THE PHYSICAL LAYER

COMP 30650: NETWORKS AND INTERNET SYSTEMS

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RECAP

1. **Properties of the physical layer**
   - Message Latency
     - Transmission
     - Propagation
2. **Types of of media**
   - Wires, fiber optics, wireless
     - Pros and cons of the media
     - Wireless very different

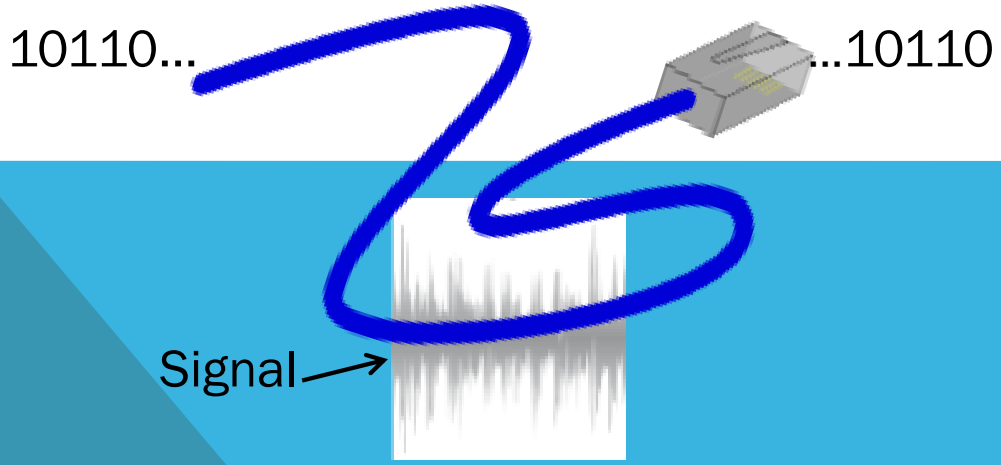
TODAY'S PLAN

- Modulation Schemes

SCOPE OF THE PHYSICAL LAYER

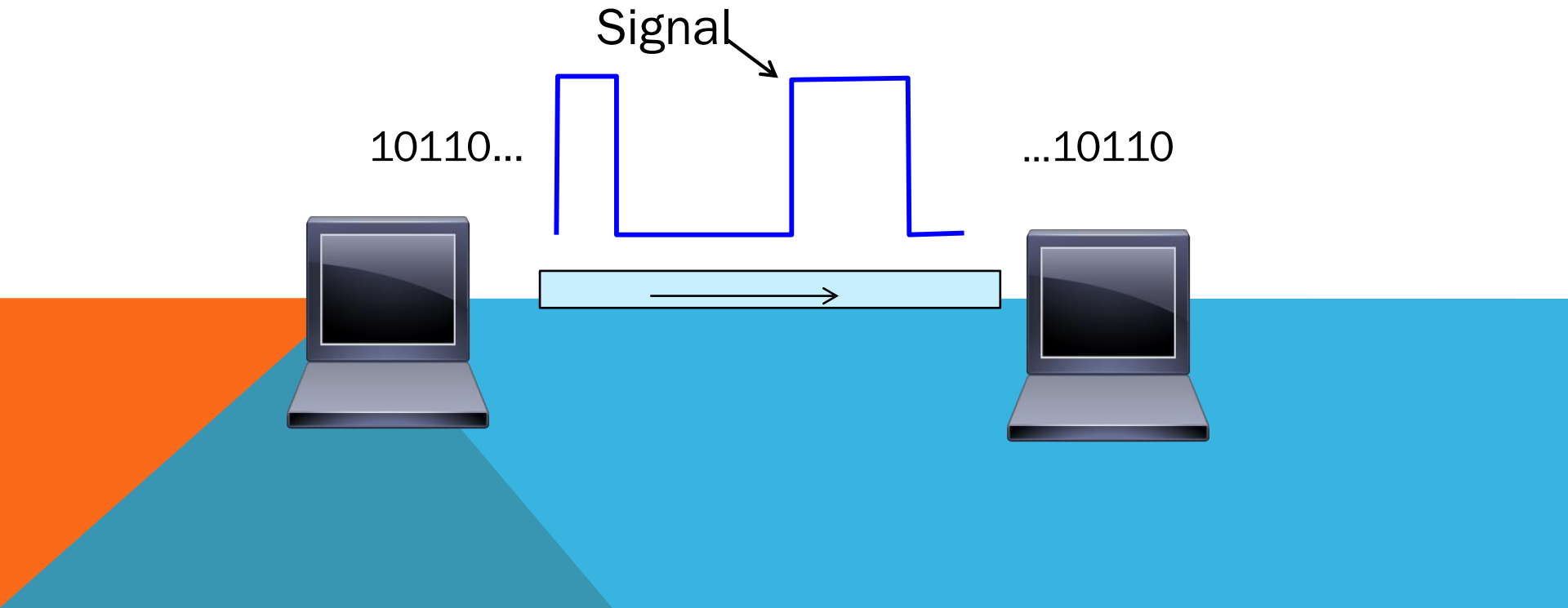
Concerns how signals are used to transfer message bits over a link

- Wires etc. carry analog signals
- We want to send digital bits (how computers communicate 1s and 0s)



TRANSMITTING DATA OVER MEDIA

Analog signals encode digital bits. We want to know how this occurs – different techniques



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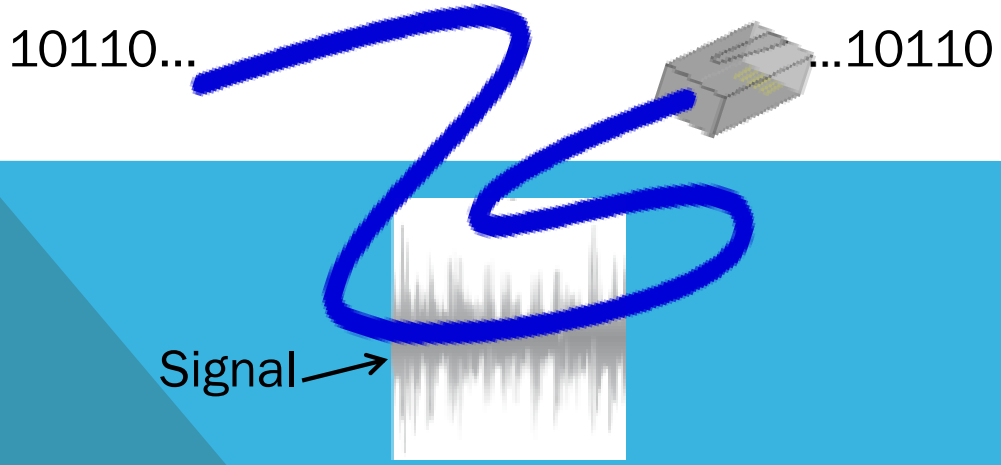

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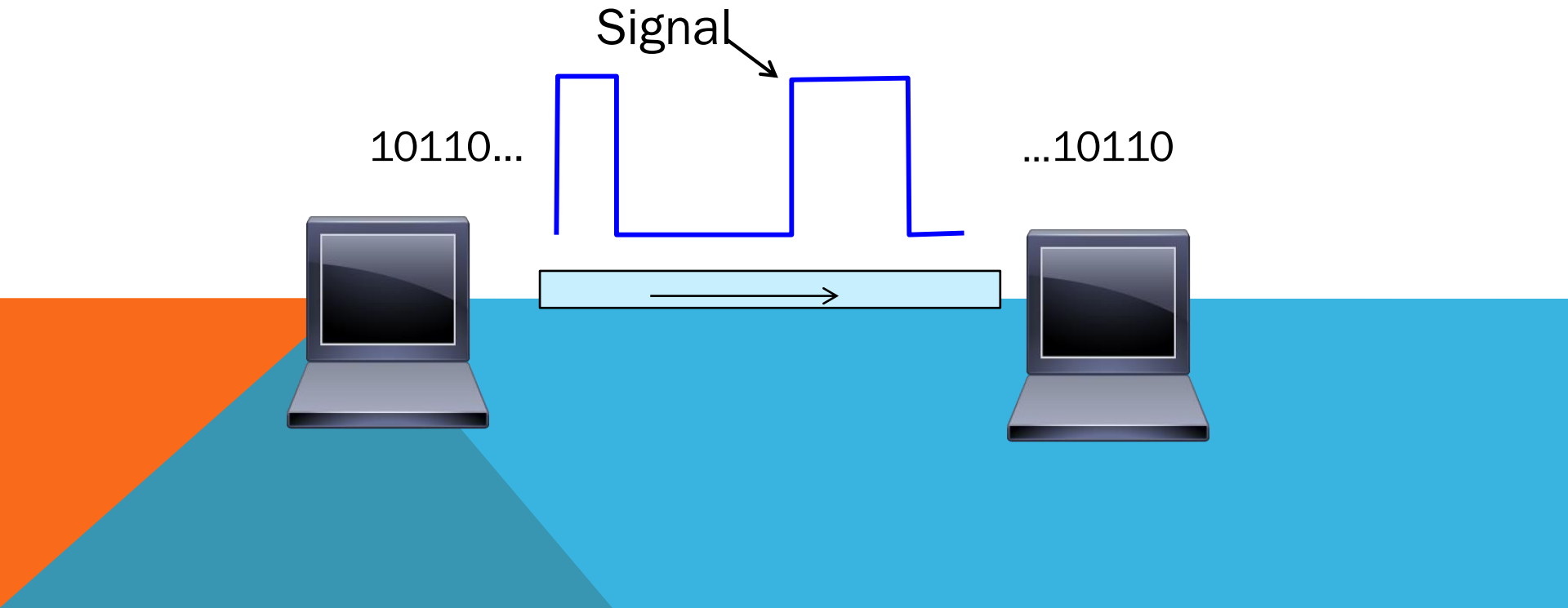
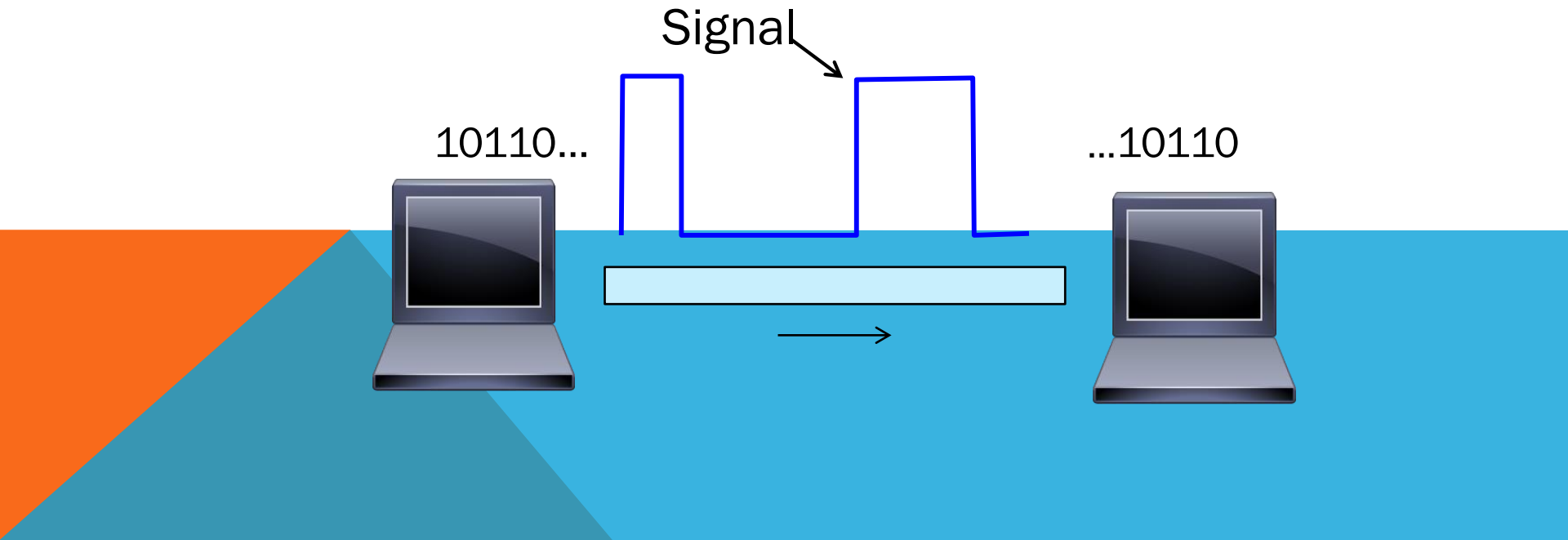


MODULATION

We've talked about signals representing bits. How, exactly does this work?

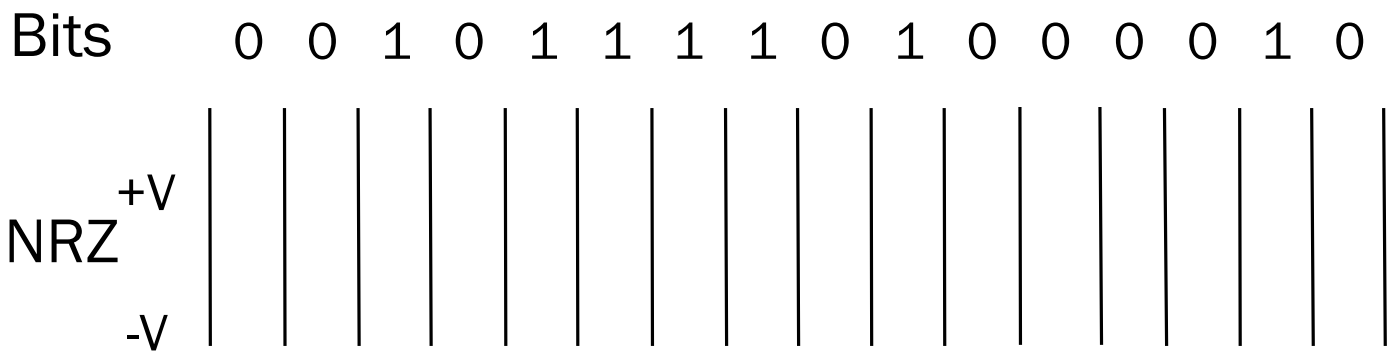
- This is the topic of modulation



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)



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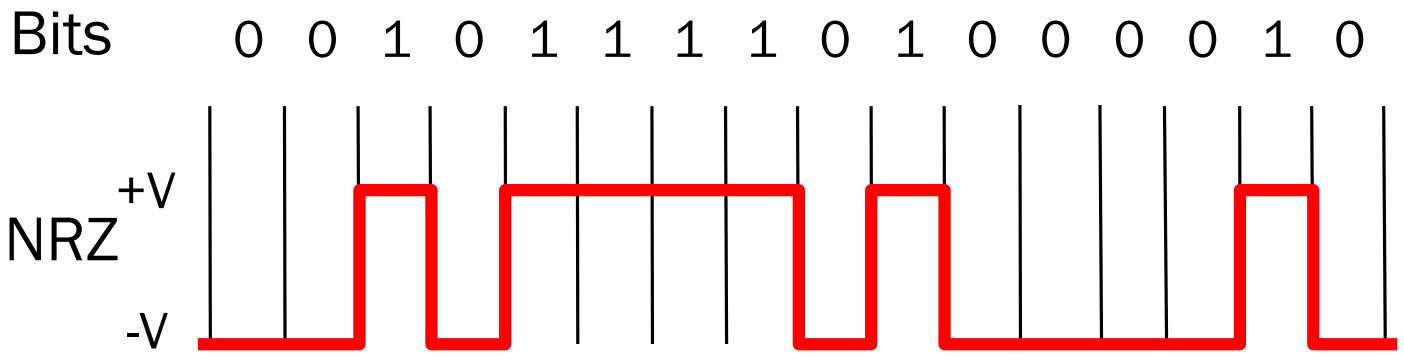

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Can use more signal levels, e.g., 4 levels is 2 bits per symbol

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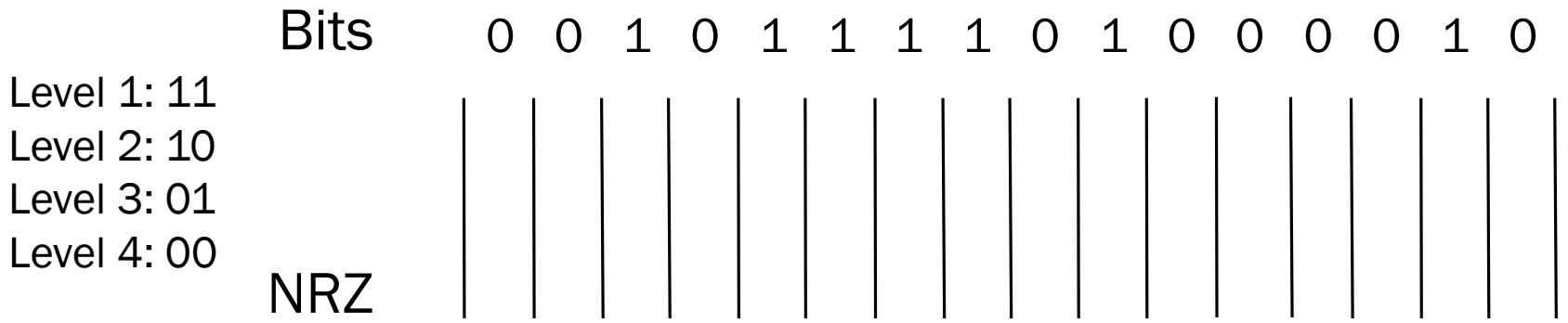

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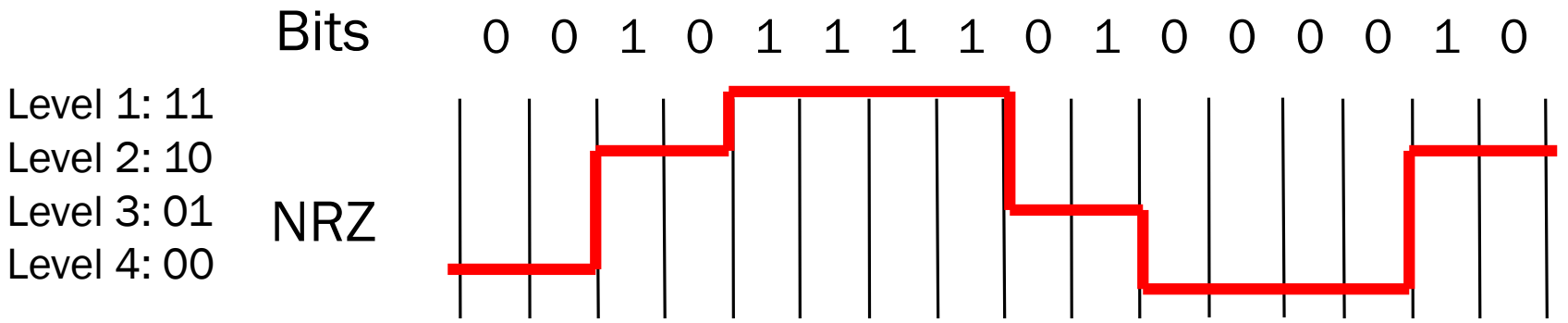

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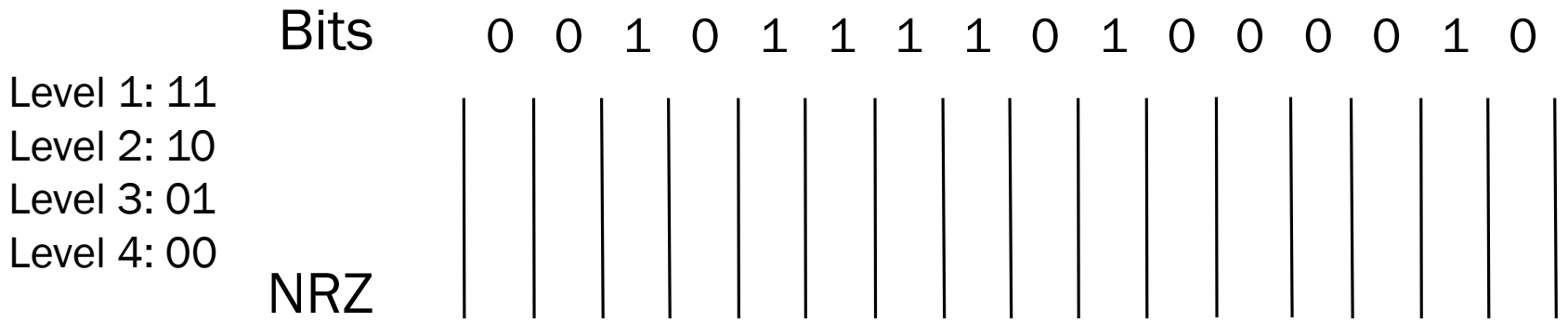

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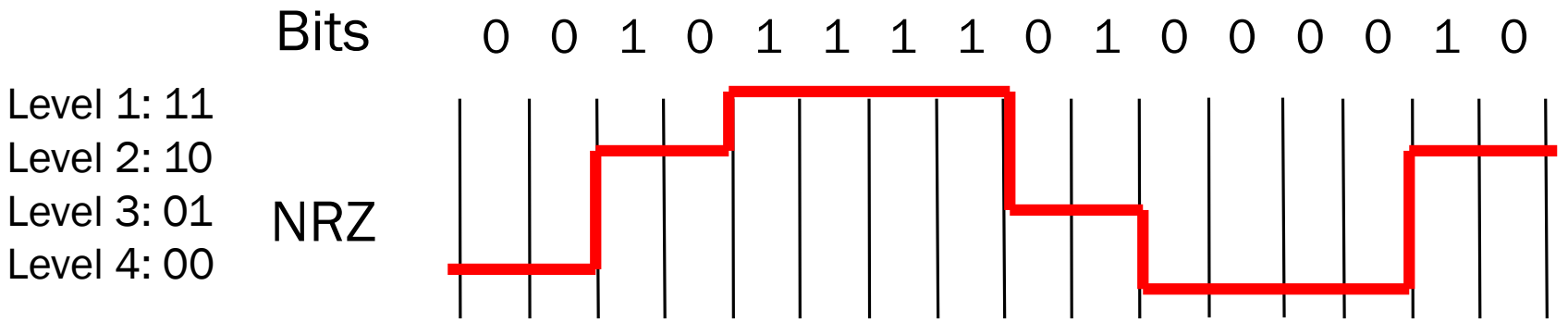
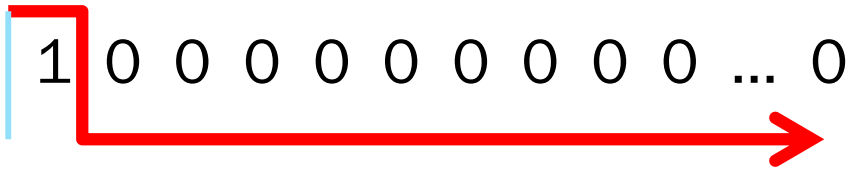


CLOCK RECOVERY

How many zeros was that?

- Receiver needs frequent signal transitions to decode bits

Several possible designs



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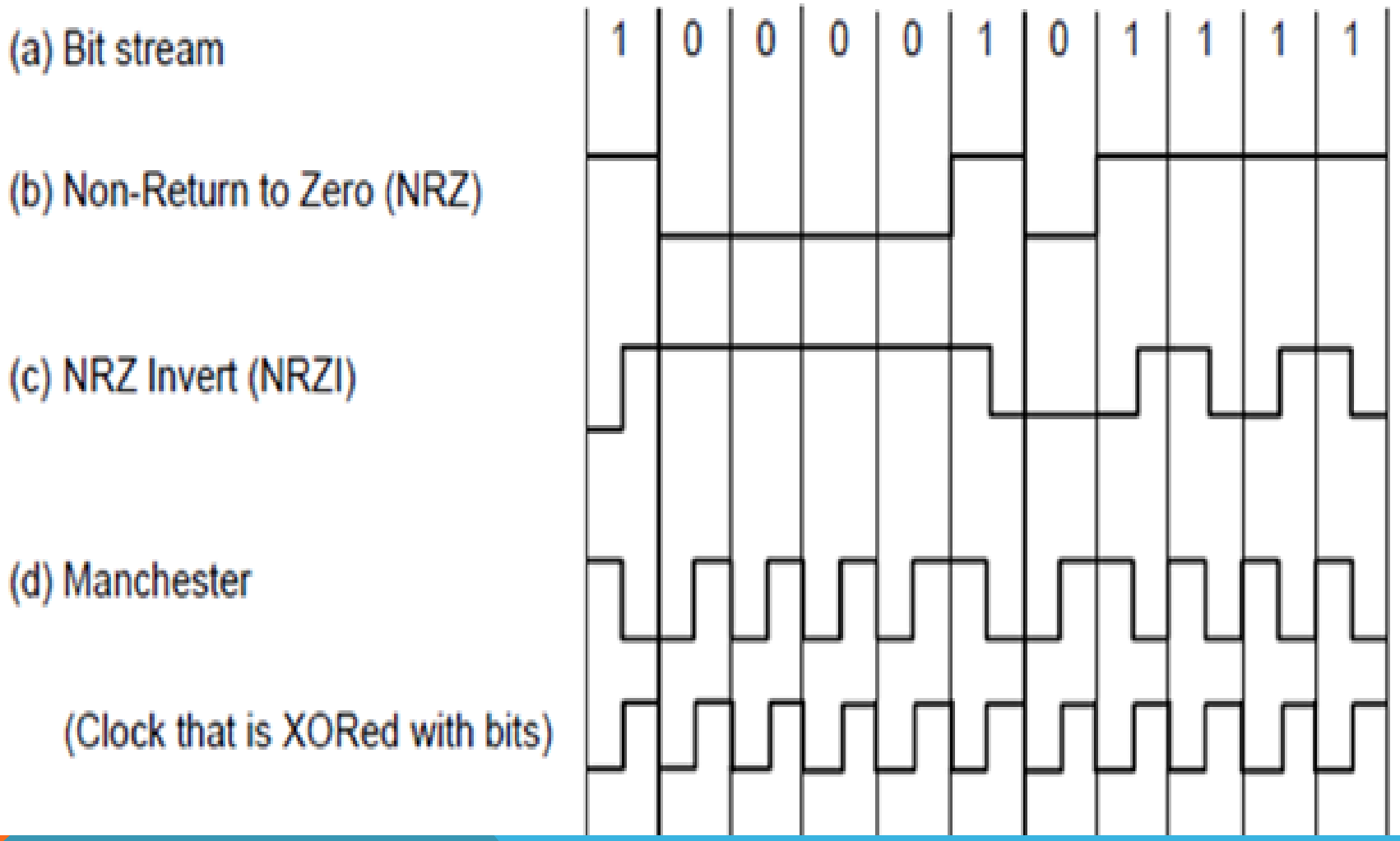
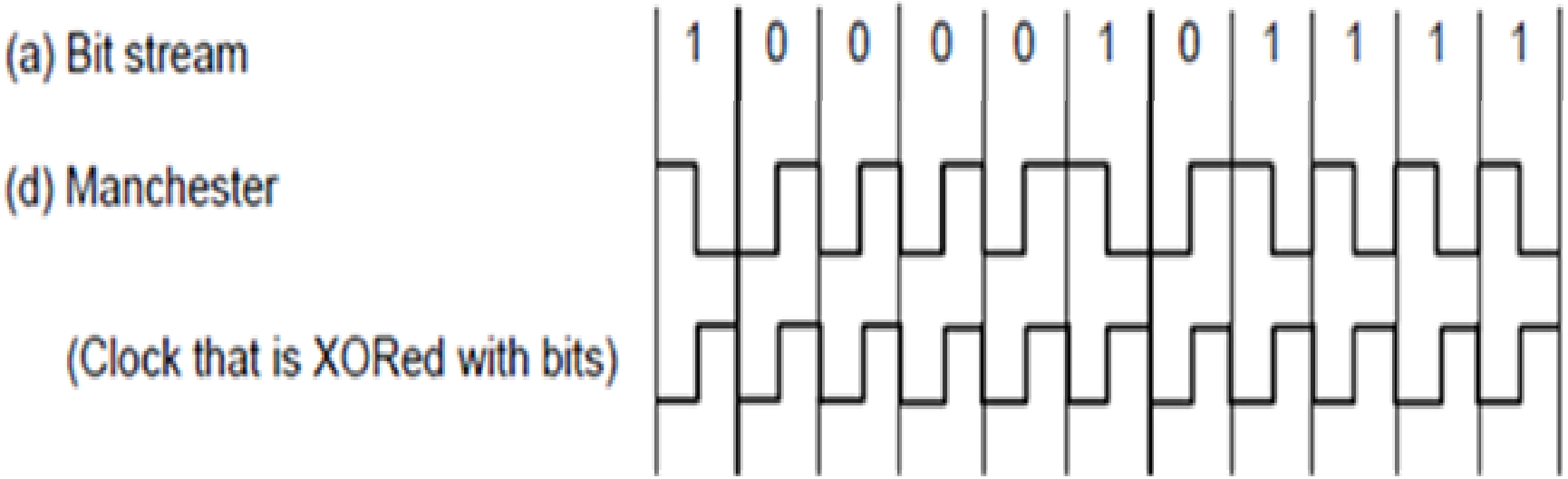


MANCHESTER ENCODING

- The original bit stream is **XORed** with a clock signal
- Clock signal runs at twice the bit rate
- Clock Signal XORed with 1 - it is inverted and gives a high to low transition
- Clock Signal XORed with 0 - gives a low to high transition



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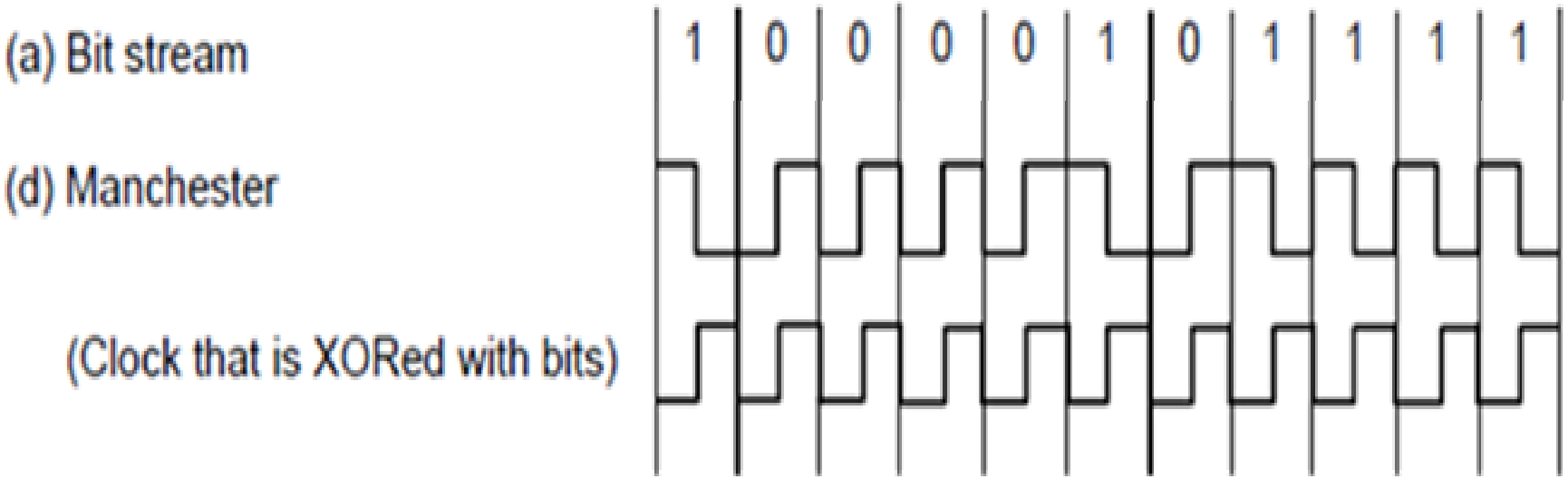

We need to send two signals the clock and encoded bit

NON RETURN ZERO INVERTED

- NRZI
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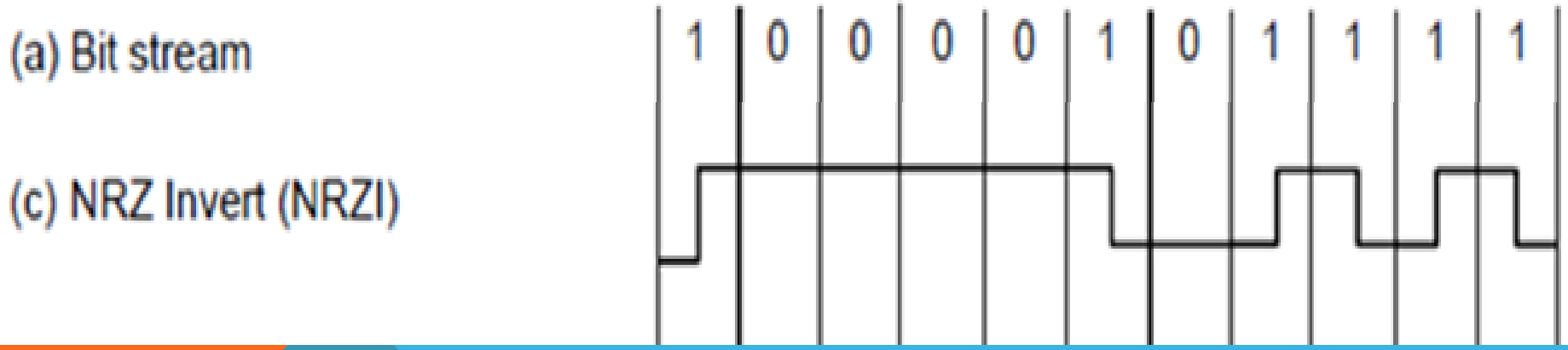

NON RETURN ZERO INVERTED

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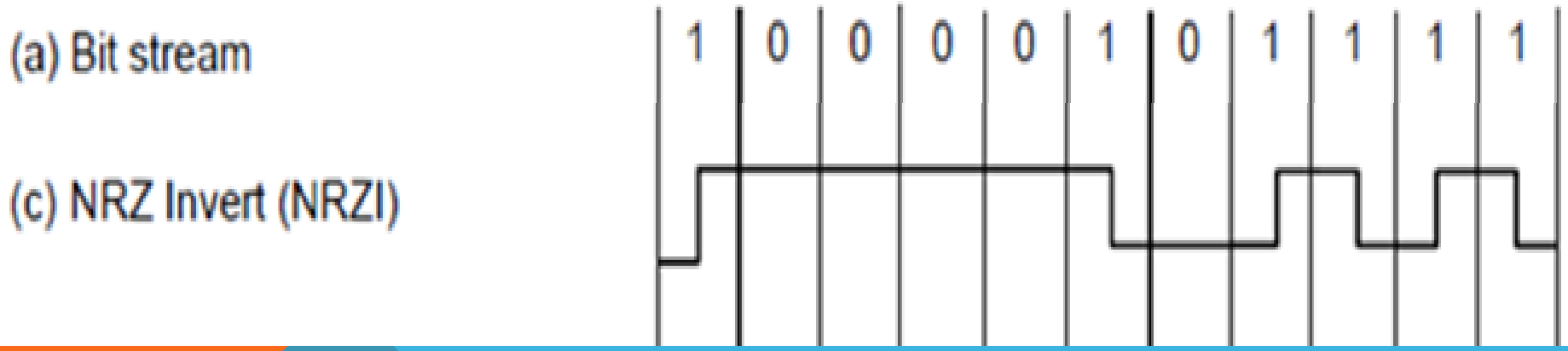
- Gets rid of long runs of 1s but still issue with long runs of zeros



CLOCK RECOVERY – 4B/5B

Map every 4 data bits into 5 code bits without long runs of zeros

- Has at most 3 zeros in a row

Data	Code	Data	Code	Data	Code	Data	Code
0000	11110	0100	01010	1000	10010	1100	11010
0001	01001	0101	01011	1001	10011	1101	11011
0010	10100	0110	01110	1010	10110	1110	11100
0011	10101	0111	01111	1011	10111	1111	11101

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Also invert signal level on a 1 (and keep the same on a 0 in order to break up long runs of 1s (NRZI)

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Message to send:

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0011	10101	0111	01111	1011	10111	1111	11101

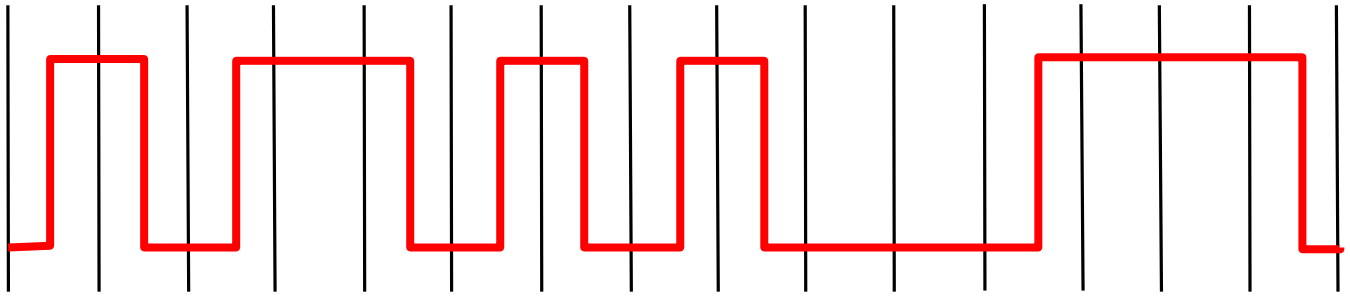
4B/5B code for reference:
1111 -> 11101, 0000 -> 11110, 0001 -> 01001

CLOCK RECOVERY – 4B/5B

Message: 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

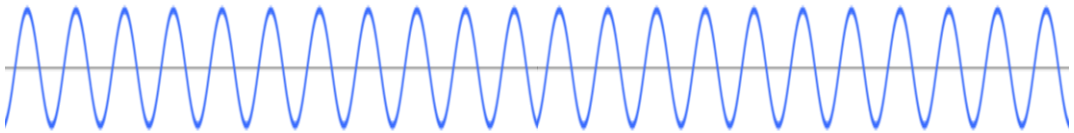
These signals do not propagate well on fiber / wireless

- Need to send at higher frequencies
- Regulation about frequencies which can be used
- Share a channel if signals use different frequencies

Passband modulation carries a signal by modulating a carrier signal

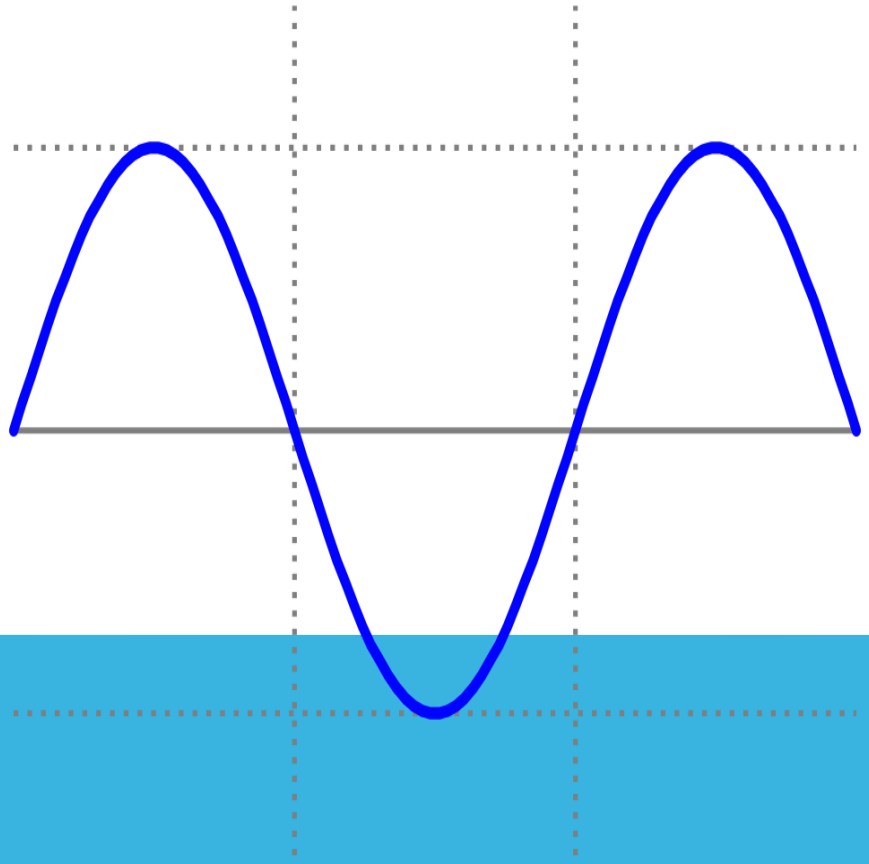
PASSBAND MODULATION

Carrier is simply a signal oscillating at a desired frequency sitting in the passband frequency:



FREQUENCY OF A WAVE

The frequency of a wave describes how many waves go past a certain point in one second. Frequency is measured in Hertz (usually abbreviated Hz)



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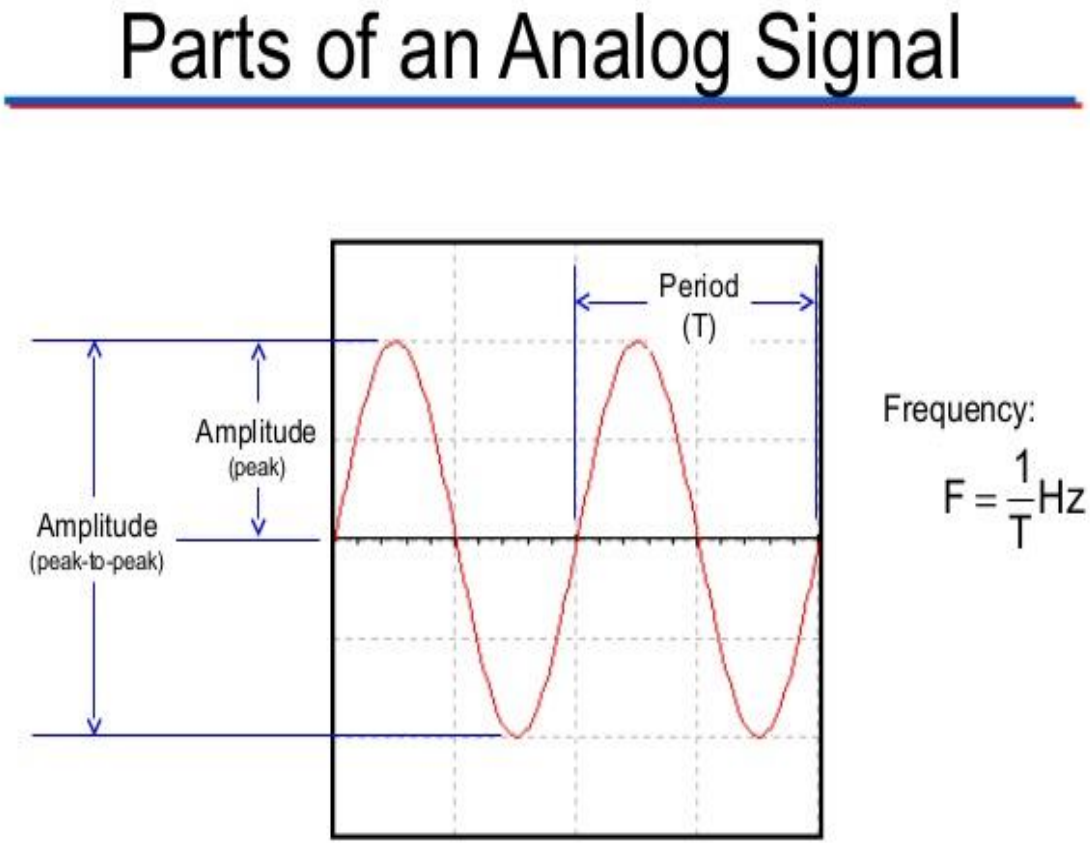

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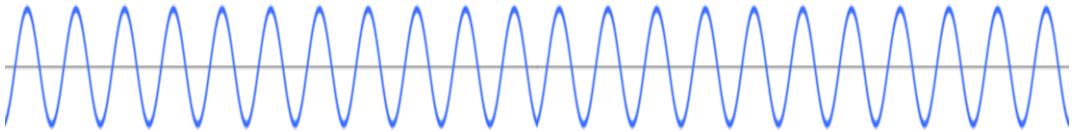
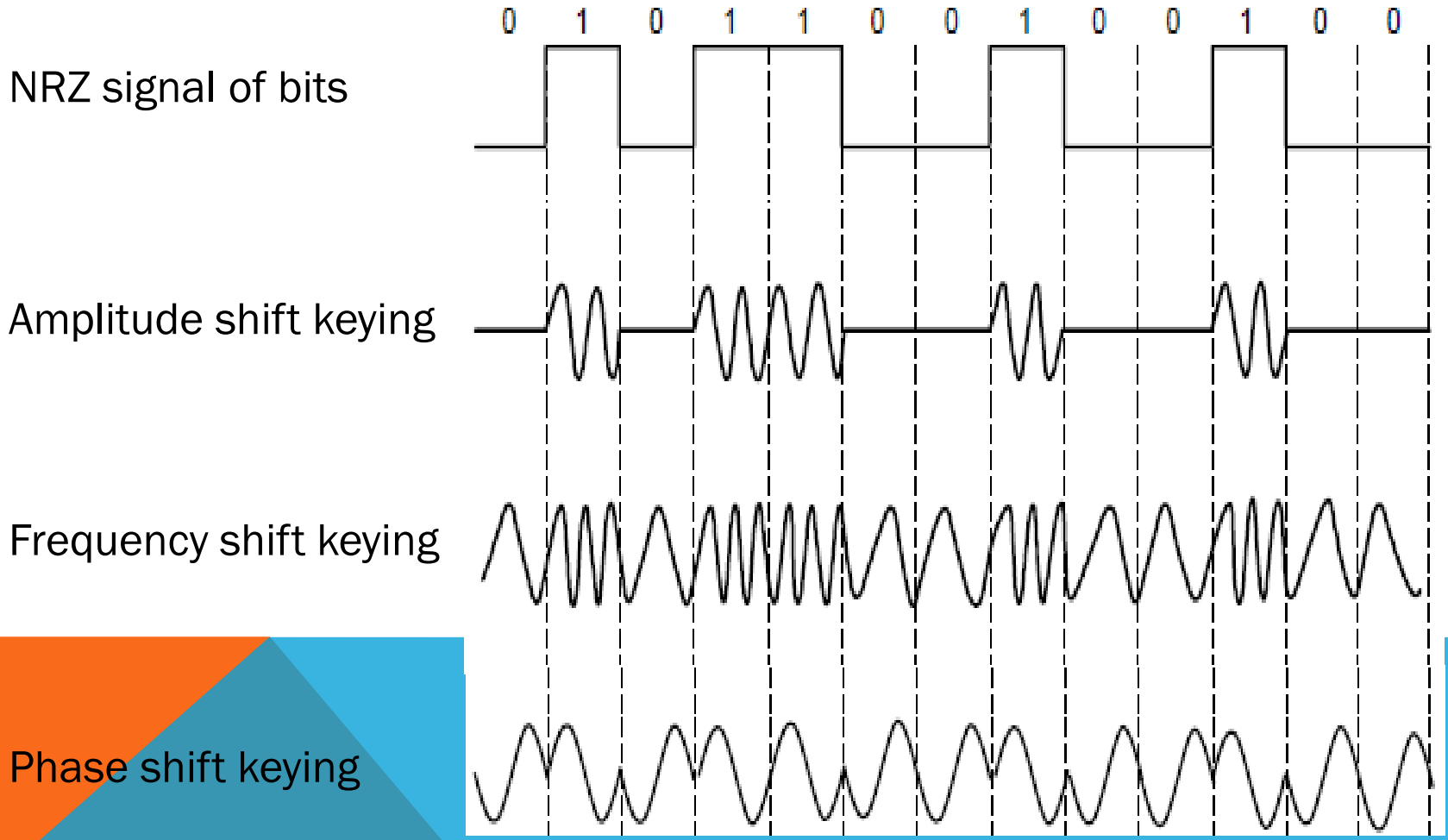


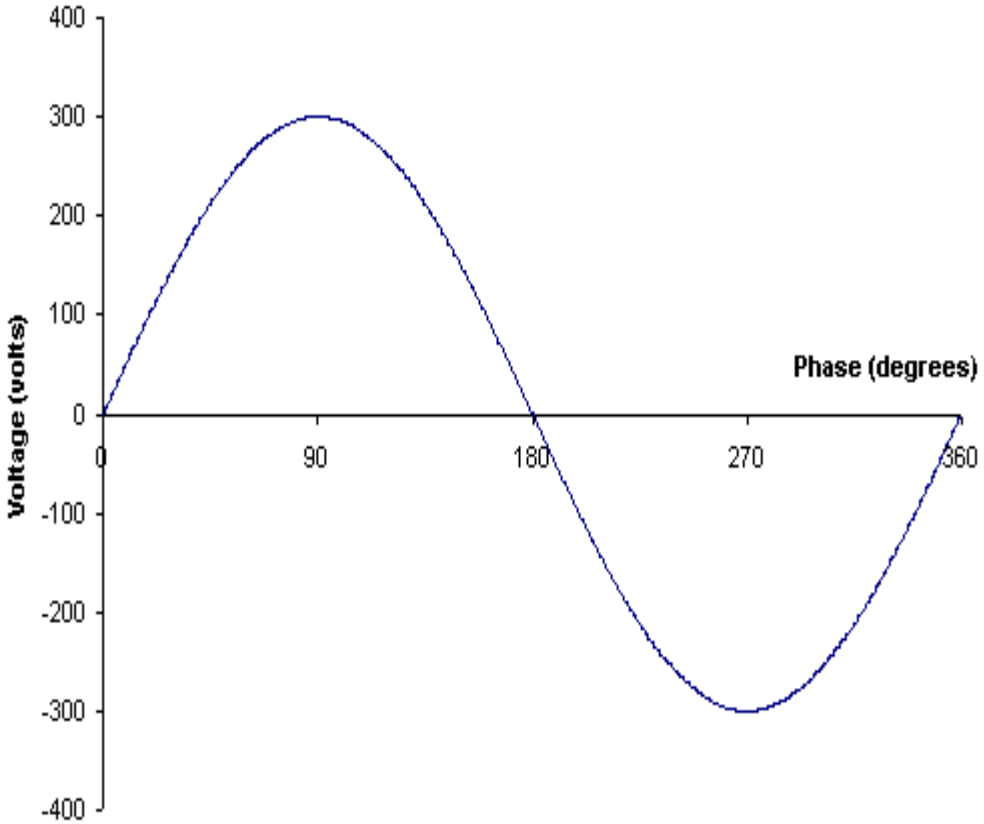
We can modulate it by changing:

- Amplitude (ASK) , frequency (FSK), or phase (PSK)

PASSBAND MODULATION



PHASE SHIFT KEYING



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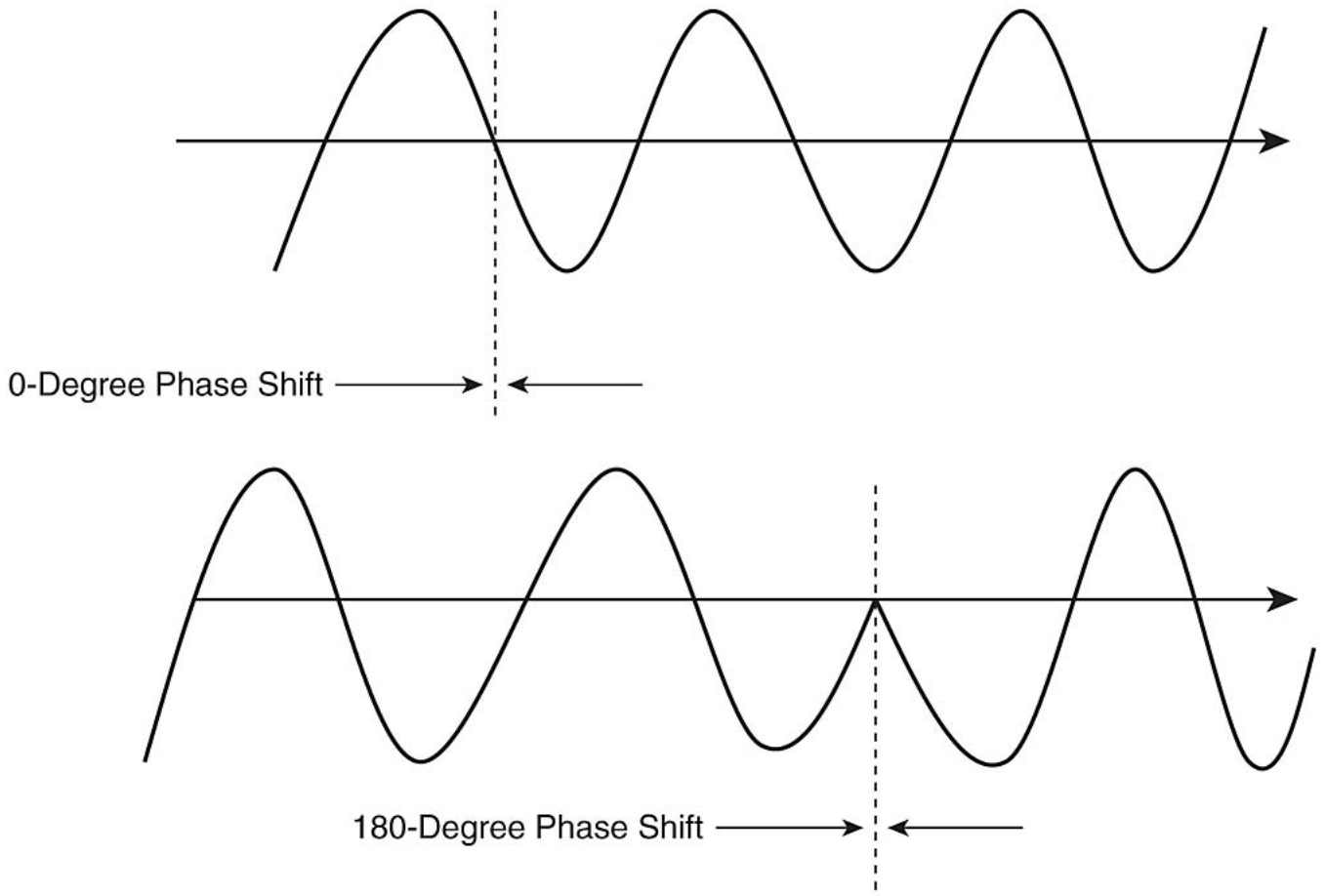


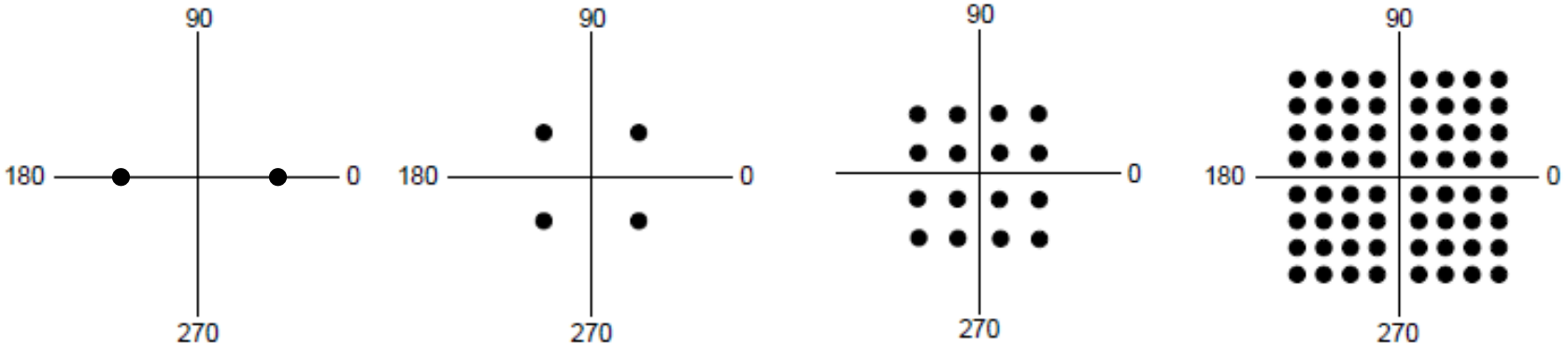
PASSBAND MODULATION

We can combine these to allow more bits per symbol.

- Cannot combine Frequency and Phase as they are related
- Frequency is the rate of change of phase over time

PASSBAND TRANSMISSION

Constellation diagrams are a shorthand to capture the amplitude and phase modulations of symbols:



BinaryPSK
2 symbols
1 bit/symbol

QuadraturePSK
4 symbols
2 bits/symbol

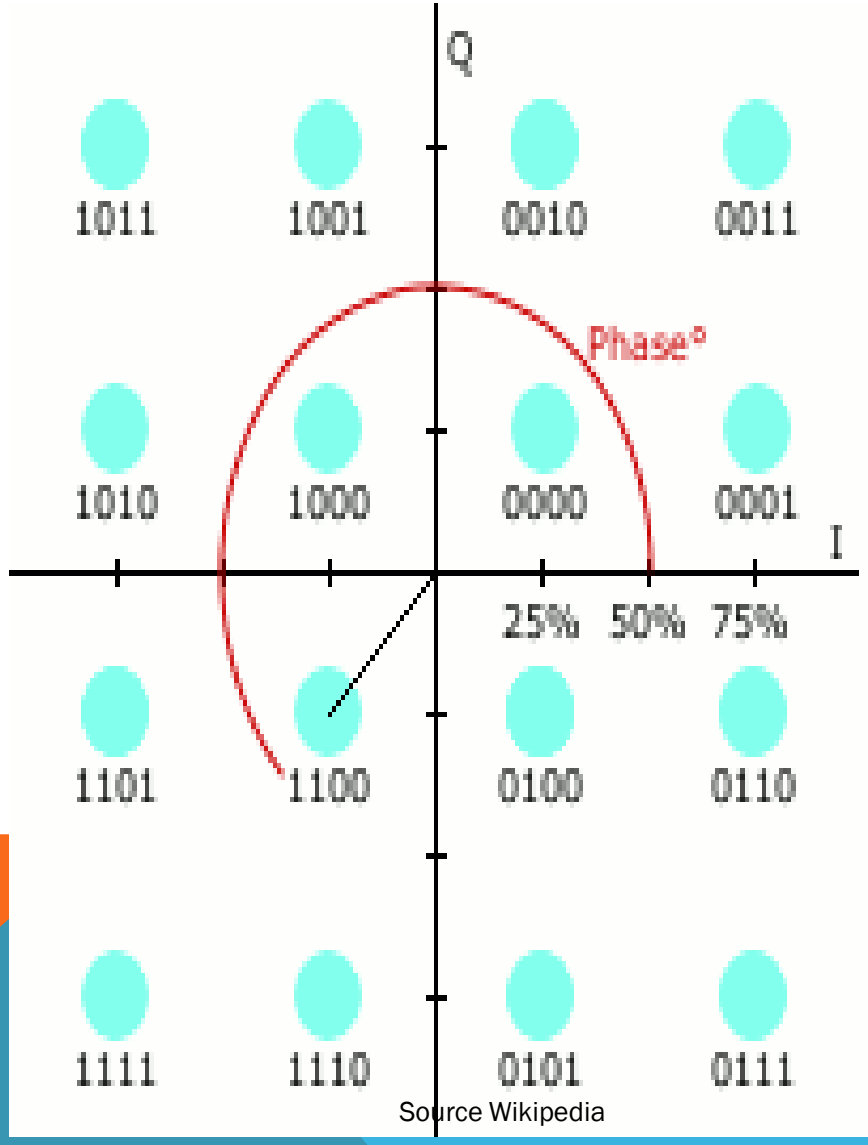
QAM-16
16 symbols
4 bits/symbol

QAM-64
64 symbols
6 bits/symbol

BPSK/QPSK varies only phase

QAM varies amplitude and phase

QAM 16 EXAMPLE



Amp	Phase	Data
25%	225°	1100

Source Wikipedia