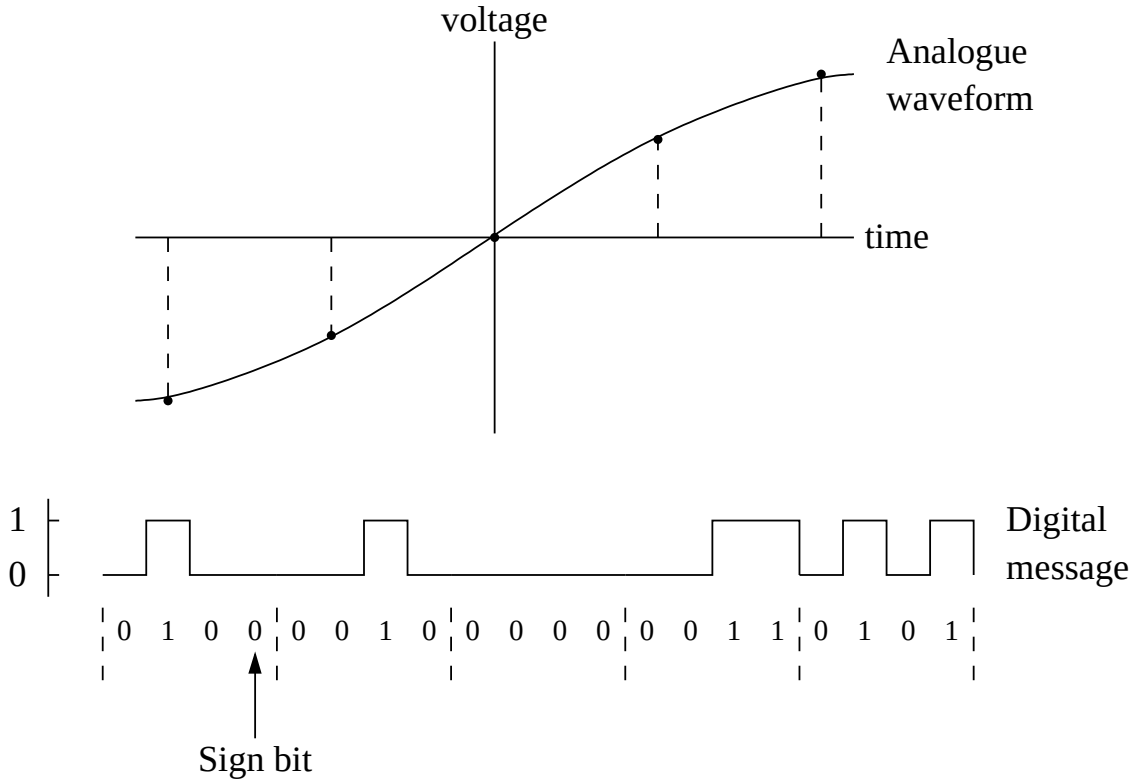
Introduction

Purpose of a communication system: to transport an information-bearing signal from a source to a user destination via a communication channel:

- **Analogue system**: the information-bearing signal varies continuously in both amplitude and time, and is used to modify some characteristic of a sinusoidal carrier wave (eg. amplitude, phase, frequency)
- **Digital system**: the information-bearing signal is processed so that it can be represented by a sequence of *discrete messages*.



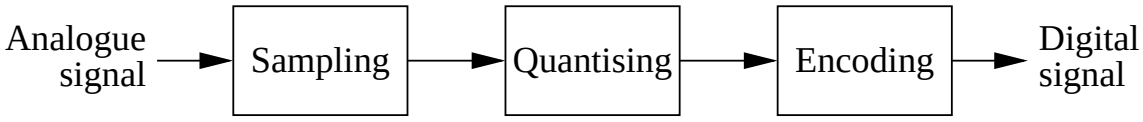
The growth of digital communications is due to:

- Computers, both as sources of data and as tools for communications.
- The *flexibility* and *compatibility* of digital communications.
- Improved *reliability*.
- The availability of wide-band channels.

- The availability of integrated solid-state technology.

1 Sources and signals

An analogue signal can be converted to digital form by **sampling**, **quantising**, and **encoding**:

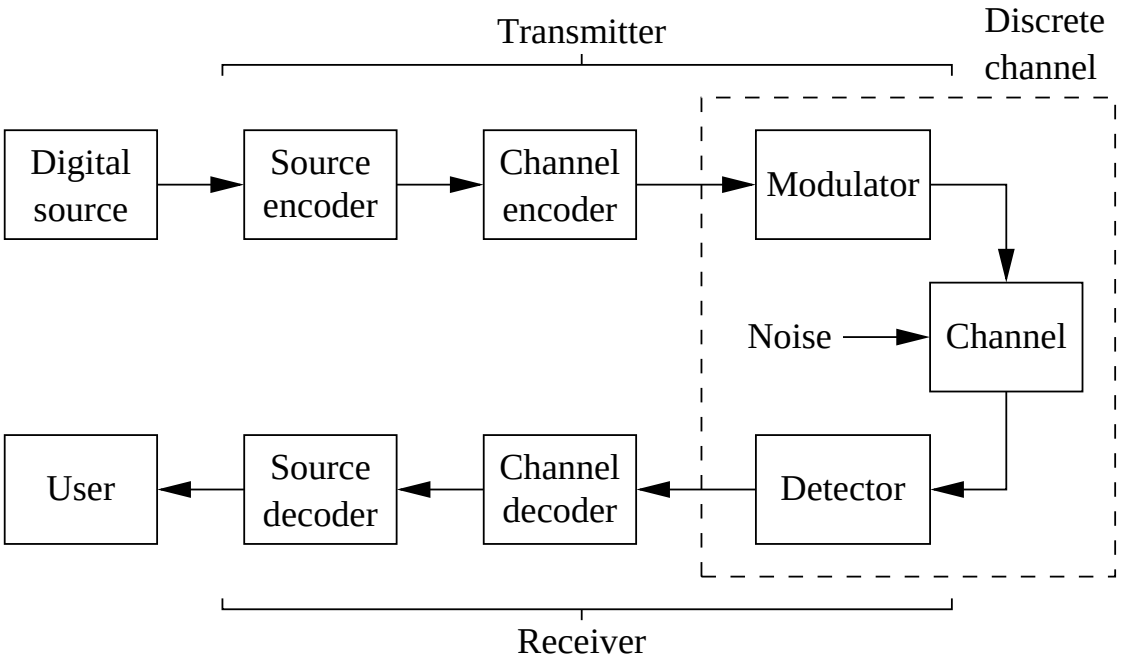


- In the *sampling* operation, only sample values of the analogue signal at uniformly spaced discrete instants of time are retained — discretisation in time.
- In the *quantising* operation, each sample value is approximated by the nearest level in a finite set of discrete levels — discretisation in value.
- In the *encoding* operation the selected level is represented by a **code word** that consists of a prescribed number of **code elements**.

The sampling and quantisation operations are *nonreversible*, and introduce errors into the digital representation of an analogue signal. However these errors are under the designer’s control, and can be made as small as required.

2 Signal processing operations in digital communications

Once the data is in a digital form, it can serve as an input to a digital communication system:



- In **source coding**, the encoder maps the digital signal at the source to another signal in digital form. The mapping is one-to-one, and is designed to eliminate or reduce redundancy. Source decoding is then simply the inverse operation. The primary benefit to be gained from source coding is to reduce bandwidth requirements.

  Morse code is an example of a source encoding technique that achieves this goal: common characters are represented by short codes, and vice versa (eg. $e \longleftrightarrow \cdot$, while $q \longleftrightarrow - - \cdot -$).

- In **channel coding**, the objective is to map the signal to a form where *reliable communication* can be achieved over a noisy channel. This may be achieved by introducing controlled redundancy into the signal. The channel decoder attempts to reconstruct the original encoder input as accurately as possible. The choice of channel coding depends considerably on the channel over which the data will be transmitted.

  Block codes, *convolutional codes*, and more recently *block turbo codes* are examples of channel encoding techniques — the literature and surrounding theory is vast.

- **Modulation** is performed to provide for *efficient transmission* of the

signal over the channel. It operates by keying shifts in the amplitude, frequency, or phase of a sinusoidal carrier wave to the channel encoder output. The detector performs demodulation, attempting to produce a signal that follows the time variations in the channel encoder output.

Modulation is required for transmitting over a band-pass channel.

These operations are not necessarily always performed in a real communication system.

3 Channels for digital communications

The details of modulation and coding used in a digital communication system depend on the characteristics of the channel and the application. *Bandwidth* and *power* constitute the primary communication resources available to the designer. Other channel characteristics are

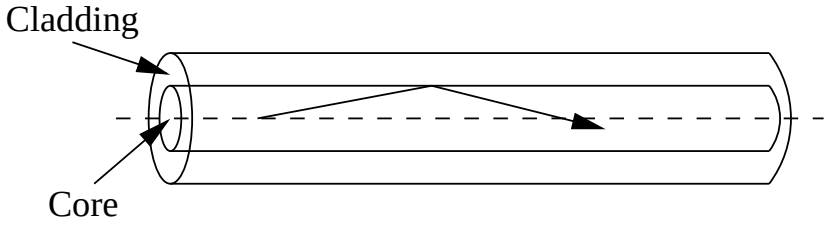
- Extent of determinism in amplitude and phase responses.
- Channel linearity or nonlinearity.
- Degree of external interference.

Some examples of communication channels are

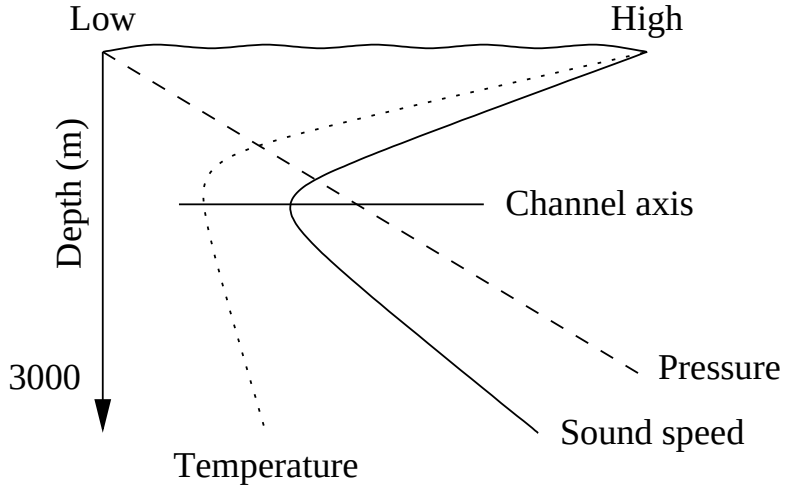
- **Telephone channel:** designed for voice-grade communication, and encompasses a variety of transmission media and a complex of switching systems. The channel has a band-pass characteristic occupying the frequency range 300 to 3400Hz, and has a high SNR of around 30dB. The channel is designed to have a flat amplitude response over the pass-band, but no particular attention is given to phase response.
- **Coaxial cable:** consists of a single wire conductor centered inside an outer conductor. The channel has a relatively high bandwidth (274Mbit/s), and is resistant to outside interference. However, the

operational characteristic requires closely spaced *repeaters* (1km intervals).

- **Optical fiber:** consists of a fine inner *core* made of silica glass, surrounded by a concentric layer of glass *cladding*. The core has a higher refractive index than the cladding, which guides the propagation of a ray of light inside the core of the fiber from one side to another. Optical fibers offer higher transmission bandwidths and longer repeater separations than coaxial cables.



- **Deep sound channel:** Due to temperature and pressure variations with depth in the ocean, a deep sound (SOFAR) channel exists which, for audio signals, operates in a similar manner to optical fibers. The channel is about 1km deep, and low-frequency sound signals can travel thousands of kilometers and still be detected.



Note that the speed of sound in water is proportional to both temperature and pressure.

- **Microwave radio:** This channel operates on line-of-site between transmitter and receiver, at frequencies of about 1–30GHz. Under

ideal atmospheric conditions the radio channel operates as a nondispersive transmission medium, capable of reliable high-speed signal transmission. At other times, however, anomalous propagation conditions may develop (multipath fading), causing severe degradation in performance.

- **Satellite channels:** consists of a satellite (usually in geostationary orbit), a uplink from a ground station, and a downlink to another ground station. On board the satellite there is a low-power amplifier, usually operating in a nonlinear mode to boost efficiency. Typically microwave frequencies are used, and the satellite acts as a repeater in the sky. However, the nonlinear nature of the channel restricts its use to constant envelope modulation techniques.

The methods used for digital communications depend on the channel characteristics.