Baseband Modulation (3A)

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11/8/13

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This document was produced by using OpenOffice and Octave.

Symbols

Groups of *k* bits forms **symbols**

$$M = 2^k$$

Alphabet (a finite symbol set) : *M* symbols

The symbol set size : *M* (M-ary system)

Bits / Symbol

$$k = \log_2 M$$

M: size of a set of message symbols $M = 2^k$

Bits / PCM Word

$$l = \log_2 L$$

L : number of quantization levels $L = 2^l$

Symbols

	T	H	I	N	K	**Message**

001010 000100 100100 011100 110100   **6-bit ASCII**

0 0 1 0 1 0 0 0 0 1 0 0 1 0 0 1 0 0 1 0 0 0 1 1 1 0 0 1 1   binary digits (binary symbols)

0 0 1 0 1 0 0 0 0 1 0 0 1 0 0 1 0 0 1 0 0 0 1 1 1 0 0 1 1

$s_0(t)\ s_0(t)\ s_1(t)\ s_0(t)\ s_1(t)\ s_0(t)\ s_0(t)\ s_0(t)\ s_0(t)\ s_1(t)\ s_0(t)\ s_0(t)$ $M = 2,\ k = 1$

binary (Pulse) waveform

001 010 000 100 100 100 011 100 110 100   8-ary digits (8-ary symbols)

1   2   0   4   4   4   3   4   6   4

$s_1(t)\ \ s_2(t)\ s_0(t)\ s_4(t)\ s_4(t)\ s_4(t)\ s_3(t)\ s_4(t)\ s_6(t)\ s_4(t)$ 8-ary (Pulse) waveform
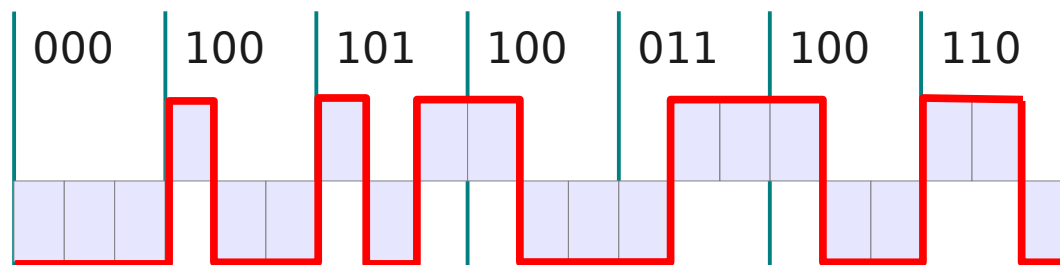
$M = 8,\ k = 3$

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Binary vs. M-ary Pulse Modulation

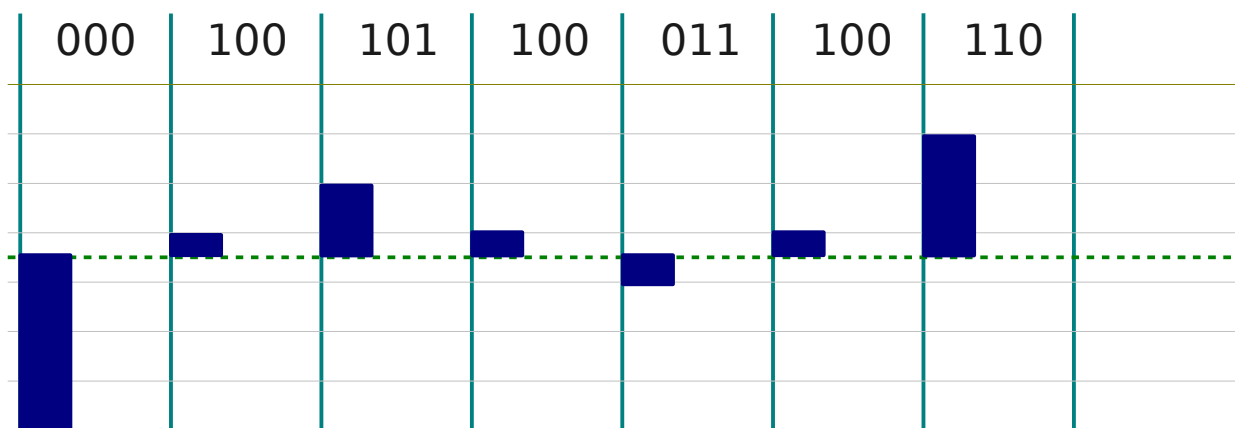| 0	4	5	4	3	4	6	**Message**
000	100	101	100	011	100	110	**Binary**

binary digits
(binary symbols)

binary (Pulse) waveform

PCM Waveform
Binary pulse modulation

8-ary digits
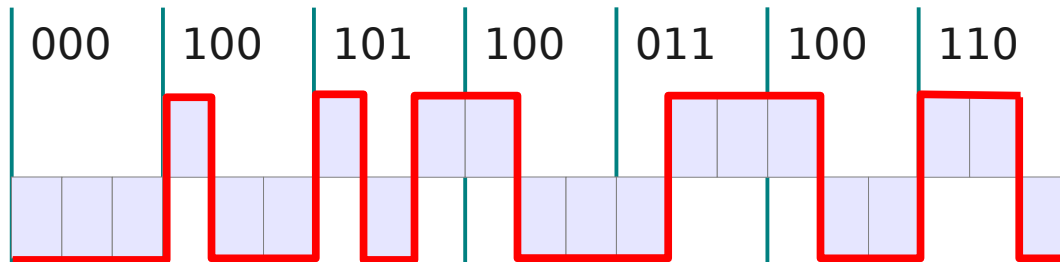(8-ary symbols)

8-ary (Pulse) waveform

M-ary pulse modulation

Time Slot

Codeword Time Slot

|←——————→| PCM Word, Symbol

| 000 | 100 | 101 | 100 | 011 | 100 | 110 |

Bit Time Slot

|←→|

Bits / PCM Word

L : number of quantization levels

$$L = 2^l$$

Bits / Symbol

M: size of a set of message symbols

$$M = 2^k$$

M-ary Pulse Modulation

PAM (Pulse Amplitude Modulation)

PPM (Pulse Position Modulation)

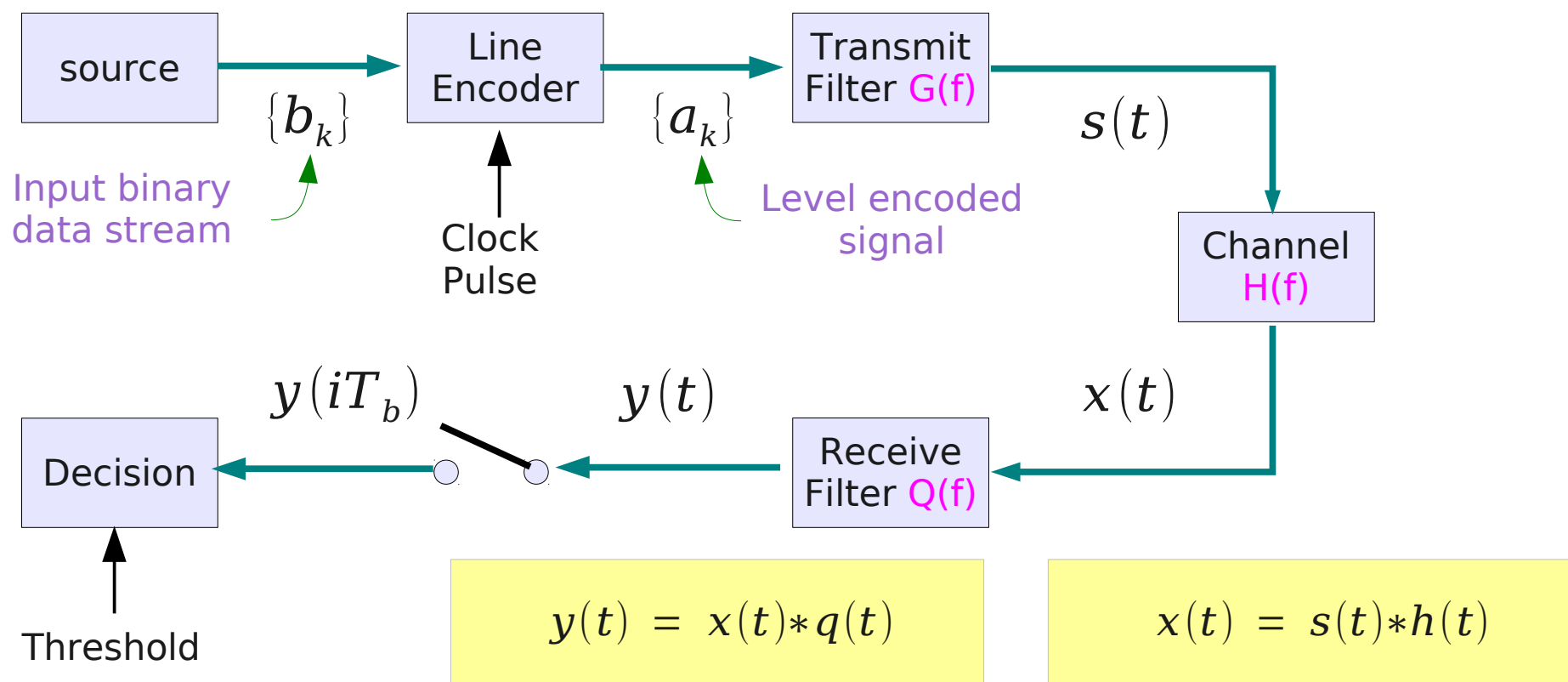**PDM** (Pulse Duration Modulation)

PWM (Pulse Width Modulation)

M-ary Pulse Modulation   M-ary alphabet set

M-ary PAM : M allowable amplitude levels are assigned to each of the M possible symbol values.
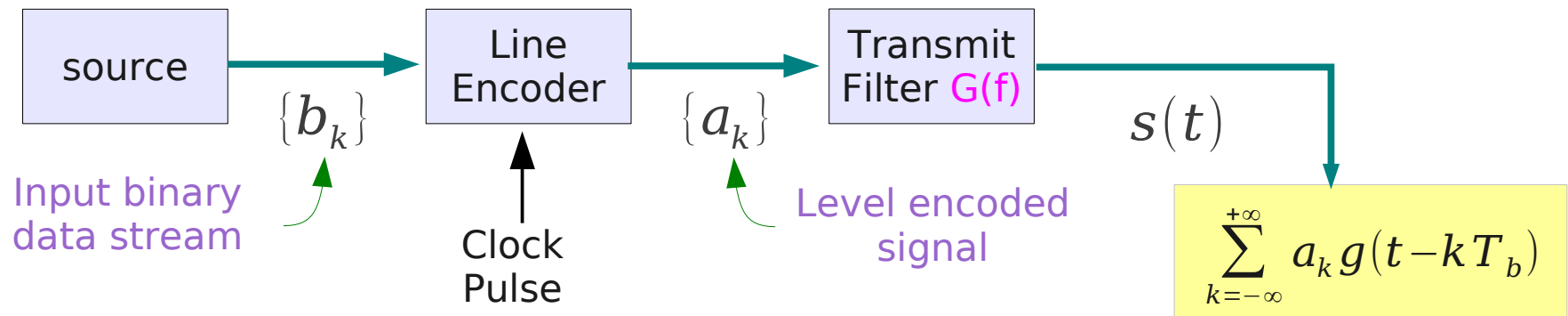
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Baseband Binary PAM System

The amplitude of transmitted pulses is varied in a discrete manner in accordance with an input stream of digital data

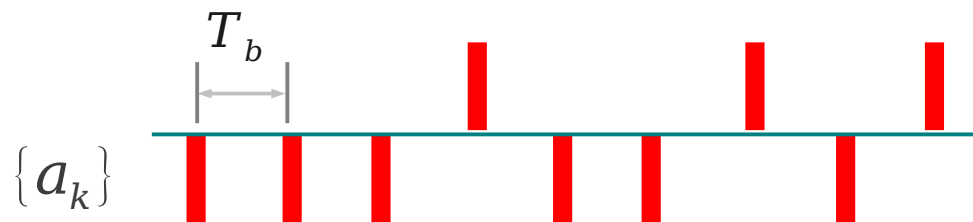$$s(t) = \sum_{k=-\infty}^{+\infty} a_k\, g(t - kT_b)$$

source → {b_k} → Line Encoder → {a_k} → Transmit Filter G(f) → $s(t)$ → Channel H(f) → $x(t)$ → Receive Filter Q(f) → $y(t)$ → $y(iT_b)$ → Decision

Input binary data stream

Clock Pulse

Level encoded signal

Threshold

$$y(t) = x(t) * q(t)$$

$$x(t) = s(t) * h(t)$$

Baseband Binary PAM System – Transmission

source $\longrightarrow$ $\{b_k\}$ Line Encoder $\longrightarrow$ $\{a_k\}$ Transmit Filter G(f) $\longrightarrow$ $s(t)$

Input binary data stream

Clock Pulse

Level encoded signal

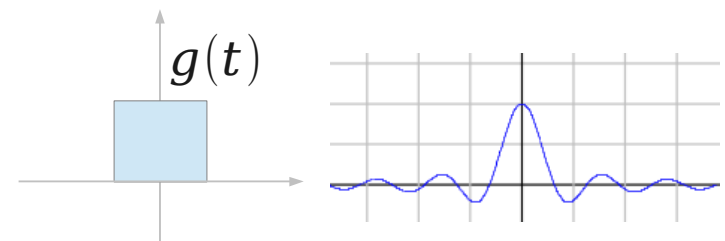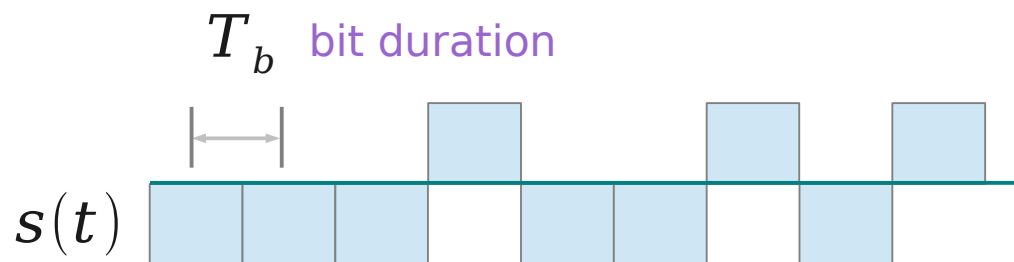$$\sum_{k=-\infty}^{+\infty} a_k g(t - k T_b)$$

$\{b_k\}$ 0 0 0 1 0 0 1 0 1

Represents binary symbol 0 or 1 at time $t = kT_b$

T_b

$\{a_k\}$

positive & negative pulses of fixed amplitude and <u>very short duration</u>

$a_k = +1$ when b_k is symbol 1

$a_k = -1$ when b_k is symbol 0

T_b bit duration

$s(t)$

$g(t)$

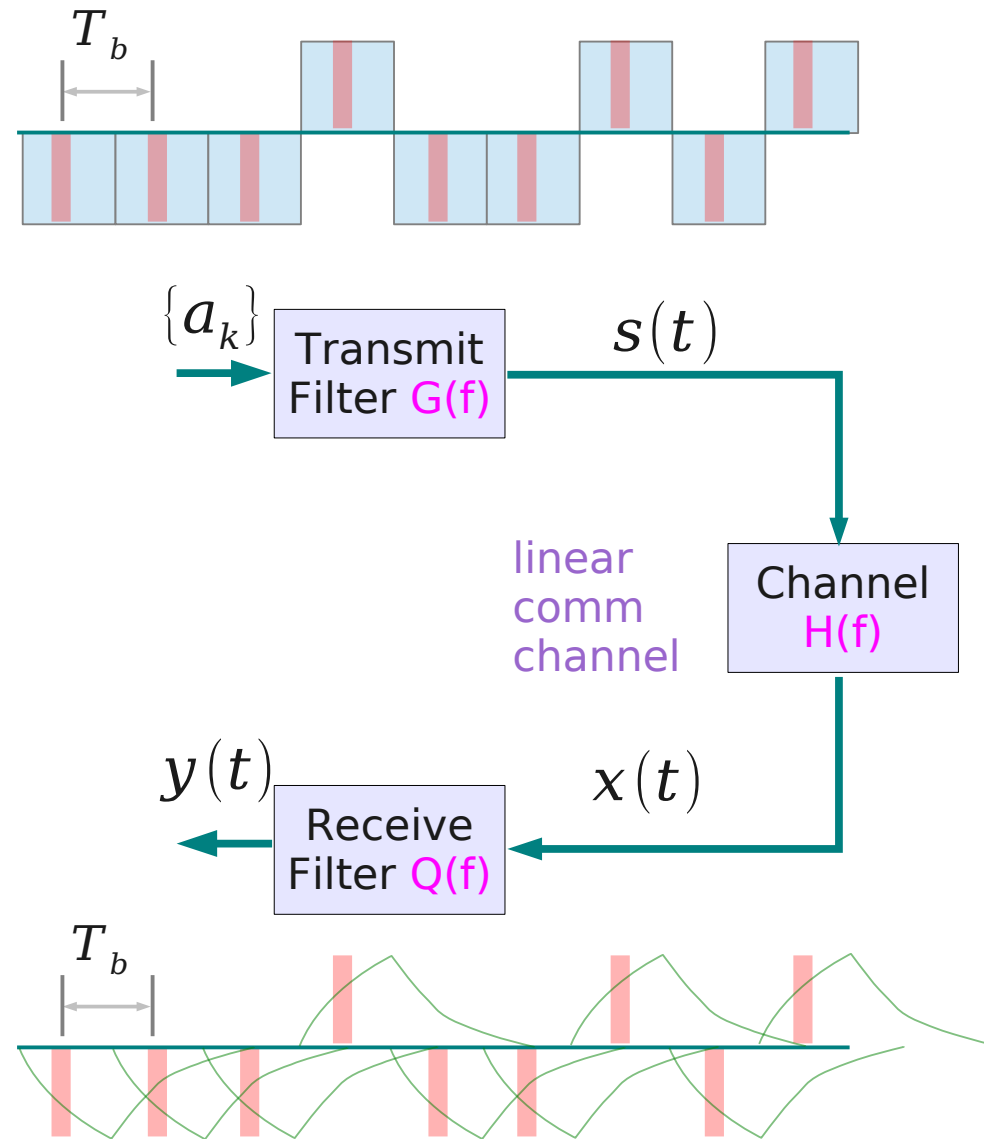# Baseband Binary PAM System – Overall Pulse Shape

$$s(t) = \sum_{k=-\infty}^{+\infty} a_k\, g(t-kT_b)$$

$$x(t) = s(t) * h(t)$$

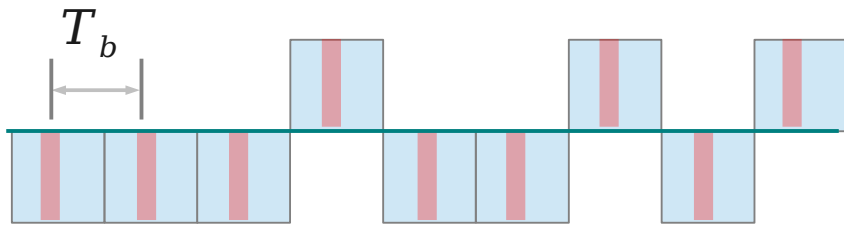$$y(t) = x(t) * q(t)$$

$$p(t) = g(t) * h(t) * q(t)$$
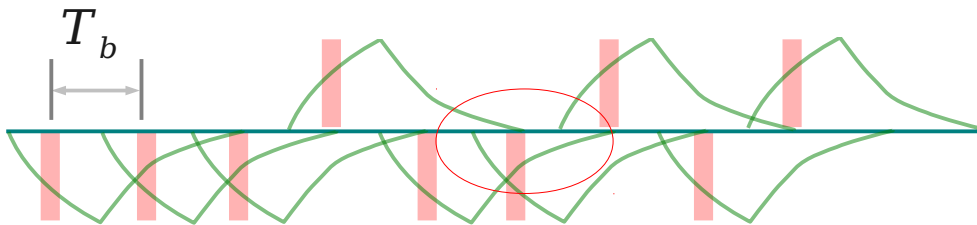
$$P(f) = G(f)H(f)Q(f)$$

T_b

$\{a_k\}$ → Transmit Filter G(f) → $s(t)$

linear comm channel

Channel H(f)

$x(t)$

$y(t)$ ← Receive Filter Q(f) ←

T_b

Baseband Binary PAM System – Tx & Rx Signals

$$s(t) = \sum_{k=-\infty}^{+\infty} a_k\, g(t-kT_b)$$

Transmit Signal

T_b

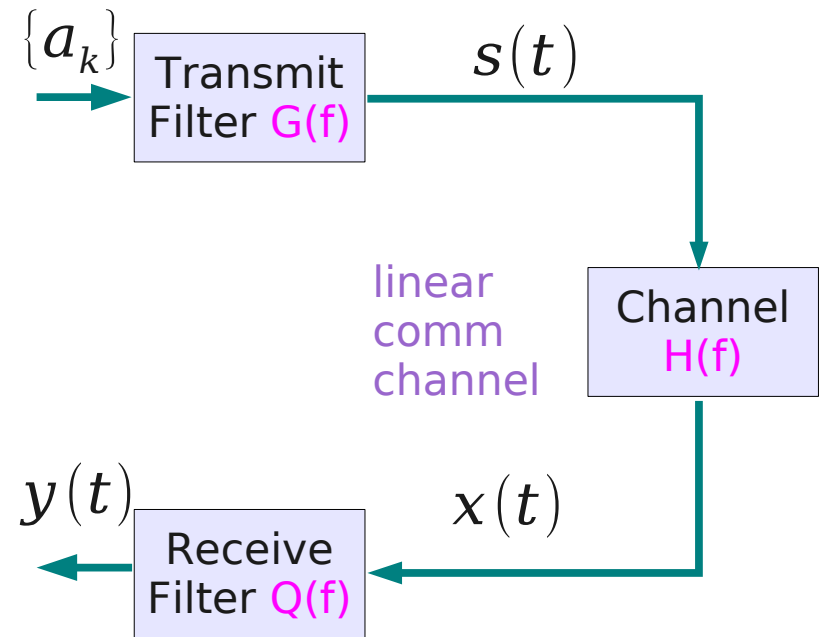$\{a_k\}$ → Transmit Filter **G(f)** → $s(t)$

Channel **H(f)**

linear comm channel

intersymbol interference

T_b

$y(t)$ ← Receive Filter **Q(f)** ← $x(t)$

$$y(t) = \sum_{k=-\infty}^{+\infty} a_k\, p(t-kT_b)$$

Receive Signal

Baseband Binary PAM System – Detection

$$y(iT_b) \qquad y(t)$$

Decision $\longleftarrow$ $\circ$ $\circ$ $\longleftarrow$ Receive Filter Q(f)
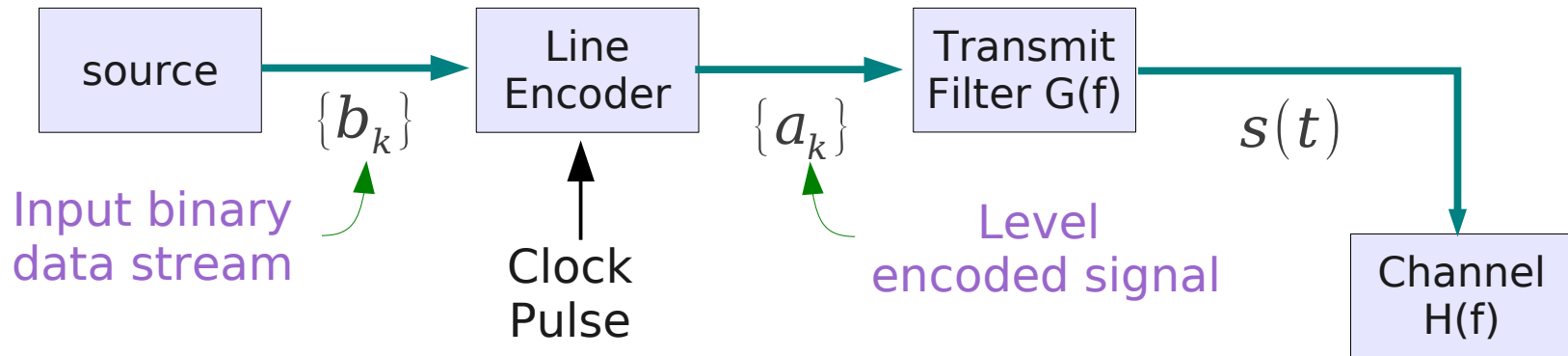
Threshold

Sample at time $t = iT_b$
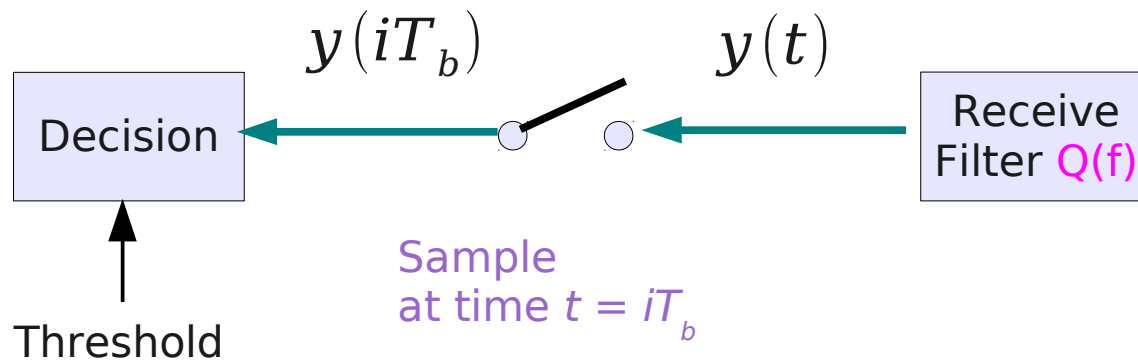
Sampled synchronously with the generator of clock pulses in the transmitter

Synchronization: established by extracting a clock or timing signal from the receive filter output

Decision making device: thresholding

M-ary PAM

The amplitude of transmitted pulses is varied in a discrete manner in accordance with an input stream of digital data

source → $\{b_k\}$ → Line Encoder → $\{a_k\}$ → Transmit Filter G(f) → $s(t)$ → Channel H(f)

Input binary data stream

Clock Pulse

Level encoded signal

M-ary PAM Bit Rate

$$T = T_b \log_2 M$$

M possible amplitude level (M>2)
M symbols
Transmits sequence of symbols

T: Symbol duration
1/T : Symbol rate

Binary PAM
Tb : Bit duration
1/Tb : Bit rate

Inter-Symbol Interference (ISI)

distortion of a signal
in which one symbol interferes with subsequent symbols.
multipath propagation
inherent non-linear filter   → long tail, smear, blur …

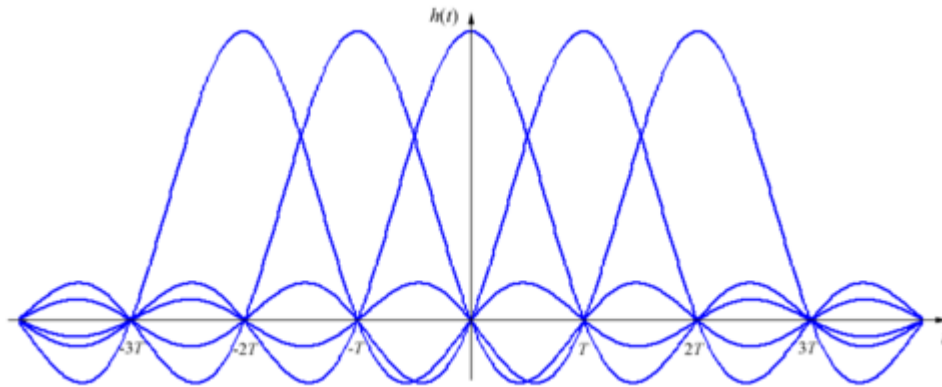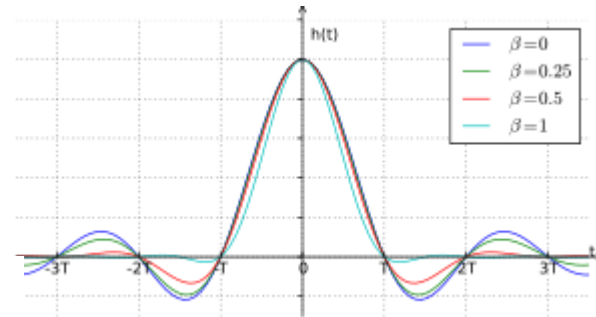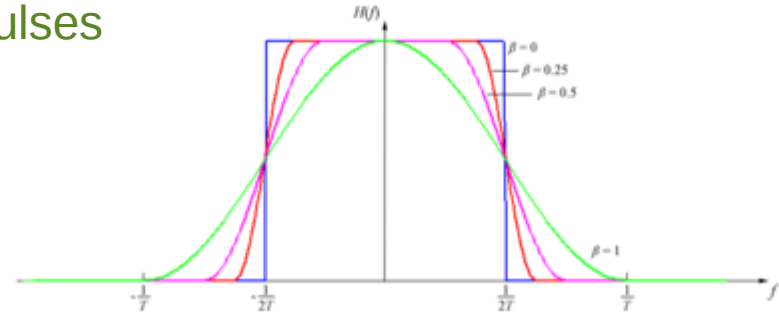- adaptive equalization
- error correcting codes
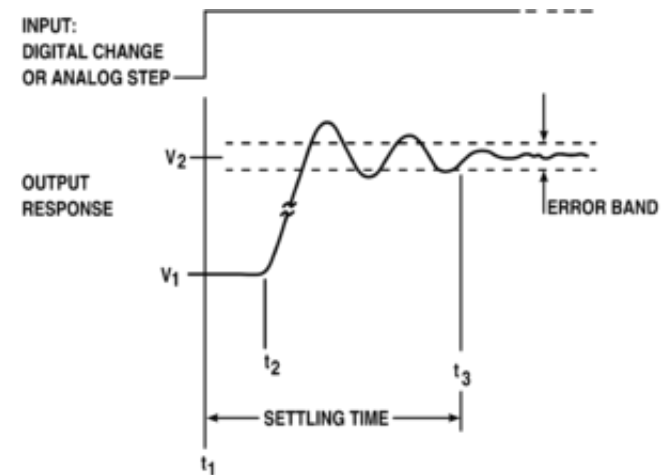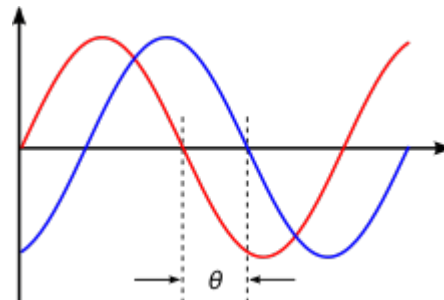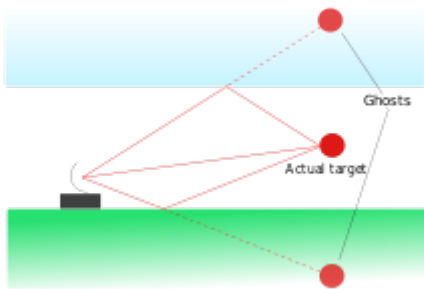
ISI in BaseBand Communication

Pulse Shaping

Changing the waveform of transmitted pulses
bandwidth constraints
control ISI (inter-symbol interference)

- Sinc Filter
- Raised Cosine Filter
- Gaussian Filter

Eye Pattern

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References

[1] http://en.wikipedia.org/
[2] http://planetmath.org/
[3] B. Sklar, "Digital Communications: Fundamentals and Applications"

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