COMP2011 -- **Networks**, Databases and Graphics

2. Encoding bits

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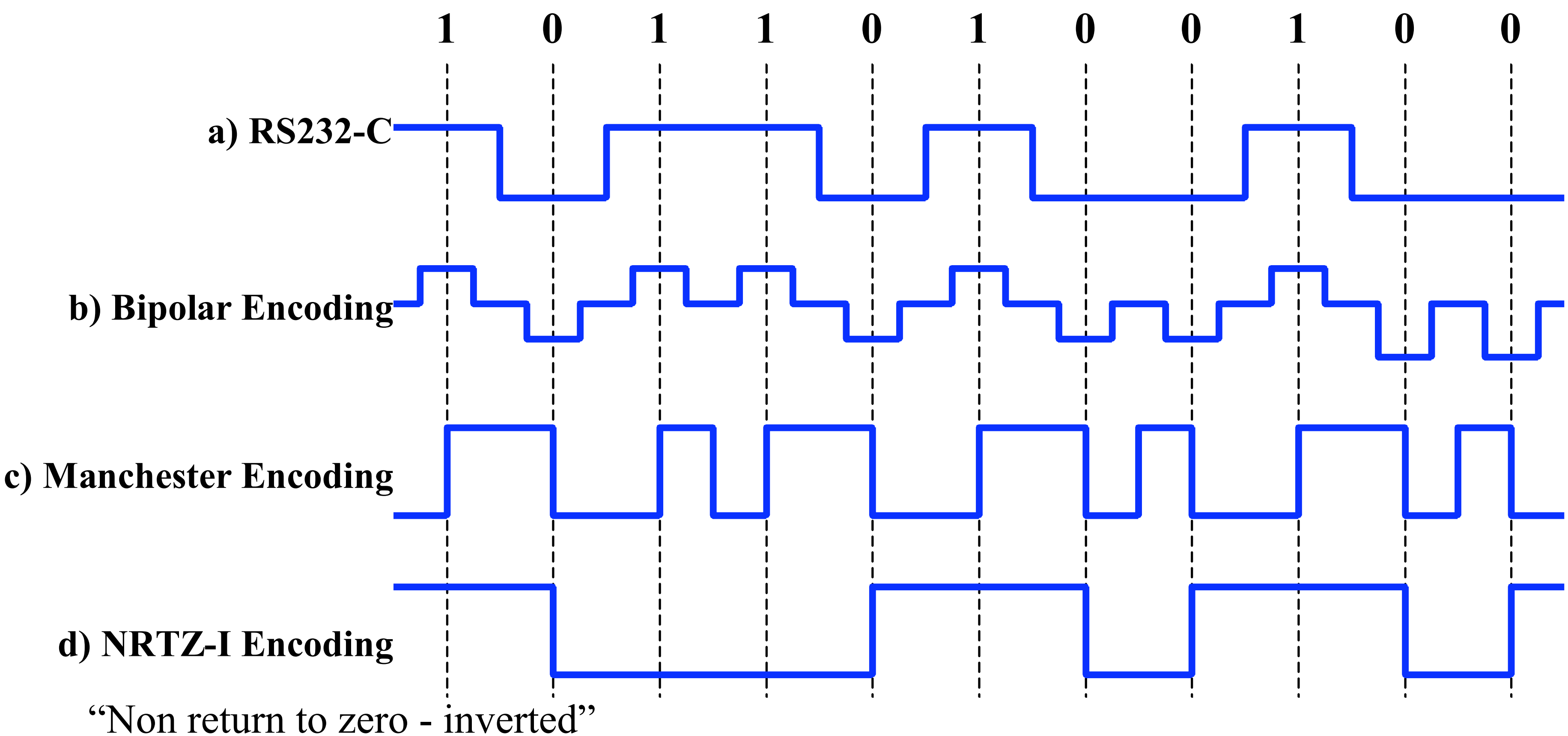
Part 1. Encoding bits

Introduction

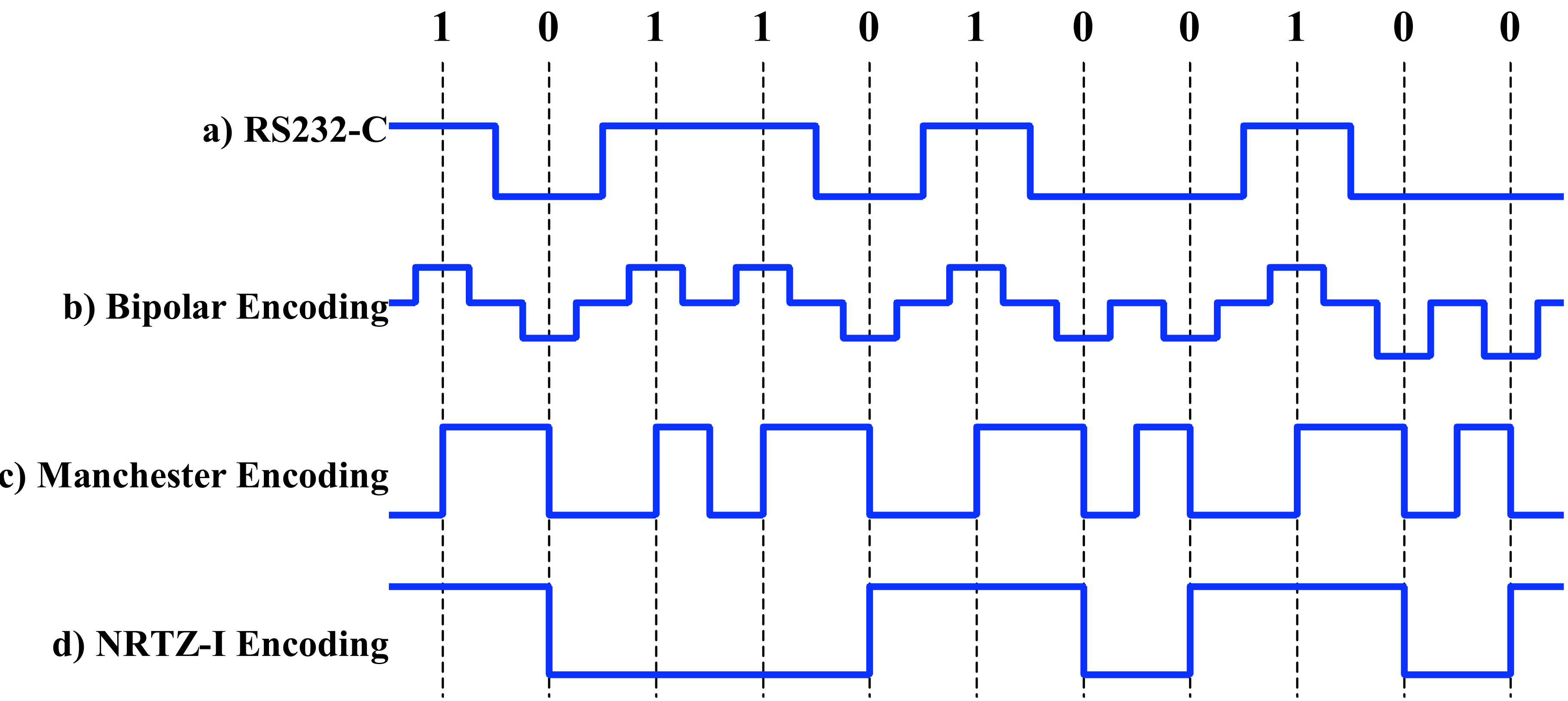
- We need to represent bits as electrical or optical signals
  – digital data -> digital or analogue signals
- Baseband – encode the bits directly
- Broadband – modulate a carrier wave
- Receiver must be able to “see” where bits begin and end
- We also need to be able to group bits into “frames”
- Receiver must be able to “see” where frames begin and end

Baseband encoding

- Digital data -> digital signal
- Receiver must sample signal at correct intervals



Baseband encoding

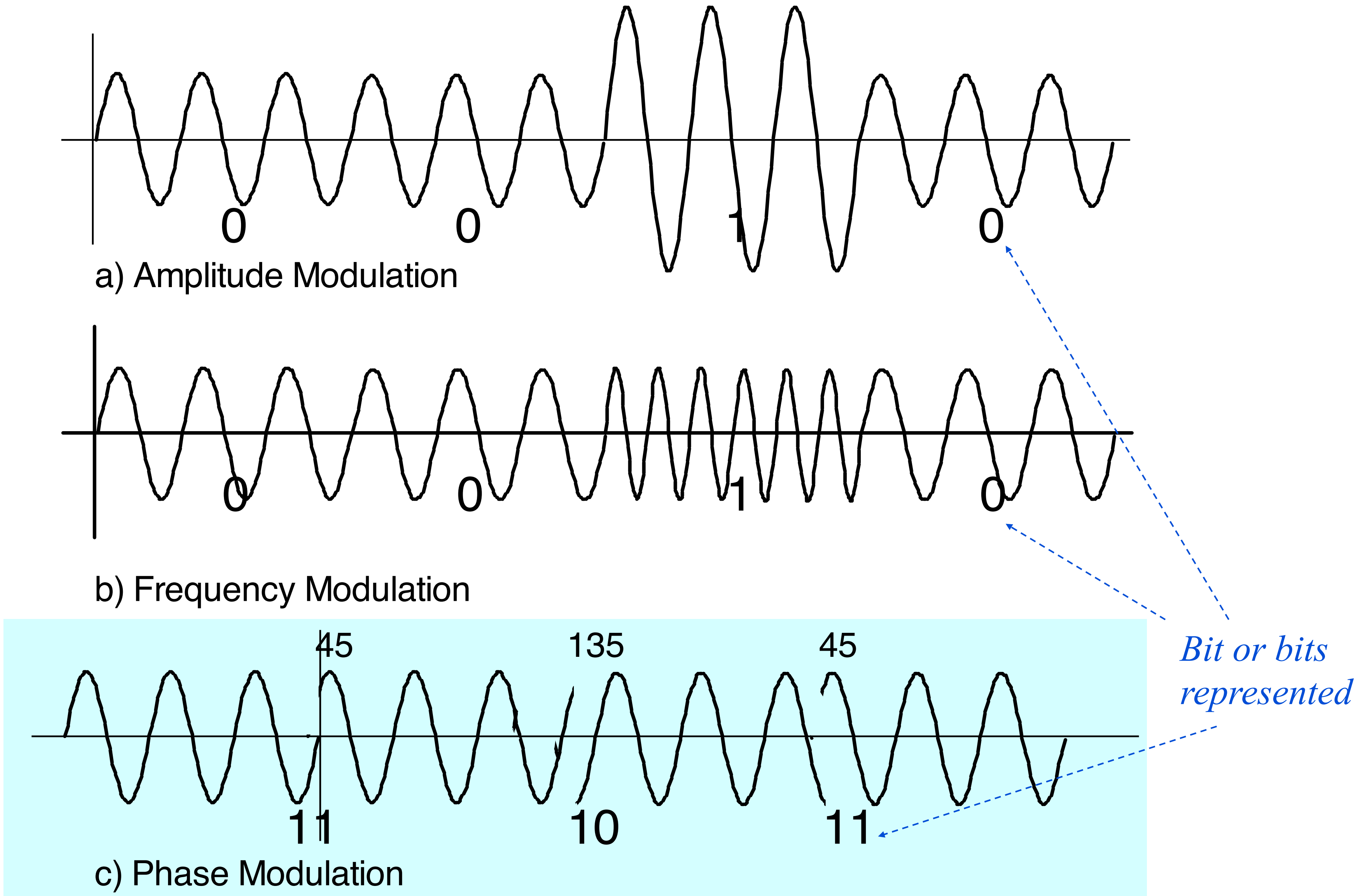


- b) and c) have transitions for every bit
- a) and d) minimise transitions

Modulation

- A typical binary digital signal makes sudden changes between levels. This is equivalent to very high frequencies.
- The PSTN cannot carry these frequencies so the binary signal will be hopelessly distorted.
  - PSTN frequency range: 300Hz-3400Hz
- To send digital data over the PSTN we have to modulate the signal – i.e. we make it look like a speech signal (digital data -> analogue signal).
- Most signals carried by communication channels are modulated forms of sinusoidal waves.

Modulation

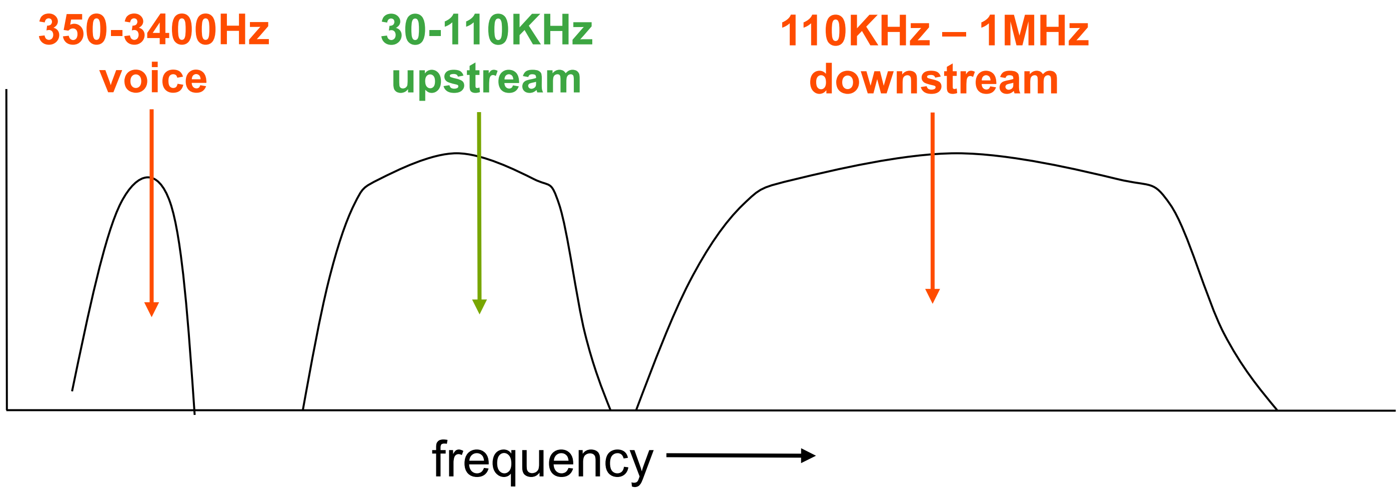

0
0
1
0
a) Amplitude Modulation
0
0
1
0
b) Frequency Modulation
45
135
45
11
10
11
c) Phase Modulation
Bit or bits represented

Phase modulation

- Phase shift encoding has many variants
- BPSK – Binary Phase-Shift Keying
  - 2 phase: 0° and 180° (bit value: 0, 1)
- QPSK – Quad Phase-Shift Keying
  - 4 phase: 45°, 135°, 225°, 315° (11, 10 , 00, 01)
  - Non-differential encoding: need to generate a reference signal to compare each symbol against
- DQPSK – Differential Phase-Shift Keying
  - 4 phases: 0°, 90°, 180°, 270° (00, 01, 11, 10)
  - Differential encoding: compare the phase of current symbol with phase of previously received symbol
- All phase-shift encoding systems need to limit long repeats of particular data values
  - e.g. QPSK 11111111, DPSK 00000000

Broadband

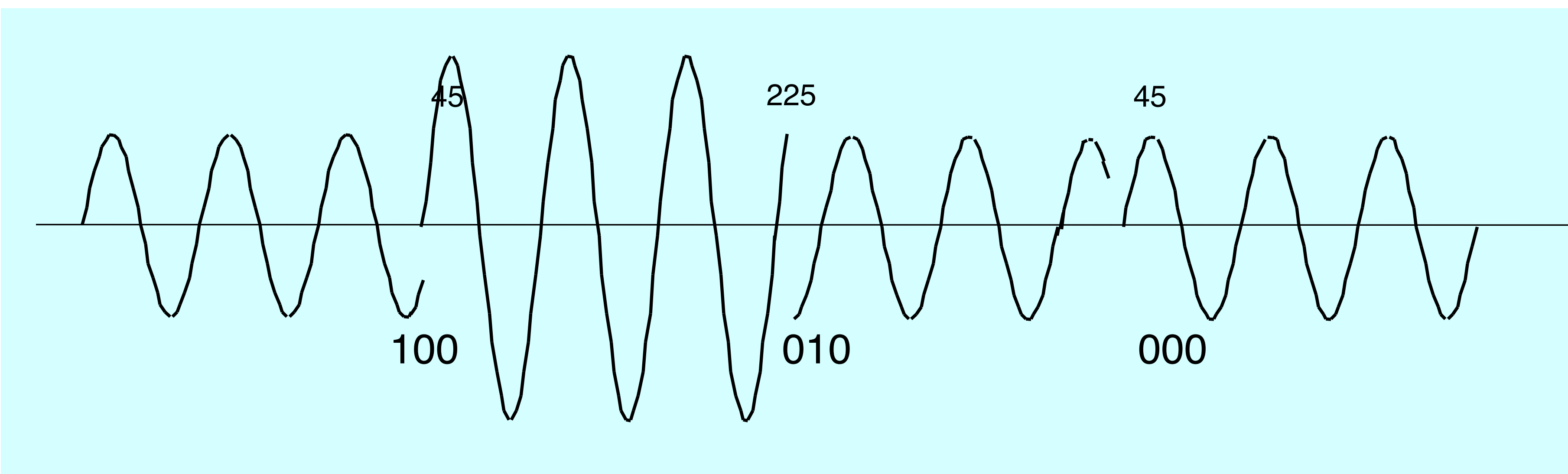
- Broadband runs over standard telephone wires



- Local loop spectrum
  - all 3 ranges can be used at once
  - downstream has highest bandwidth so higher capacity than upstream
  - non-broadband phone has filter to remove frequencies above voice

Broadband

- Using phase & amplitude modulation
  - An example: 2 amplitudes, 4 phase changes 45°, 135°, 225°, 315°
    - no amplitude change, 45° phase change - data 000
    - amplitude change, 45° phase change - data 100
  - In practice, broadband is much more complex than this



Part 2. Signal bandwidth

1. Signalling
2. Baseband signalling
   (no carrier wave)
3. Broadband signalling
   (mapped to a carrier wave)

Signalling

- Any signal can be considered to consist of a combination of sinusoidal signals of different frequencies each with its own amplitude.
- Signals of different frequencies don’t interact: this means that they can be separated out from a channel by appropriate filtering.
- The bandwidth of a signal is the range of frequencies in a signal.
- The maximum signal data rate within a transmission is controlled by the bandwidth, B, of the transmission and is
  2B signals/second.
- The actual signal rate may well be less than the maximum: it depends on the encoding system.
- The maximum data rate in bits/sec is $2B\log_2 M$, where M is the number of bits a signal used in a transmission.

The maximum frequency f_m

- The maximum frequency, f_m, in a signal is determined by the shortest time period, t_s, between 2 edges in the same direction in a signal: 2 up or 2 down

$$f_m = 1/t_s$$

- Same definition for baseband and broadband signals

Baseband signalling [1]

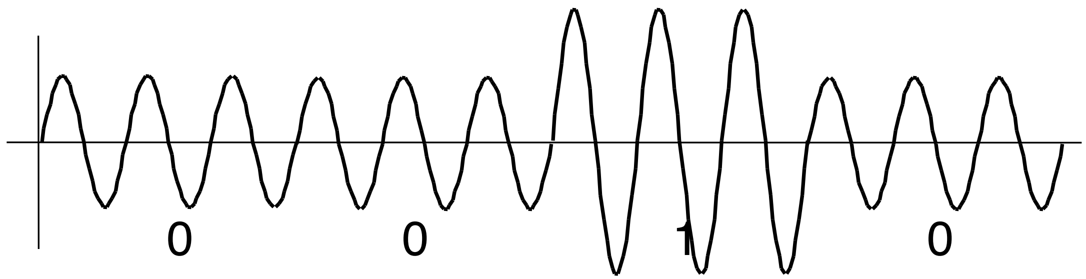
- A baseband signal (no carrier wave) has a range of frequencies from 0Hz upwards
  - 0Hz: produced by a very long series of repeats of one signal, e.g. 00000…..0000000000.....
- The maximum frequency of a baseband signal $f_m = 1/t_s$
- Bandwidth = $freq_{max} - freq_{min} = f_m – 0 = f_m$
- The maximum signal capacity = $2f_m\log_2M$.

Baseband signalling [2]

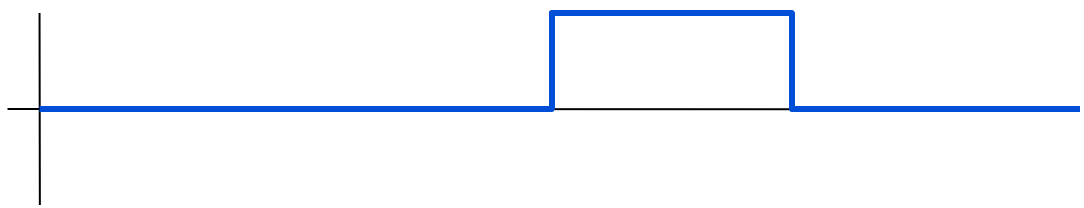
- The sharp transitions (rising/falling edges) of a baseband signal, e.g RS232C, produce signals with higher frequencies than f_m defined above.
- These higher frequencies do not carry extra information: they merely allow the transitions to be more clearly recognised.
- They do require the bandwidth of the channel to be larger than f_m without any gain in the data rate
  - or rather, the signal cannot use the full frequency range or capacity of the channel

Broadband signalling [1]

transmission
= carrier + signal



signal



Frequency range of **signal**: $0 - f_m$ bandwidth: f_m

Frequency of **carrier**: f_c bandwidth: 0

Frequency range of **carrier + signal**: $f_c - f_m/2$ to $f_c + f_m/2$ bandwidth : f_m

Sampling rate to completely recreate carrier + signal: $2*(f_c + f_m/2)$

Sampling rate to completely recreate signal: $2f_m$

Channel Capacity = $2f_m \log_2(M) = 2f_m \log_2(2) = 2f_m$
(M=2 because signal has two symbols: 0 and 1)

Broadband signalling [2]

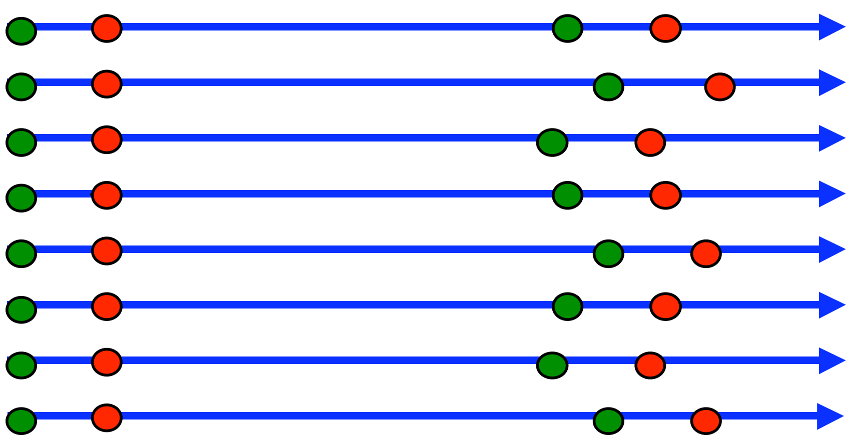
- Broadband does not try to transmit sharp transitions so as to reduce the higher frequency components in the transmission
  – So that the transmission frequencies can be better matched to the physical channel being used
  – or, it can use more of the capacity of the channel than baseband can

Part 3.   Frame

Serial or Parallel?

- Digital data is usually stored in 8-bit, 16-bit or 32-bit chunks
- Parallel transmission sends several bits in parallel – e.g. computer bus

– only for short distance due to the problems of “skew”

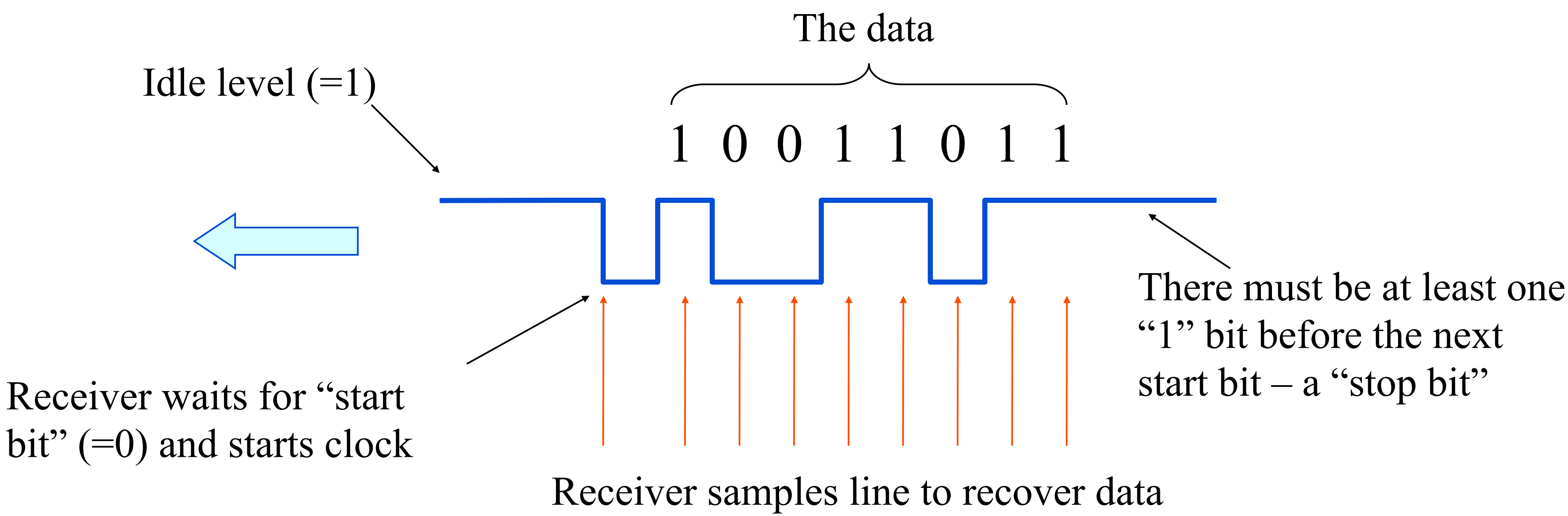


- Serial transmission sends bits successively

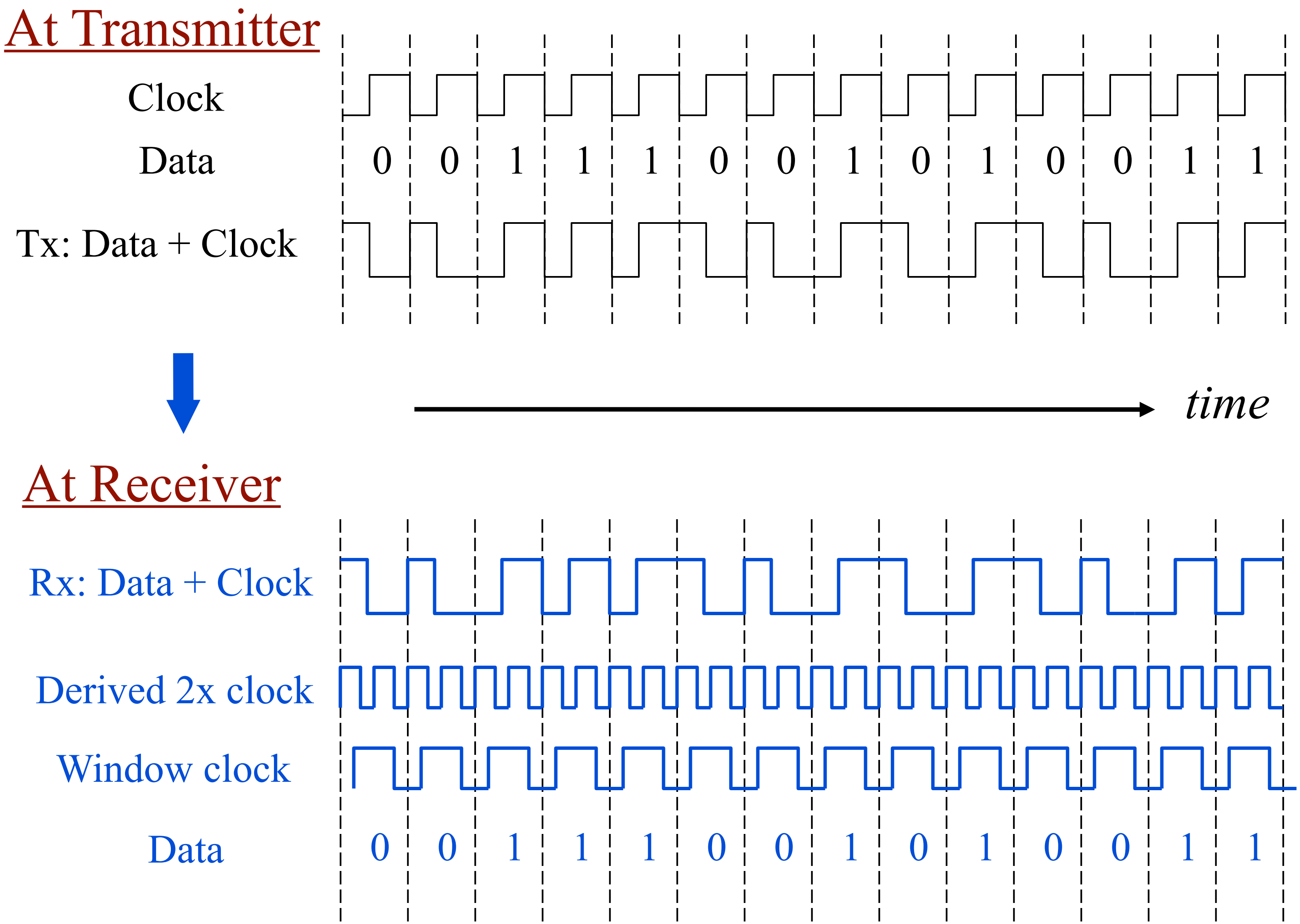
– most data transmission is serial

Asynchronous Framing

- Async. frames usually carry 8 bits
  - Receiver must detect start then count in the bits
  - Receiver must clock bits at the same rate as the transmitter

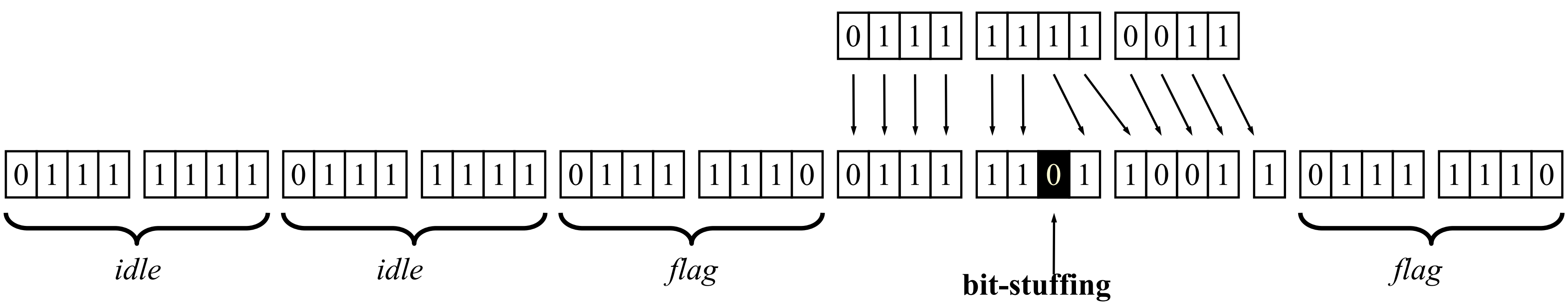


Synchronous serial data transfer



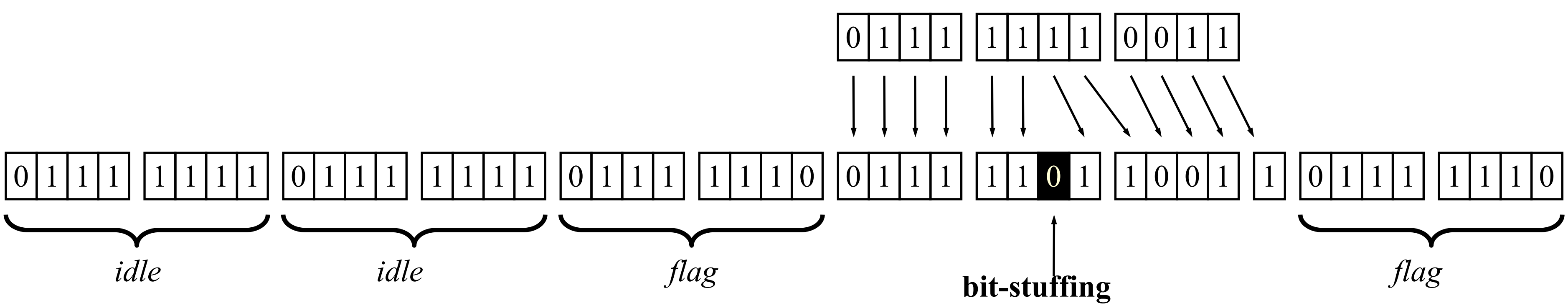
Bit-oriented Synchronous Framing

- Data may be arbitrary length
- Special bit patterns:
  - ***flag*** - 01111110
  - ***idle*** - 01111111
- One ***flag*** at start of data and one at end of data
- Several ***idle*** patterns before the start ***flag***
  - bit-synchronisation



Bit-oriented Synchronous Framing

- If data contain ***flag*** or ***idle*** patterns, i.e. 5 successive 1s, a 0 bit is inserted
  - bit-stuffing, transparency
  - done by hardware, ‘on the fly’
- This type of framing is used in most digital networks, e.g. LANs, ISDN, Frame Relay etc.



Part 4. Review

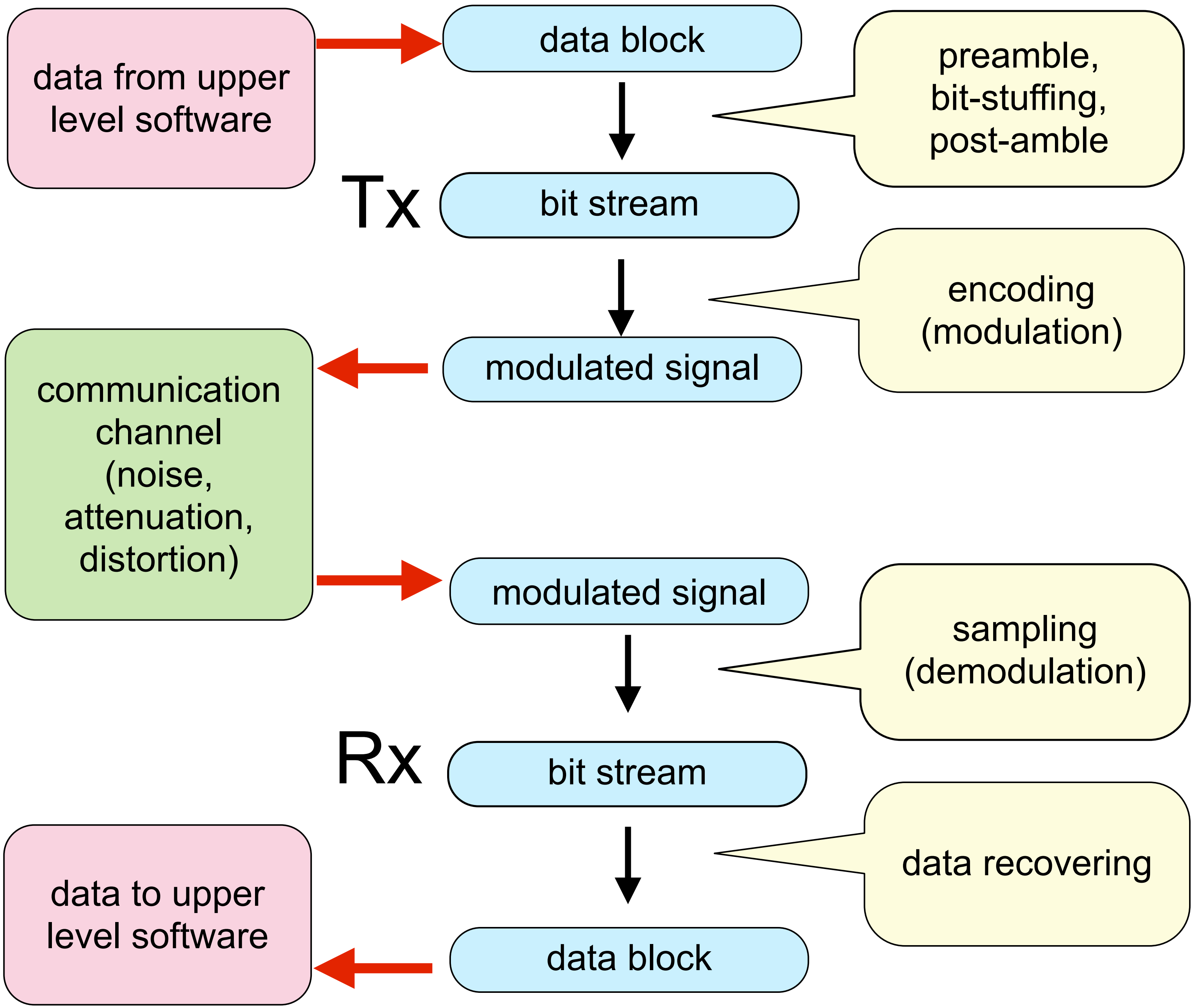
The story so far………

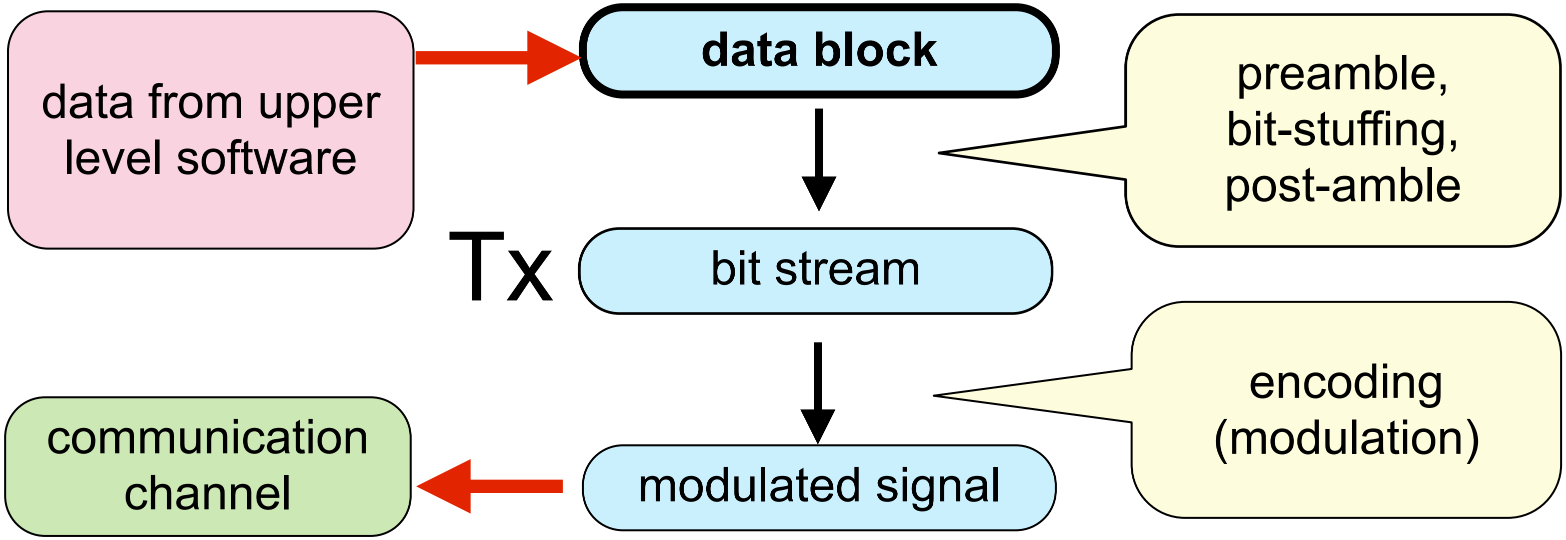
we have examined the transmission of data over a communication channel at the lowest (physical) level.

we have covered briefly the transmission of a block of data, i.e. bit-oriented synchronous framing.

Note: a “packet” is an example of a block.

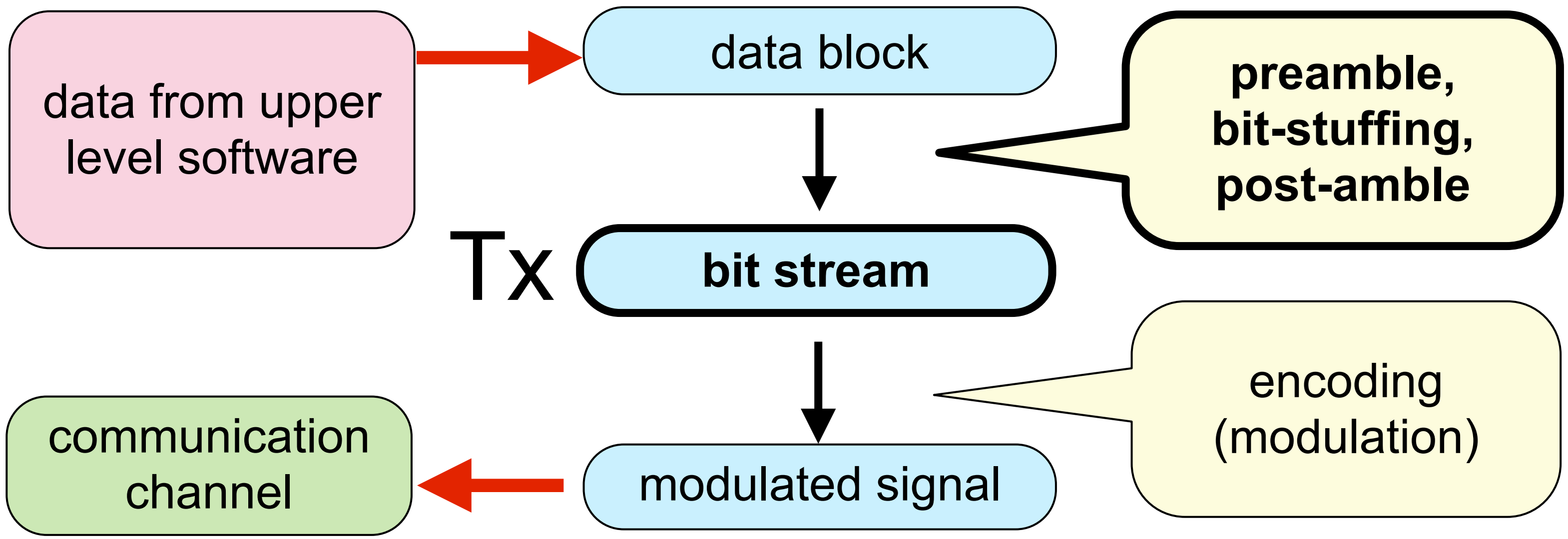
Let us review process of sending a block of data over a communication channel, using a broadband encoding scheme.


data from upper level software
data block
preamble, bit-stuffing, post-amble
Tx
bit stream
encoding (modulation)
communication channel (noise, attenuation, distortion)
modulated signal
modulated signal
sampling (demodulation)
Rx
bit stream
data recovering
data to upper level software
data block



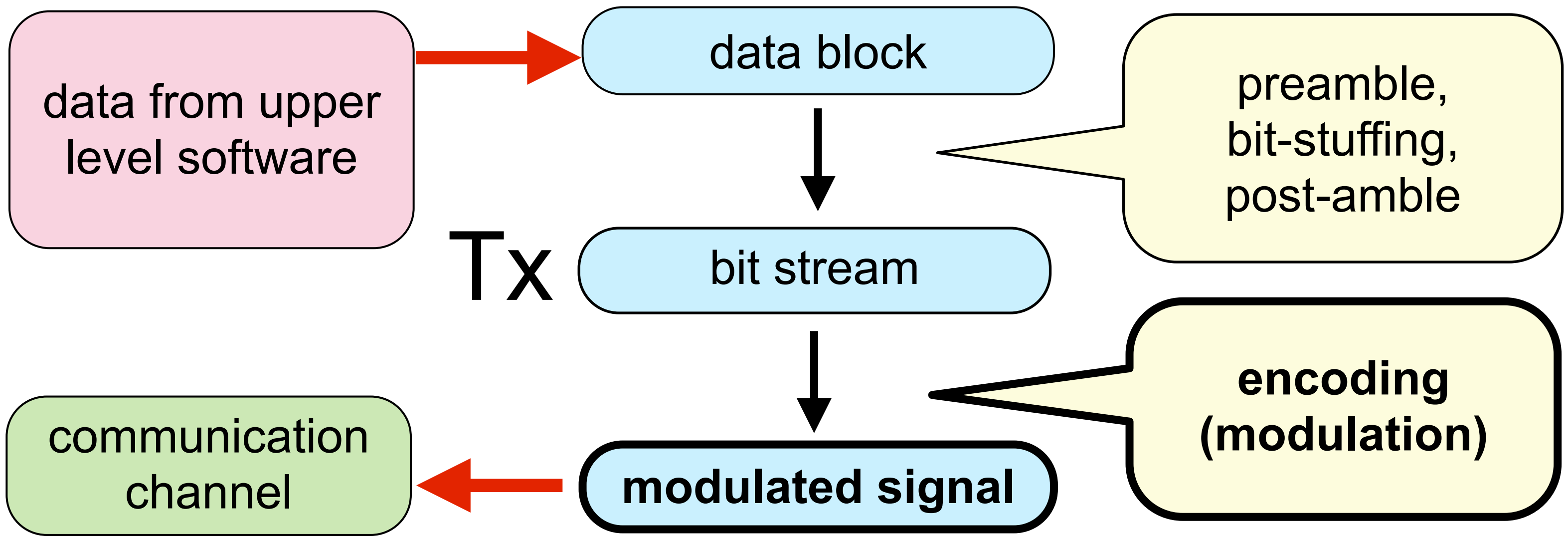
A block of "data" is a set of bytes provided by a higher (usually software) level:

- what data bytes represent is not known at physical level, only understood at higher levels;
- size of block is determined by software but limited to what hardware can manage;
- whether block is one of a set of blocks or not is not relevant.



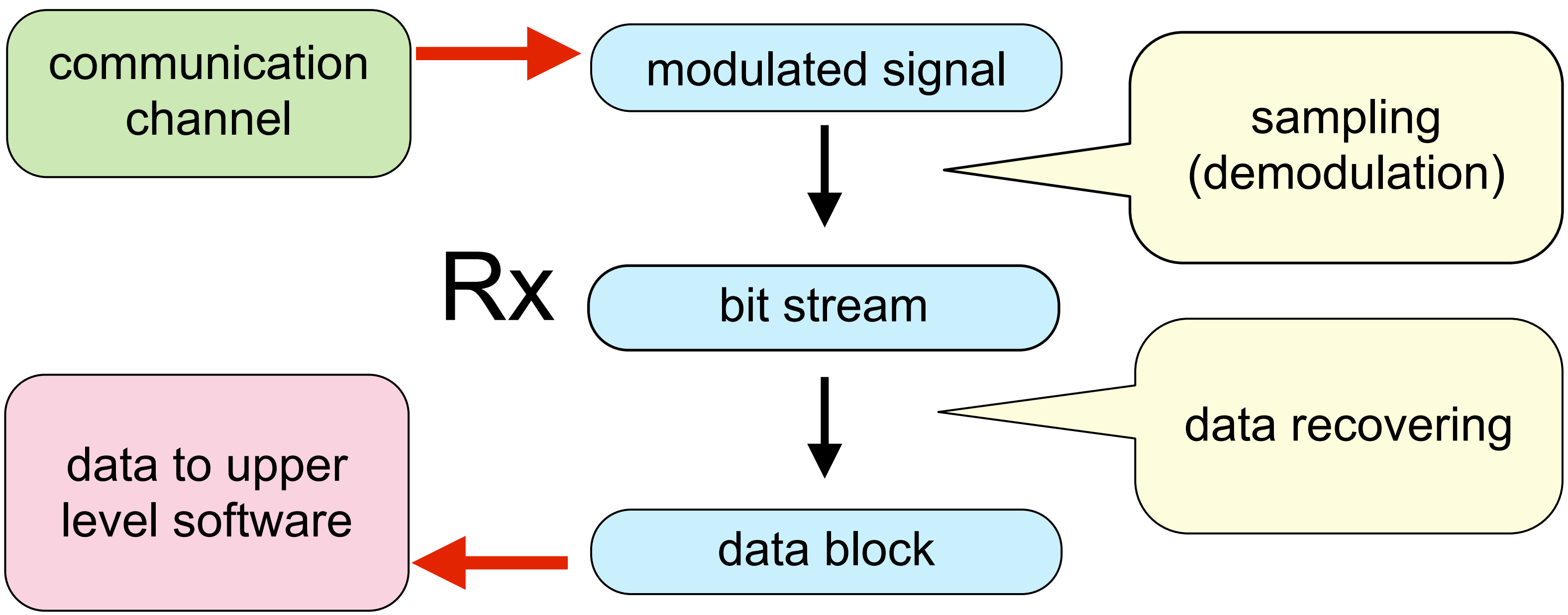
Processing of data to produce a bit stream for transmission

- prepend any pre-amble to the start of block, e.g. “idle” and “flag” bytes in bit-oriented synchronous framing;
- do any processing of data in block, e.g. to prevent particular bit sequences from occurring by applying “bit-stuffing”;
- append any post-amble to end of block, e.g. “flag” byte in bit-oriented synchronous framing, or hardware generated CRC bits (covered later).



- The logic values are modulated on to the carrier frequency using the modulation technique appropriate to the broadband technology used by the channel, i.e. amplitude, frequency, phase modulation or some combination of these. The modulated signal is sent down the channel.
- The frequency range in the sent signal is (fc-(fm/2)) to (fc+(fm/2)), where fc is the carrier frequency, and fm is bandwidth of the bit stream.
- Broadband techniques are used for long distance transmissions (anything greater that a few feet), because they produce transmission signals with smaller bandwidths than baseband techniques.

- Rx samples the incoming signal at twice the maximum bandwidth expected in the signal, i.e. at 2xfd if the channel bandwidth is being fully utilised.
  - It does not need to sample at (2fc+fm) as the carrier frequency is not of interest. This sampling process demodulates the received signal to recover the data bit stream.
- The receiver decodes the bit stream, removes any pre-amble or post-amble, and removes any bit-stuffing etc.
  - Edges in the bit stream are used to keep the Rx clock synchronised to the (implicit) clock in the signal stream.



The End