure 2 can only operate in one direction. To provide two – way transmission, as in telephone we have to completely duplicate the multiplexing facilities, with the components connected in reverse order.

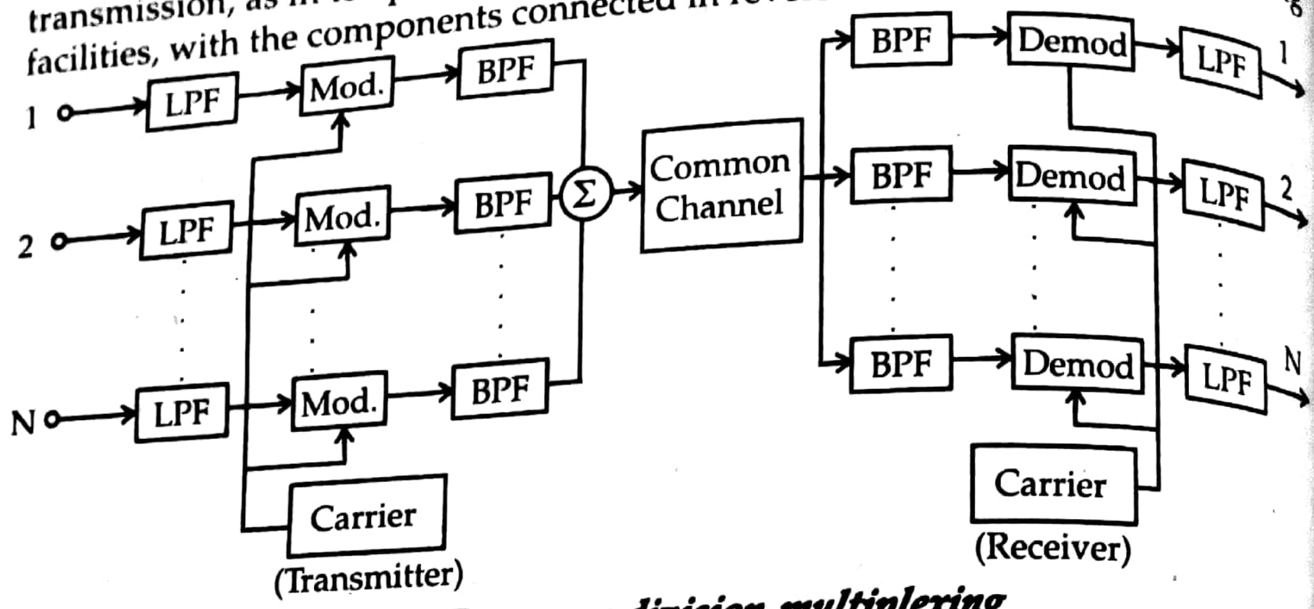

Fig. 2 Frequency division multiplexing

Frequency Translation

In the processings of signals in communication, it is often convenient (or) necessary to translate the modulated wave upward or down ward in frequency, so that it occupies a new frequency band. This is accomplished by multiplication of the signal by a locally generated sine wave, and subsequent filtering.

For example, consider the DSBSC wave $S(t) = m(t) . \cos 25 f_c t$

The modulating wave m(t) is limited to the frequency band $-\omega \leq f \leq \omega$.

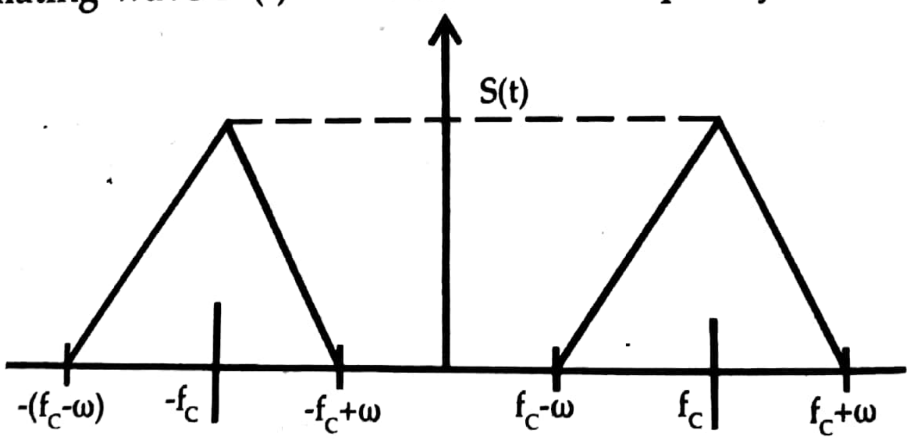

Fig. 3

The spectrum of S(t) therefore occupies the bands $(f_c-\omega) \leq f \leq (f_c+\omega) \leq f \leq (-f_c+\omega)$ as shown in the figure 3.

Suppose it is required to translate this modulated wave downward to its frequency, so that its carrier frequency is changed from f_c to a new value f_0 where $f_0 < f_c$. To accomplish this requirement, we first multiply sinusoidal wave of frequency f_1 supplied by a local oscillator to obtain

$$V_1(t) = S(t)\ \mathrm{Cos}2\pi f_1 t$$

$$V_1(t) = m(t)\ \mathrm{Cos}(2\pi f_c t)\ \mathrm{Cos}\ 2\pi f_1 t$$

$$V_1(t) = \frac{1}{2} m(t)\ \mathrm{Cos}(2\pi(f_c - f_1)t) + \frac{1}{2} m(t)\ \mathrm{Cos}(2\pi(f_c + f_1)t)$$

The multiplier output $V_1(t)$ consists of two DSBSC waves, one with a carrier frequency of $f_C - f_1$ and the other with a carrier frequency of $f_C + f_1$. The spectrum of $V_1(t)$ is shown in figure 4.

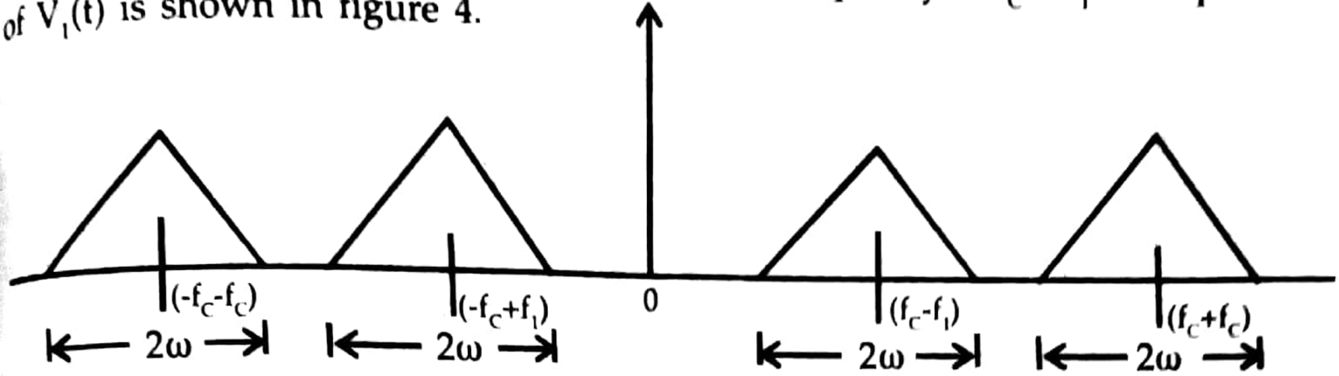

Fig. 4.

Let the frequency f_1 of the oscillator be chosen so that $f_C - f_1 = f_0$

From the figure 4, we see that the modulated wave with the desired carrier frequency f_C may be extracted by passing the multiplier output $V_1(t)$ through a band pass filter of midband frequency f_0 and bandwidth 2ω, provided

$$f_C + f_1 - \omega > f_C + f_1 + \omega \text{ (or) } \qquad f_1 > \omega$$

The filter output is $V_2(t) = \frac{1}{2} m(t)\ \mathrm{Cos}[2\pi(f_C - f_1)t]$

$$V_2(t) = \frac{1}{2} m(t)\ \mathrm{Cos}(2\pi f_O t)$$

This output is the desired modulated wave, translated downwards, and is own in the figure 5.

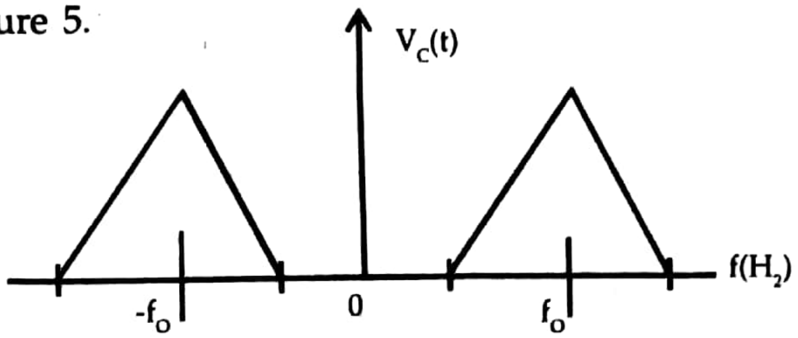

Fig. 5 Spectrum of downward translated wave

The block diagram of a mixer is shown in figure 6. It is used for frequency translation of a modulated wave. The operation is called as mixing or superheterodyning. For the implementation of a mixer, we may use a multiplier and a bandpass filter as shown in figure.

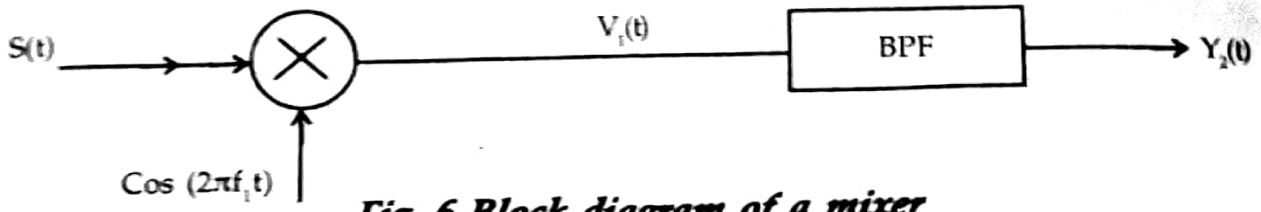

Fig. 6 Block diagram of a mixer

The multiplier is usually constructed by using non-linear (or) switching device, similar to modulators. Mixing is a linear operation, and it preserves the relation of the side bands of the incoming modulated wave to the camera.

Time Division Multiplexing

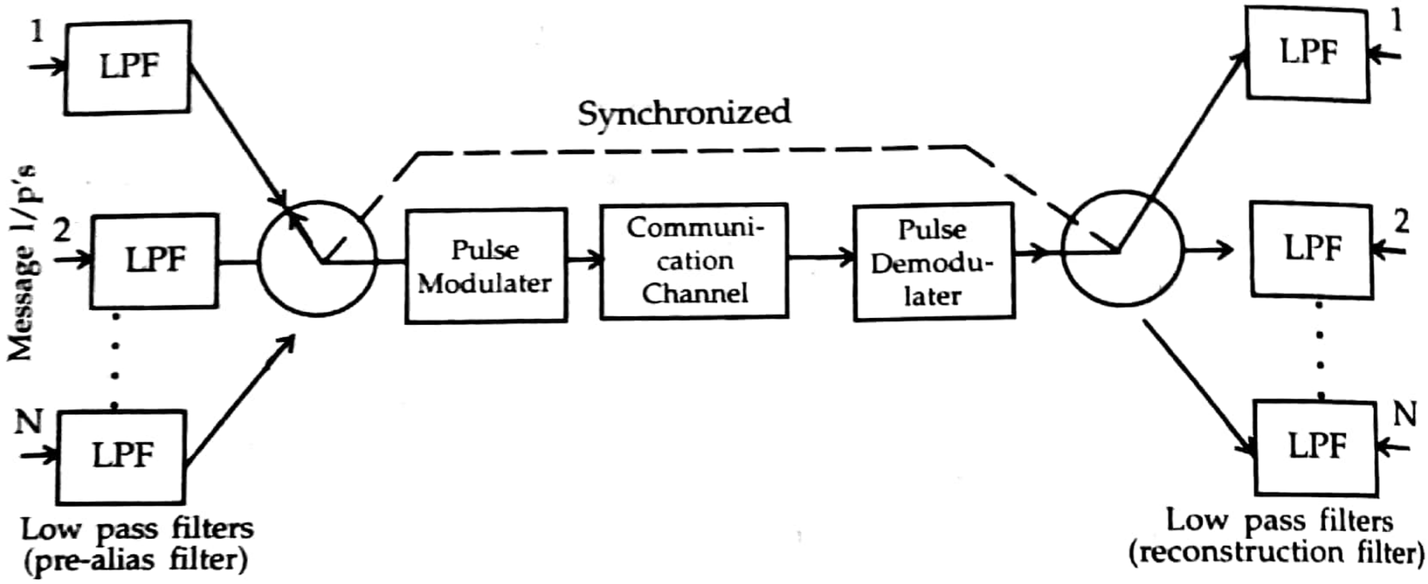

Fig. 7 Time Division Multiplexing

The sampling theorem forms the basis to transmit the message signal m(t) as samples of the signal m(t) taken uniformly at a rate slightly greater than the Nyquist rate. An important implication of this sampling process is the conservation of time. When message is used by another independent message source on a time shared basis. Thus we get a Time – division multiplexing (TDM) system.

The TDM system is illustrated in fig.7. Each input signal is first passed through a low pass pre-alias filter to remove the frequencies that are nonessential to signal reproduction. The low pass filter outputs are then passed to a commutator.

This commutator has two main functions

To take narrow samples of the input message signal at a rate of f_s slightly greater than 2ω, where ω is the cut off frequency of the filter.

To sequentially interleave these N samples inside the sampling interval T_s. The multiplexed signals is applied to the pulsed modulator, which is used to convert the multiplexed signal into suitable form, so as to transmit them over the common channel.

At the receiving end, the received signal is applied to a pulse demodulator, which performs the reverse operation of the pulse modulator. The samples at the output of demodulator are distributed to the appropriate low – pass reconstruction filters by a decommutator, which operates in synchronism with that of the commutator switch in the transmitter.

Comparison of TDM and FDM

TDM and FDM accomplish the same end by different means. Indeed they may be classified as dual techniques.

The individual TDM channels are assigned to distinct slots but jumbled together in frequency domain.

a) TDM involves simple instrumentation, FDM requires an analog subcarrier modulation, NBF and demodulator for every message channel, all of which are replaced by TDM commutator and decommutator switching circuits.

b) TDM synchronisation is slightly more demanding than that of suppressed carrier FDM.

c) TDM is invulnerable to the usual causes of cross talk.

   In FDM imperfect bandpass filtering and linear cross modulation give rise to cross talk.

   TDM cross talk immunity does depend on the transmission band width and absence of delay distortion.

d) The use of multiplexers allows a TDM system to accommodate different signals whose band width on pulse rates may differ by more than an order of magnitude.

e) TDM may (or) may not be advantageous when the transmission medium is subject to fading. Rapidly wide band fading might strike only occasional pulses in a TDM channel, in other cases all the TDM channels would be affected.

But slow narrowband fading wipes out all the TDM channels, where as it might hunt only one FDM channel

6.11 Time Division Multiplexing in PAM

The sampling theorem enables us to transmit the complete information contained in a band limited message signal g(t) by using samples of g(t) taken uniformly at a nyquist rate. An important feature of the sampling process is a conversation of time. ie. the transmission of the message samples engages the transmission channel for only fraction of the sampling interval on a periodic basis. Hence some of the time interval between adjacent samples is cleared for use by other independent message sources on a time shared basis. Such a scheme is named as *"Time division multiplex system"* (TDM). It enables a simultaneous transmission of different signals on a common channel without loss of information.

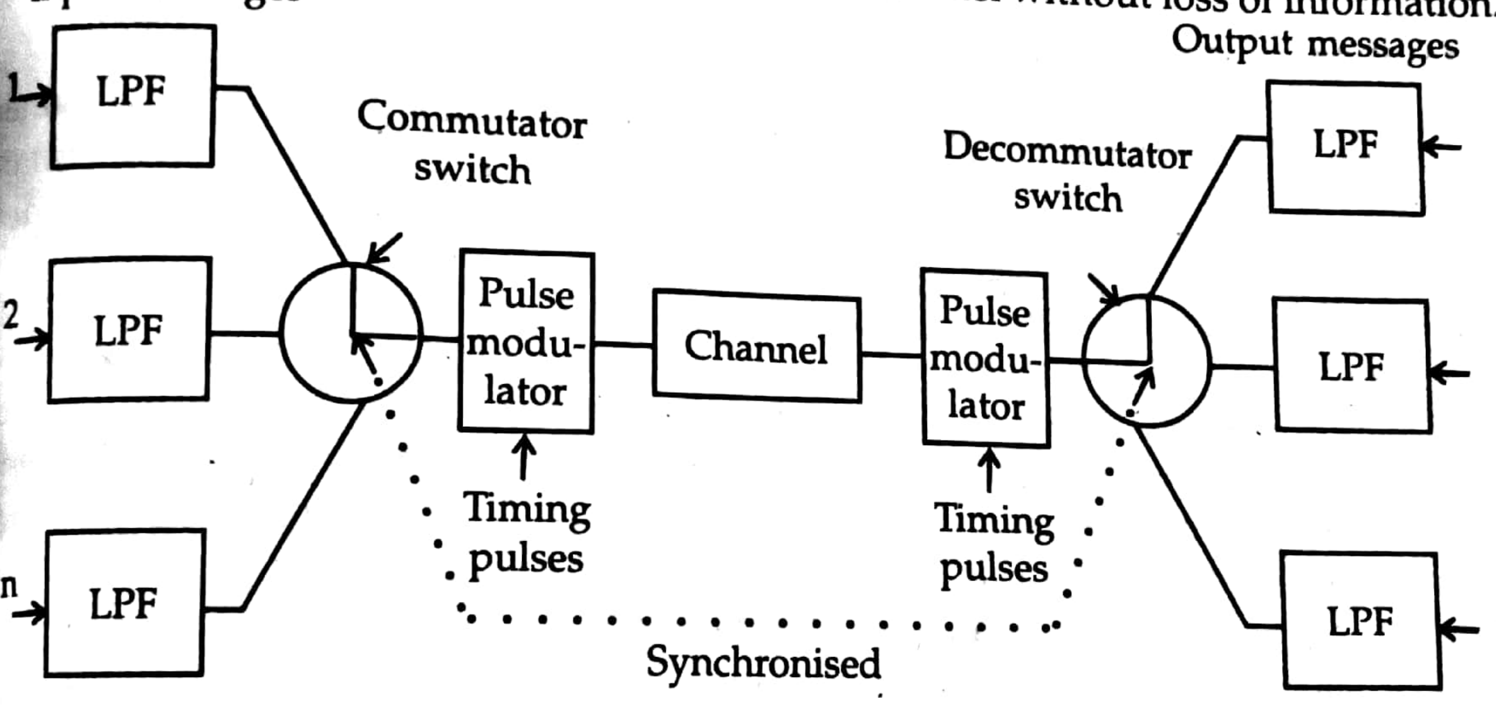

Fig. 6.31 Time division multiplexing

The block diagram of TDM system is shown in fig.6.31. Each input message signal is first restricted by low pass filter to remove the frequencies that are not essential to an adequate signal representation. The lowpass filter outputs one then applied to commutator switch. The function of the commulator has two fold.

(1) to take narrow sample of each of the 'N' input messages at a rate of $1/T_s$ that is slightly higher than 2ω. where 'ω' is the cutoff frequency of the lowpass filter.

(2) to sequentially interleave these N sample inside a sampling interval T_s. It is the main function of the time division multiplex operation.

Following the commutation process, the multiplexed signal is applied to a pulse modulator, the purpose of which is to transform the multiplexed signal into a form suitable for transmission over the common channel.

The time division multiplexing process introduces a bandwidth expansion factor 'N', because the scheme must squeeze 'N' samples derived from 'N' independent message sources into a time slot equal to sampling interval.

At the receiving end of the system, the received signal is applied to a pulse demodulator which performs the reverse operation of the pulse modulator. The narrow samples produced at the pulse demodulator output are distributed to the appropriate lowpass filter by means of decommutator. The decommutator properly synchronized with the commutator in the transmitter, it is essential for satisfactory operation of the system. The way of synchronization is implemented depends on the method of pulse modulation used to transmit the multiplexed sequence of samples. TDM is immune to amplitude non linearities in the channel as a source of cross talk because, the different message signals are not simultaneously impressed on the channel.

6.12 PULSE CODE MO...