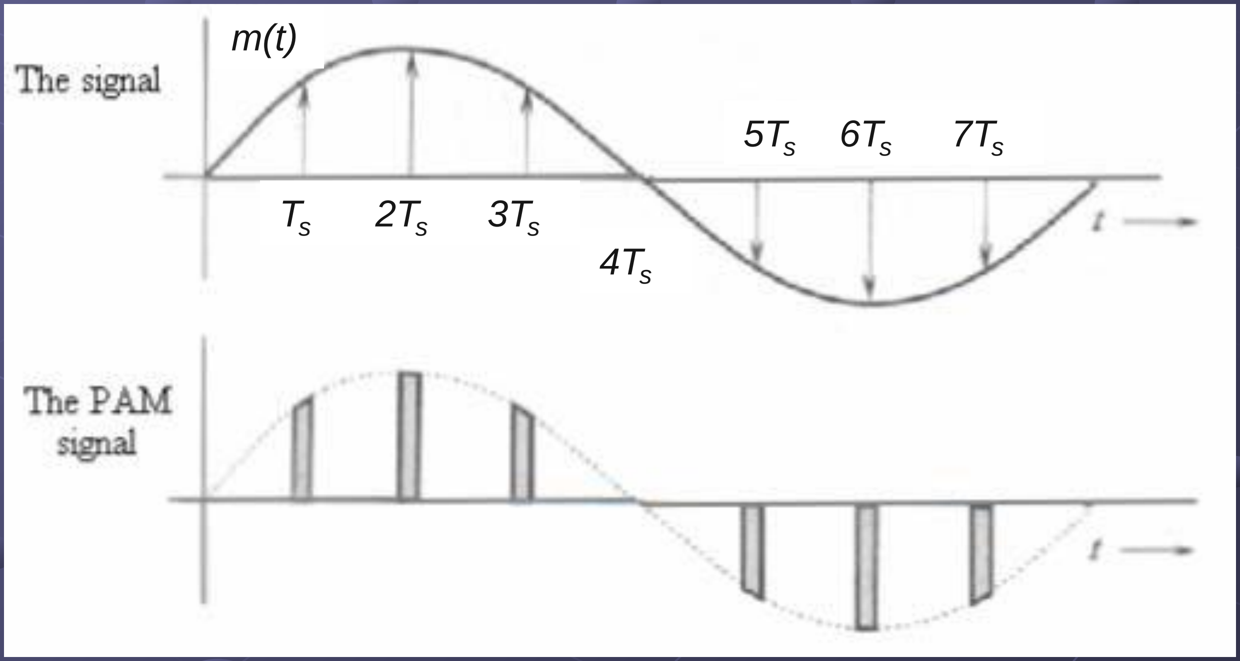
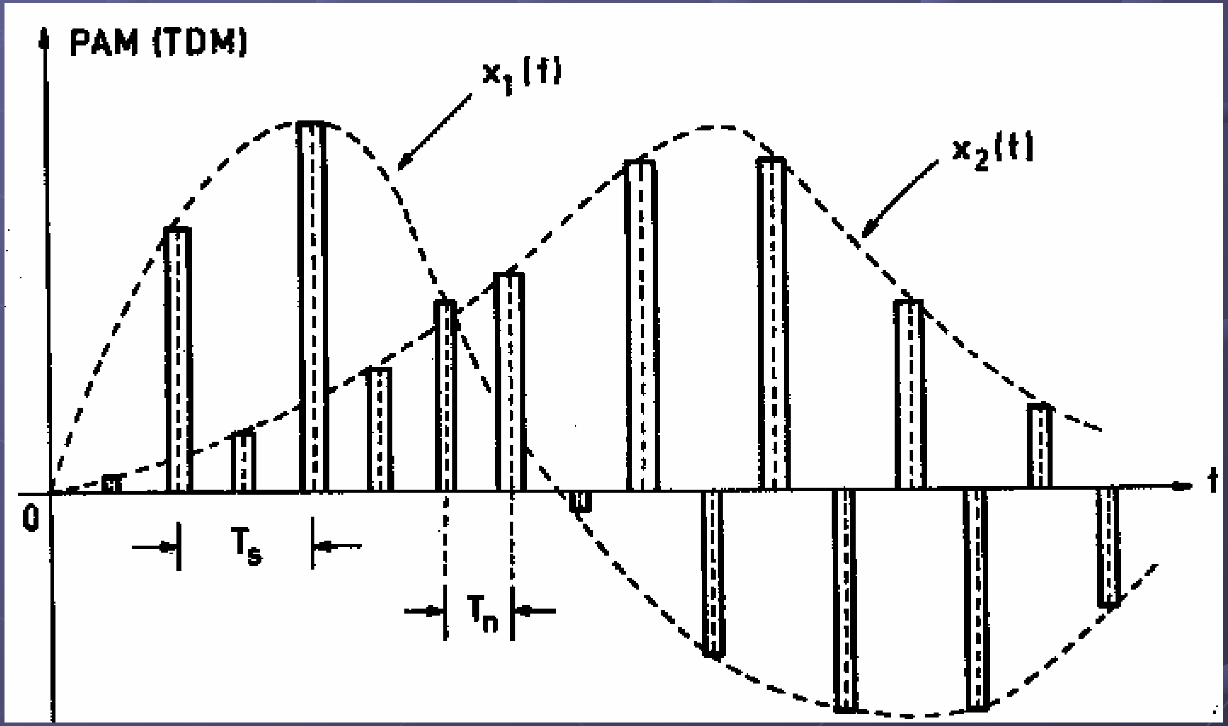
Time division multiplexing TDM

- The sampling theorem states that a given message signal $m(t)$ can be transmitted as a sequence of samples of $m(nT_s)$ as shown



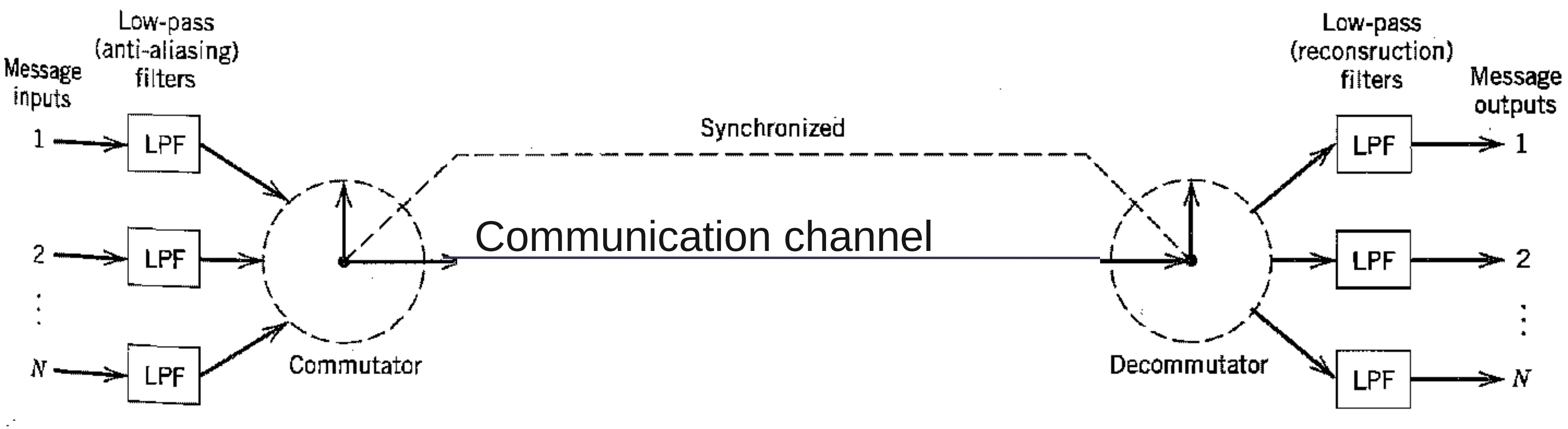
TDM graphical representation for two signals

- This leaves space for other samples to be interleaved in the same sampling interval



TDM block diagram

- In TDM *N* signals can be transmitted simultaneously using a single channel
- This can be achieved by using the block diagram shown below



TDM block diagram

- The commutator switch takes samples from each input signal and interleave them
- The operating frequency of the commutator switch is given by $f_N = Nf_s$
- Where $f_s = 2f_m$ is the sampling frequency for each signal provided that all *N* signals have the same bandwidth

TDM block diagram

- If the N signals have different bandwidths, then f_s is selected as the sampling frequency of the signal with the highest frequency content
- If signals with different bandwidths are to be TDM multiplexed, then the signals with same bandwidth are grouped together and sampled on the same f_s

TDM example

Two signals are to be transmitted using PAM TDM. The first signal has a bandwidth of 0-8 kHz, the second signal bandwidth is 0-10 kHz. The two signals are sampled equally. The sampled signals are passed through a low pass filter before transmission

TDM example

a) What is the minimum clock frequency of the PAM system (commutator clock)
b) What is the minimum cutoff frequency of the low pass filter used before transmission that will preserve the amplitude information on the output pulses

TDM example

c) What would be the minimum bandwidth if theses two signals were frequency multiplexed using normal AM techniques and SSB techniques

Example 1 solution

a) The minimum clock frequency of the PAM system can be found from

$$f_N = Nf_s = N \times (2f_{m1}) = N \times (2f_{m2})$$
$$f_N = 2 \times 2 \times 10 \ kHz = 40 \ kHz$$

b) The minimum bandwidth of the transmission filter can be found from

$$BW = \frac{1}{2T_n} = \frac{f_N}{2}$$
$$BW = \frac{40 \ kHz}{2} = 20 \ kHz$$

Example 1 solution

- The above equation for the bandwidth can be concluded from the fact that, the transmitted samples can be viewed as a new signal $f_3(t)$ sampled at a sampling rate of T_n
- This sampling rate is equivalent to a frequency $f_N = \frac{1}{T_n} = 2f_{m3}$

Example 1 solution

- Where f_{m3} is the maximum frequency content of $f_3(t)$
- From the above discussion we can see that the cutoff frequency of the filter must be greater than the $f_{m3} = \frac{1}{2T_n}$ in order to pass $f_3(t)$ without distortion

Example 1 solution

c) If the previous two signals were frequency multiplexed, then sent using AM carrier, then the minimum bandwidth would be

$$BW = 2\left(f_{m1} + f_{m2}\right)$$

$$BW = 2(8+10) = 36\ kHz$$

If SSB modulation is used then the bandwidth would be

$$BW = f_{m1} + f_{m2}$$

$$BW = 8+10 = 18\ kHz$$

3.8 Twenty-four voice signals are sampled uniformly and then time-division multiplexed. The sampling operation uses flat-top samples with 1 μs duration. The multiplexing operation includes provision for synchronization by adding an extra pulse of sufficient amplitude and also 1 μs duration. The highest frequency component of each voice signal is 3.4 kHz.

(a) Assuming a sampling rate of 8 kHz, calculate the spacing between successive pulses of the multiplexed signal.

(b) Repeat your calculation assuming the use of Nyquist rate sampling.

(a) The sampling interval is T_s = 125 μs. There are 24 channels and 1 sync pulse, so the time alloted to each channel is $T_c = T_s/25$ = 5 μs. The pulse duration is 1 μs, so the time between pulses is 4 μs.

(b) If sampled at the nyquist rate, 6.8 kHz, then T_s = 147 μs, T_c = 5.88 μs, and the time between pulses is 4.88 μs.

Twelve different message signals, each with a bandwidth of 10 kHz, are to be multiplexed and transmitted. Determine the minimum bandwidth required for each method if the multiplexing/modulation method used is

(a) FDM, SSB.

(b) TDM, PAM.

(a) The bandwidth required for each single sideband channel is 10 kHz. The total bandwidth for 12 channels is 120 kHz.

(b) The Nyquist rate for each signal is 20 kHz. For 12 TDM signals, the total data rate is 240 kHz. By using a sinc pulse whose amplitude varies in accordance with the modulation, and with zero crossings at multiples of (1/240) ms, we need a minimum bandwidth of 120 kHz.

A PAM telemetry system involves the multiplexing of four input signals: $s_i(t)$, $i = 1, 2, 3, 4$. Two of the signals $s_1(t)$ and $s_2(t)$ have bandwidths of 80 Hz each, whereas the remaining two signals $s_3(t)$ and $s_4(t)$ have bandwidths of 1 kHz each. The signals $s_3(t)$ and $s_4(t)$ are each sampled at the rate of 2400 samples per second. This sampling rate is divided by 2^R (i.e., an integer power of 2) to derive the sampling rate for $s_1(t)$ and $s_2(t)$.

(a) Find the maximum value of R.

(b) Using the value of R found in part (a), design a multiplexing system that first multiplexes $s_1(t)$ and $s_2(t)$ into a new sequence, $s_5(t)$, and then multiplexes $s_3(t)$, $s_4(t)$, and $s_5(t)$.

(a) The Nyquist rate for $s_1(t)$ and $s_2(t)$ is 160 Hz. Therefore, $\frac{2400}{2^R}$ must be greater than 160, and the maximum R is 3.

(b) With $R = 3$, we may use the following signal format to multiplex the signals $s_1(t)$ and $s_2(t)$ into a new signal, and then multiplex $s_3(t)$ and $s_4(t)$ and $s_5(t)$ including markers for synchronization: