SNS COLLEGE OF TECHNOLOGY

An Autonomous Institution

Coimbatore-35

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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

19ECB301-ANALOG AND DIGITAL COMMUNICATION

III YEAR/ V SEMESTER

UNIT 3 – DIGITAL COMMUNICATION

TOPIC – **INTER SYMBOL INTERFERENCE**

UNIT III –Digital Communication

UNIT III DIGITAL COMMUNICATION 9+6

THEORY

Block diagram of Digital communication, Low pass Sampling, Quantization- Types.

Baseband Transmission: Properties of Line codes- Power Spectral Density of Line codes –ISI- Nyquist criterion for distortion less transmission – Correlative coding – Eye pattern – Equalization- Linear equalization, Decision -feedback equalization, Adaptive linear equalizer.

Inter Symbol Interference

- Digital data is represented by electrical pulse, communication channel is always band limited.

- When the channel bandwidth is greater than bandwidth of pulse, spreading of pulse is very less.

- But when channel bandwidth is close to signal bandwidth, i.e. if we transmit digital data which demands more bandwidth which exceeds channel bandwidth, spreading will occur and cause signal pulses to overlap. This overlapping is called **Inter Symbol Interference**.,

- ISI causes degradations of signal if left uncontrolled.

- Similar to interference caused by other sources, ISI causes degradations of signal if left uncontrolled. This problem of ISI exists strongly in Telephone channels like coaxial cables and optical fibers.

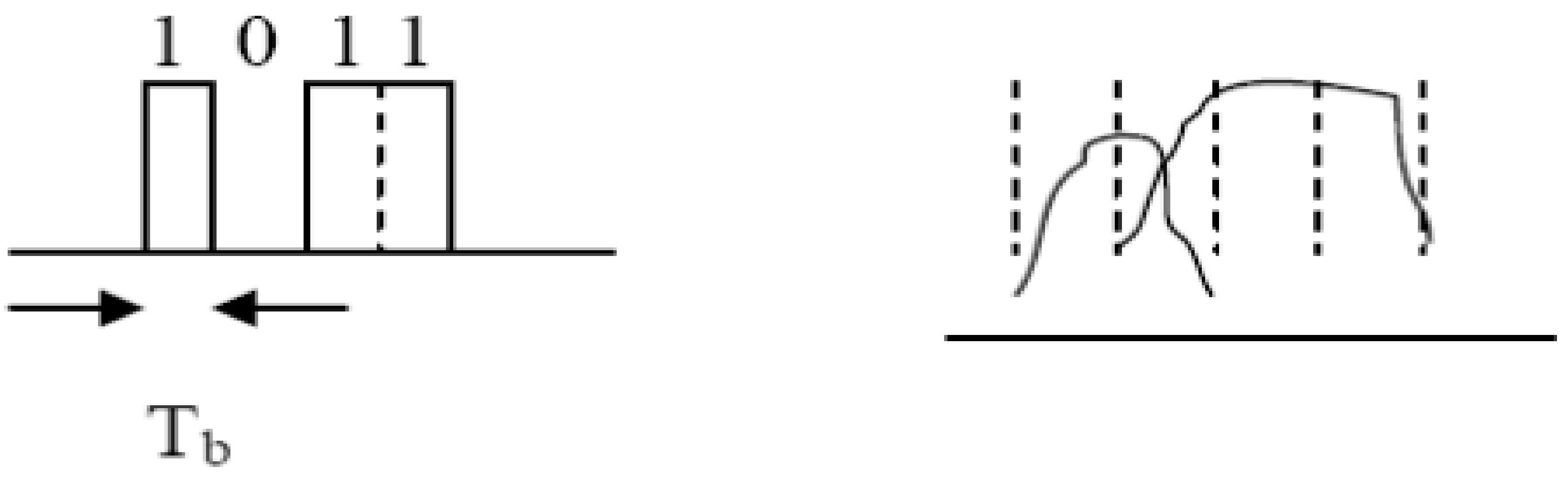
- The main objective is to study the effect of ISI, when digital data is transmitted through band limited channel and solution to overcome the degradation of waveform by properly shaping pulse.

- Raised cosine response meets the Nyquist ISI criterion. Consecutive raised-cosine impulses demonstrate the zero ISI property between transmitted symbols at the sampling instants.

- At t=0 the middle pulse is at its maximum and the sum of other impulses is zero.

- In communications, the Nyquist ISI criterion describes the conditions which, when satisfied by a communication channel (including responses of transmit and receive filters), result in no intersymbol interference or ISI.

- It provides a method for constructing band-limited functions to overcome the effects of intersymbol interference.



Transmitted Waveform Pulse Dispersion

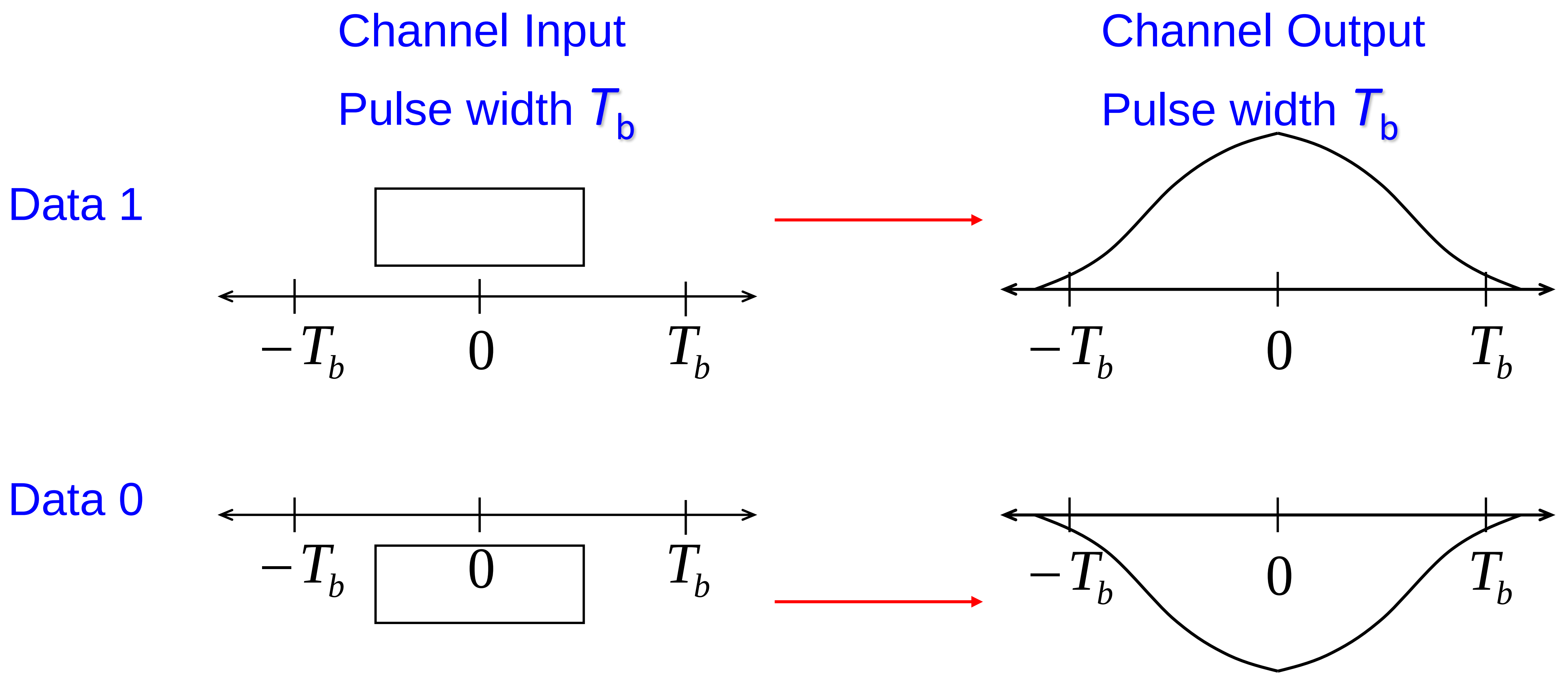
- The effect of sequence of pulses transmitted through channel is shown in fig. The Spreading of pulse is greater than symbol duration, as a result adjacent pulses interfere.

- i.e. pulses get completely smeared, tail of smeared pulse enter into adjacent symbol intervals making it difficult to decide actual transmitted pulse.

Intersymbol Interference

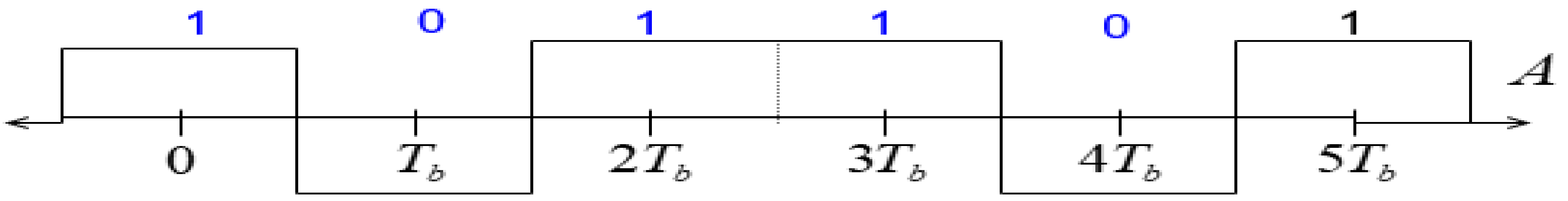
Intersymbol interference (ISI) occurs when a pulse spreads out in such a way that it interferes with adjacent pulses *at the sample instant.*

Example: assume polar NRZ line code. The channel outputs are shown as spreaded (width T_b becomes $2T_b$) pulses shown (Spreading due to bandlimited channel characteristics).

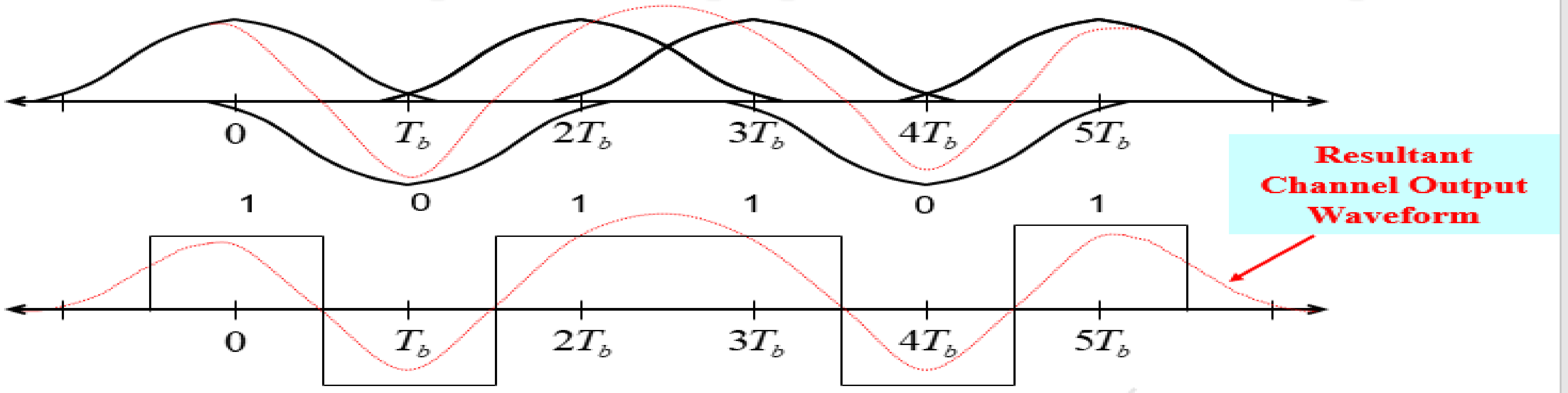


Intersymbol Interference

➢ For the input data stream:

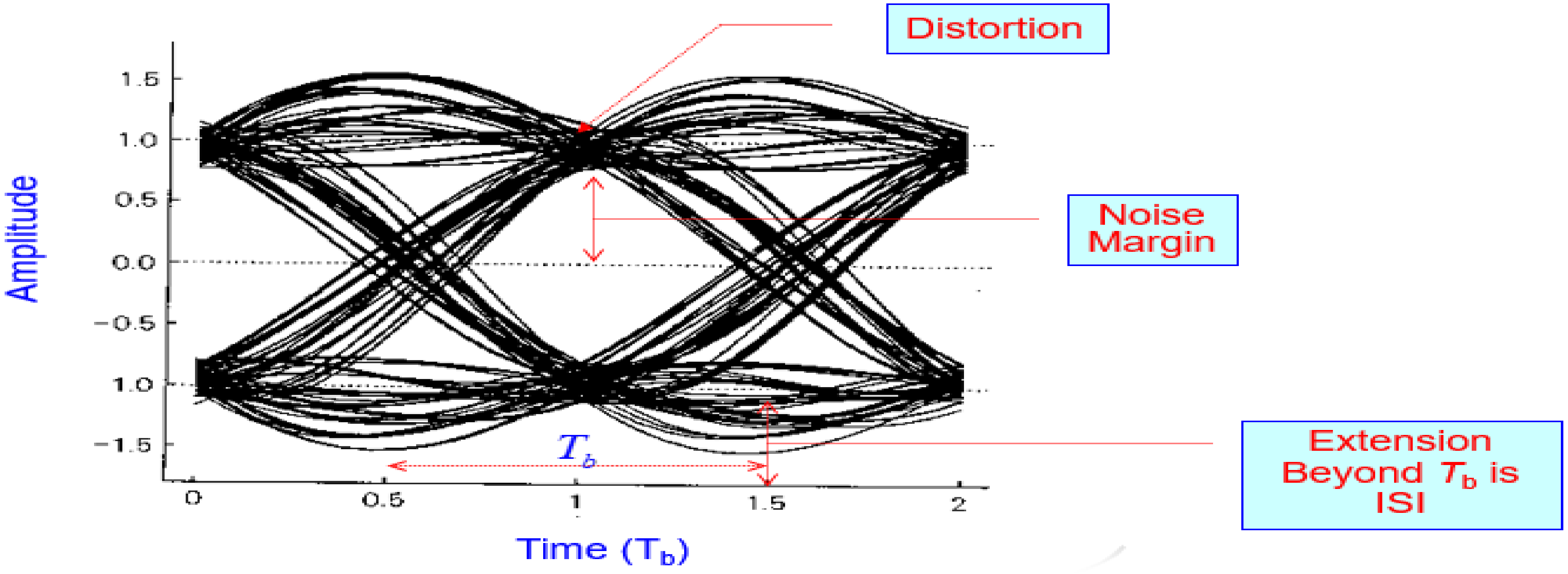


➢ The channel output is the superposition of each bit's output:



ISI on Eye Patterns

- The amount of ISI can be seen on an oscilloscope using an ***Eye Diagram*** or ***Eye pattern***.



Intersymbol Interference

➢ If the rectangular multilevel pulses are filtered improperly as they pass through a communications system, they will spread in time, and the pulse for each symbol may be smeared into adjacent time slots and cause ***Intersymbol Interference.***

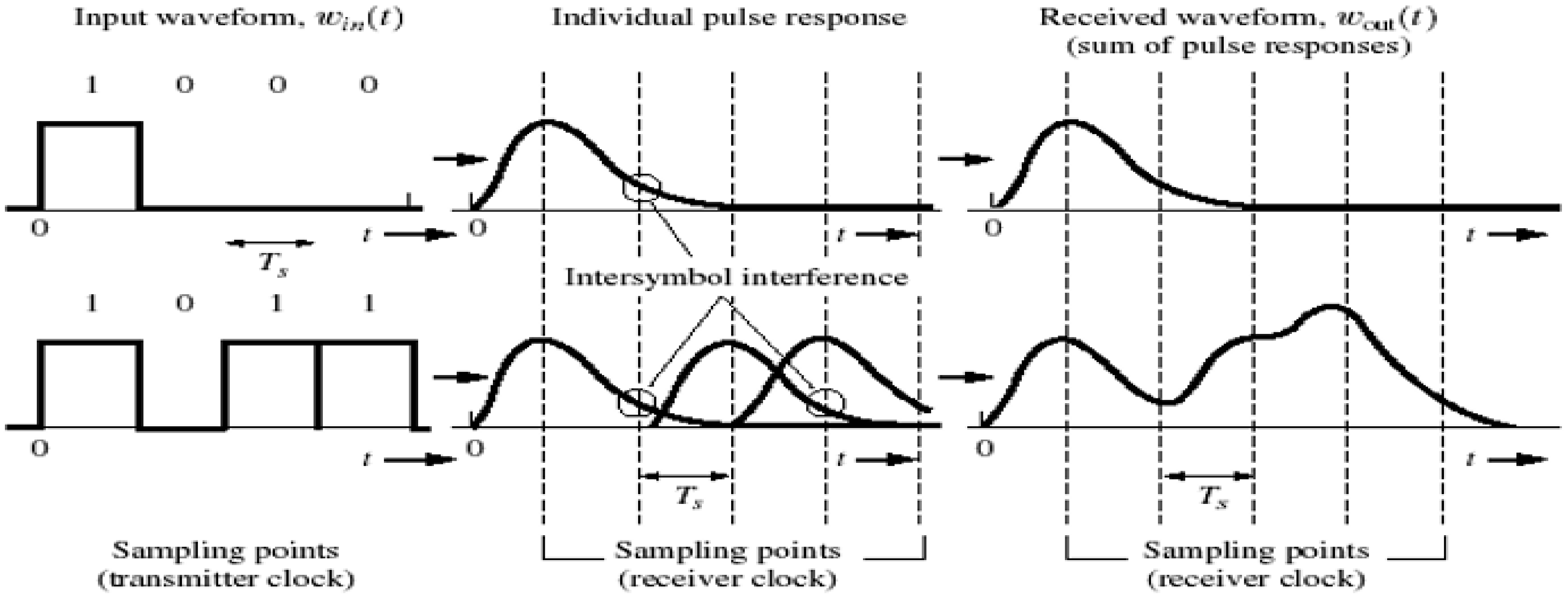


Figure 3–23 Examples of ISI on received pulses in a binary communication system.

Combating ISI

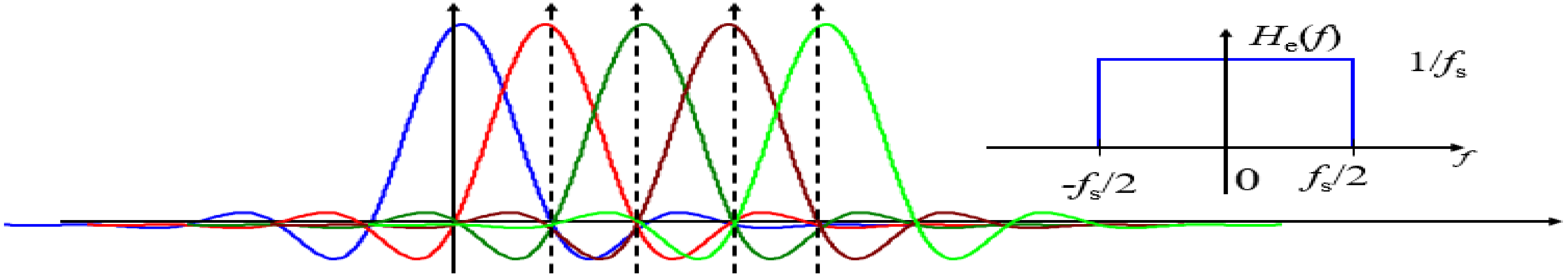
- Three strategies for eliminating ISI:
  - Use a line code that is absolutely bandlimited.
    - Would require Sinc pulse shape.
    - Can't actually do this (but can approximate).
  - Use a line code that is zero during adjacent sample instants.
    - It's okay for pulses to overlap somewhat, as long as there is no overlap at the sample instants.
    - Can come up with pulse shapes that don't overlap during adjacent sample instants.
      - Raised-Cosine Rolloff pulse shaping
  - Use a filter at the receiver to "undo" the distortion introduced by the channel.
    - Equalizer.

Nyquist's First Method for Zero ISI

- There will be **NO ISI and the bandwidth requirement will be minimum (Optimum Filtering)** if the transmit and receive filters are designed so that the overall transfer function $H_e(f)$ is:

$$H_e(f) = \frac{1}{f_s}\prod\left(\frac{f}{f_s}\right) \quad h_e(t) = \frac{\sin \pi f_s t}{\pi f_s t} \quad \text{Where} \quad f_s = \frac{1}{T_s}$$

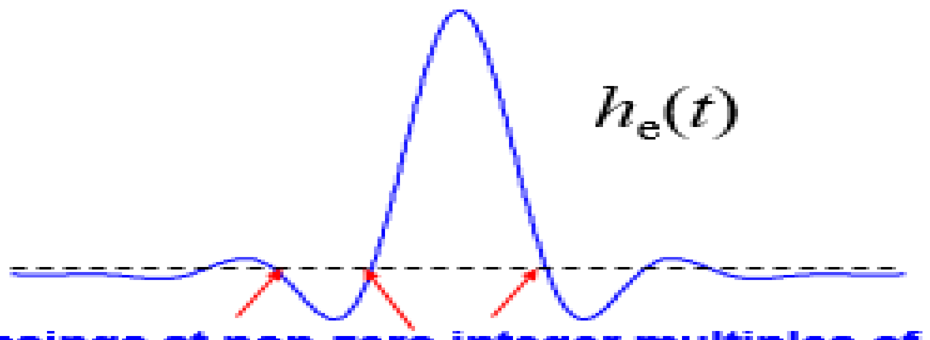
- This type of pulse will allow signalling at a baud rate of $D=1/T_s=2B$ (for Binary $R=1/T_s=2B$) where B is the absolute bandwidth of the system.

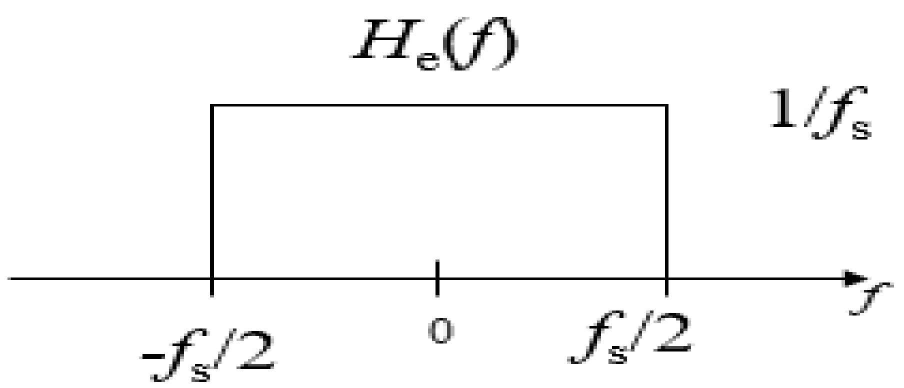


Absolute bandwidth is: $B = \frac{f_s}{2}$ MINIMUM BANDWIDTH

Signalling Rate is: $D=1/T_s = 2B$ Pulses/sec

Nyquist's First Method for Zero ISI





Zero crossings at non-zero integer multiples of the bit period

- Since pulses are not possible to create due to:
  - Infinite time duration.
  - Sharp transition band in the frequency domain.

- The Sinc pulse shape can cause significant ISI in the presence of timing errors.
  - If the received signal is not sampled at *exactly* the bit instant (Synchronization Errors), then ISI will occur.

- We seek a pulse shape that:
  - Has a more gradual transition in the frequency domain.
  - Is more robust to timing errors.

  Yet still satisfies Nyquist's first method for zero ISI.

Nyquist Filter

- **Raised Cosine Filter is also called a NYQUIST FILTER.**
- **NYQUIST FILTERS refer to a general class of filters that satisfy the NYQUIST's First Criterion.**
- **Theorem:** A filter is said to be a Nyquist filter if the effective transfer function is :

$$H_e(f) = \begin{cases} \Pi\left(\frac{f}{2f_0}\right) + Y(f), & |f| < f_0 \\ 0, & f \quad \text{Elsewhere} \end{cases}$$

$Y(f)$ is a real function and even symmetric about $f = 0$:

$$Y(-f) = Y(f), \qquad |f| < 2f_0$$

Y is odd symmetric about $f = f_0$:

$$Y(-f + f_0) = -Y(f + f_0), \qquad |f| < f_0$$

- There will be no intersymbol interference at the system output if the symbol rate is

$$D = f_s = 2f_0$$

Thank You