CSE461:
Introduction to Computer Communication Networks

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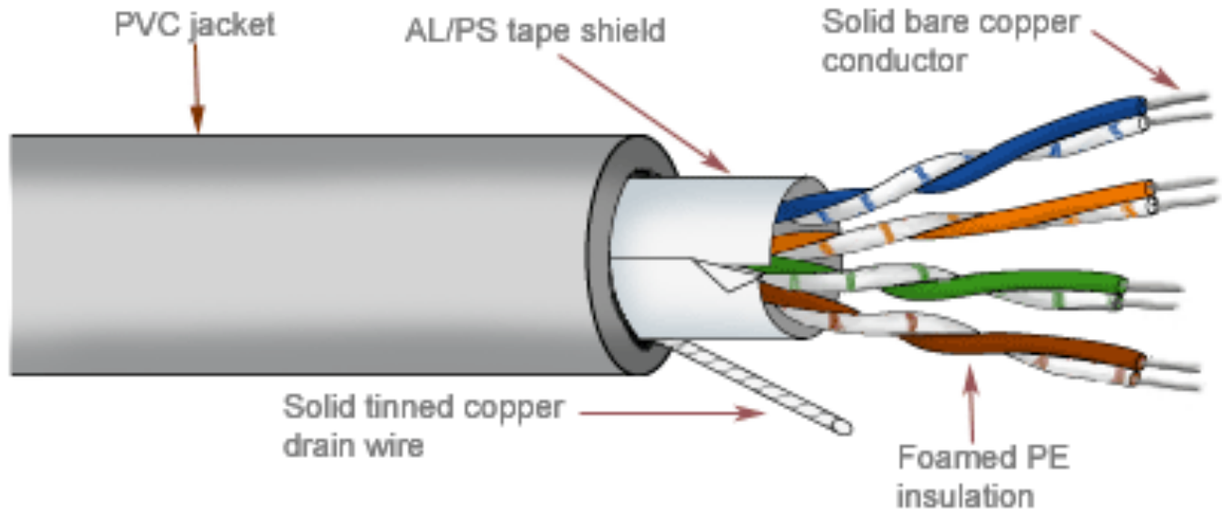
TODO

- Bits to signals and back again
- How does a wired protocol like Ethernet work?
- How do wireless protocols work?
- Machine learning + wireless

Ethernet

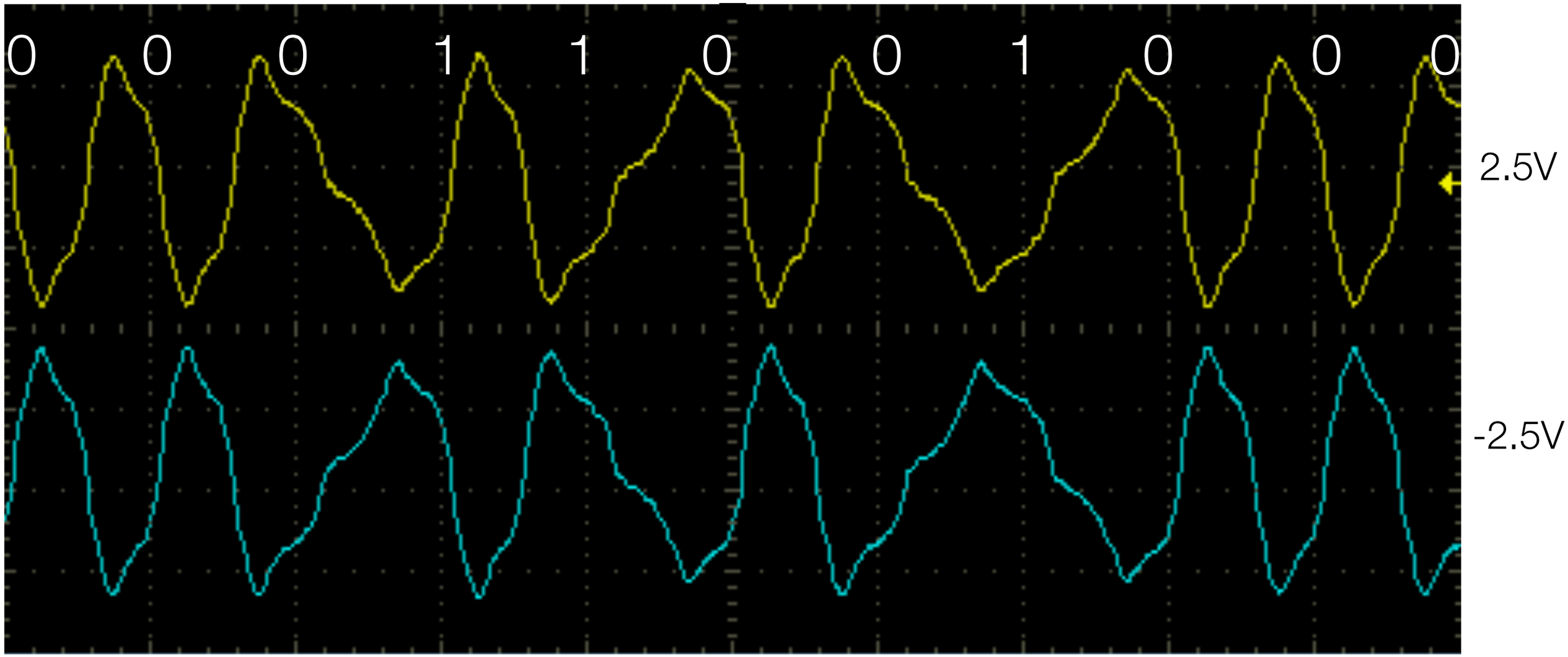


1980	1995	1999	2006
10Mb →	100Mb →	Gigabit →	10Gb
40Gb →	100Gb →	200/400 Gb →	Terabit
2010	2010	2017	> 2020

COMING SOON

COMING SOON

Baseband Data



10MBit Ethernet uses Manchester encoding

100MBit (Fast Ethernet)

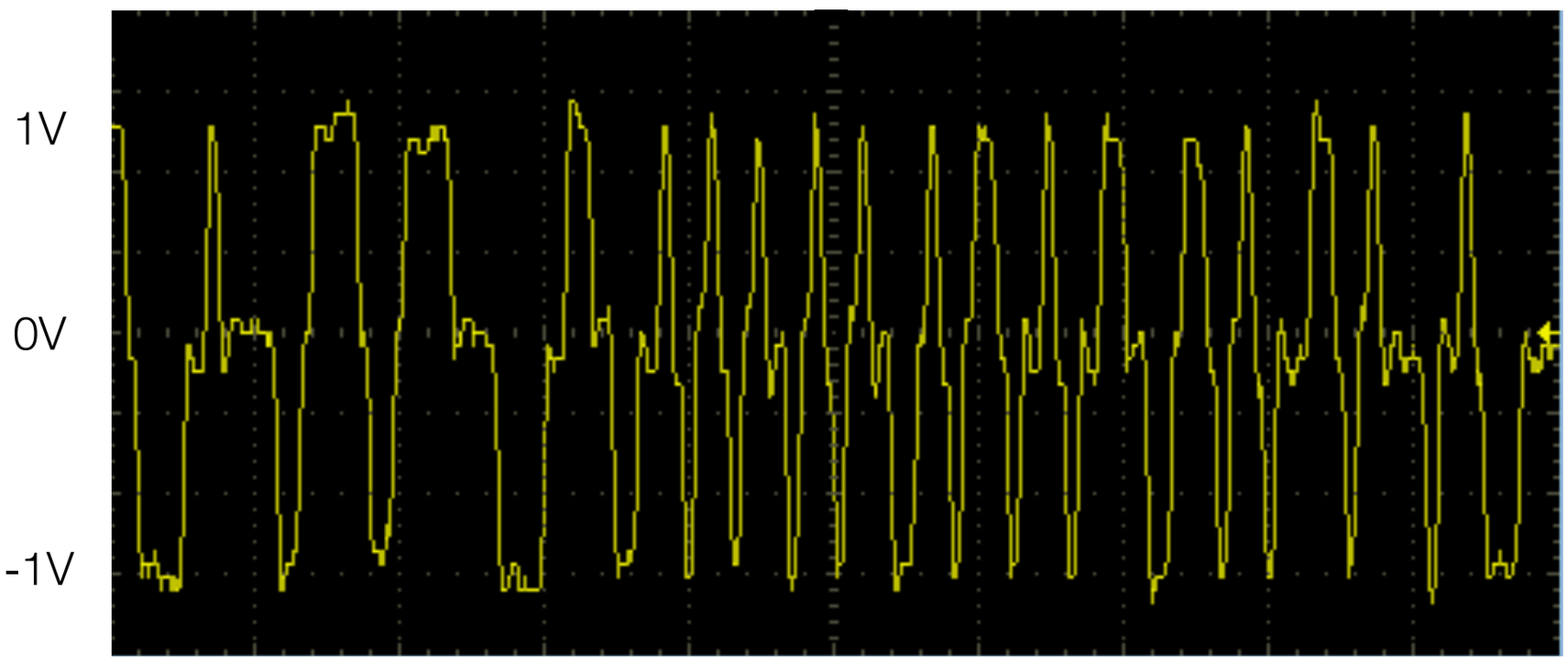
4 bits → 4B/5B → Scramble → MLT-3

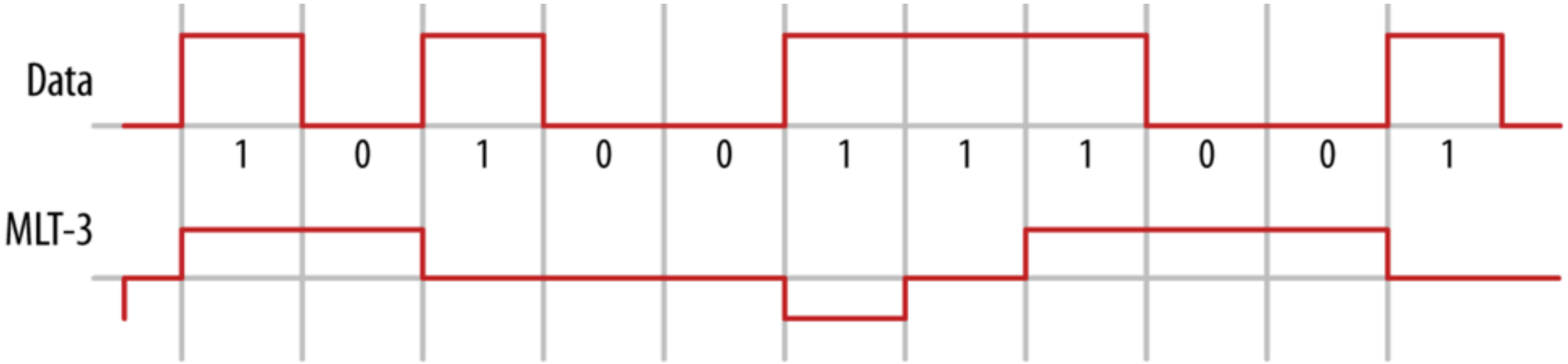
16 hex symbols
16 control symbols

At least 2 bit transitions per block for clock recovery

Spread across multiple frequencies to reduce interference

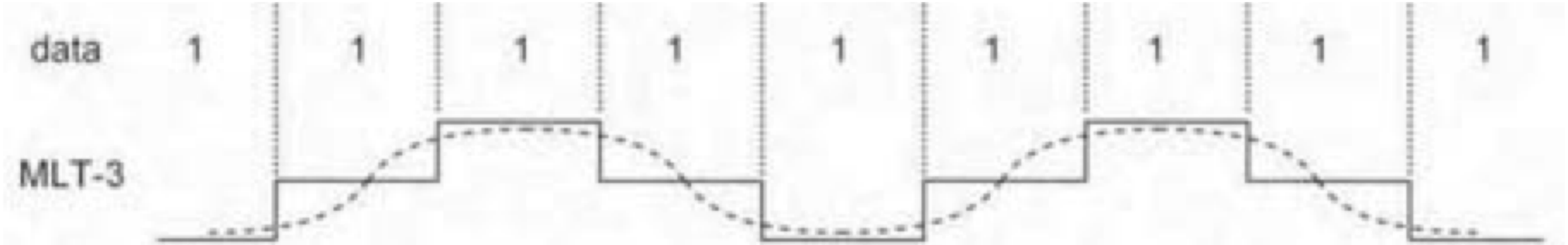
Reduce bandwidth





0: no transition, 1: transition

1 → 0 → -1 → 0 → 1

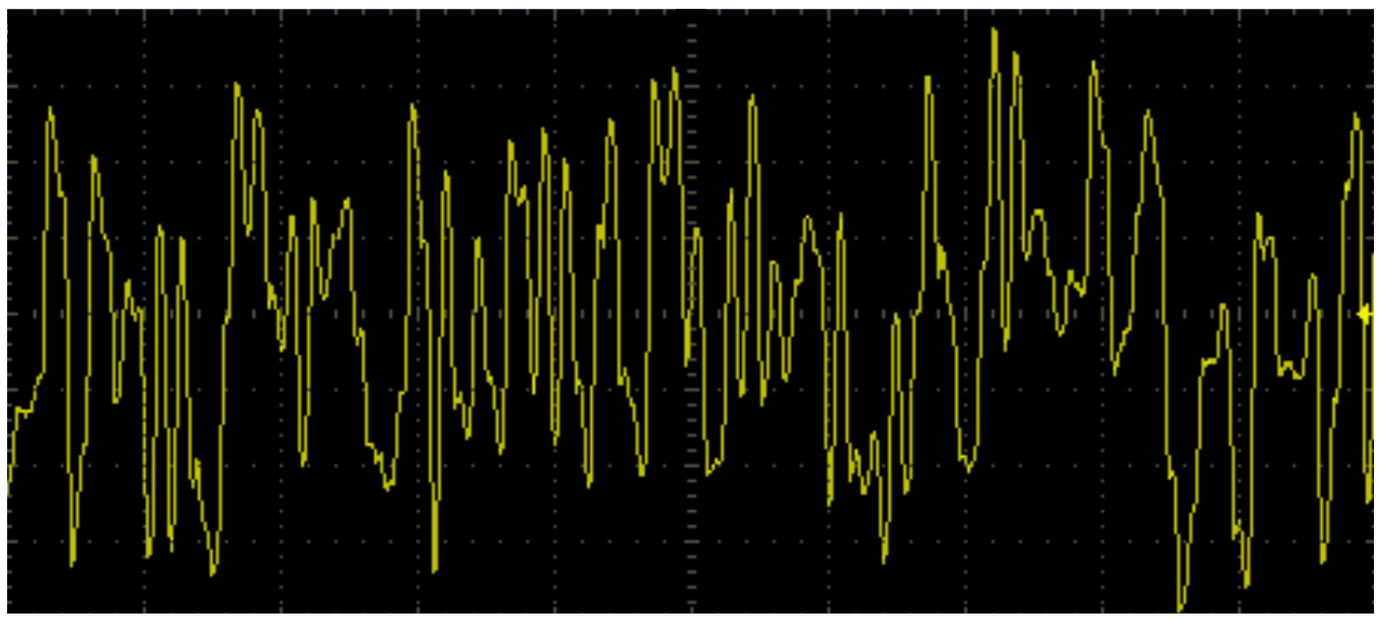


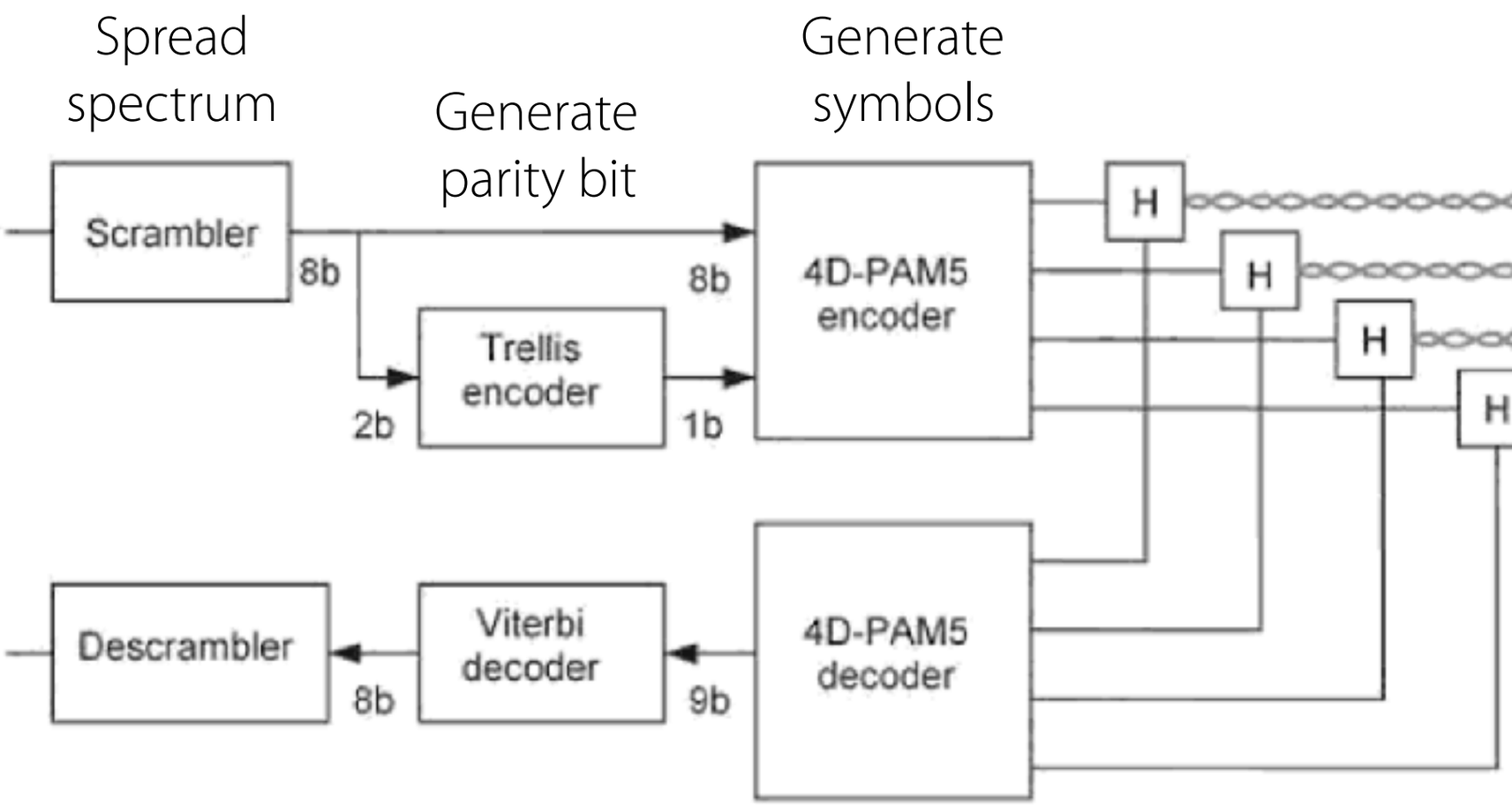
4B/5B creates 125MBaud signal

MLT-3 reduces fundamental frequency to 31.25MHz

Gigabit Ethernet

- 125MBaud per twisted pair.
- 500MBaud in total (2 bits per symbol)
- 4D-PAM5 (5 voltage levels, spread across 4 channels)
- Trellis modulation for parity bit





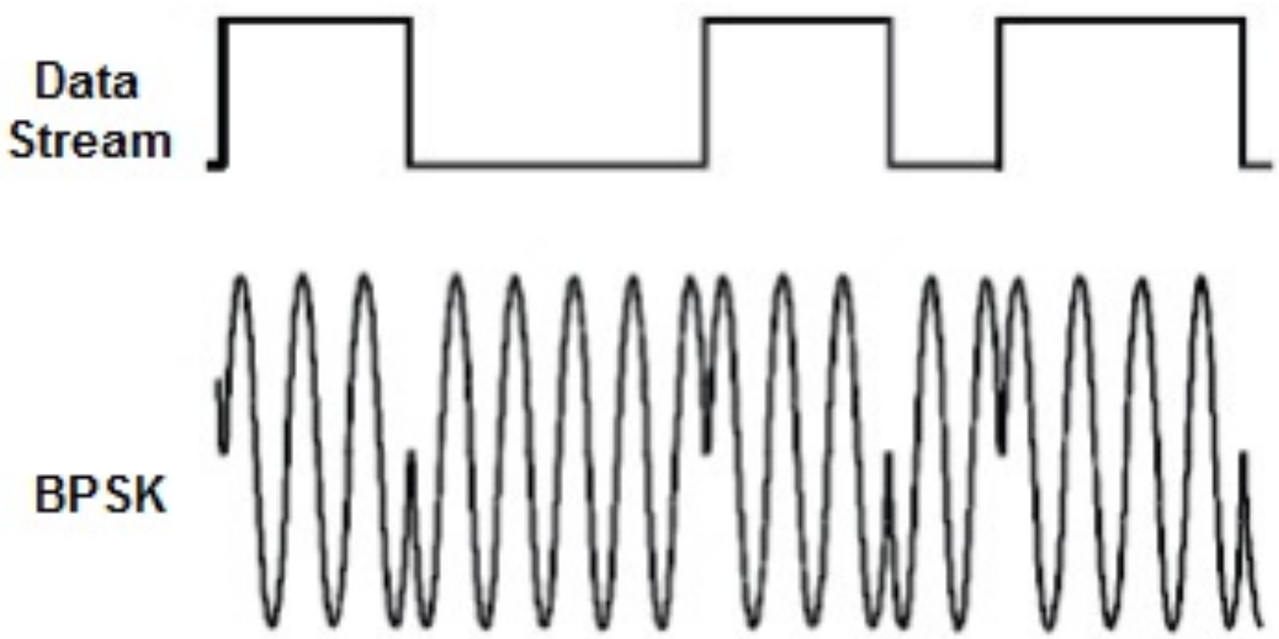
Channels are interdependent

5^4=625 symbols in total

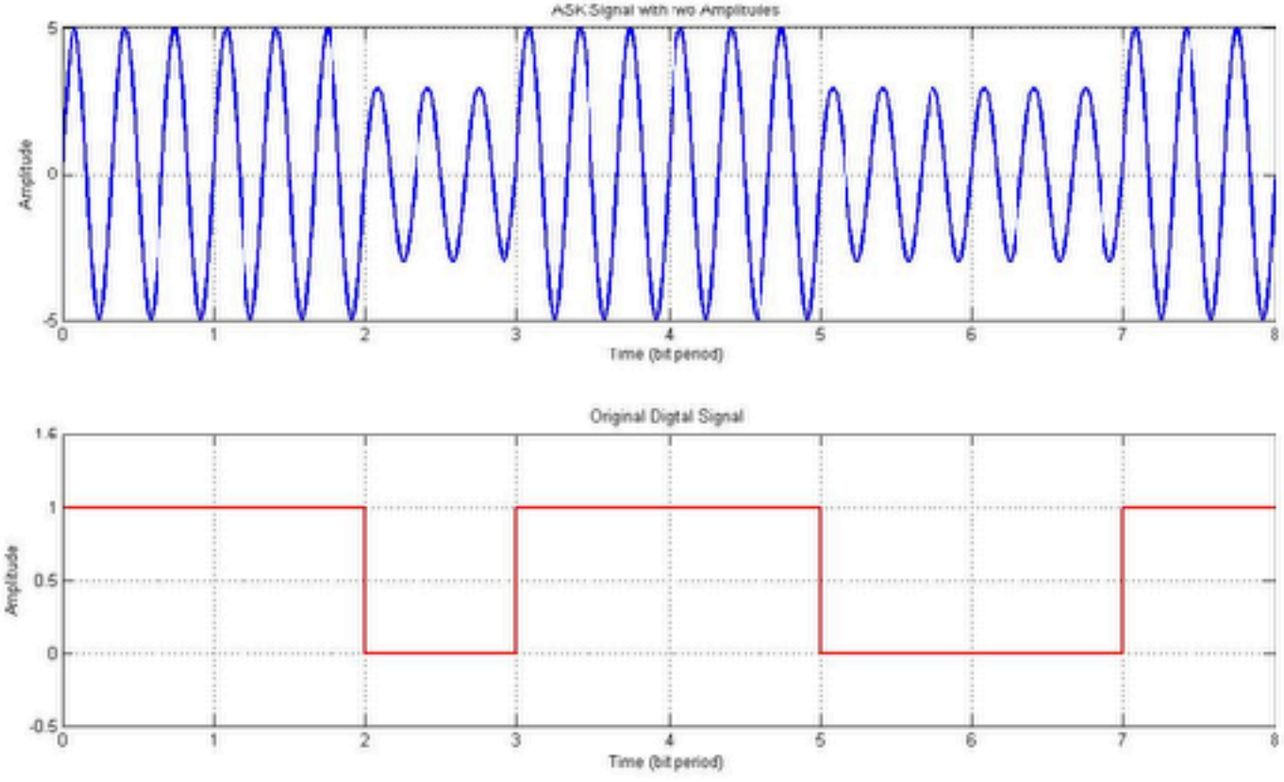
Encode 9 bit word: 8 data bits + 1 parity bit.
2^9=512 possible bitstrings

Remaining 113 symbols used for control or discarded

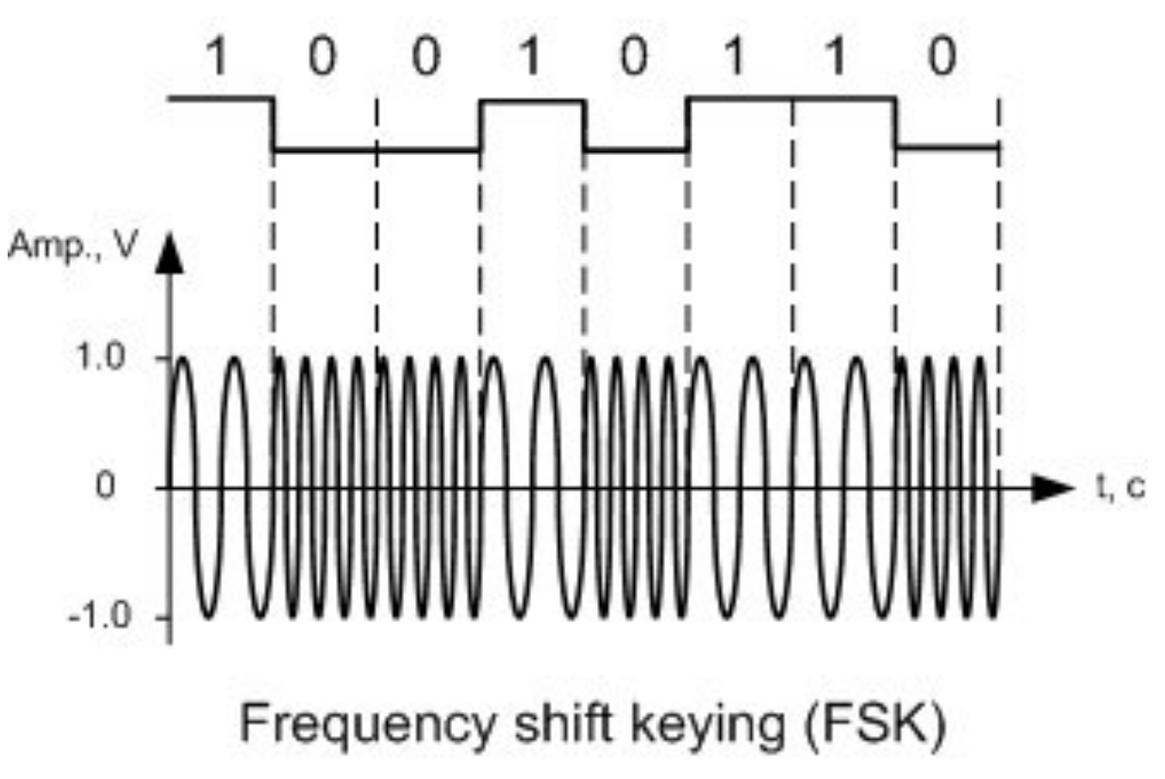
Phase



Modulate data onto a carrier wave
Often 900MHz, 2.4GHz, 5GHz



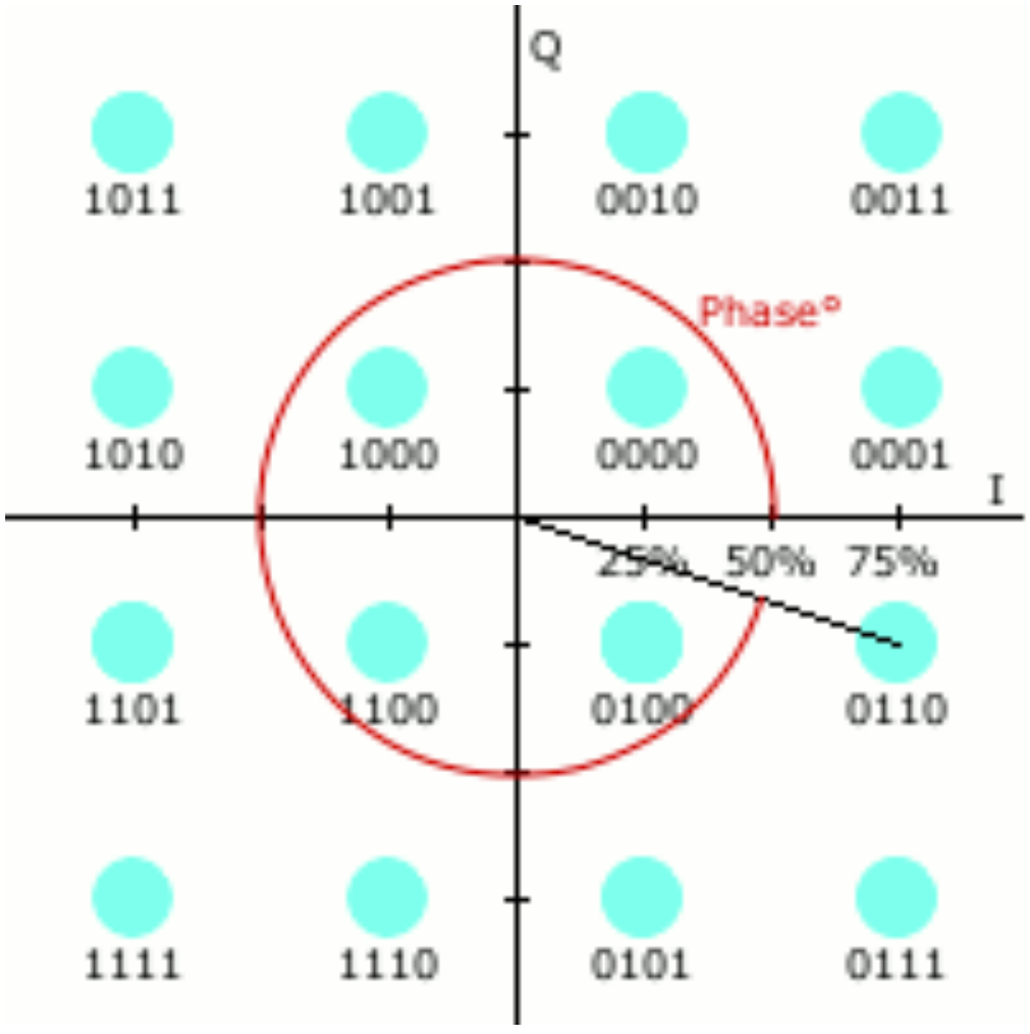
Amplitude



Frequency

Each symbol has a unique AMPLITUDE and PHASE

16QAM: 4 symbols per bit



Amp	Phase	Data
25%	225°	1100
75%	135°	1001
25%	315°	0100
75%	247°	1110
25%	225°	1100
75%	337°	0110

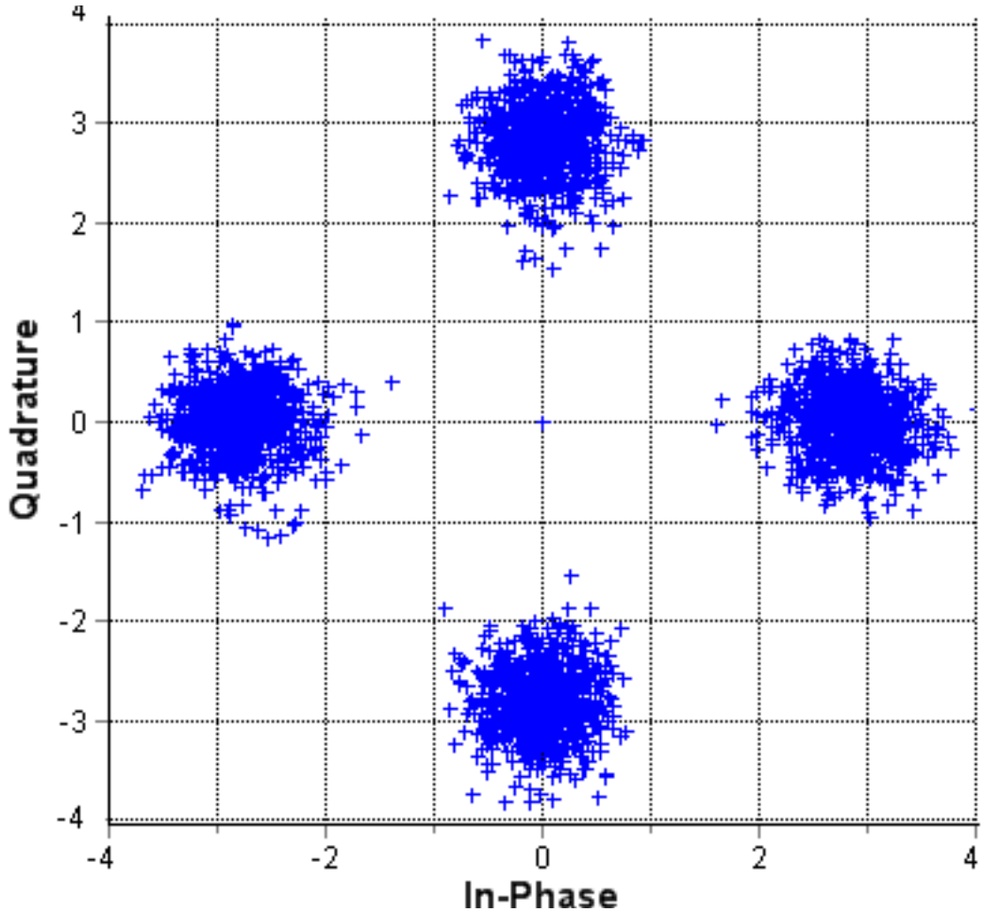
Take the real value (x-axis) and the imaginary value (y-axis)

Create In-phase and Quadrature (IQ) waves

Multiply IQ waves by carrier wave frequency and transmit

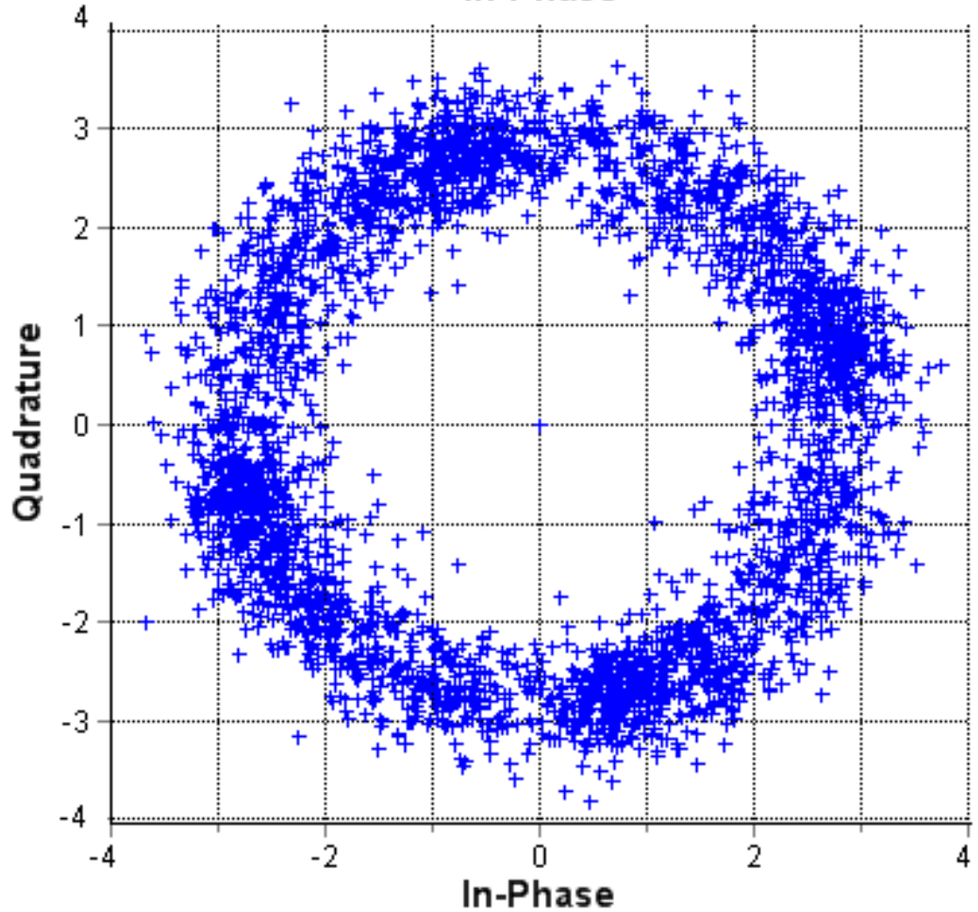
$$I(t)\cos(2\pi f_0 t) - Q(t)\sin(2\pi f_0 t)$$

At receiver low-pass filter signal to get back I/Q

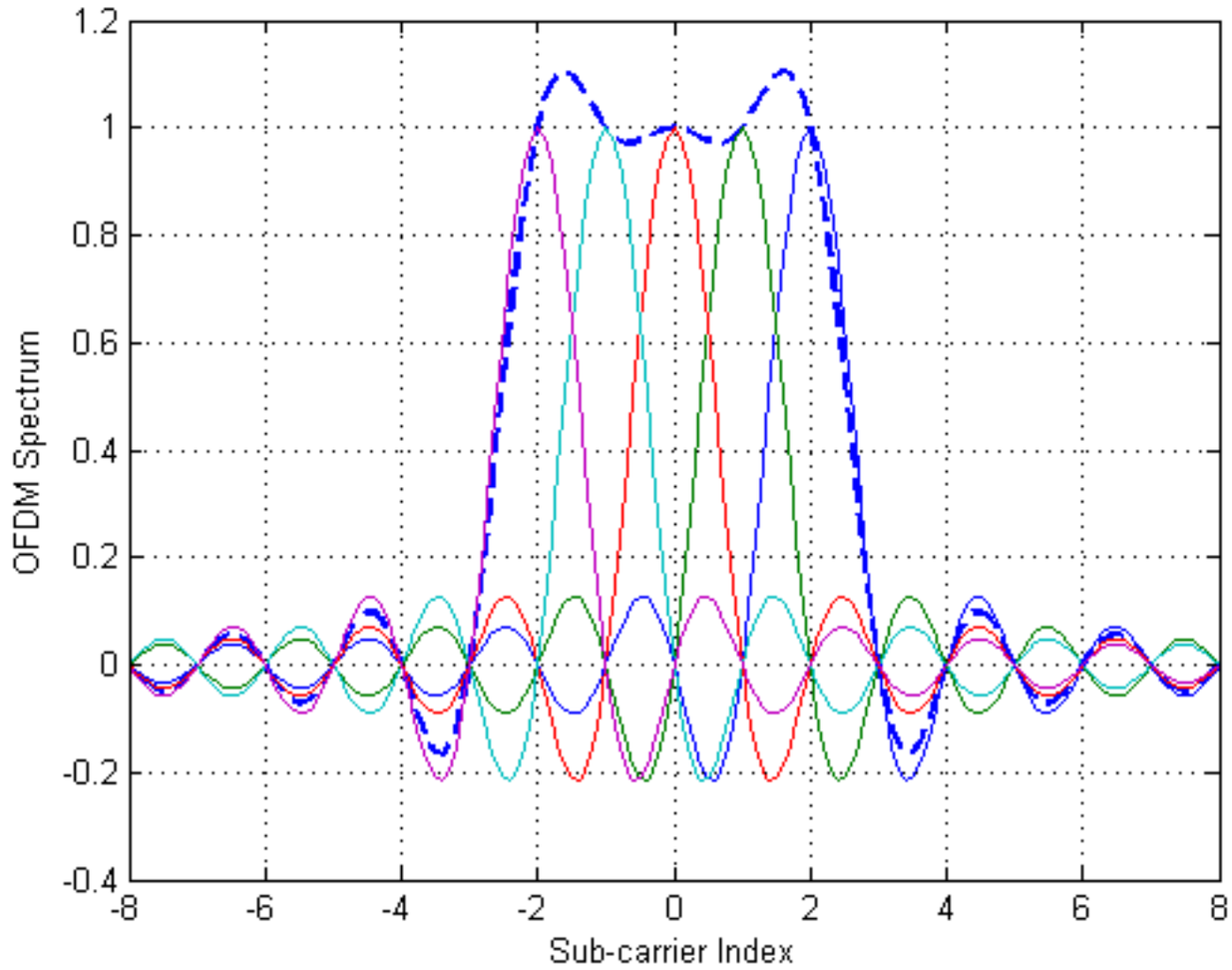


Attenuation (loss over distance)
Points move closer

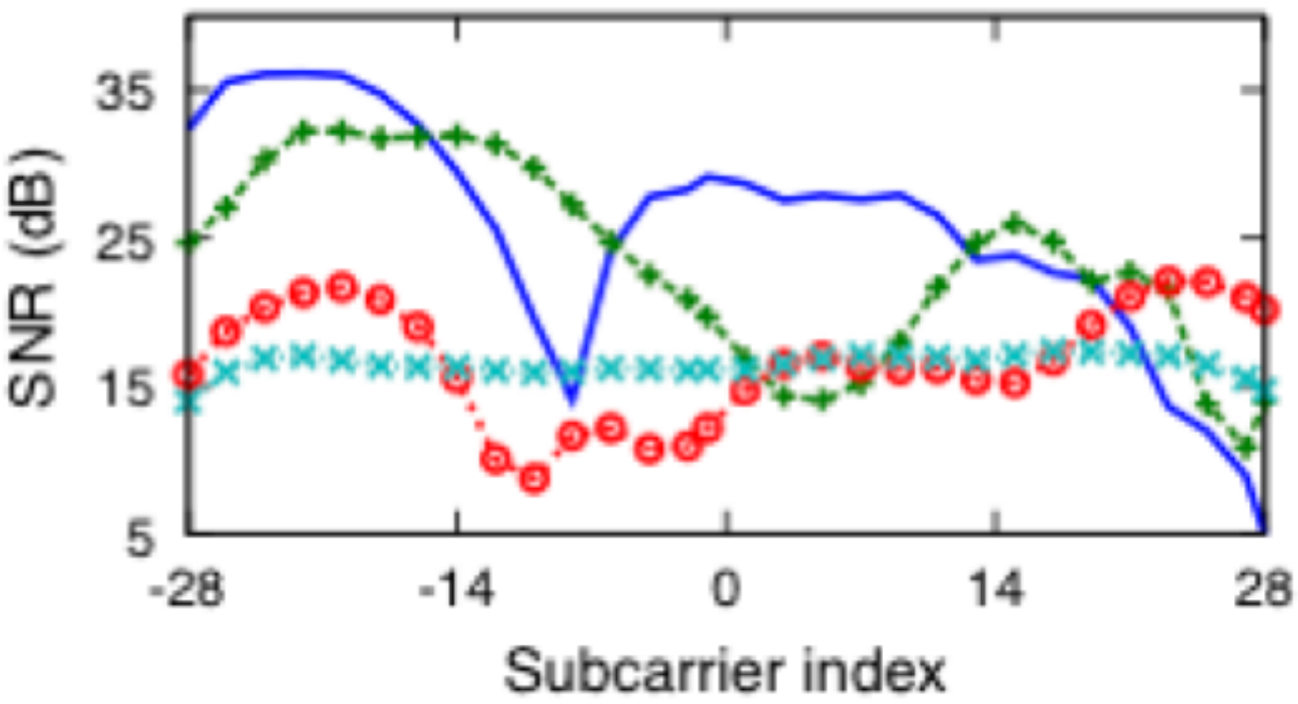
Noise
Points blur



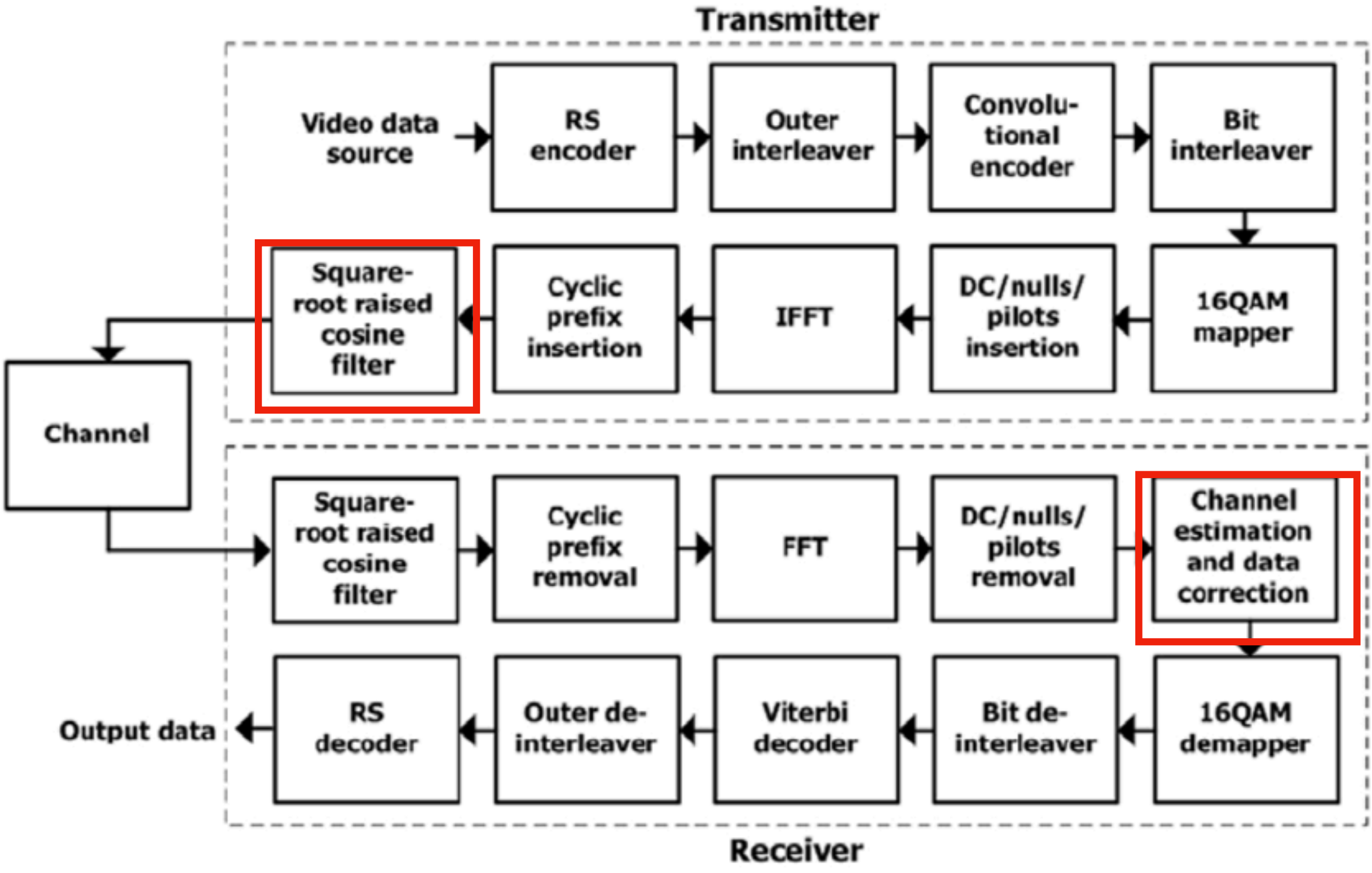
After fading and multipath



Many protocols use OFDM
Multiple streams of data over a channel
More robust to interference



Frequency-selective fading



Channel estimation: Estimate channel taps from packet preamble

Square-Root raised cosine filter: matched filtering, less ISI

Viterbi decoder: undo convolutional code (error correcting code)

Wi Fi ™

NB - IoT

sigfox

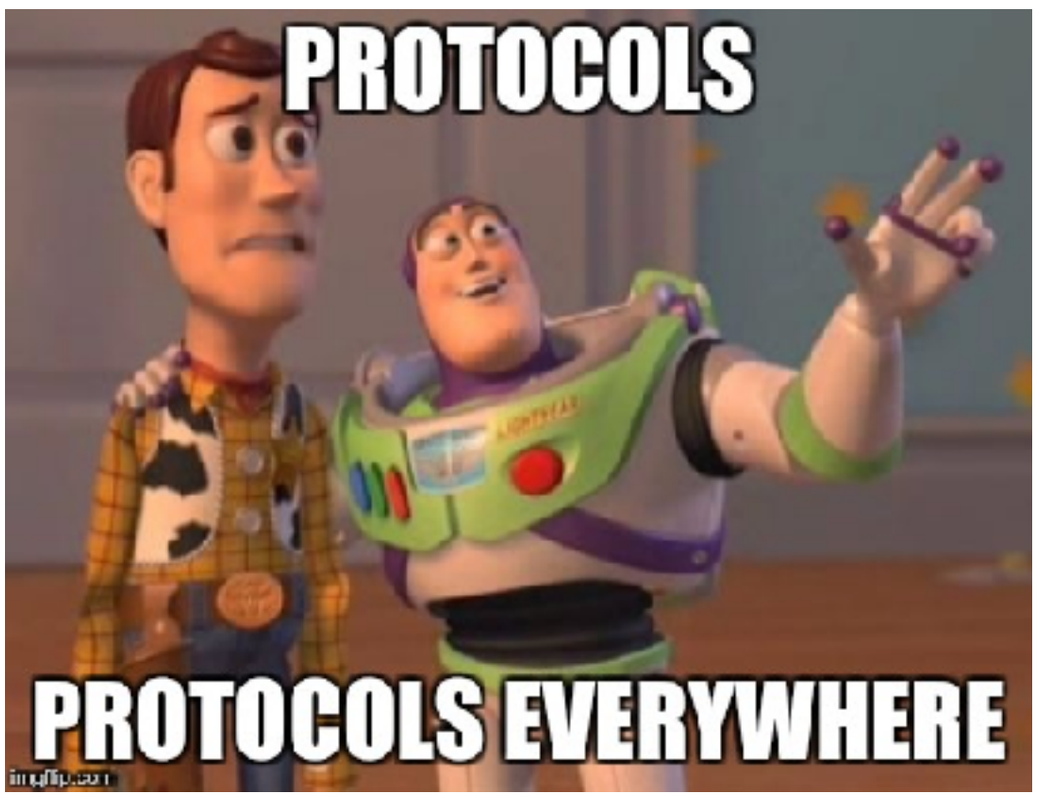
LoRa®

Bluetooth™

RFID

Z-WAVE®

ZigBee®



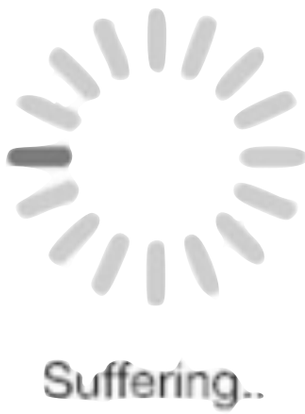
ISM bands

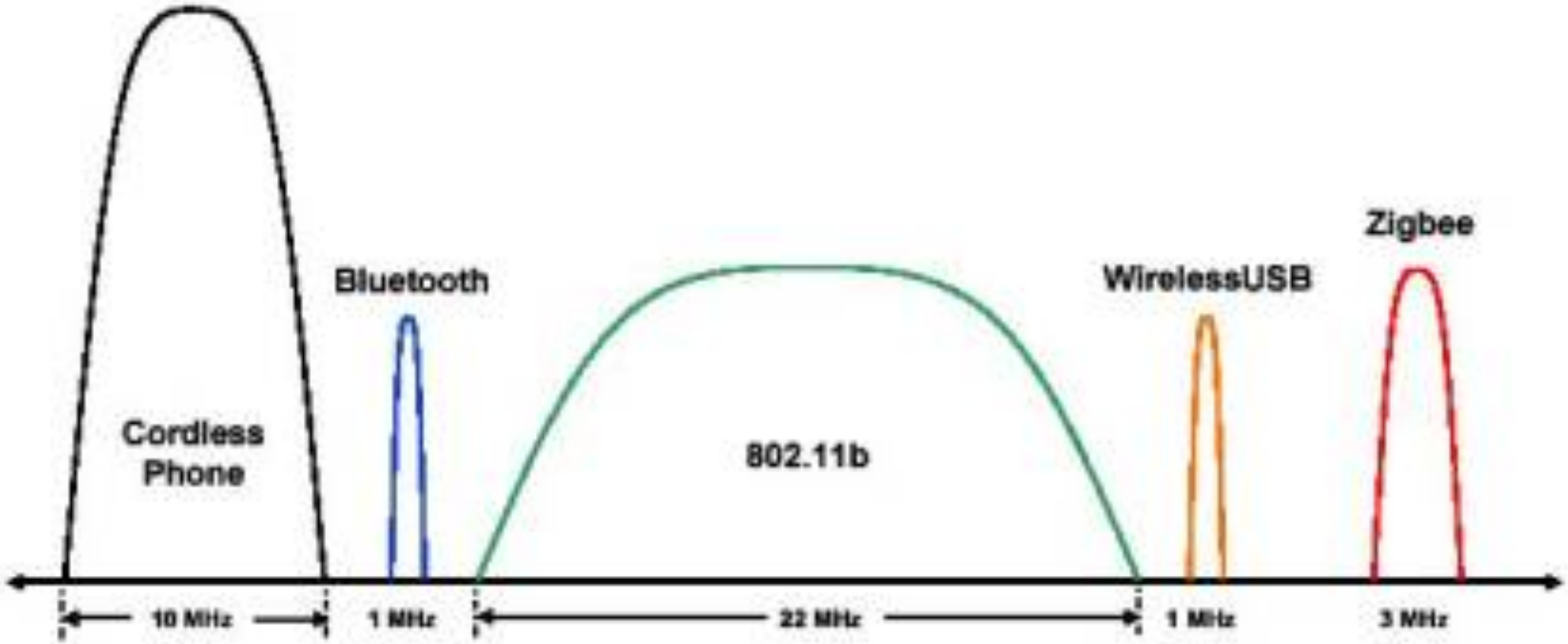
- Reserved for industrial, scientific, medical purposes

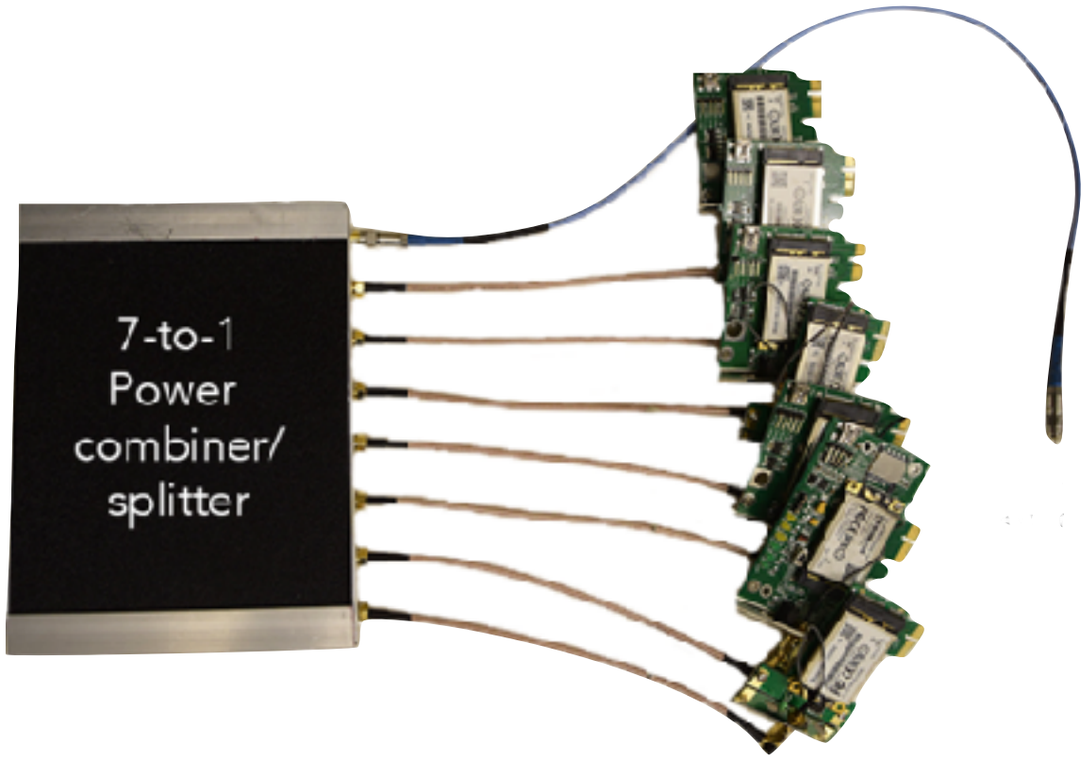
- Originally not for communication
- But used for short-range communication

- Longer range like cellular, satellite, amateur radio, FM radio use other reserved bands

- Common bands: 900MHz, 2.4GHz, 5GHz







Combine transmissions over several frequency channels. Get Gigabit/s speeds

Packet Collisions

- CSMA
    - Check channel, RTS/CTS
    - Exponential backoff
- Standard for Wi-Fi, BLE, Zigbee
- What about other protocols?

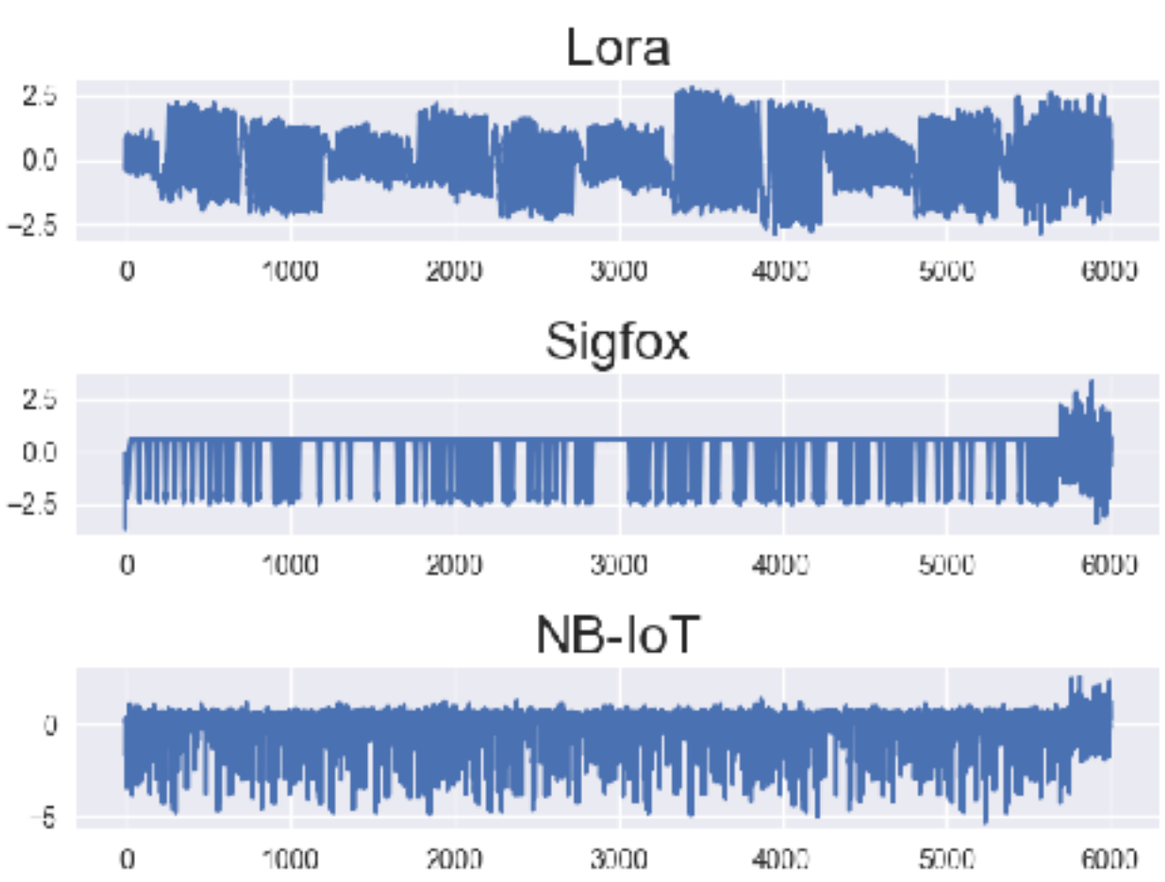
Lora, Sigfox, NB-IoT

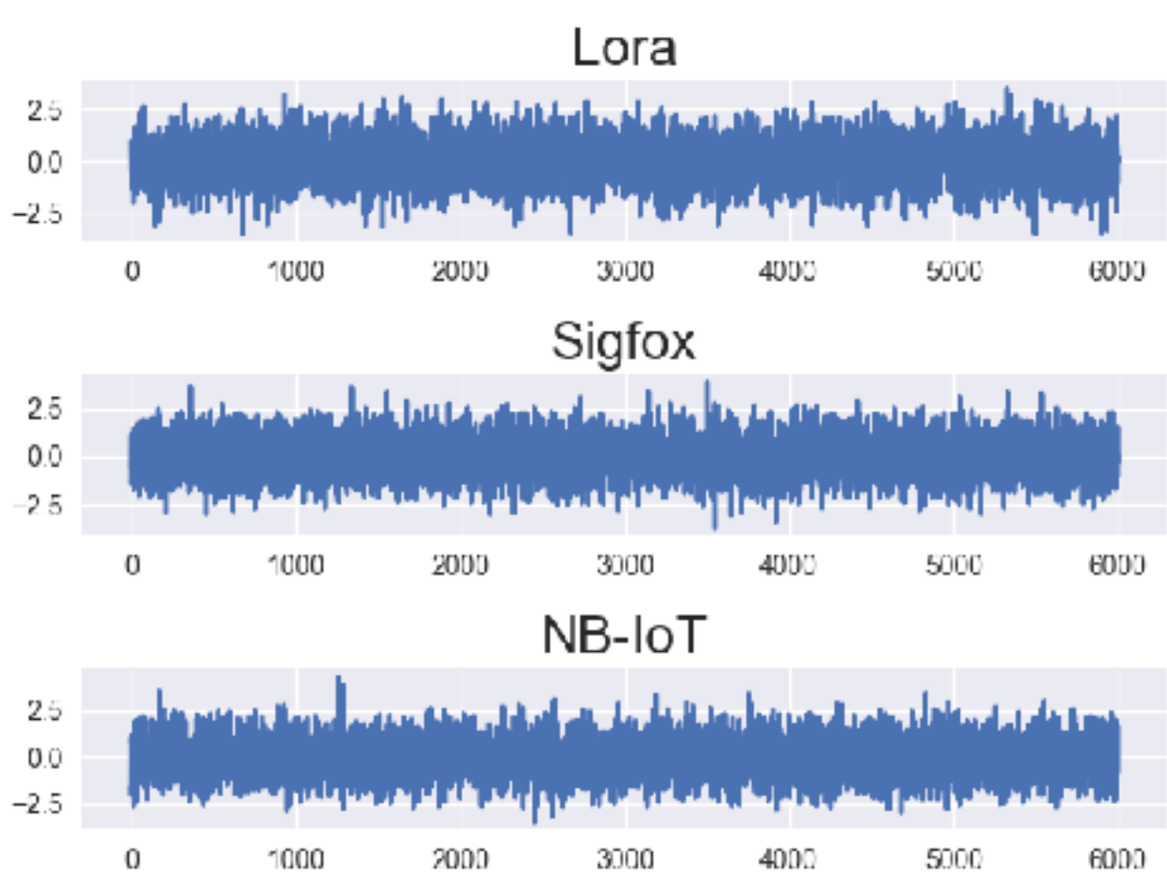
Long range + can be decoded BELOW the noise floor

Lora range: > 10 miles

No MAC protocols yet!

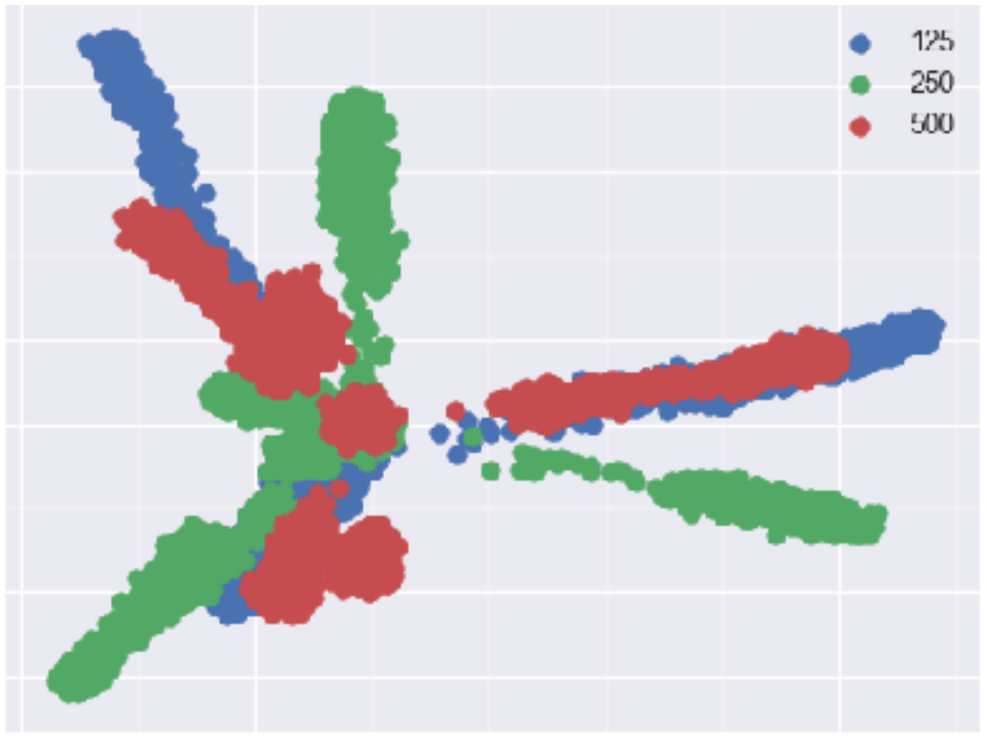
Lora, Sigfox and Z-wave are proprietary (unlike Wi-Fi)

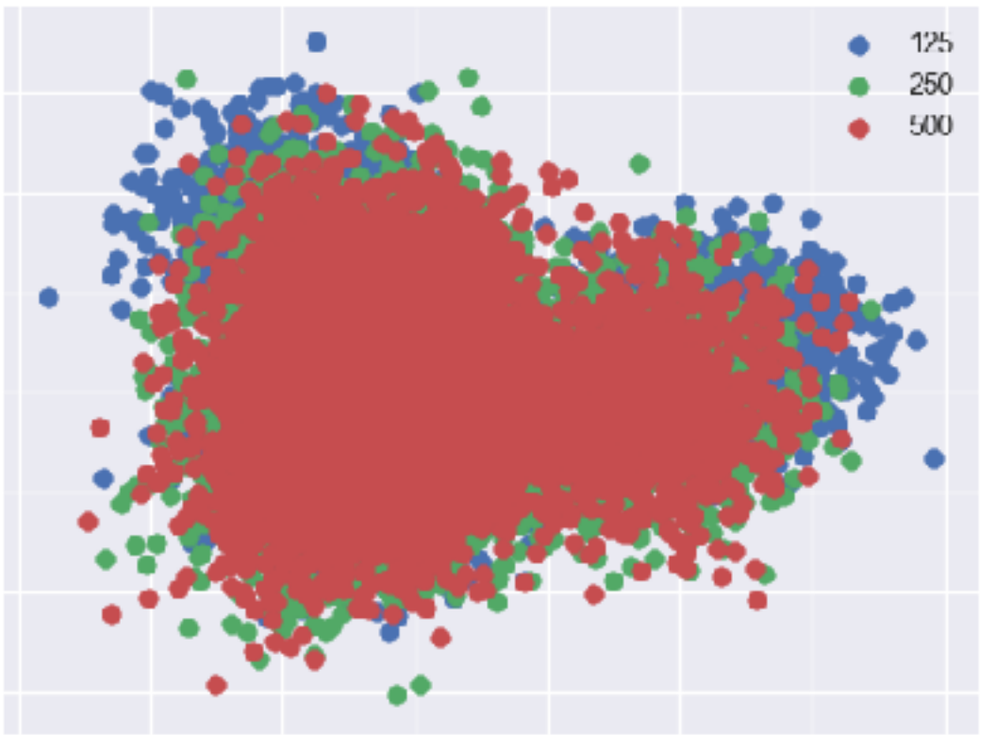




Dimensionality reduction

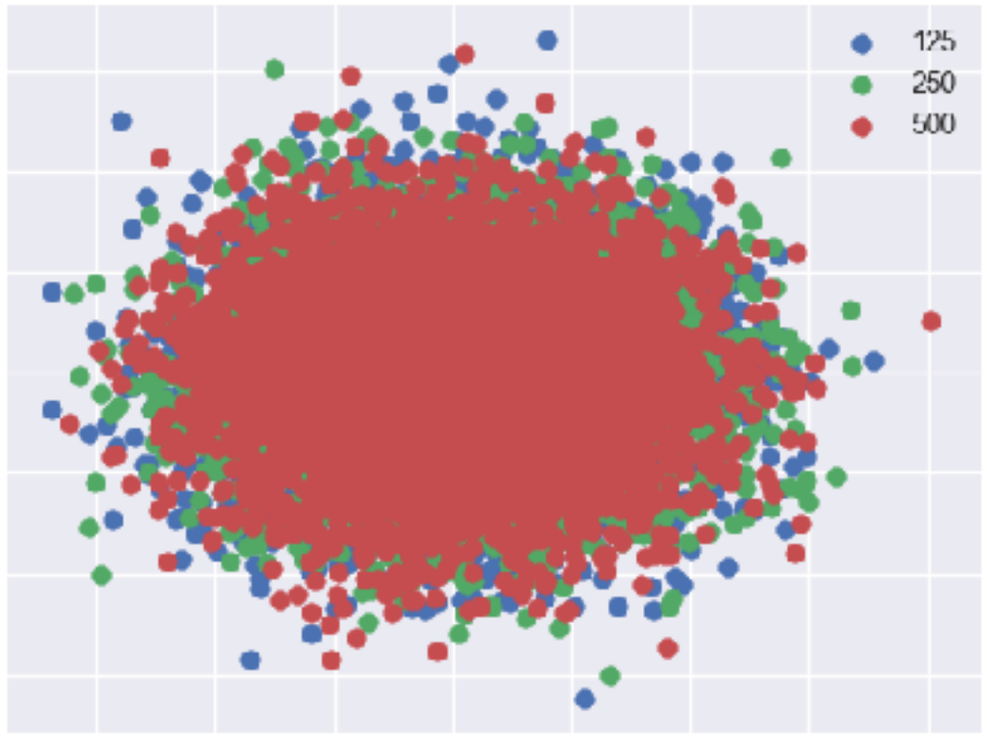
SNR=-10





SNR=-20

SNR=-30



Machine learning underneath the noise floor