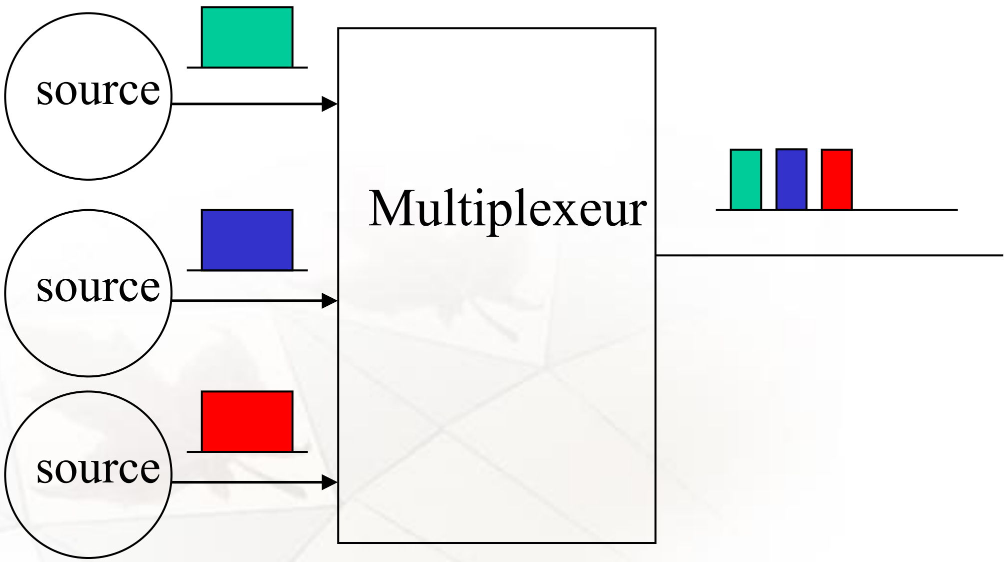
ELG3175 Introduction to Communication Systems

Binary and M-ary Pulse Modulation

Digital system

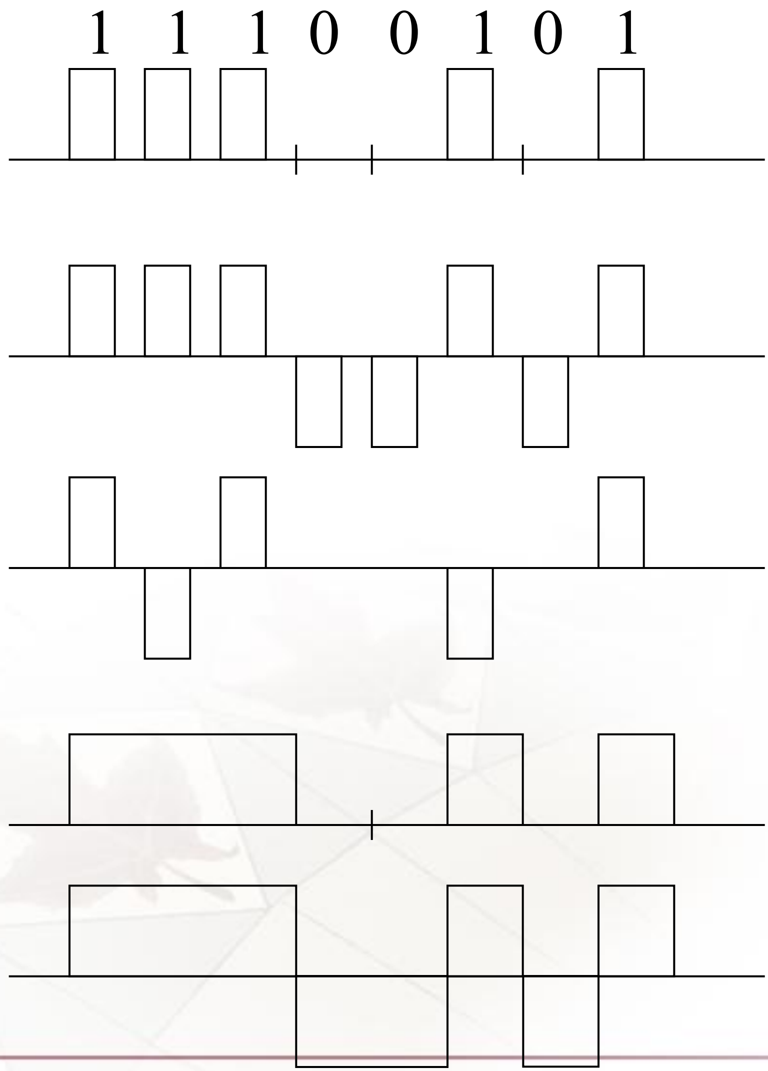
- A source produces digital symbols for transmission (bits, bytes etc).
- Multiple sources can be time division multiplexed (TDM).



Binary Pulse Modulation

- We consider two different types of binary pulse modulation: Pulse amplitude modulation (PAM) and pulse position modulation (PPM)
- We assume that the source is producing data in the form of a binary sequence of 0s and 1s at a rate of R_b bps.
- Return to Zero (RZ), non return to zero (NRZ).
  - RZ: The pulse duration is less than the symbol duration.
  - NRZ: The pulse duration is the same as the symbol duration.

Binary PAM



RZ "all or nothing" "1" = $p(t)$, "0" = 0.

RZ antipodal "1" = $p(t)$, "0" = $-p(t)$.

RZ bipolar "1" alternates between $p(t)$ and $-p(t)$, "0" = 0

NRZ all or nothing"1" = $p(t)$, "0" = 0.

NRZ antipodal "1" = $p(t)$, "0" = $-p(t)$.

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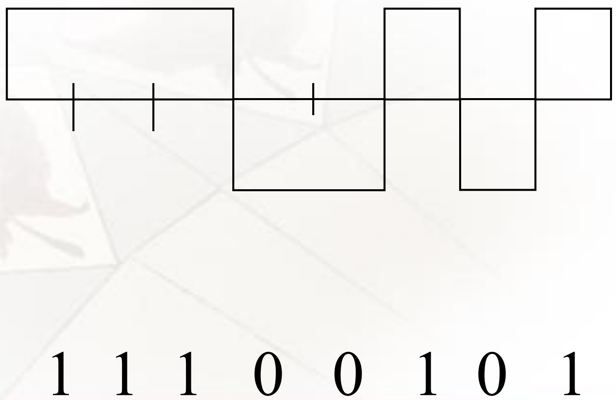
Signal design

- Desired properties:
  - Minimize bandwidth.
  - Minimize transmission power keeping performance and bandwidth requirements in mind
  - No DC components since transformers are used in repeaters.
  - Should be able to recover clock information from signal.

Binary PAM

- Simplest digital modulation method
- Information bit “1” is represented by a pulse of amplitude A and “0” by a pulse of amplitude –A.
- Pulses are transmitted at a rate $R_b = 1/T_b$ bps where T_b = bit interval.



Binary Pulse Position Modulation (PPM)

- Information bit "1" is transmitted by sending a pulse of amplitude A on the first half of the bit interval
  - $s_1(t) = A$ $0<t<T_b/2$, 0 otherwise
- Information bit "0" is transmitted by sending a pulse of amplitude A on the second half of the bit interval.
  - $s_0(t) = A$ $T_b/2<t<T_b$, 0 otherwise.

M-ary PAM

- We can group bits into symbols
  - 00 01, 10, 11 = 4-ary
  - 000, 001, 010, 011, 100, 101, 110, 111 = 8-ary
  - $M = 2^k$, where k is the number of bits per symbol.
  - $R_s = 1/T_s$ is the symbol rate in symbols/sec, where T_s = symbol interval.
- Each symbol is assigned a pulse of different amplitude
  - 4-ary 00 = A, 01 = 3A, 10 = -A, 11 = -3A
  - 8-ary...

M-ary PPM

- Divide up the symbol duration into non-overlapping sections.

Pulse shapes and bandwidth

- For PAM:

$$s_{PAM}(t) = \sum_{i=0}^{L} a_i\, p(t - iT_s) = p(t) * \sum_{i=0}^{L} a_i \delta(t - iT_s)$$

Let $\sum_{i=0}^{L} a_i \delta(t - iT_s) = y(t)$

Then $S_{PAM}(f) = P(f)Y(f)$

$$B_{PAM} = B_p.$$

We can show that the same is true for PPM

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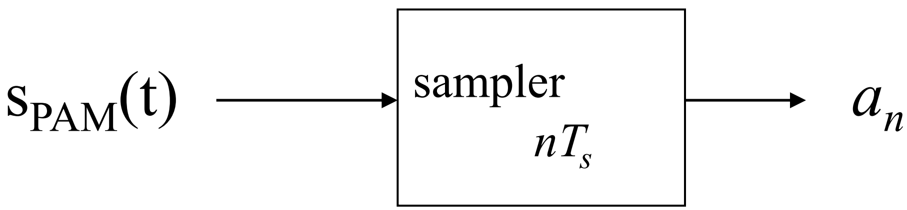
Detection of data



$$s_{PAM}(nT_s) = \sum_{i=0}^{L} a_i\, p(nT_s - iT_s) = \sum_{i=0}^{L} a_i\, p\left[(n-i)T_s\right] = a_n + \sum_{\substack{i=0 \\ i \neq n}}^{L} a_i\, p\left[(n-i)T_s\right]$$

The second term is Intersymbol interference (ISI)

Nyquist criterion for zero ISI

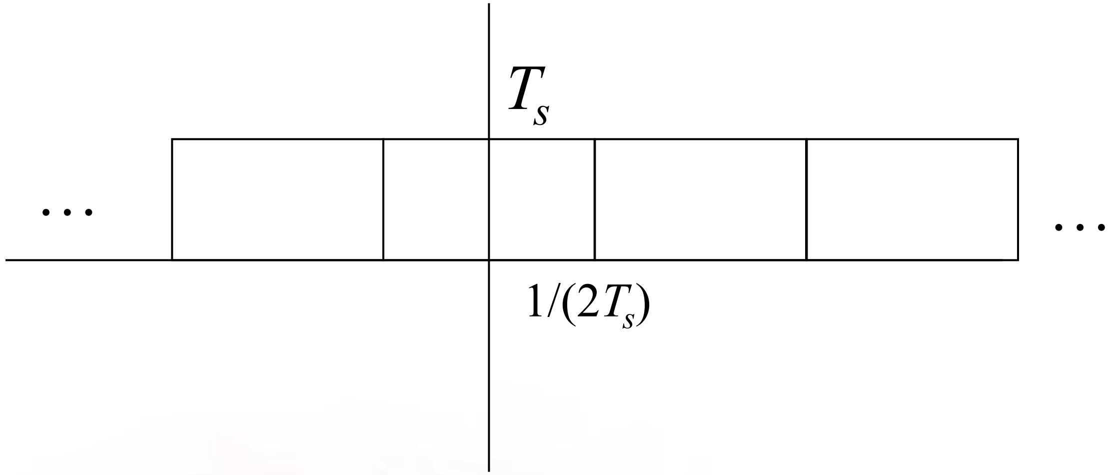
$$p(t) = \begin{cases} 1 & t = 0 \\ 0 & t = nT_s \ (n \neq 0) \end{cases}$$

$$p_s(t) = \sum_{n=-\infty}^{\infty} p(nT_s)\delta(t - nT_s) = \delta(t)$$

$$P_S(f) = \frac{1}{T_s} \sum_{n=-\infty}^{\infty} P\left(f - \frac{n}{T_s}\right) = 1$$

Therefore $$\sum_{n=-\infty}^{\infty} P\left(f - \frac{n}{T_s}\right) = T_s$$

Minimum bandwidth of PAM signal



$$P_{min}(f)=T_s\Pi(fT_s)$$
$$P_{min}(t) = \mathrm{sinc}(t/T_s)$$

Pulses that satisfy Nyquist's Zero ISI Criterion

- $\text{sinc}(t/T_s)$ produces minimum bandwidth of $1/2T_s$.
- $\text{sinc}^2(t/T_s)$ has bandwidth $1/T_s$ (twice as much as minimum bandwidth).
- Raised cosine pulse produces signal with bandwidth $(1/2T_s)(1+\alpha)$, where α is the roll-off factor.

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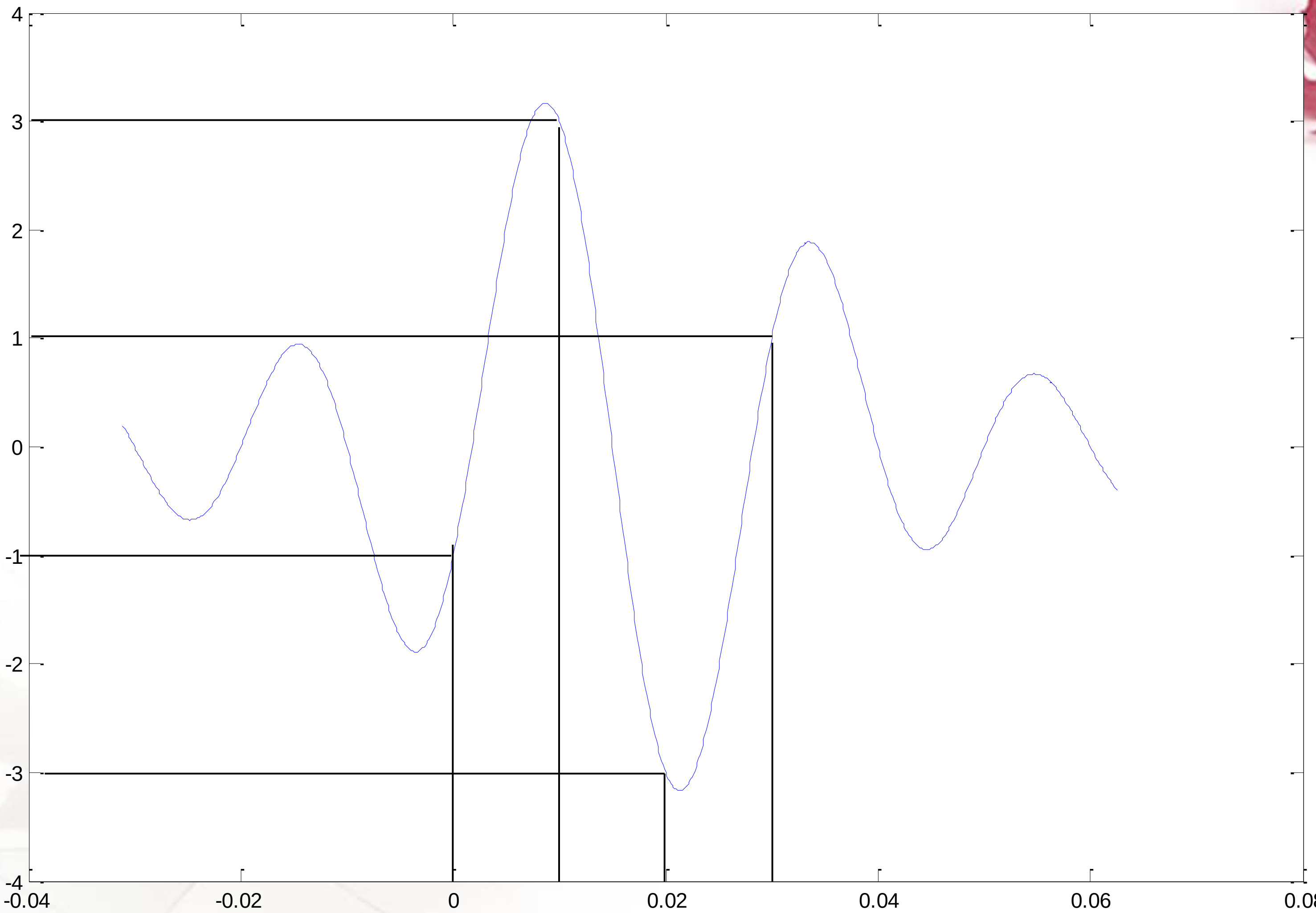

$p(t) = \mathrm{sinc}$

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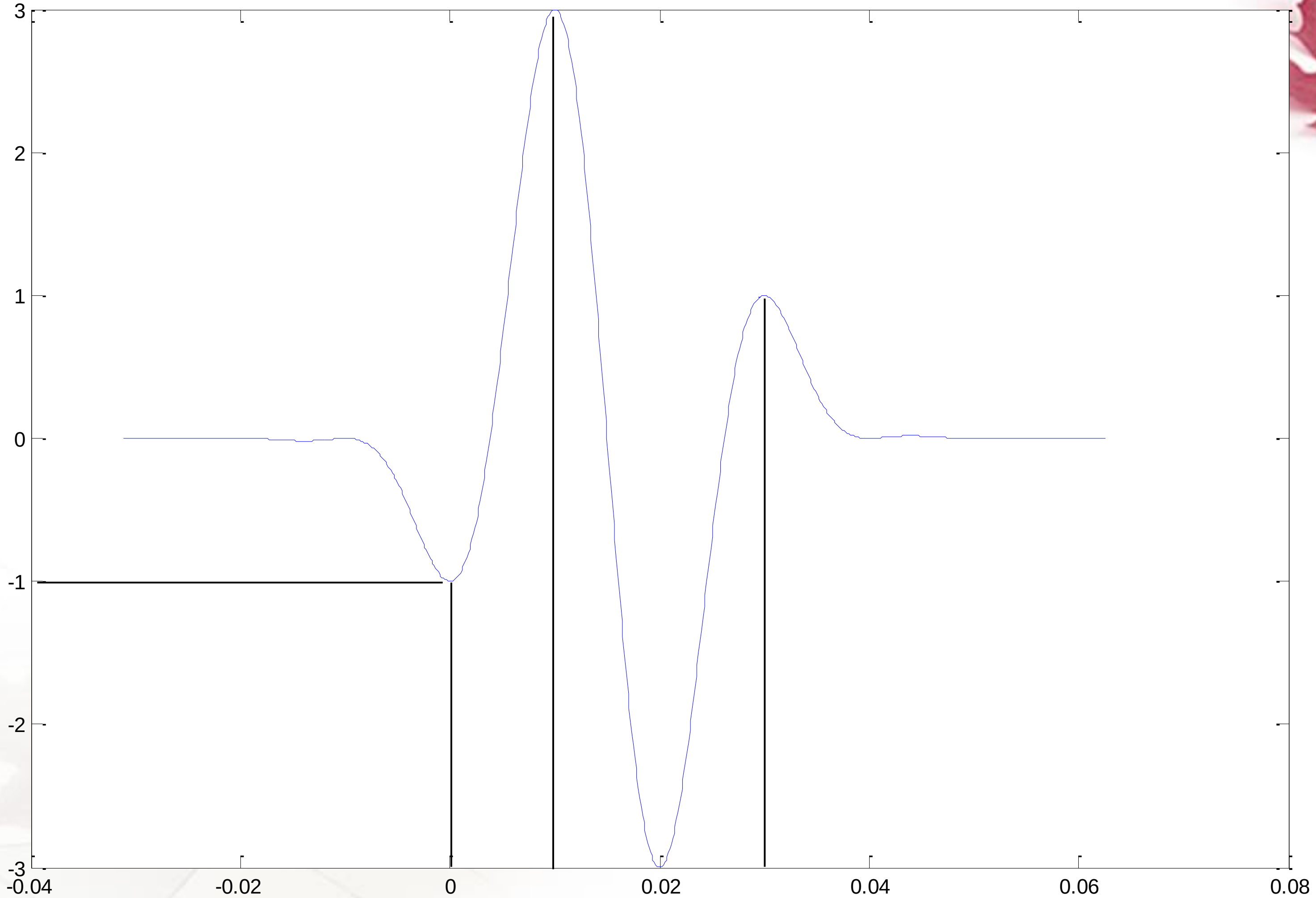

$$p(t) = \mathrm{sinc}^2$$

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