Systems and Information Theory 4 - Channels and Waveforms

4.1 Introduction & Objectives

This topic discusses the way in which a channel is utilised for communication, and explains how to choose a signalling waveform.

At the end of the topic you will be able to:

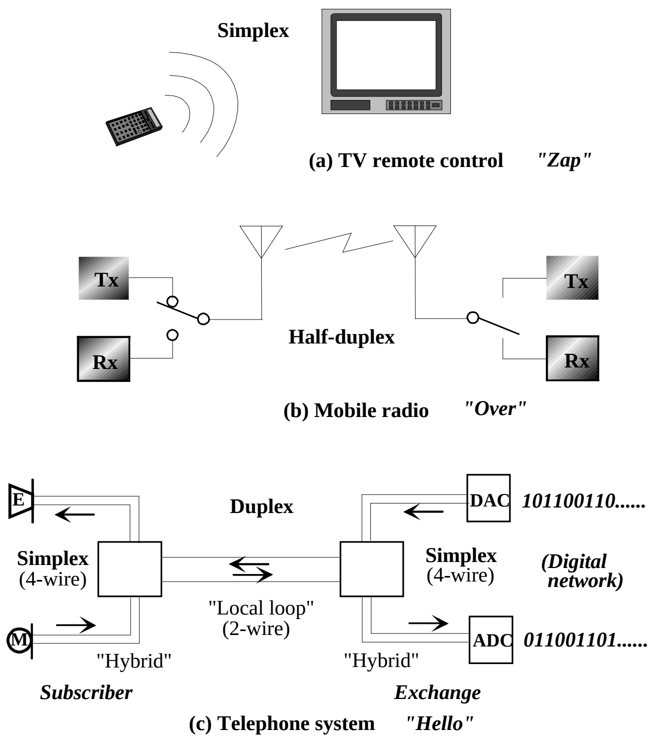
State the difference between Simplex, Half-duplex and Duplex protocols
Explain why polar signalling is more efficient than unipolar
Give examples of RZ and NRZ waveforms
Show through examples how the choice of linecode affects dc level drift, bandwidth and clock synchronisation

4.2 Essential Reading

You will find this material in any elementary comms textbook, especially the following

Usher and Guy, "Information and Communication for Engineers"
Bateman, A, " Digital Communications"
Petersen, “Audio, Video and Data Telecommunications"

4.3 The Transmission protocol



A communication channel can be classified according to the *transmission protocol* in use: it can be in **Simplex, Half-duplex or Full-Duplex** mode.

A **simplex** channel transmits in one direction only: for example, radio or tv broadcasting, or a remote control for a tv or Hi-Fi.

A **half-duplex** channel can transmit in either direction *but not at the same time*. An example is a single frequency radio channel with a Tx/Rx[1] combination at either end as used in mobile radio for taxis, police or emergency services[2]. (not to be confused with mobile phones.)

A **full-duplex** channel can transmit in both directions simultaneously, like any form of telephone, traditional or mobile. A channel that appears to be full-duplex often consists of two simplex channels in parallel. (**Fig 10-1c**), or is a half-duplex channel with rapidly alternating send and receive modes.

Fig 4-1 Transmission protocols

[1] Tx = transmitter: Rx = Receiver!

[2] Such channels require an operational protocol to control their use: eg the use of "Over" to transfer the channel to the other party.

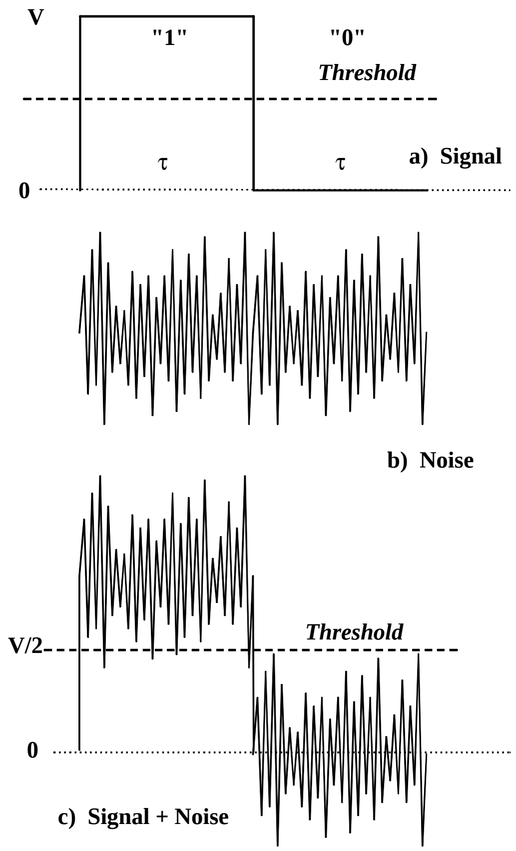
4.4 Signalling Waveforms

A digitised signal is represented by a signalling waveform chosen to suit the channel. However, the obvious **On/Off** representation of the 0/1 binary code is seldom used for the following reasons.

4.4.1 Peak and Average signal power

Consider a mobile phone: the average power transmitted determines the battery life of the phone, and a low peak power allows the use of cheaper transistors in its output stage. Both peak and average power are affected by the choice of waveform.

4.4.1.1 The On/Off (Unipolar) waveform



A pulse of amplitude V has a peak power V^2:.

Assuming an equal number of 1's and 0's in a typical message the *average* power will be $V^2/2$.

The detection threshold separating 1's from 0's would normally be set half way, giving a ***noise margin*** of V/2.

The on/off waveform is called a *Unipolar* signal.

Fig 4.2 A Unipolar waveform

4.4.1.2 The Polar waveform

A **polar** waveform, as shown in **Fig 4.3**, with an amplitude of +/-V/2 has the same noise margin as the unipolar waveform if the detection threshold is set at 0.

However, the peak and the average signal power are now only $V^2/4$.

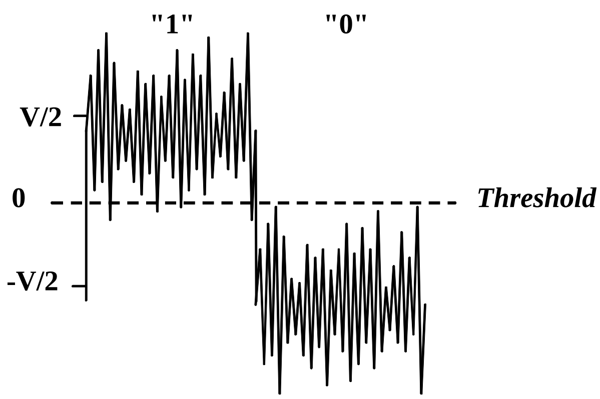


Fig 4.3. A Polar Waveform

***For the same noise immunity as an "on/off" signal, the polar waveform has a 3dB saving in average power, and a 6dB saving in peak power*.**

4.4.2 Synchronisation and clock recovery - NRZ and RZ waveforms

As well as being energy efficient – eg polar signalling better than on-off signalling– we must be able to locate the position in time of each symbol so that we can correctly sample its value. This is the *synchronisation* problem. In telephone systems it may be feasible to transmit a clock signal over a parallel network, but it is more usual *for the signal to contain its own timing information*. This can be obtained from the edges of the symbols, but the problem with unipolar and polar signals is that there are no edges for long strings of 0's or 1's so that we may lose synchronisation - see **Fig 4.4 (a).**

These signals do not give good clock recovery and are described as *Non-Return-To Zero* (NRZ) waveforms. **Fig 4.4(b)** shows a *Return-To-Zero* (RZ) polar signal which has edges for every symbol. It can be seen that it gives a precise clock signal when rectified. Note, however, that there are many more short pulses in this waveform, which increases the bandwidth of the signal.

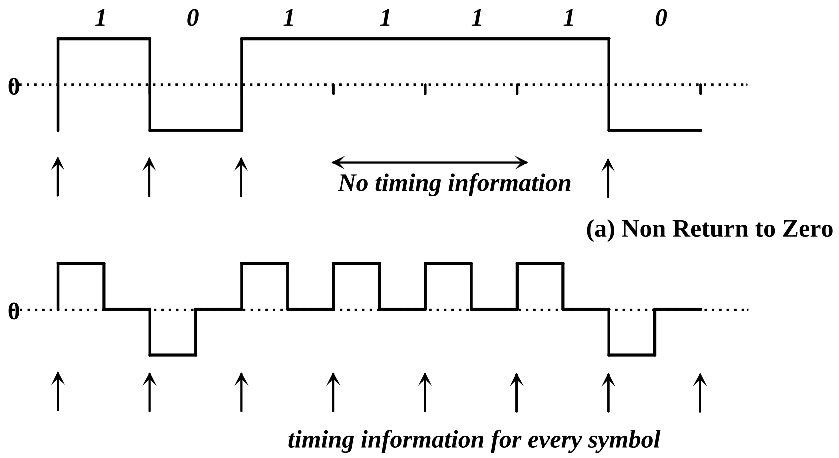


Fig 4.4 Recovery of timing information

4.4.3 DC level drift

If the symbol probabilities are equal, the overall average value, or dc level, of a polar waveform will be zero, however, for a long string of 0's or 1's the *short-term* dc level will drift down or up (**Fig 4.5**).

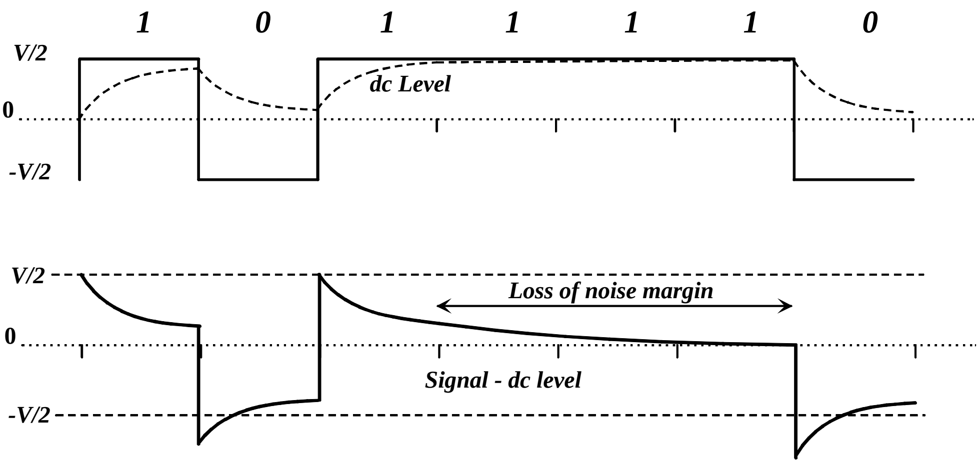


Fig 4.5 DC level drift

This is a problem for networks that are ac-coupled through capacitors, transformers or ac amplifiers, ie where the frequency response does not extend down to dc. The effect is to cause the signal level to drift towards zero during a long string of 0's or 1's and the noise margin is reduced, thus increasing the error rate.

This can be avoided by the use of of a signalling waveform that *has zero average value for every symbol*. **Fig 4.6.** shows a *split-phase* signal (known as Manchester coding) that is used on local area computer networks (LANs).

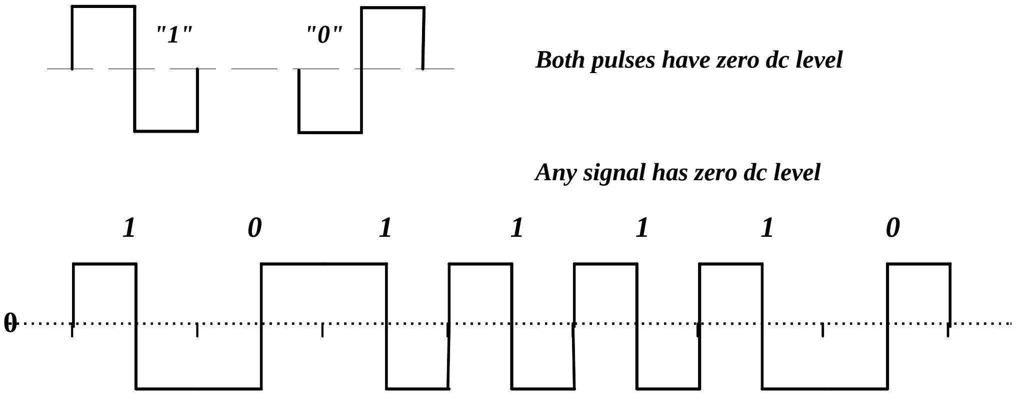


Fig 4.6 Split-phase or Manchester coding

4.4.4 The linecode

The signalling waveform is known as the *line-code*: we have shown that desirable properties for a line-code are

- good clock recovery (RZ waveforms)
- zero dc level (polar signals, Manchester coding)
- large noise margin. (polar signals)
- low bandwidth (NRZ)

In addition we look for

- data transparency,

  so that its properties are retained whatever the message might be, and

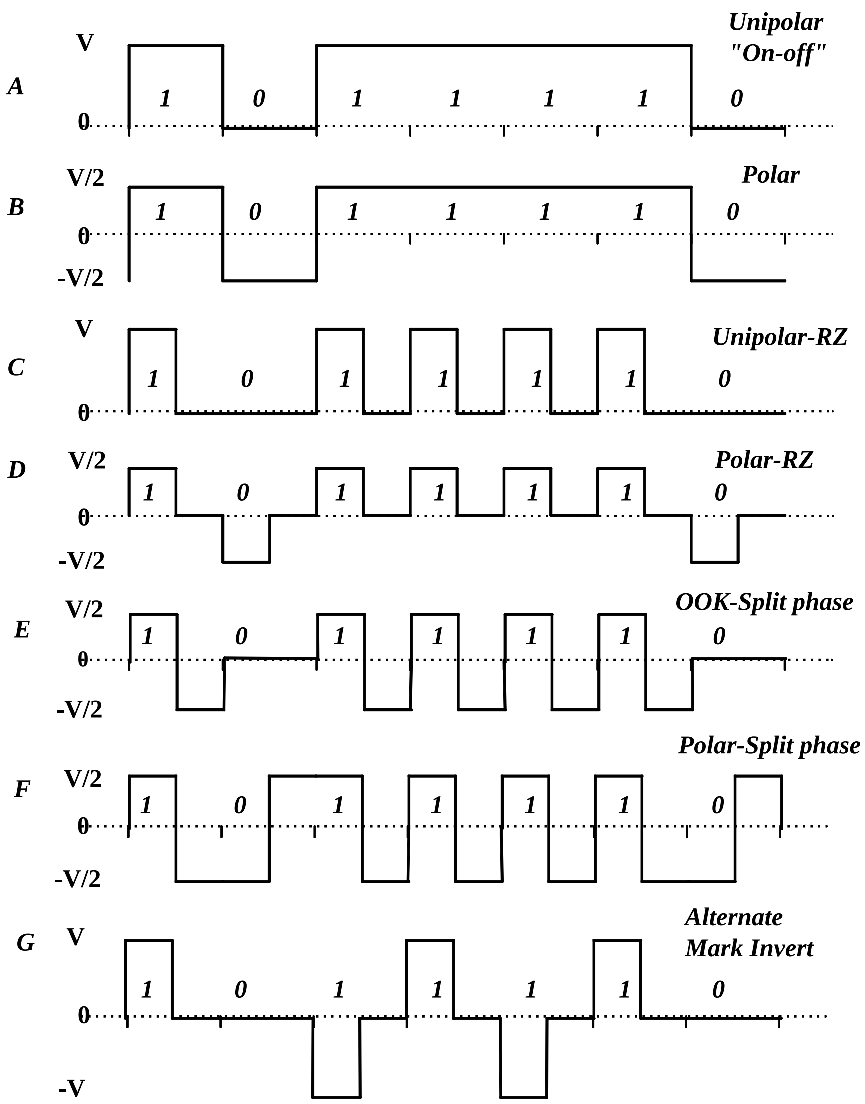
- ability to detect errors,

  since some errors are unavoidable.

It is apparent that some of these requirements conflict with each other, and the choice of a code will depend on what is most important for that channel.

Line codes for Baseband signalling

(*constant noise margin* $^V/_2$)



Av Power	*Pk Power*	*Timing*	*DC Level*	*Bandwidth*