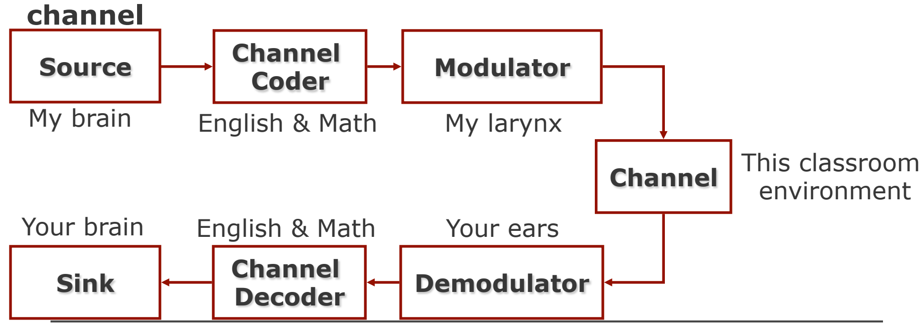
Let's look at the communication process

- **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**



In this quick review/intro

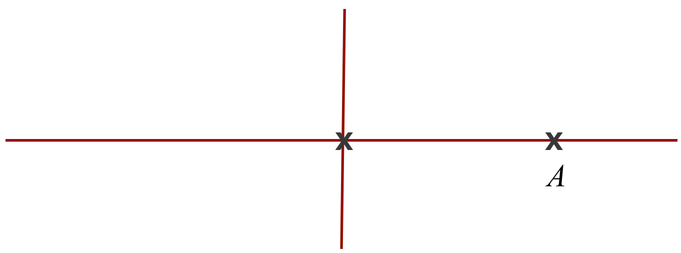
- **We can't worry about the source…**
- **So we'll assume that**
  - **It is a digital (as opposed to analog) source, and,**
  - **All of the bits are relevant (it is compressed), and,**
  - **There's no error correction (coding)**
  - **We don't care about the interpretation of the bits, just their 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)**

Pulse Amplitude modulation

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

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

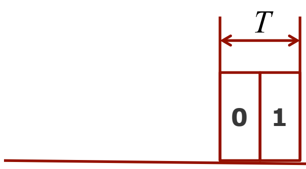
- This is a one-dimensional signal: I only need one axis to plot all of the possible values
- We can draw a "constellation diagram"



- The decoder will be simple!

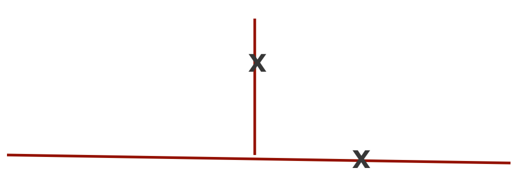
Or, we could "move the pulse

- Pulse Position Modulation (PPM)



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

- The constellation diagram is now 2-D,



- Because the signals are "orthogonal" in time

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

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