1. Python / Jupyter

- python 3.5 + jupyter will be used for all labs
- introduce jupyter interactively
- If they have questions about python see me

2. Complex numbers

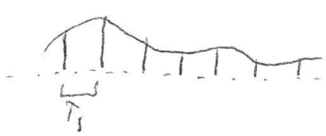
- $a + bi$

aside: the algebraic "closure" of the reals.

- Euler's identity: $e^{i\theta} = \cos\theta + i\sin\theta$ (discuss multiplication)
- we will model radio signals using complex numbers
  - This is due to hardware reasons, but also mathematically convenient.
  - Called "quadrature sampling"

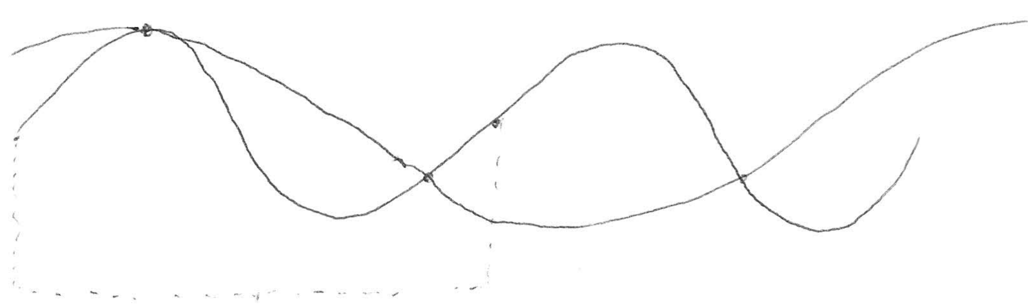
3. Sampling.

- real radio signals are continuous, but we will sample them discretely.



Add Oversampling

- How often do we need to sample?



$f = \frac{1}{T}$

- So if we're too slow, there is some ambiguity.
- Nyquist showed that to get perfect reconstruction, it's sufficient to sample at twice the highest frequency.
  - with complex numbers, sample rate must be at least the highest or most negative frequency
- This means - for most applications - bandwidth = sample rate

4. DFT

- In the last example, talked about the "frequency" of the signal. But there's no reason a signal can't have multiple frequencies

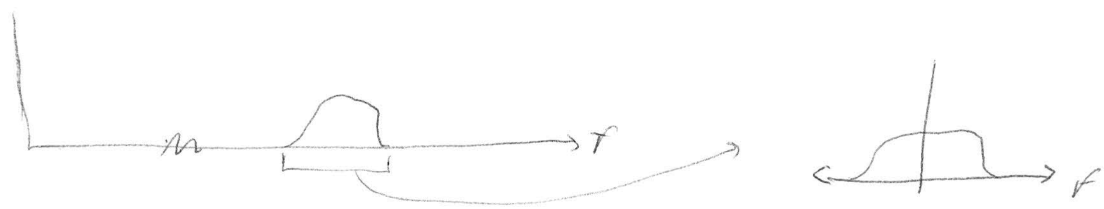
- A discretely sampled signal will also have a discrete spectrum.
- The <u>Fourier Transform</u> is a way of going ~~from~~ between time domain and frequency domain
    - There is both a continuous version and a discrete version.

$$X[k] = \sum_{n=0}^{N-1} x_n e^{-i 2\pi \frac{kn}{N}}$$

- aside: complex exponential
- intuition: the exponential is "unwinding" the signal at different rates.

5. The spectrum

- All signals have some bandwidth.
- In wireless, typically the bandwidth is much smaller than the center frequency
  - called "narrowband", though the distinction is arbitrary
  - unlike audio signals (e.g., voice).
- Digital wireless signals are almost always at baseband



* Spectrograph demonstration *