UNIT- III

BASEBAND TRANSMISSION AND RECEPTION

Inter symbol Interference

Generally, digital data is represented by electrical pulse, communication channel is always band limited. Such a channel disperses or spreads a pulse carrying digitized samples passing through it. 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 InterSymbol Interference. In short it is called ISI. 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

![Transmitted Waveform and Pulse Dispersion](Source:Brainkart)

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. First let us have look at different formats of transmitting digital data. In base band transmission best way is to map digits or symbols into pulse waveform. This waveform is generally termed as Line codes.
EYE PATTERN

The quality of digital transmission systems are evaluated using the bit error rate. Degradation of quality occurs in each process modulation, transmission, and detection. The eye pattern is experimental method that contains all the information concerning the degradation of quality. Therefore, careful analysis of the eye pattern is important in analyzing the degradation mechanism.

• Eye patterns can be observed using an oscilloscope. The received wave is applied to the vertical deflection plates of an oscilloscope and the saw tooth wave at a rate equal to transmitted symbol rate is applied to the horizontal deflection plates, resulting display is eye pattern as it resembles human eye.

• The interior region of eye pattern is called eye opening

![Eye Pattern Diagram](Source:Brainkart)

We get superposition of successive symbol intervals to produce eye pattern as shown below.

![Interpretation of Eye Pattern](Source:Brainkart)
• The width of the eye opening defines the time interval over which the received wave can be sampled without error from ISI
• The optimum sampling time corresponds to the maximum eye opening
• The height of the eye opening at a specified sampling time is a measure of the margin over channel noise.

The sensitivity of the system to timing error is determined by the rate of closure of the eye as the sampling time is varied. Any non linear transmission distortion would reveal itself in an asymmetric or squinted eye. When the effected of ISI is excessive, traces from the upper portion of the eye pattern cross traces from lower portion with the result that the eye is completely closed.

**Example of eye pattern:**

Binary-PAM Perfect channel (no noise and no ISI)

![Example of eye pattern](Source:Brainkart)

**EQUALISING FILTER**

Adaptive equalization

• An equalizer is a filter that compensates for the dispersion effects of a channel. Adaptive equalizer can adjust its coefficients continuously during the transmission of data.

Pre channel equalization

• requires feed back channel
• causes burden on transmission.

**Post channel equalization**

Achieved prior to data transmission by training the filter with the guidance of a training sequence transmitted through the channel so as to adjust the filter parameters to optimum values.

**Adaptive equalization**

It consists of tapped delay line filter with set of delay elements, set of adjustable multipliers connected to the delay line taps and a summer for adding multiplier outputs.

![Adaptive equalization](Source:Brainkart)

The output of the Adaptive equalizer is given by

\[ Y(nt) = \sum C_i x(nt - iT) \]

Ci is weight of the ith tap Total number of taps are M. Tap spacing is equal to symbol duration T of transmitted signal. In a conventional FIR filter the tap weights are constant and particular designed response is obtained. In the adaptive equaliser the Ci's are variable and are adjusted by an algorithm.

Two modes of operation

1. Training mode
2. Decision directed mode

**Mechanism of adaptation**

[Diagram of mechanism of adaptation]

*Fig 3.4 Mechanism of adaptation (Source: Brainkart)*

**Training mode**

A known sequence \( d(nT) \) is transmitted and synchronized version of it is generated in the receiver applied to adaptive equalizer. This training sequence has maximal length PN Sequence, because it has large average power and large SNR, resulting response sequence (Impulse) is observed by measuring the filter outputs at the sampling instants. The difference between resulting response \( y(nT) \) and desired response \( d(nT) \) is error signal which is used to estimate the direction in which the coefficients of filter are to be optimized using algorithms.

**Matched Filter**

It is obtained by correlating a known delayed signal, or *template*, with an unknown signal to detect the presence of the template in the unknown signal. This is equivalent to convolving the unknown signal with a conjugated time-reversed version of the template. The matched filter is the optimal linear filter for maximizing the signal-to-noise ratio (SNR) in the presence of additive stochastic noise.

Matched filters are commonly used in radar, in which a known signal is sent out, and the reflected signal is examined for common elements of the out-going signal. Pulse compression is an example of matched filtering. It is so called because the impulse response is matched to input pulse signals. Two-dimensional matched filters are commonly used in image processing, e.g., to
improve the SNR of X-ray observations. Matched filtering is a demodulation technique with LTI (linear time invariant) filters to maximize SNR. It was originally also known as a *North filter*.

**Pulse Shaping**

It is the process of changing the waveform of transmitted pulses. Its purpose is to make the transmitted signal better suited to its purpose or the communication channel, typically by limiting the effective bandwidth of the transmission. By filtering the transmitted pulses this way, the inter symbol interference caused by the channel can be kept in control. In RF communication, pulse shaping is essential for making the signal fit in its frequency band.

Typically pulse shaping occurs after line coding and modulation.

**Need for pulse shaping**

Transmitting a signal at high modulation rate through a band-limited channel can create inter symbol interference. As the modulation rate increases, the signal's bandwidth increases. When the signal's bandwidth becomes larger than the channel bandwidth, the channel starts to introduce distortion to the signal. This distortion usually manifests itself as inter symbol interference.

The signal's spectrum is determined by the modulation scheme and data rate used by the transmitter, but can be modified with a pulse shaping filter. Usually the transmitted symbols are represented as a time sequence of dirac delta pulses. This theoretical signal is then filtered with the pulse shaping filter, producing the transmitted signal.

In many base band communication systems the pulse shaping filter is implicitly a boxcar filter. Its Fourier transform is of the form $sin(x)/x$, and has significant signal power at frequencies higher than symbol rate. This is not a big problem when optical fibre or even twisted pair cable is used as the communication channel. However, in RF communications this would waste bandwidth, and only tightly specified frequency bands are used for single transmissions. In other words, the channel for the signal is band-limited. Therefore better filters have been developed, which attempt to minimize the bandwidth needed for a certain symbol rate.

An example in other areas of electronics is the generation of pulses where the rise time need to be short; one way to do this is to start with a slower-rising pulse, and decrease the rise time, for example with a step recovery diode circuit.
Pulse shaping filters

A typical NRZ coded signal is implicitly filtered with a sinc filter.

Not every filter can be used as a pulse shaping filter. The filter itself must not introduce inter symbol interference — it needs to satisfy certain criteria. The Nyquist ISI criterion is a commonly used criterion for evaluation, because it relates the frequency spectrum of the transmitter signal to intersymbol interference.

Examples of pulse shaping filters that are commonly found in communication systems are:

- Sinc shaped filter
- Raised-cosine filter
- Gaussian filter

Sender side pulse shaping is often combined with a receiver side matched filter to achieve optimum tolerance for noise in the system. In this case the pulse shaping is equally distributed between the sender and receiver filters. The filters' amplitude responses are thus point wise square roots of the system filters.

Other approaches that eliminate complex pulse shaping filters have been invented. In OFDM, the carriers are modulated so slowly that each carrier is virtually unaffected by the bandwidth limitation of the channel.
Sinc filter

It is also called as Boxcar filter as its frequency domain equivalent is a rectangular shape. Theoretically the best pulse shaping filter would be the sinc filter, but it cannot be implemented precisely. It is a non-causal filter with relatively slowly decaying tails. It is also problematic from a synchronization point of view as any phase error results in steeply increasing inter symbol interference.

Raised-cosine filter

Raised-cosine is similar to sinc, with the tradeoff of smaller side lobes for a slightly larger spectral width. Raised-cosine filters are practical to implement and they are in wide use. They have a configurable excess bandwidth, so communication systems can choose a trade off between a simpler filter and spectral efficiency.

Gaussian filter

This gives an output pulse shaped like a Gaussian function.

Nyquist criterion

When the baseband filters in the communication system satisfy the Nyquist criterion, symbols can be transmitted over a channel with flat response within a limited frequency band, without ISI. Examples of such baseband filters are the raised-cosine filter, or the sinc filter as the ideal case.