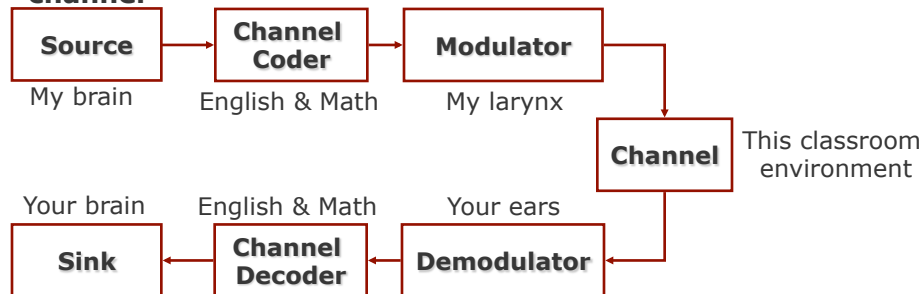


Let's look at the communication process

- The purpose of communication is to convey information from one entity to another
- We need to "encode" the information in some agreed-upon way
- We need to "modulate" the data to create a physical waveform
- The modulated waveform travels over a physical channel



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Week 1 1-1

In this quick review/intro

- We can't worry about the source...
- So we'll assume that
 - It is a digital (as opposed to analog) source, and,
 - All of the bits are relevant (it is compressed), and,
 - There's no error correction (coding)
- We don't care about the interpretation of the bits, just their value
- Modulation, we'll quickly look at common digital modulations
 - Pulse Amplitude Modulation (PAM)/Pulse Position Modulation (PPM)
 - Phase modulation (PM)
 - Frequency Shift Keying
 - Quadrature Amplitude Modulation (QAM)

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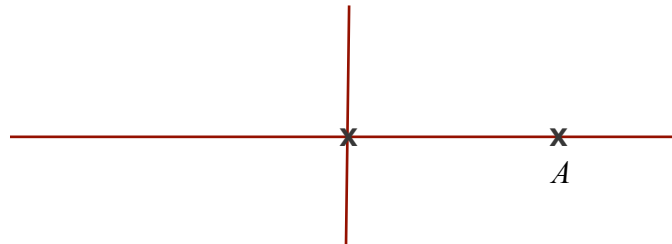
Week 1 1-2

Pulse Amplitude modulation

- It's simple! Just turn the pulse on or off!

$$m(t; b_k) = \begin{cases} 0 & b_k = 0 \\ A & b_k = 1 \end{cases}$$

- This is a one-dimensional signal: I only need one axis to plot all of the possible values
- We can draw a "constellation diagram"



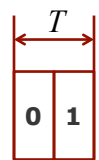
- The decoder will be simple!

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Week 1 1-3

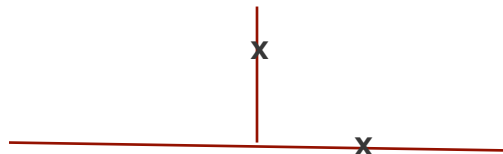
Or, we could "move the pulse"

- Pulse Position Modulation (PPM)



$$m(t; b_k) = \begin{cases} p\left(t, \frac{T}{2}\right) & kT \leq t < (k+0.5)T \text{ and } b_k = 0 \\ p\left(t - \frac{T}{2}, \frac{T}{2}\right) & (k+0.5)T \leq t < (k+1)T; b_k = 1 \end{cases}$$

- The constellation diagram is now 2-D,



- Because the signals are "orthogonal" in time

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Week 1 1-4

Orthogonality

- From a communication system/signal processing standpoint, we say that two systems are orthogonal over a symbol duration of T if

$$\int_0^T x_1(\tau)x_2^*(\tau)d\tau = 0$$

- We'll look at several different kinds of orthogonality as we go
- Clearly, PPM is "better" than PAM for the same amount of energy, because the samples are farther apart...
- ...but proof of this statement requires CMPE320

The actual transmitted signal

- The transmitted signal is modulated onto a carrier, typically taken to be $c(t) = \cos(2\pi f_c t)$
- So, for PAM/PPM

$$s(t; b_k) = m(t; b_k)c(t) = m(t; b_k)\cos(2\pi f_c t)$$

- ...and in the frequency domain

$$S(f) = M(f) * C(f) = M(f; b_k) * \left(\frac{1}{2}\delta(f - f_c) + \frac{1}{2}\delta(f + f_c) \right)$$

- There are a few more complications, but I'll skip them right now.
- You can see that the spectrum depends on the value of the bit! And that can be random! And that leads to CMPE320-type issues...which I can't do right now.

So let's look at the other kinds of modulation

- Phase modulation changes the phase, but not the amplitude...
- ...so it's a constant-amplitude, energy efficient, but bandwidth inefficient method
- Very commonly used!
- Simplest version is BPSK

$$\begin{aligned}
 s(t; b_k) &= \cos(2\pi f_c t + b_k \pi) \\
 &= \cos(2\pi f_c t) \cos(b_k \pi) - \sin(2\pi f_c t) \sin(b_k \pi) \\
 &= (-1)^{b_k} \cos(2\pi f_c t)
 \end{aligned}$$

