

Computer Networks

Modulation (§2.5)



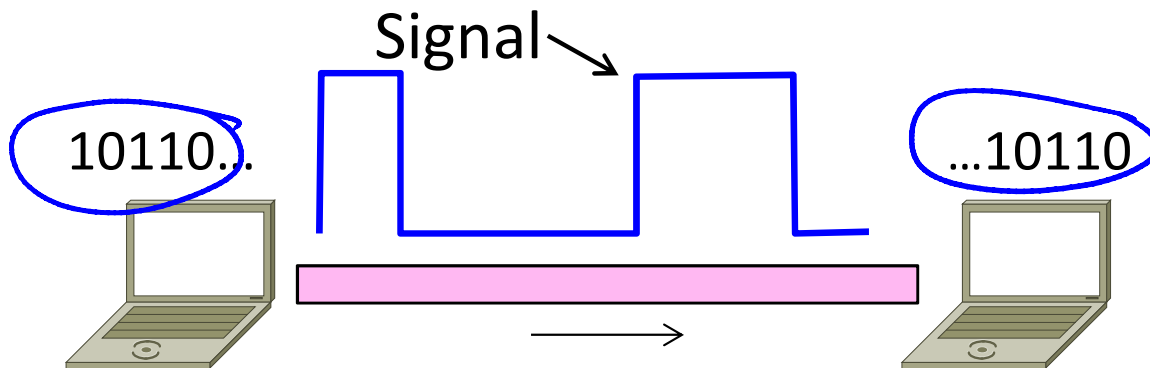
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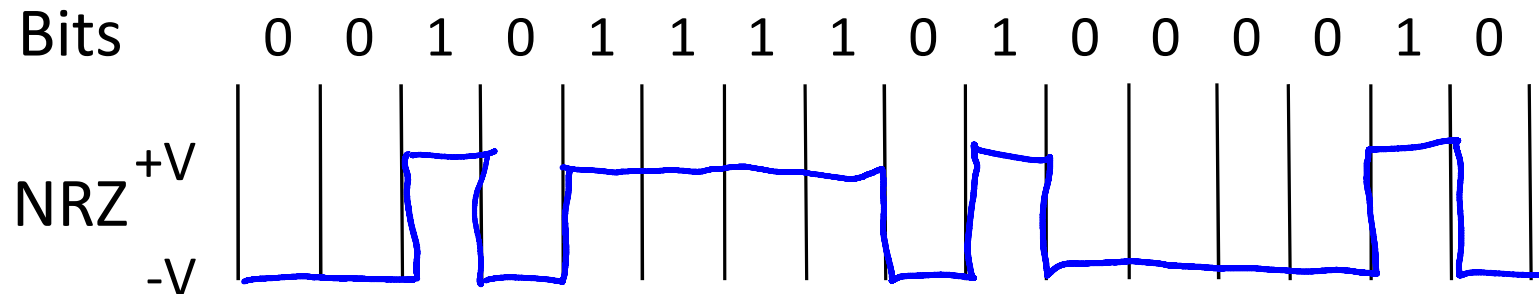
Topic

- We've talked about signals representing bits. How, exactly?
 - This is the topic of modulation



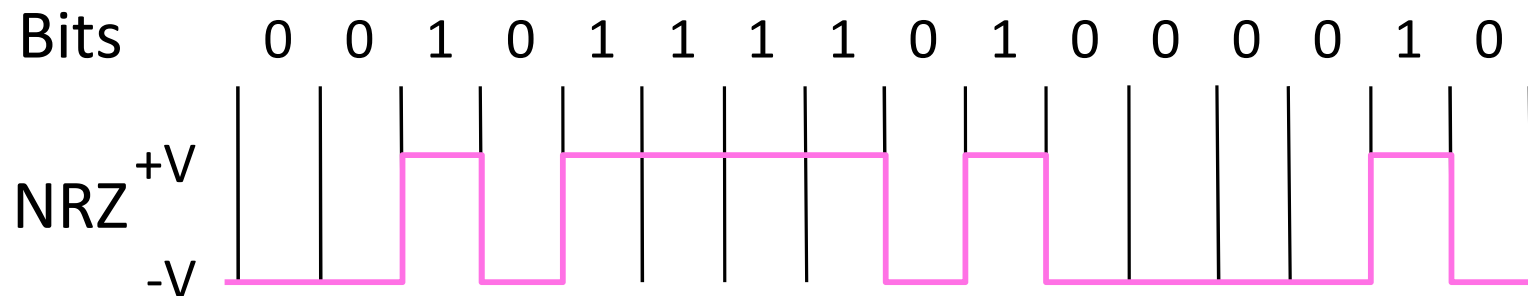
A Simple Modulation

- Let a high voltage ($+V$) represent a 1, and low voltage ($-V$) represent a 0
 - This is called NRZ (Non-Return to Zero)



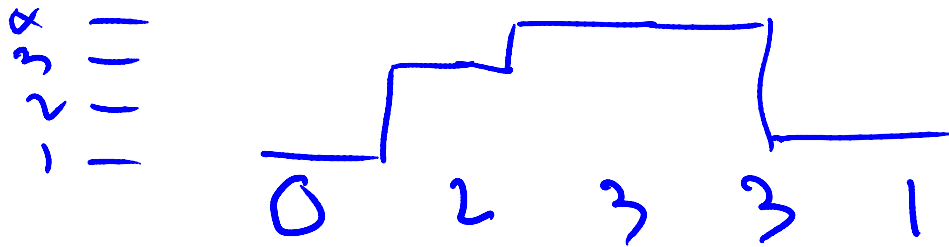
A Simple Modulation (2)

- Let a high voltage ($+V$) represent a 1, and low voltage ($-V$) represent a 0
 - This is called NRZ (Non-Return to Zero)



Many Other Schemes

- Can use more signal levels, e.g., 4 levels is 2 bits per symbol

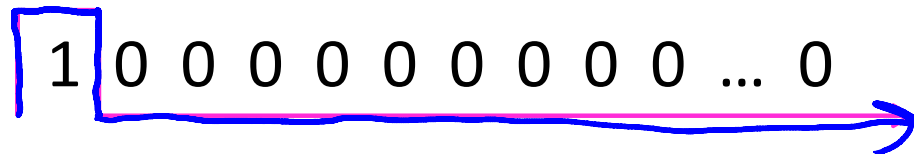


- Practical schemes are driven by engineering considerations
 - E.g., clock recovery »

Clock Recovery

- Um, how many zeros was that?
 - Receiver needs frequent signal transitions to decode bits

1 0 0 0 0 0 0 0 0 0 ... 0



- Several possible designs
 - E.g., Manchester coding and scrambling (§2.5.1)

Clock Recovery – 4B/5B

- Map every 4 data bits into 5 code bits without long runs of zeros
 - 0000 → 11110, 0001 → 01001,
1110 → 11100, ... 1111 → 11101
 - Has at most 3 zeros in a row
 - Also invert signal level on a 1 to break up long runs of 1s (called NRZI, §2.5.1)

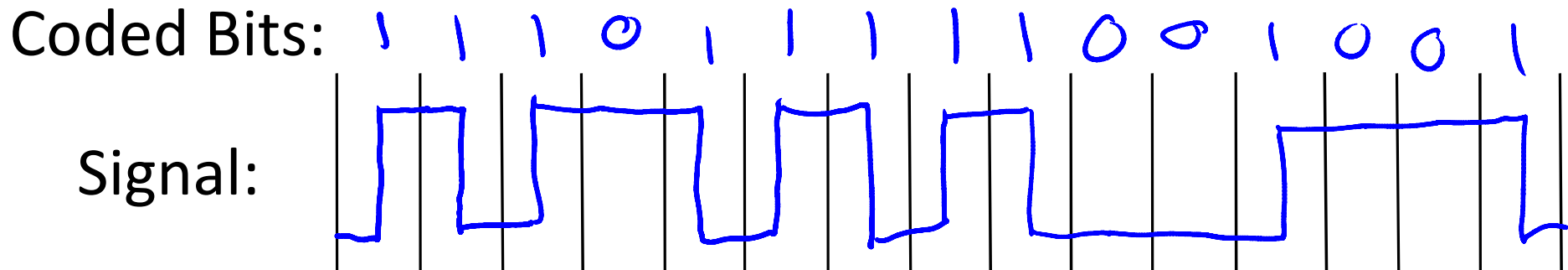
invert

Clock Recovery – 4B/5B (2)

- 4B/5B code for reference:

→ 0000 → 11110, 0001 → 01001, 1110 → 11100, ... 1111 → 11101

- Message bits: 1 1 1 1 0 0 0 0 0 0 0 1

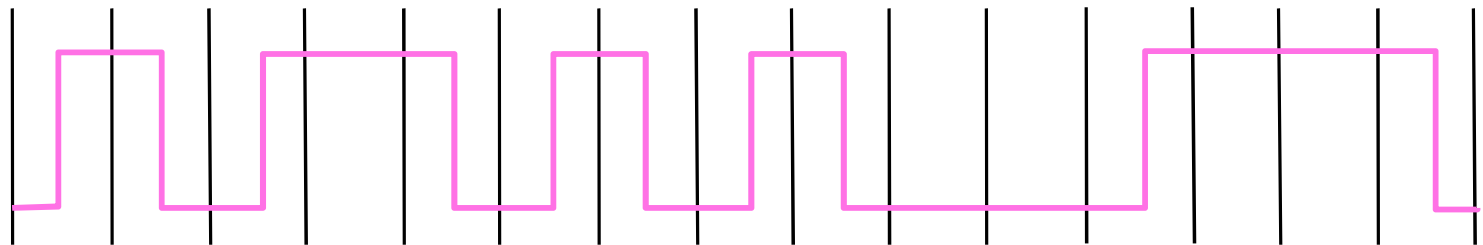


Clock Recovery – 4B/5B (3)

- 4B/5B code for reference:
 - 0000 → 11110, 0001 → 01001, 1110 → 11100, ... 1111 → 11101
- Message bits: 1 1 1 1 0 0 0 0 0 0 0 1

Coded Bits: 1 1 1 0 1 1 1 1 1 0 0 1 0 0 1

Signal:

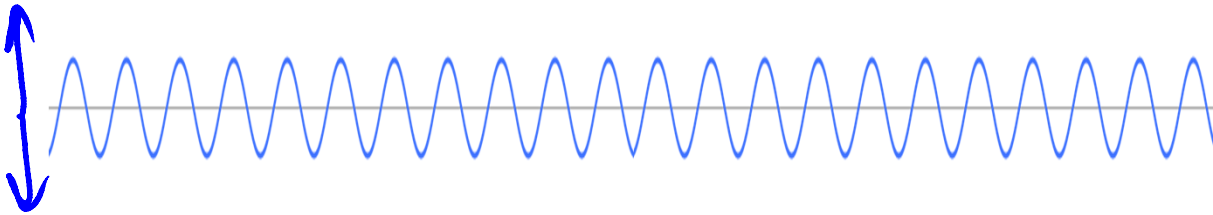


Passband Modulation

- What we have seen so far is baseband modulation for wires
 - Signal is sent directly on a wire
- These signals do not propagate well on fiber / wireless
 - Need to send at higher frequencies
- Passband modulation carries a signal by modulating a carrier

Passband Modulation (2)

- Carrier is simply a signal oscillating at a desired frequency:



- We can modulate it by changing:
 - Amplitude, frequency, or phase



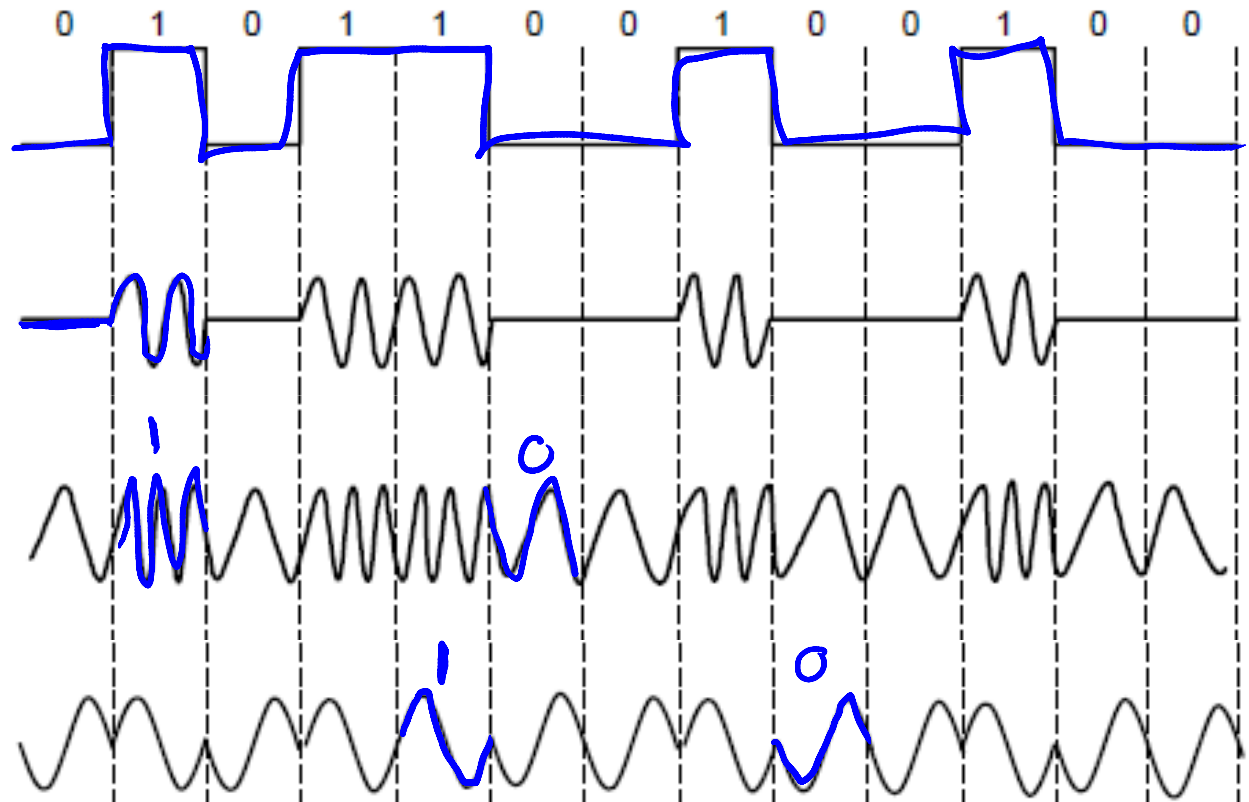
Passband Modulation (3)

NRZ signal of bits

1. Amplitude shift keying

2. Frequency shift keying

3. Phase shift keying



END

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