Qassim University
College of Engineering
Electrical Engineering Department
Electronics and Communications

# Course: EE322 Digital Communications

**Prerequisite:** EE320

**Text Book:** Simon Haykin & Michael Moher, "Communication Systems", John Wiley, 5th edition 2010.

**Ref Book:** Simon Haykin, "Communication Systems", John Wiley, 4th edition, 2001.

www.wiley.com/go/global/haykin

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# InterSymbol Interference (ISI)

Digital data: broad spectrum + significant low-frequency.

We require the use of a low-pass channel with a bandwidth large enough to accommodate the essential frequency content of the data.

The frequency response of a practical channel deviates from that of an ideal low-pass filter.

Each received pulse is affected somewhat by adjacent pulses, thereby giving rise to a common form of interference called ***intersymbol interference* (ISI)** which arises when the communication channel is dispersive.

Intersymbol interference is a major source of bit errors in the reconstructed data stream at the receiver output.

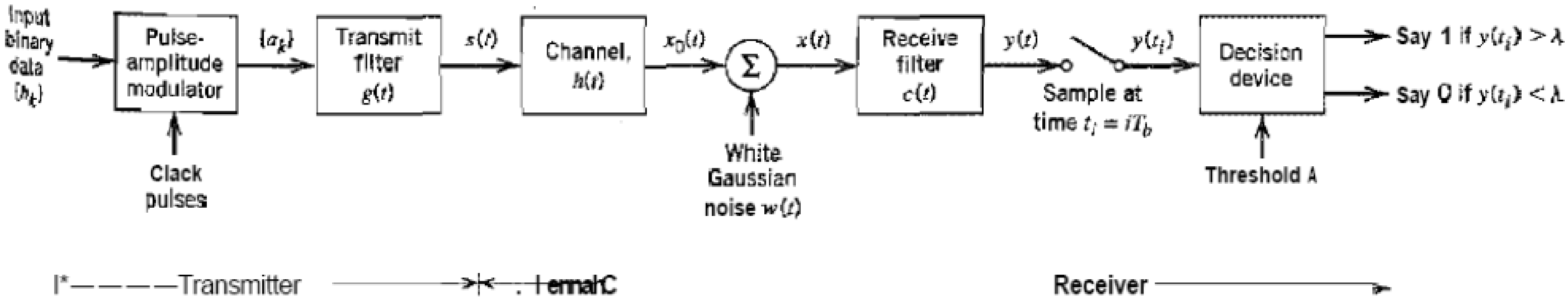



**FIGURE 4.7** Baseband binary *data* transmission *system.*

The incoming binary sequence $\{b_k\}$ consists of symbols 1 and 0, each of duration $T_b$. The pulse-amplitude modulator modifies this binary sequence into a new sequence of short pulses (approximating a unit impulse), whose amplitude $a_k = 1$ if symbol $b_k$ is 1 and $a_k = -1$ if symbol $b_k$ is 0 (polar NRZ form). This sequence of short pulses is applied to **a transmit filter** of impulse response g(t), producing the transmitted signal s(t).

$$s(t) = \sum_k a_k g(t - kT_b)$$

The signal s(t) is modified as a result of transmission through the channel of impulse response h(t). In addition, the channel adds random noise to the signal at the receiver input. The noisy signal x(t) is then passed through **a receive filter** of impulse response c(t). The resulting filter output y(t) is sampled synchronously with the transmitter, with the sampling instants being determined by a clock or timing signal that is usually extracted from the receive filter output. Finally, the sequence of samples thus obtained is used to reconstruct the original data sequence by means of a decision device.

Channel noise and intersymbol interference (ISI) affect on the performance of baseband-pulse transmission systems (bit error rate).

ISI arises because of deviations in the frequency response of a channel from the Nyquist channel (ideal low-pass filter ).

The result of these deviations is that the received pulse corresponding to a particular data symbol is affected by the tail ends of the previous symbols pulses and the front ends of the subsequent symbols pulses.

# EYE PATTERN

One way to study intersymbol interference in a PCM or data transmission system experimentally is to apply the received wave to the vertical deflection plates of an oscilloscope and to apply a sawtooth wave at the transmitted symbol rate R = 1/T to the horizontal deflection plates. The waveforms in successive symbol intervals are thereby translated into one interval on the oscilloscope display, as illustrated in this Fig.

For the case of a binary wave for which T = $T_b$. *The resulting display is called an eye pattern because of its* resemblance to the human eye for binary waves. The interior region of the eye pattern is called the *eye opening.*

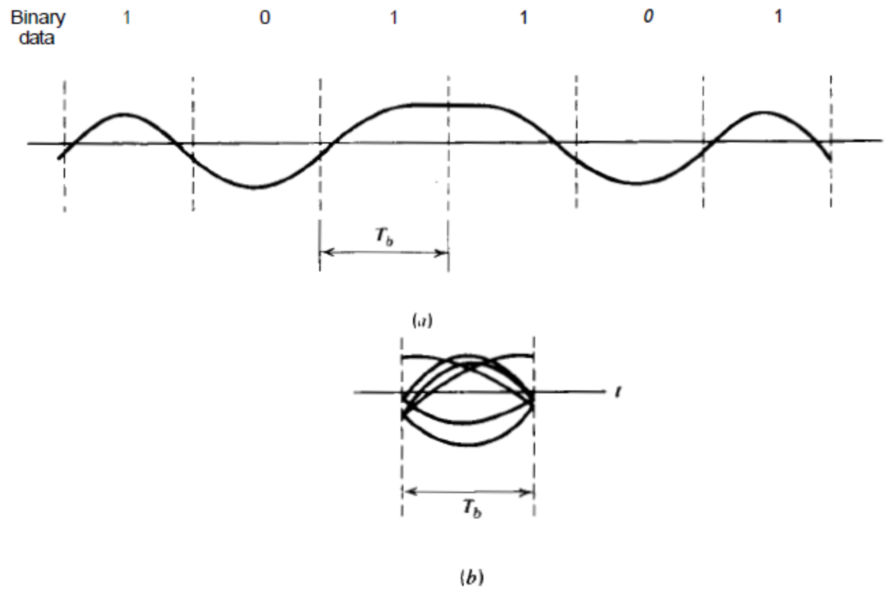
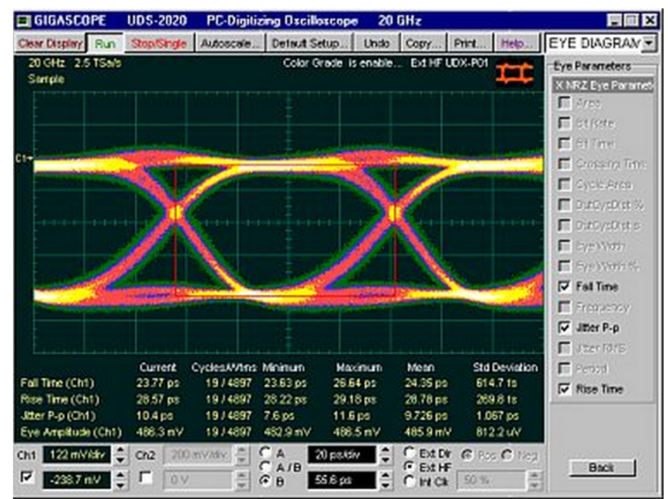
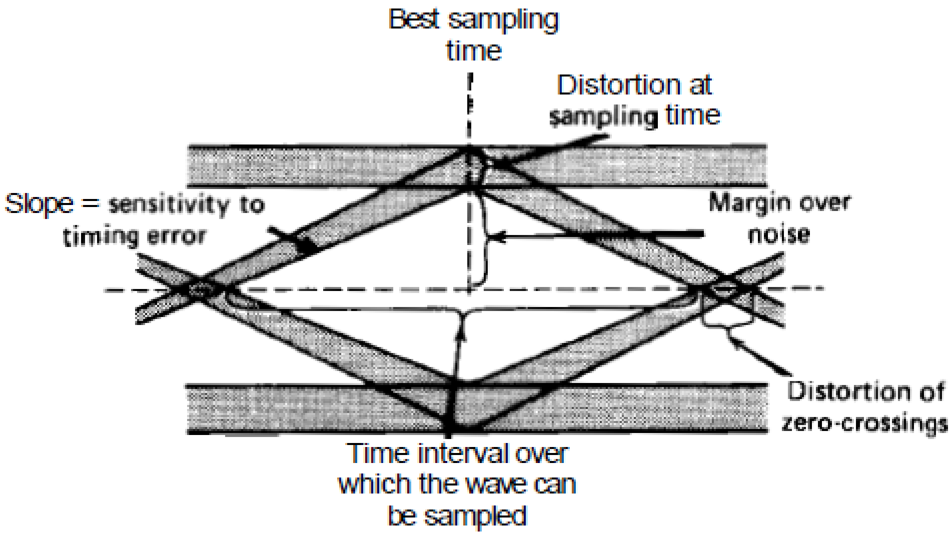



**Figure 6.18** (a) Distorted binary wave. (b) Eye pattern.




**An example of 12-Gbit eye-diagram measurement**



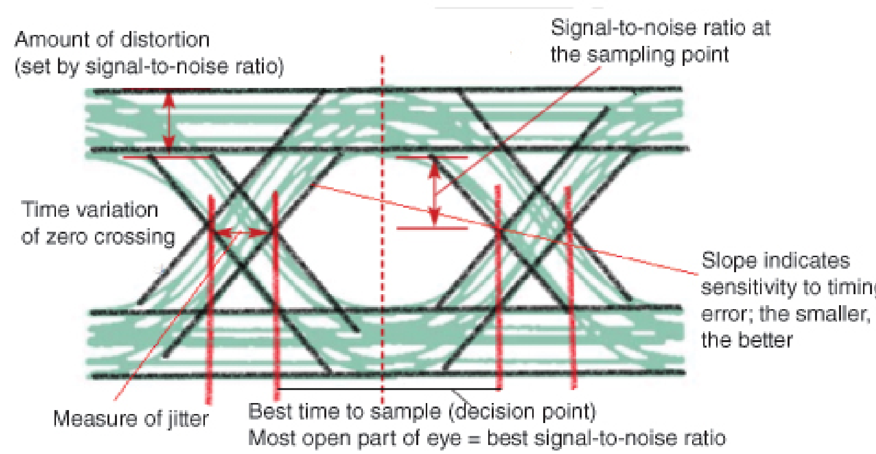




**Figure 6.19** Interpretation of eye pattern.

1. The width of the eye opening defines the time interval over which the received wave can be sampled without error from intersymbol interference. It is apparent that the preferred time for sampling is the instant of time at which the eye is open widest

2. The sensitivity of the system to timing error is determined by the rate of closure of the eye as the sampling time is varied.

3. The height of the eye opening, at a specified sampling time, defines the margin over noise.

When the effect of intersymbol interference is severe, traces from the upper portion of the eye pattern cross traces from the lower portion, with the result that the eye is completely closed. In such a situation, it is impossible to avoid errors due to the combined presence of intersymbol interference and noise in the system, and a solution has to be found to correct for them.