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

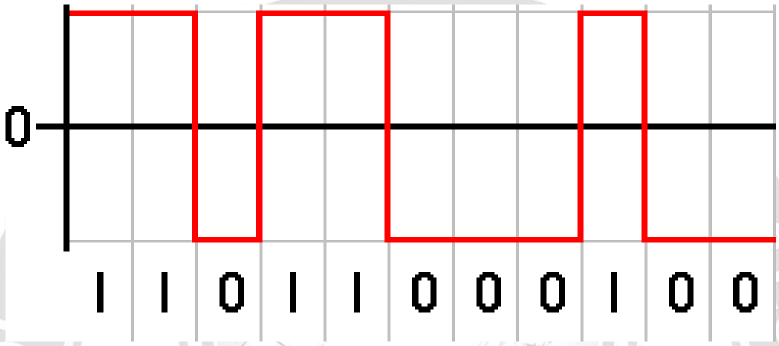
Transmitting a signal at high modulation rate through a band-limited channel can create inter symbol interference. As the modulation rate increases, the signal's bandwidth increases. When the signal's bandwidth becomes larger than the channel bandwidth, the channel starts to introduce distortion to the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



(Source:Brainkart)

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

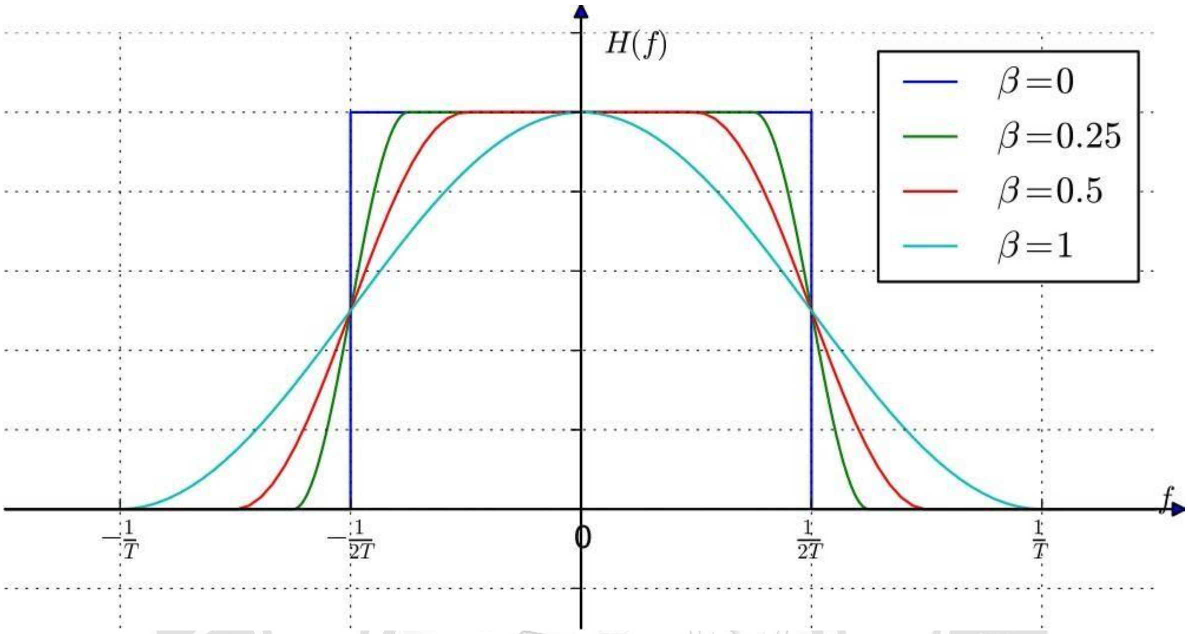


Fig 3.5 Amplitude response of raised-cosine filter with various roll-off factors (Source:Brainkart)

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.

Correlative Coding

So far, we've discussed that ISI is an unwanted phenomenon and degrades the signal. But the same ISI if used in a controlled manner, is possible to achieve a bit rate of **2W** bits per second in a channel of bandwidth **W** Hertz. Such a scheme is called as **Correlative Coding** or **Partial response signaling schemes**.

Since the amount of ISI is known, it is easy to design the receiver according to the requirement so as to avoid the effect of ISI on the signal. The basic idea of correlative coding is achieved by considering an example of **Duo-binary Signaling**.

Duo-binary Signaling:

The name duo-binary means doubling the binary system's transmission capability. To understand this, let us consider a binary input sequence $\{a_k\}$ consisting of uncorrelated binary digits each having a duration T_a seconds. In this, the signal **1** is represented by a **+1** volt and the symbol **0** by a **-1** volt.

Therefore, the duo-binary coder output c_k is given as the sum of present binary digit a_k and the previous value a_{k-1} as shown in the following equation.

ck=ak+ak−1ck=ak+ak−1

The above equation states that the input sequence of uncorrelated binary sequence $\{a_k\}$ is changed into a sequence of correlated three level pulses $\{c_k\}$. This correlation between the pulses may be understood as introducing ISI in the transmitted signal in an artificial manner.