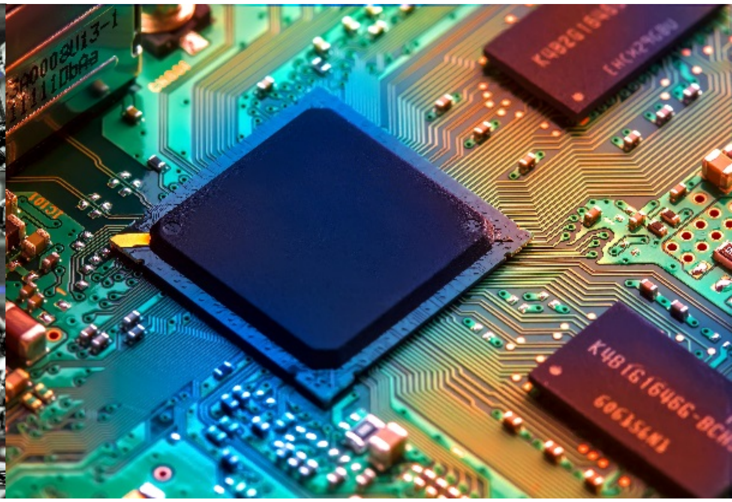
FMCW Radar? Never Heard of it

Spencer Markowitz
The TA for most of you



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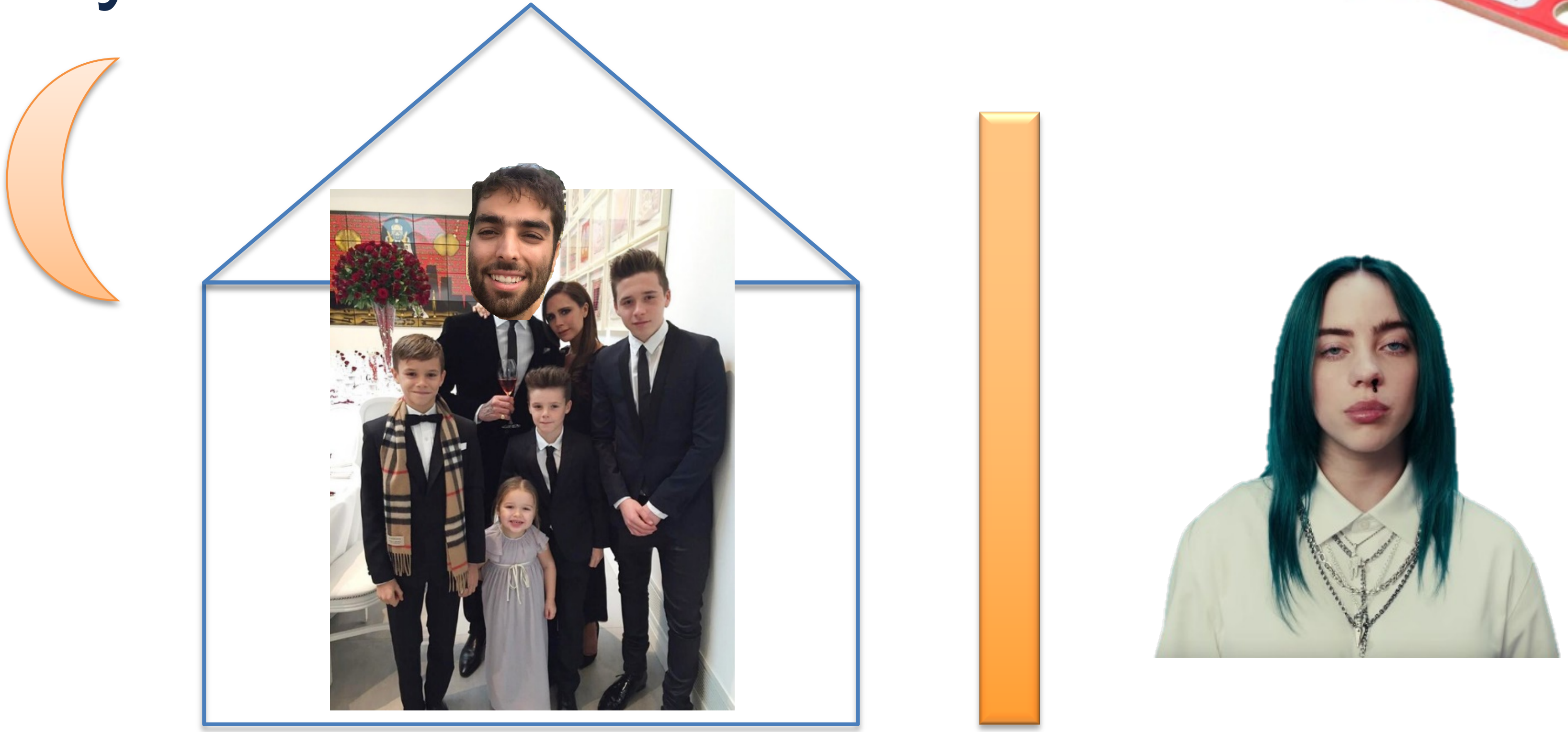
Why aren’t cameras enough?

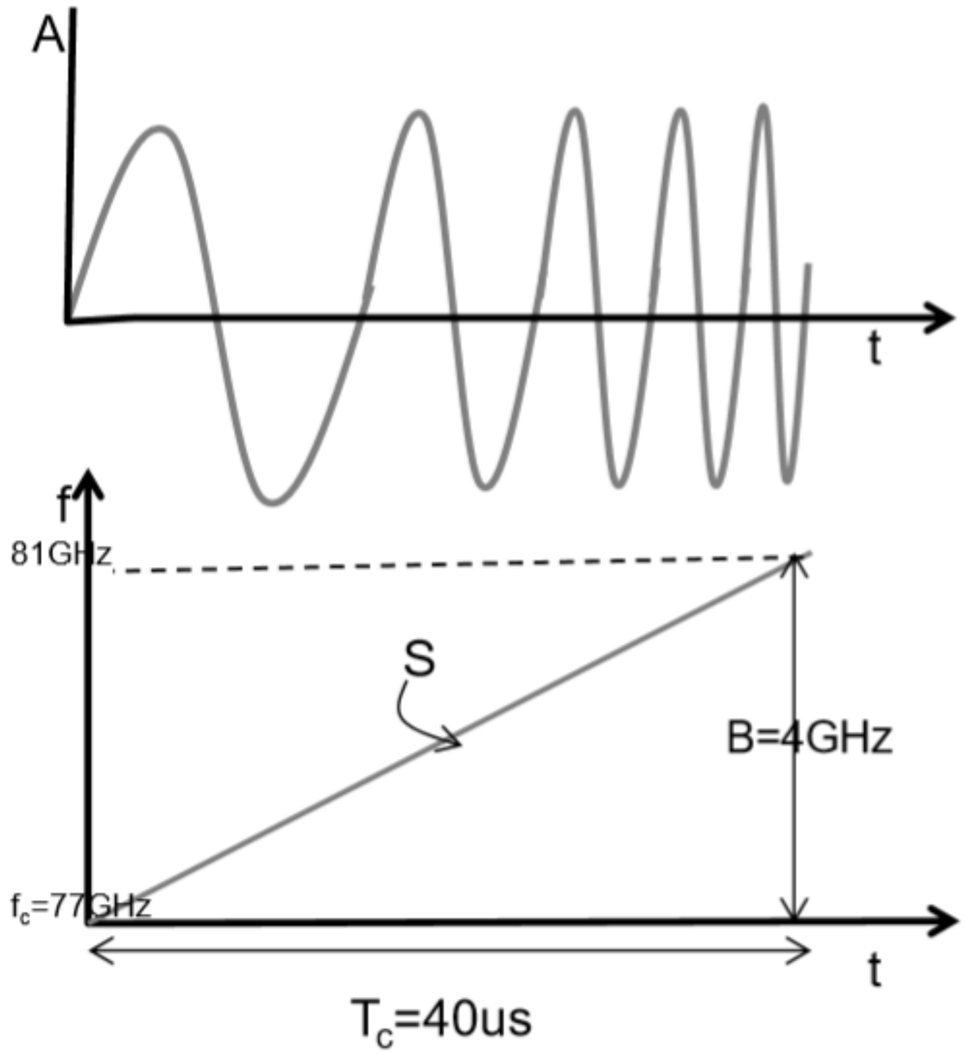
- Low light conditions
- Occlusion
- Accurate velocity measurements
- Privacy



Radars send chirps and listen for reflections.

- The chirp's frequency increases linearly (our particular radar).
- That's where the "FM" comes from.

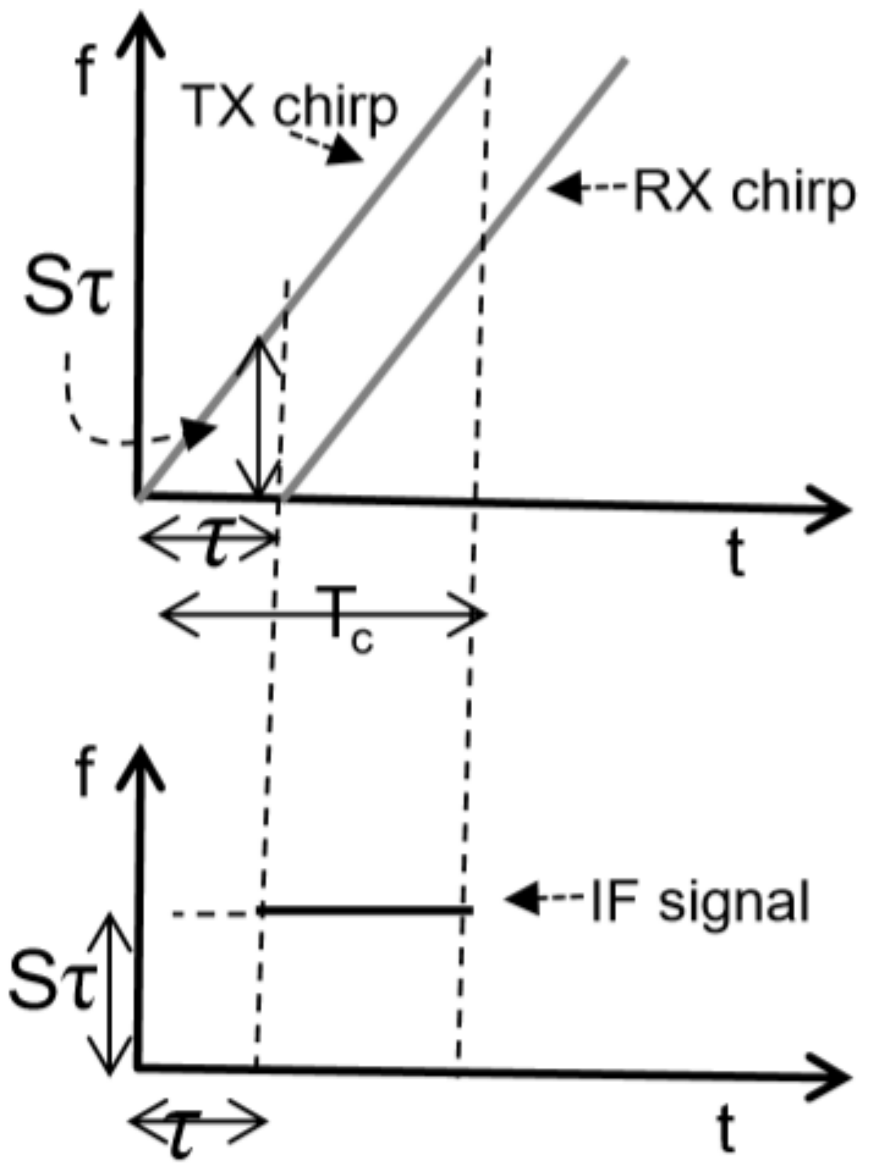
1. S = slope
2. B = bandwidth
3. T_c = chirp period



Getting the range from a reflection

- The reflected signal is just a time delayed (τ) version of the transmitted one.
- The difference in frequency is constant and a function of τ.
- The frequency difference is

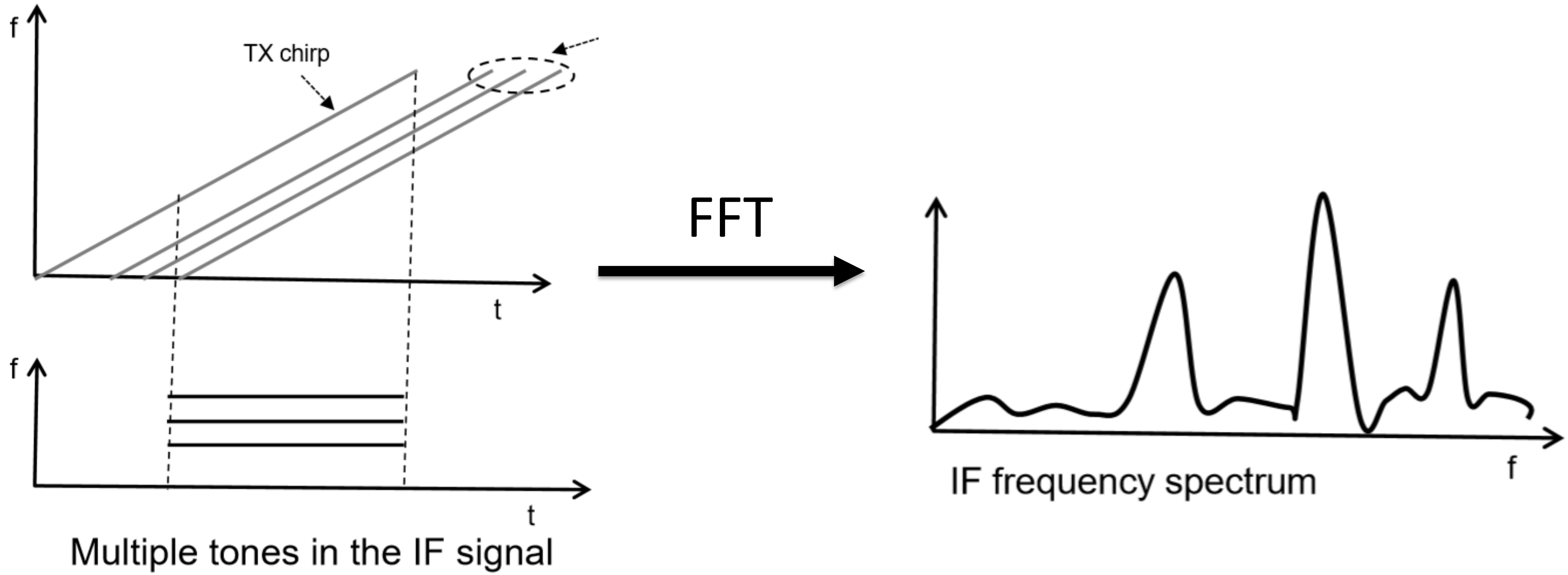
$$S\tau = \frac{S(2d)}{c}$$



How do we subtract frequencies again?

- Mixing signals outputs the sum/difference of the two frequencies.
- The difference is what we care about here.

Multiple objects gets us multiple reflections



Remember Frequency resolution in audio?

For two objects separated by a distance Δd, the difference in their IF frequencies is given by $\Delta f = \frac{S2\Delta d}{c}$

Since the observation interval is T_c, this means that

$$\Delta f > \frac{1}{T_c} \Rightarrow \frac{S2\Delta d}{c} > \frac{1}{T_c} \Rightarrow \Delta d > \frac{c}{2ST_c} \Rightarrow \frac{c}{2B} \quad \text{(since } B=ST_c\text{)}$$

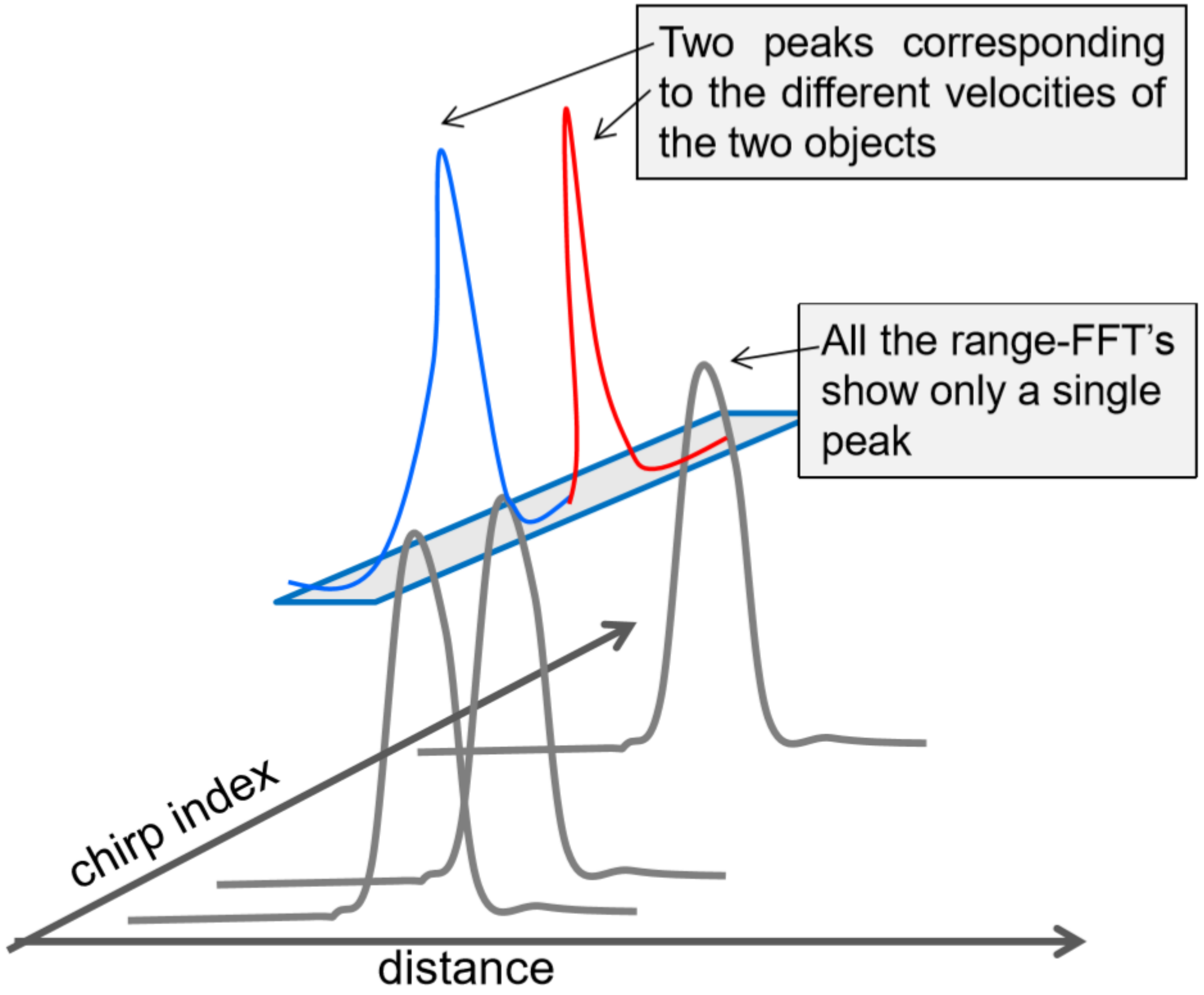
The lowest detectable frequency must have one full period in the duration of a signal.

Difference in range too small? Use the phase!

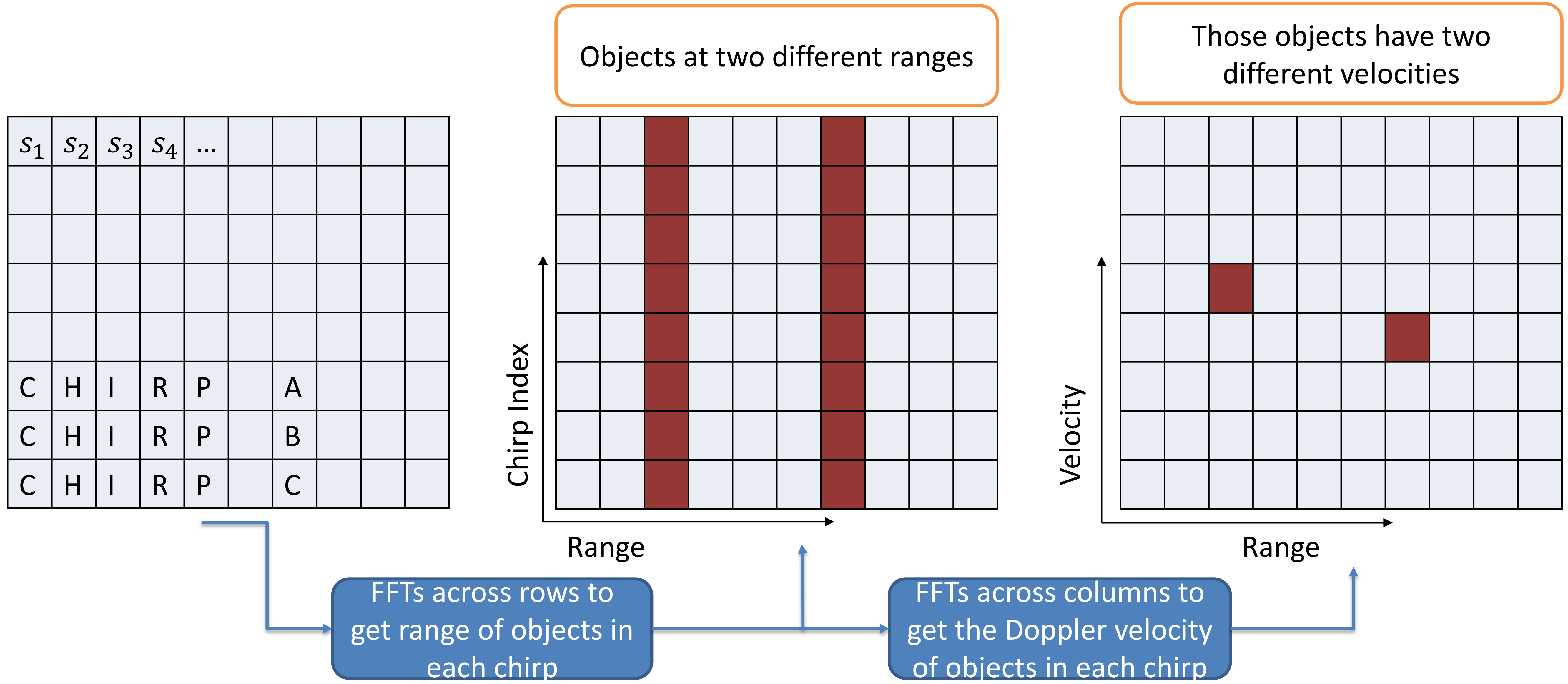
- Phase is much more responsive than the frequency to small changes in range.
- Let's say we want to measure velocity.
  - We send chirps at a very fast rate
  - Between each chirp, the magnitude peak will hardly move.
  - But the phase will!

Measuring velocity (Doppler)

- Send consecutive chirps (this includes time for sampling)
- Take the FFT across multiple chirps

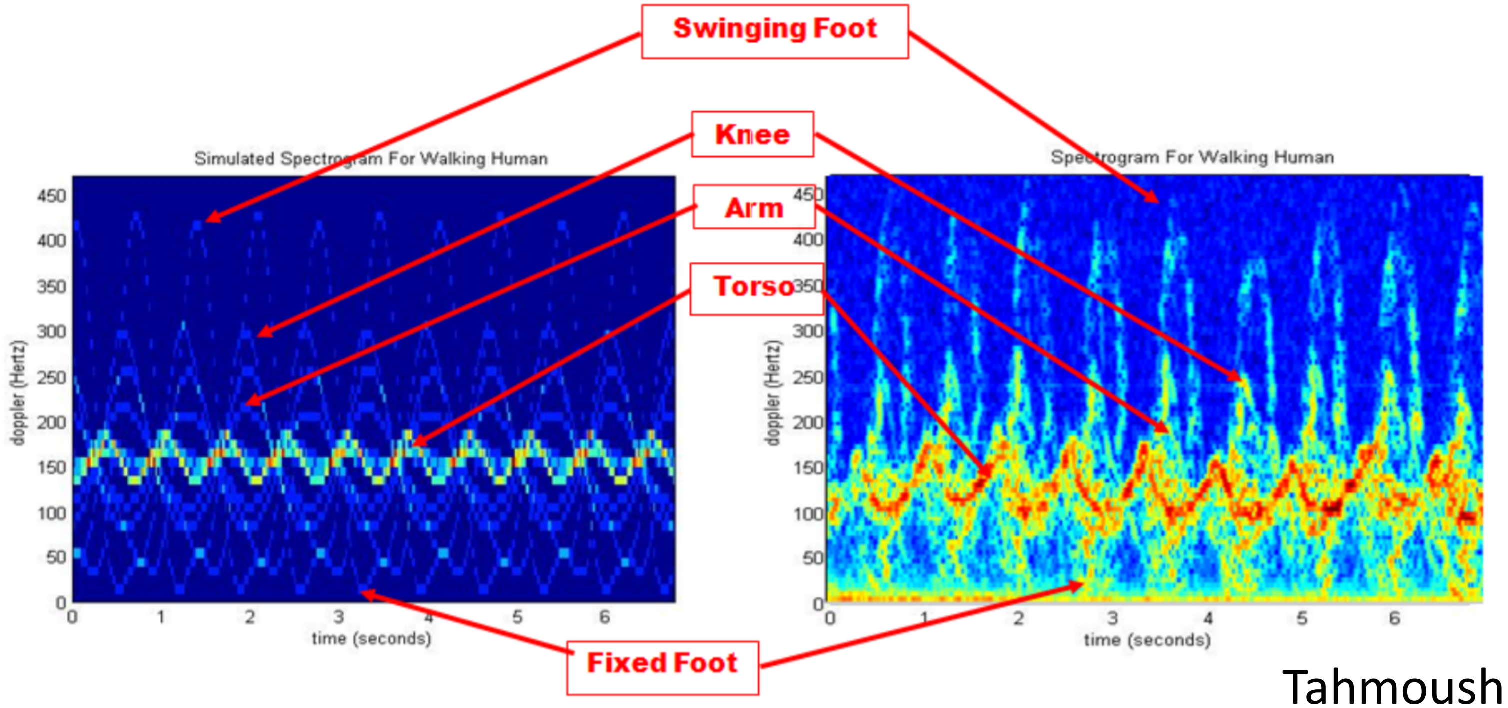


Making this clearer with frames



Doppler velocity for non-rigid objects

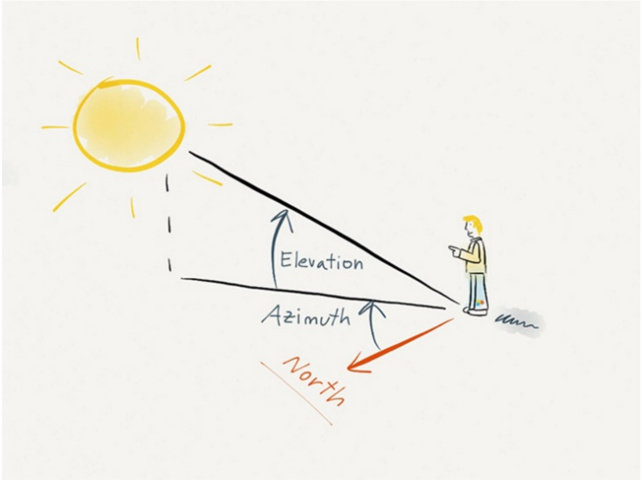
- A moving ball will have one velocity measurement
  - "That pitch was 98 mph and 5 mph and 72 mph and …"
- Will a human have just one velocity measurement?



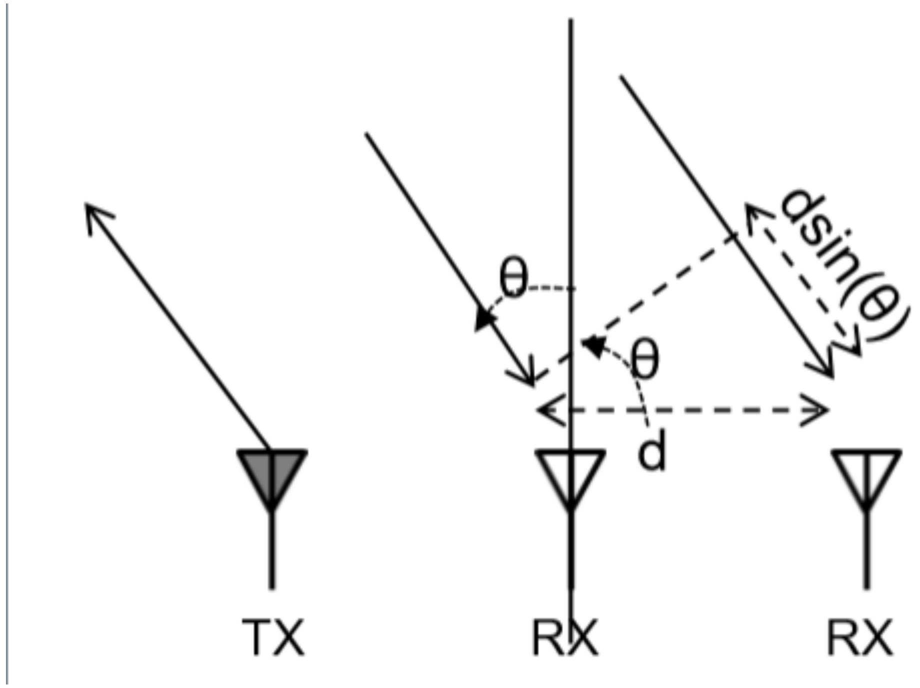
Micro-Doppler

Tahmoush et al.

Finding the angle of the target

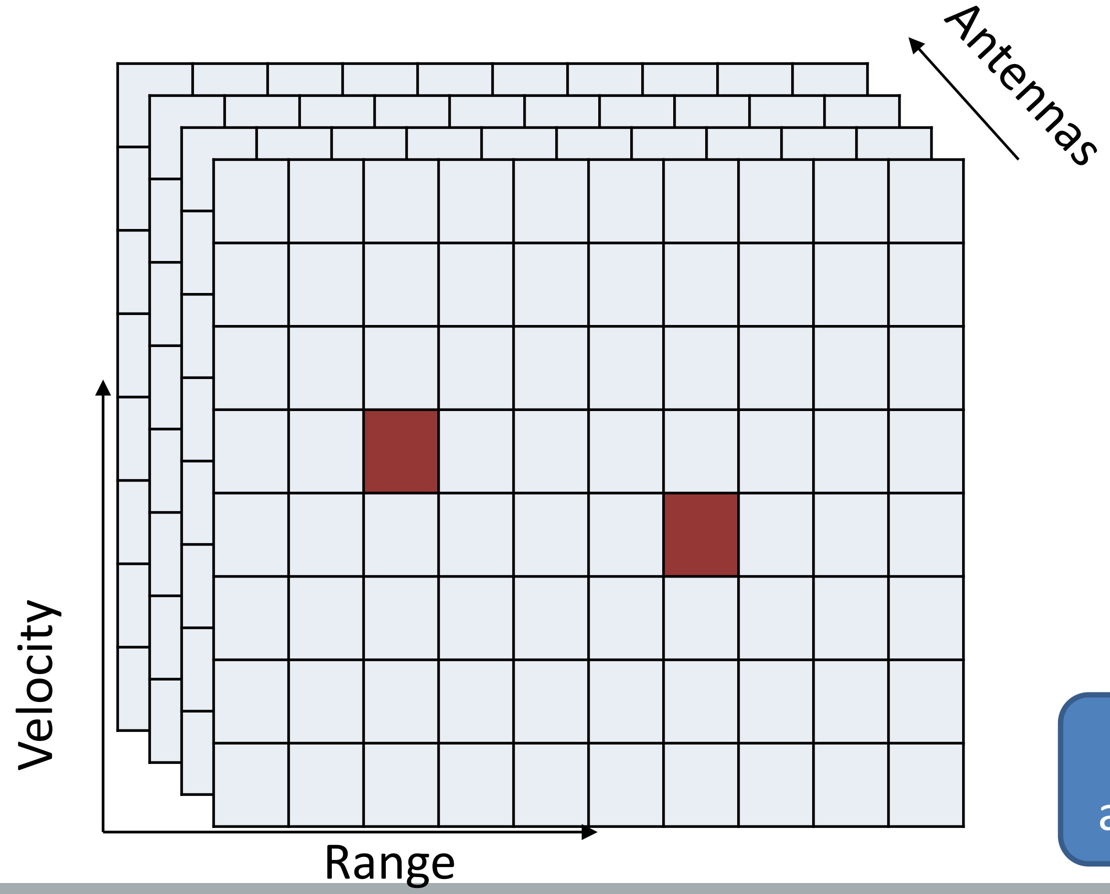


- To get to the farther antenna, the signal travels more.
- This causes the phase to increase with each additional antenna.
- Take the FFT to find the rate of this change to get the angle.

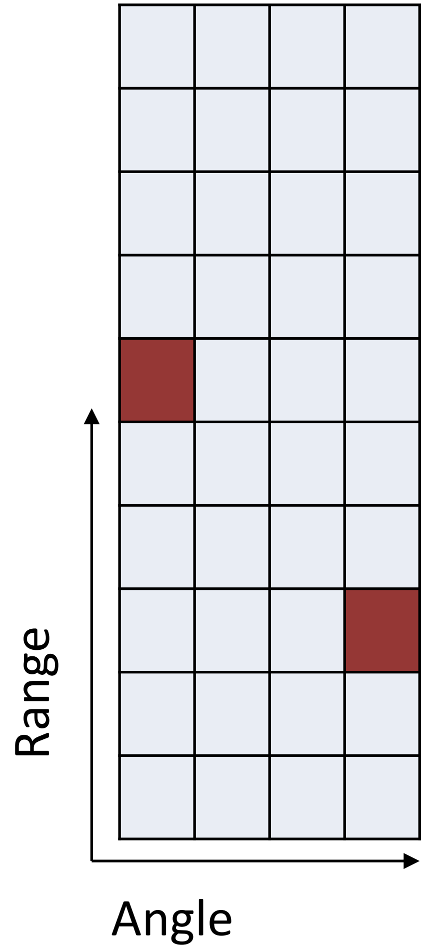


Finding the angle

- Now assume we have a frame for each antenna
  - Last example was for one antenna

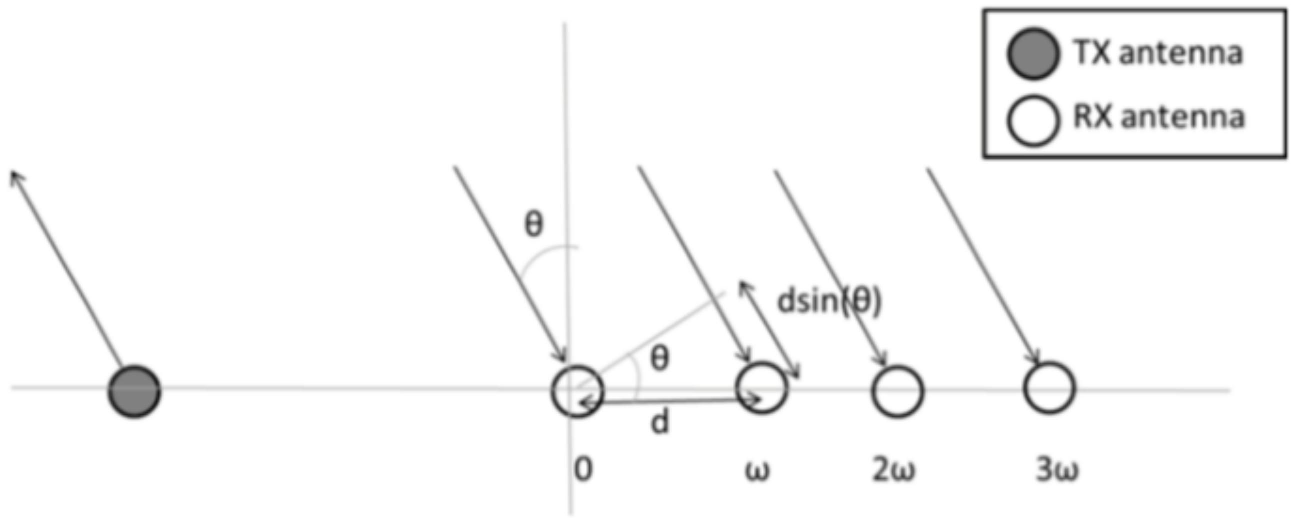


FFTs across the antennas to get angle



More than one antenna

- More distance traveled => more phase accumulated



2x4 = 1x8? Obviously*

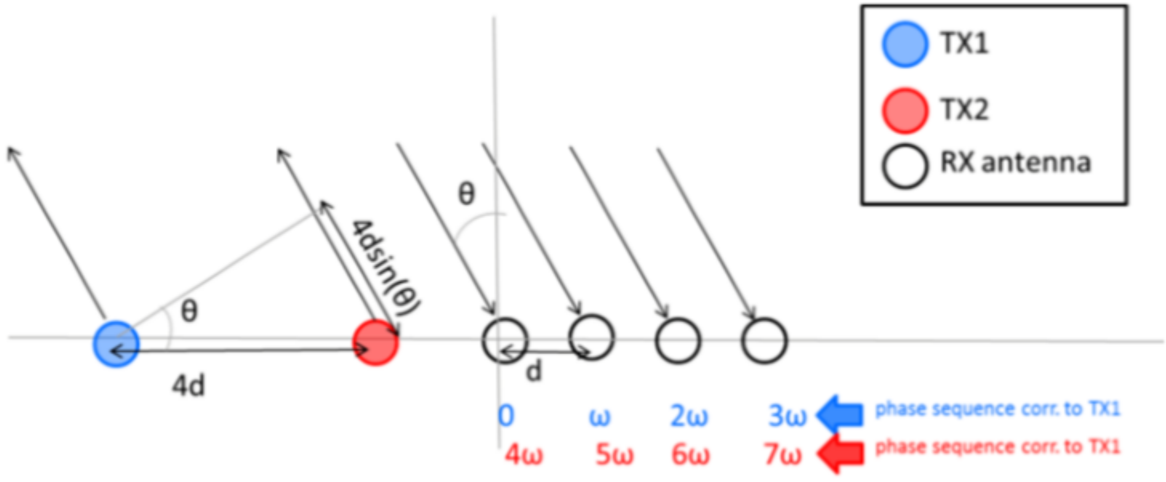
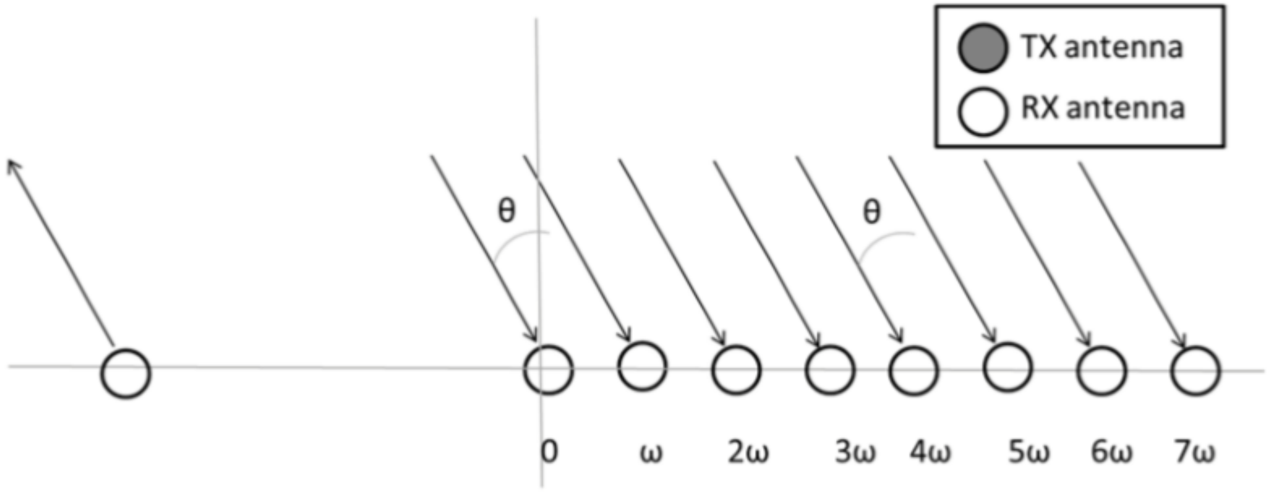
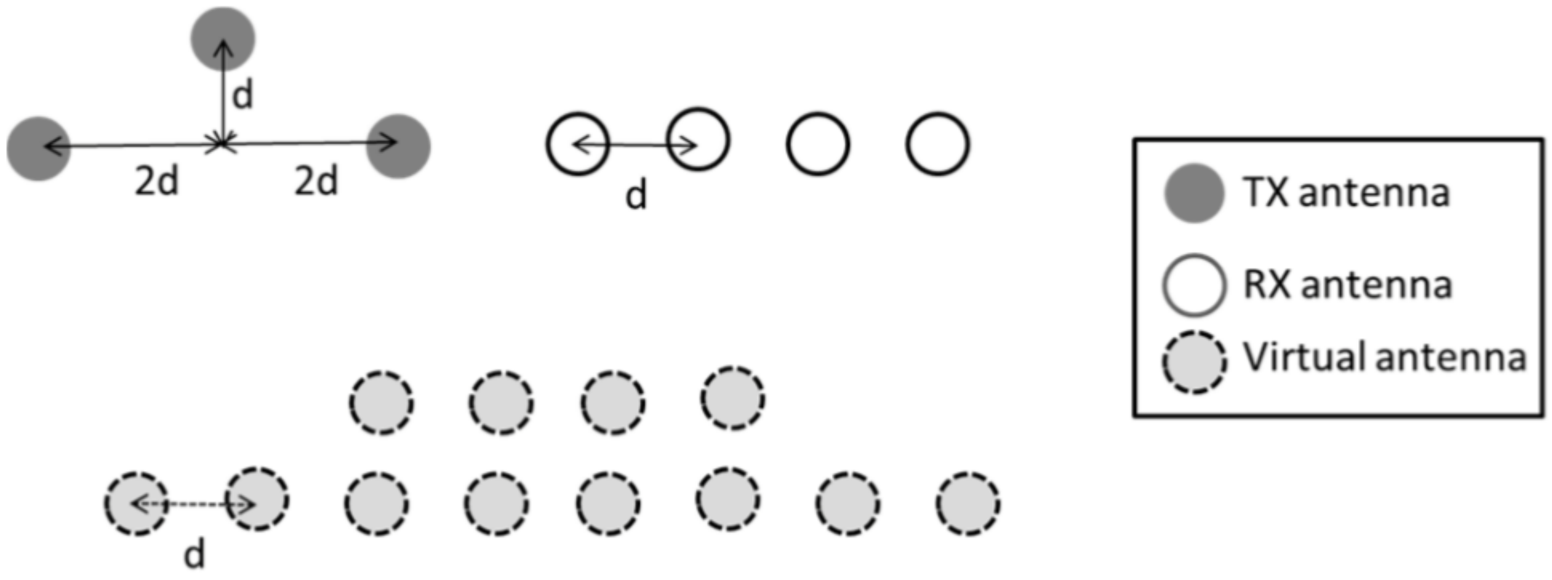


Figure 5. Principle of MIMO Radar



2D virtual antennas

- Angular resolution in 2 dimensions



What to tell your friends

- Radars send chirps and sample the responses
- If you stack chirps vertically and stack multiple antenna frames…
  - FFT of samples in each chirp => ranges
  - FFT across chirps => velocities
  - FFT across antennas => angles
- Micro doppler provides features for object or action identification

References

- Many diagrams were from TI's introduction to FMCW radar
  - D. Tahmoush and J. Silvious, "Visualizing and displaying radar micro-doppler data," Proceedings of SPIE - The International Society for Optical Engineering, vol. 8021, 05 2011
- TI MIMO Radar Application Report