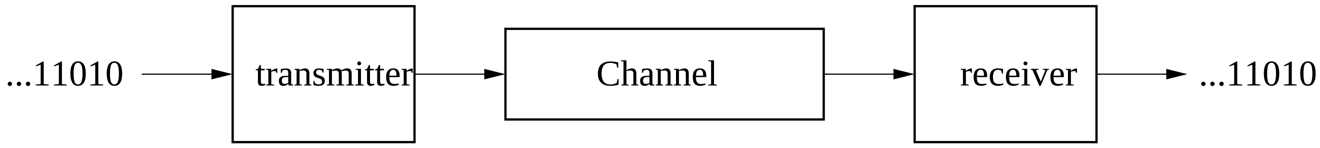
Physical Layer

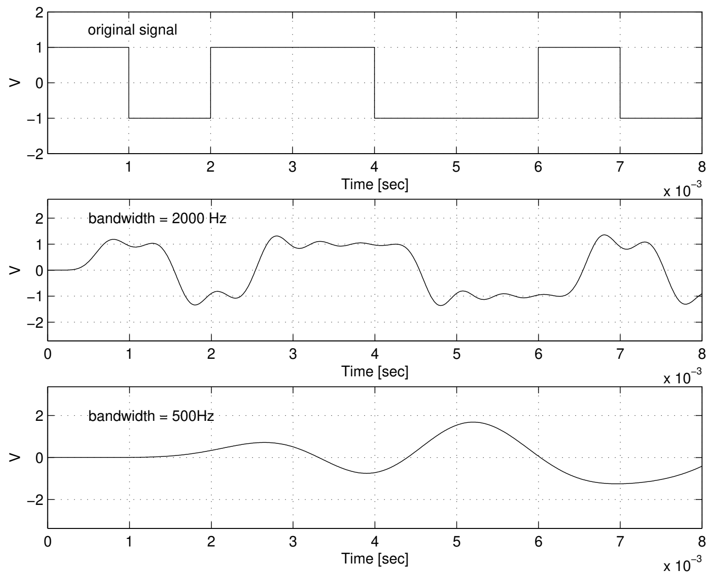
I) Signal, Bandwidth, and Noise

1. Point-to-Point Communication Systems

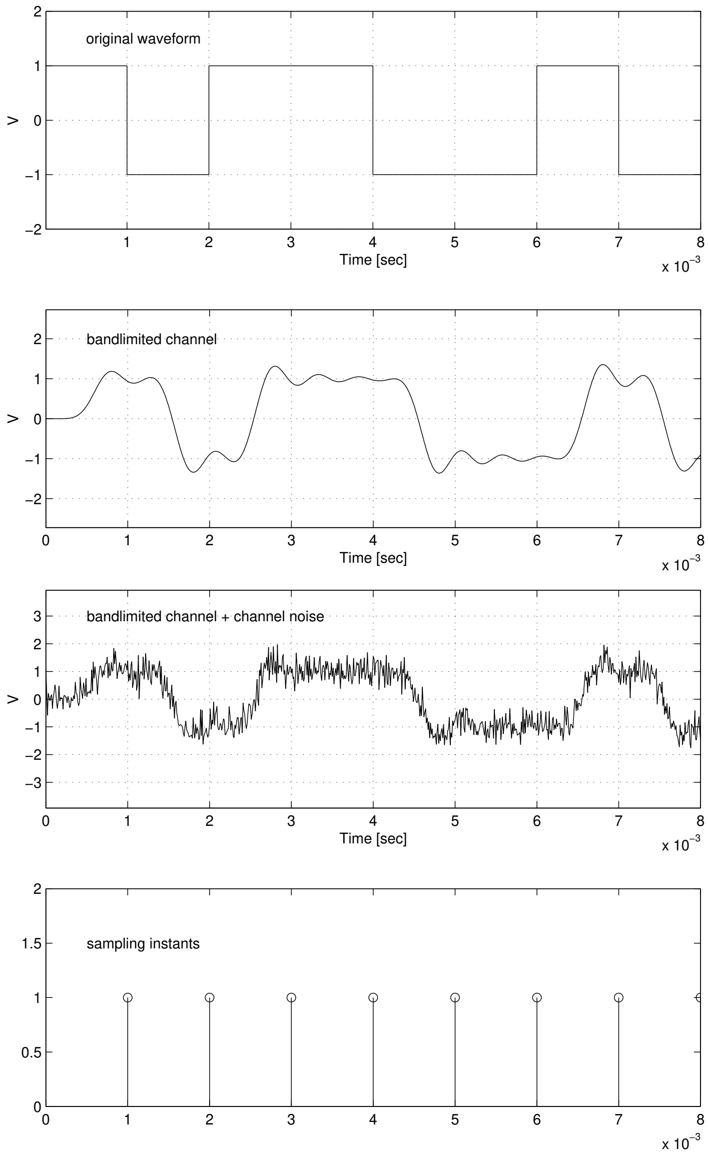


2. Channel Bandwidth

- The frequency range of the channel where the spectral components of the signal are transmitted without distortion. The spectral components outside the bandwidth will be attenuated significantly.
- The degree of transmission distortion, hence the data rate, depends on the channel bandwidth.



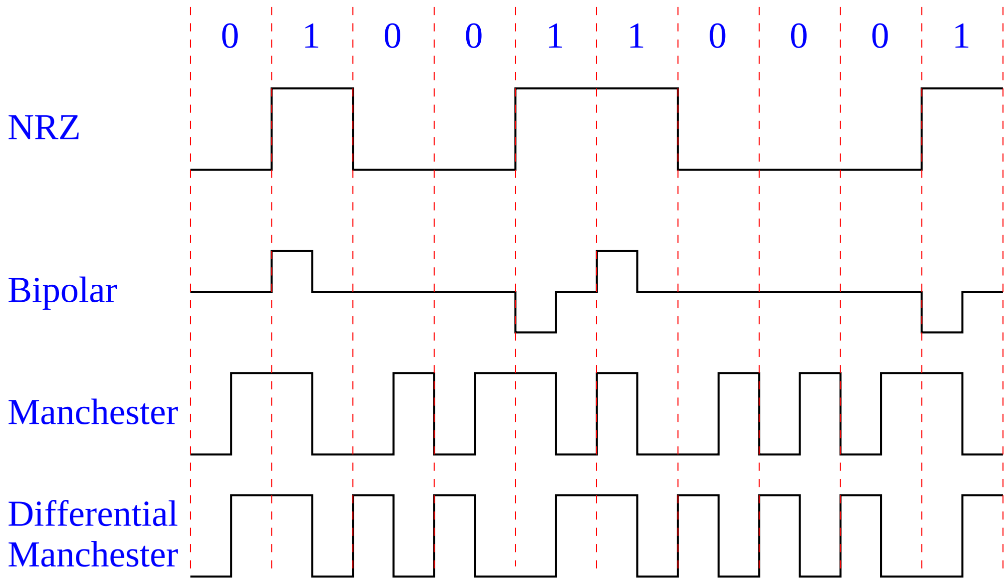
3. Effect of Limited Bandwidth and Noise



- Channel capacity = B $\log_2$(S/N +1)

II) <u>Baseband Transmission</u>

1. Digital Encoding Schemes



- Nonreturn-to-Zero (NRZ)
  - 0 = low level; 1 = high level.
- Bipolar
  - 0 = no line signal; 1 = positive and negative level, alternating for successive ones.
- Manchester
  - 0 = transition from high to low in middle of bit interval.
  - 1 = transition from low to high in middle of bit interval.
- Differential Manchester
  - Manchester with differential coding.

2. Advantages and Disadvantages of Various Coding Schemes

- NRZ
  - Widely used in data communications.
  - Relatively simple and low cost.
  - bandwidth = data rate.
  - Lack of self-clocking capability.
  - Large dc component, can not use a.c. coupling device.
- Manchester
  - Used in Ethernet and Token Ring.
  - Self-clocking capability.
  - bandwidth = 2 $\times$ data rate.
  - no dc component.
- Bipolar
  - Used for digital transmissions in telephone system.
  - Bandwidth = data rate.
  - No dc component.
  - Error detection.
  - Lack of self-clocking capability.

III) Bit Synchronization

1. Separated channel is used to carry the clock signal.

2. Timing information is embedded into a transmitted waveform.

   - Manchester code.
   - require larger channel bandwidth.

3. 4 of 5 group code (FDDI)

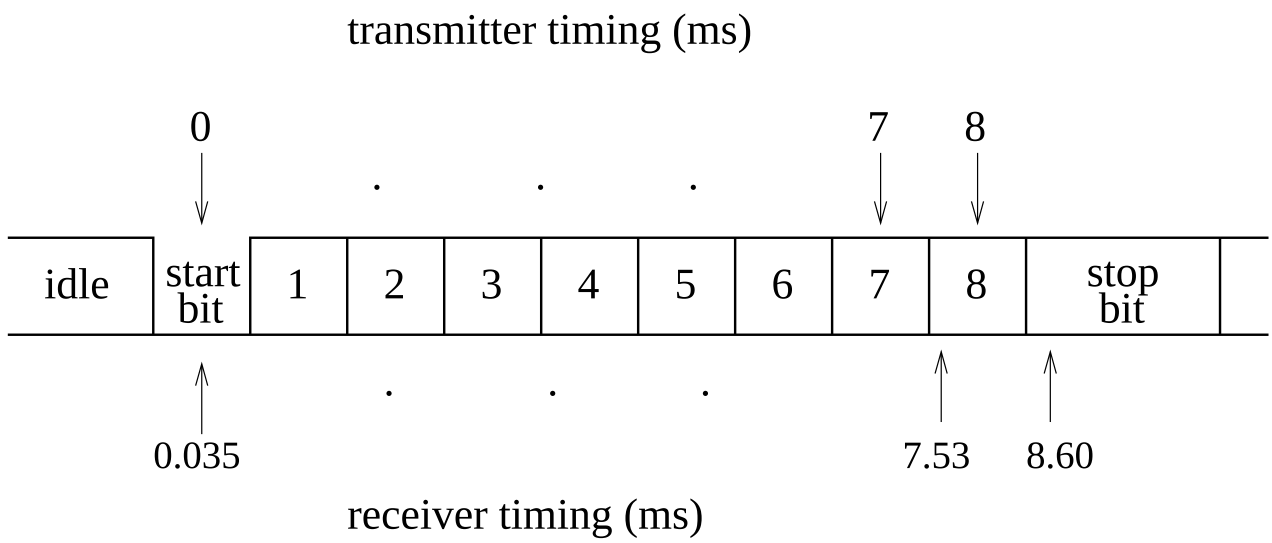
4-bit data group	5-bit symbol	4-bit data group	5-bit symbol
0000	11110	1000	10010
0001	01001	1001	10011
0010	10100	1010	10110
0011	10101	1011	10111
0100	01010	1100	11010
0101	01011	1101	11011
0110	01110	1110	11100
0111	01111	1111	11101

4. Bipolar variations: B8ZS and HDB3.

III) Transmission Mode

1. Asychronous Transmission

- Data is transmitted one character a time.
- Character is generated and transmitted in an arbitrary interval.
- Stop and start bits provide bit and character synchronization.
- Timing error example:



- No bit synchronization error if the difference between the two clocks is no more than 5%.
- Simple to implement.
- Large overhead: 8-bit data, 3-bit overhead.
- For slow transmission ($\leq$ 19.2kbps).

2. <u>Synchronous Transmission</u>

- For high speed transmission.
- Block of binary data is transmitted without start and stop bits.
- The content of each frame is encapsulated between a pair of reserved bytes for character and frame synchronization.
- Character-oriented protocols
  - Binary synchronous control (bisync).
  - Each frame is made up of a variable number of 8-bit characters.
  - Data transparency: character stuffing.

Original Data

· · ·	A	DLE	ETX	· · ·	B	STX	· · ·

Transmitted Frame

DLE	STX	· · ·	A	DLE	DLE	ETX	· · ·	B	STX	· · ·	DLE	ETX

character stuffing

- Bit-oriented protocols
  - High Level Data-Link Control (HDLC)
  - Format

idle				idle
1111	flag	Data	flag	111111

flag = 01111110

  - Data transparency: bit stuffing.

Original Data

. . . 10010111011111101111101110 . . .

Transmitted Frame

flag	. . . 1001011101111101011111001110 . . .	flag

bit stuffing

- A zero is inserted after each bit pattern "11111".
- The stuffed zeros will be removed by the receiver.

IV) Transmission Error Detection

1. Parity check

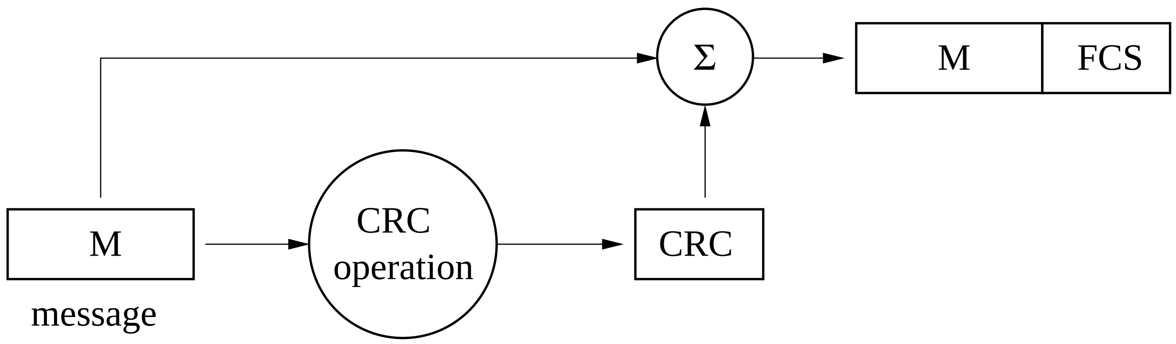
Bits in characters	A	B	C	X	Y	Z
1	1	1	1	1	1	1
2	0	0	0	0	0	0
3	0	0	0	1	1	1
4	0	0	0	1	1	1
5	0	0	0	0	0	0
6	0	1	1	0	0	1
7	1	0	1	0	1	0
even parity	0	0	1	1	0	0

2. Block Sum Check (BSC)

Bits in characters	A	B	C	X	Y	Z	BSC
1	1	1	1	1	1	1	0
2	0	0	0	0	0	0	0
3	0	0	0	1	1	1	1
4	0	0	0	1	1	1	1
5	0	0	0	0	0	0	0
6	0	1	1	0	0	1	1
7	1	0	1	0	1	0	1
even parity	0	0	1	1	0	0	0

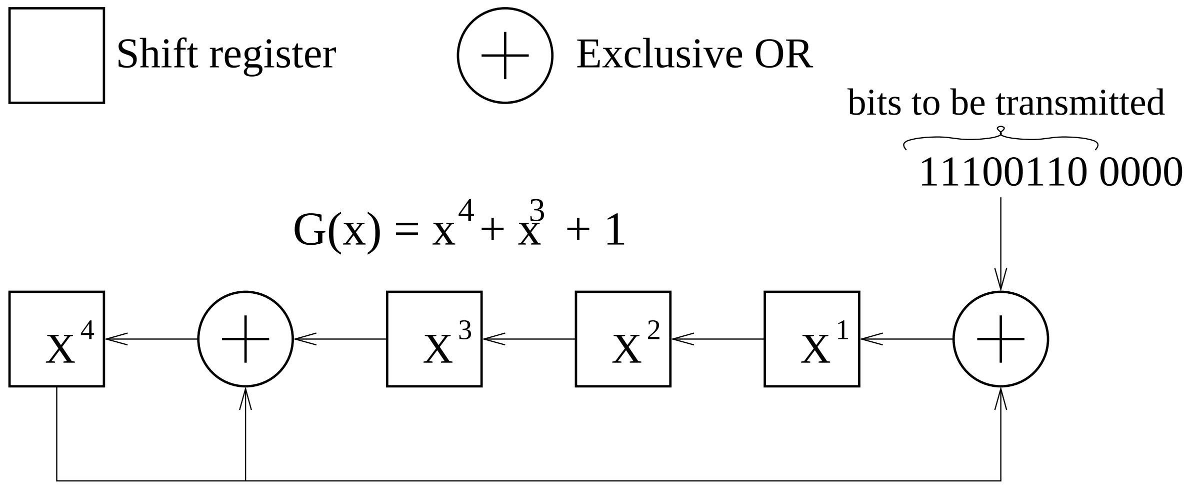
3. Cyclic Redundancy Check (CRC)

- The CRC operation generates and appends frame-check sequence (FCS) to the data such that the overall data frame is exactly divisible (modulo 2 arithmetic) by a generator polynomial, G.
- The receiver divides the incoming frame by the same G. If there is no remainder after the division, the receiver assumes no transmission error in the frame.



- Operation procedures:
  (a) Append r zeros to M.
  (b) M 2^r / G = quotient + remainder/G.
  (c) The remainder is the FCS.

- Three widely used versions of generator polynomial:
  - CRC-16 (USA): $G(x) = x^{16} + x^{15} + x^2 + 1$
  - CRC-CCITT (Europe): $G(x) = x^{16} + x^{15} + x^5 + 1$
  - CRC-32 (IEEE-802 standard): $G(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^2 + x + 1$
- The CRC method can detect:
  - all single, double, and triple -bit errors.
  - any odd number of errors.
  - any burst error for which the length of the burst is less than the length of CRC.
  - Most larger burst error (over 99%).
- Implementation:



4. <u>One's Complement</u>

- Used in IP and TCP.
- Easier to implement than CRC in software.