Lecture 10

Today [- Most figures from the Slides]

- Distance Estimation
- Wireless Sensing
    - Dynamic Multipath

Time of Flight

C * delay ~ Distance
Phase h = $\frac{-2*\pi}{\lambda} * d \mod 2 * \pi$

-> Find d

Multipath Effect
Multipath profile (Shortest path -> Direct path)
$h_{\lambda_1} = \alpha e^{-j\frac{2*\pi}{\lambda_1}d}$
-> $ h_{\lambda_k} = \alpha_k^j e^{-j\frac{2*\pi}{\lambda_k}d_j} $

P(d) = $\sum h_{\lambda_k} e^{+j\frac{2*\pi}{\lambda_k}d}$ -> Undo the Phase. If not line up, get a smaller and smaller value
P(d) = $\sum_k \alpha_k e^{-j\frac{2*\pi}{\lambda_k}(d_1-d)}$
Try different λ_k, $\sum_k \alpha_k e^{-j\frac{2*\pi}{\lambda_k}}$ becomes really small, then adding up strong signals
Try different d get different multi-path profile
-> Canceling the imaging part and adding up the real part of the signal

Narrow bandwidth -> Resolution decrease
If the measurement is far away, distance ambiguity happens -> lose unambiguous range

WiTrack

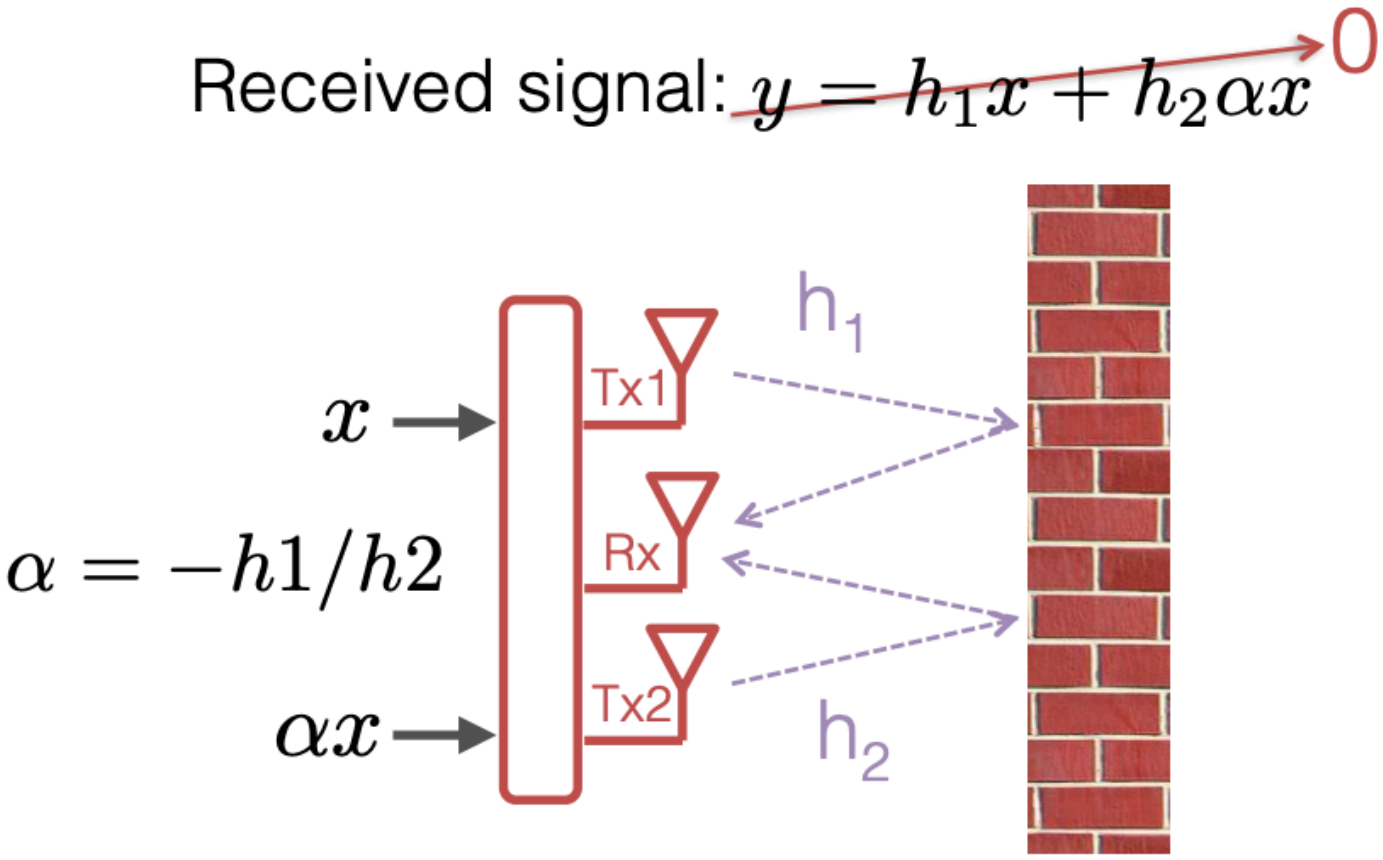
WiVi:

Challenge:

- Wall reflection is 10,000x stronger than any reflections coming from behind the wall
- Tracking people from the reflection

How can we eliminate the wall's reflection?
Idea: transmit two waves cancel each other when they reflect off static objects but not moving objects

Two transmit antennas and one receive antenna
$Y = h_1 * x + h_2 \alpha x$
->$\alpha = -\frac{h_1}{h_2}$

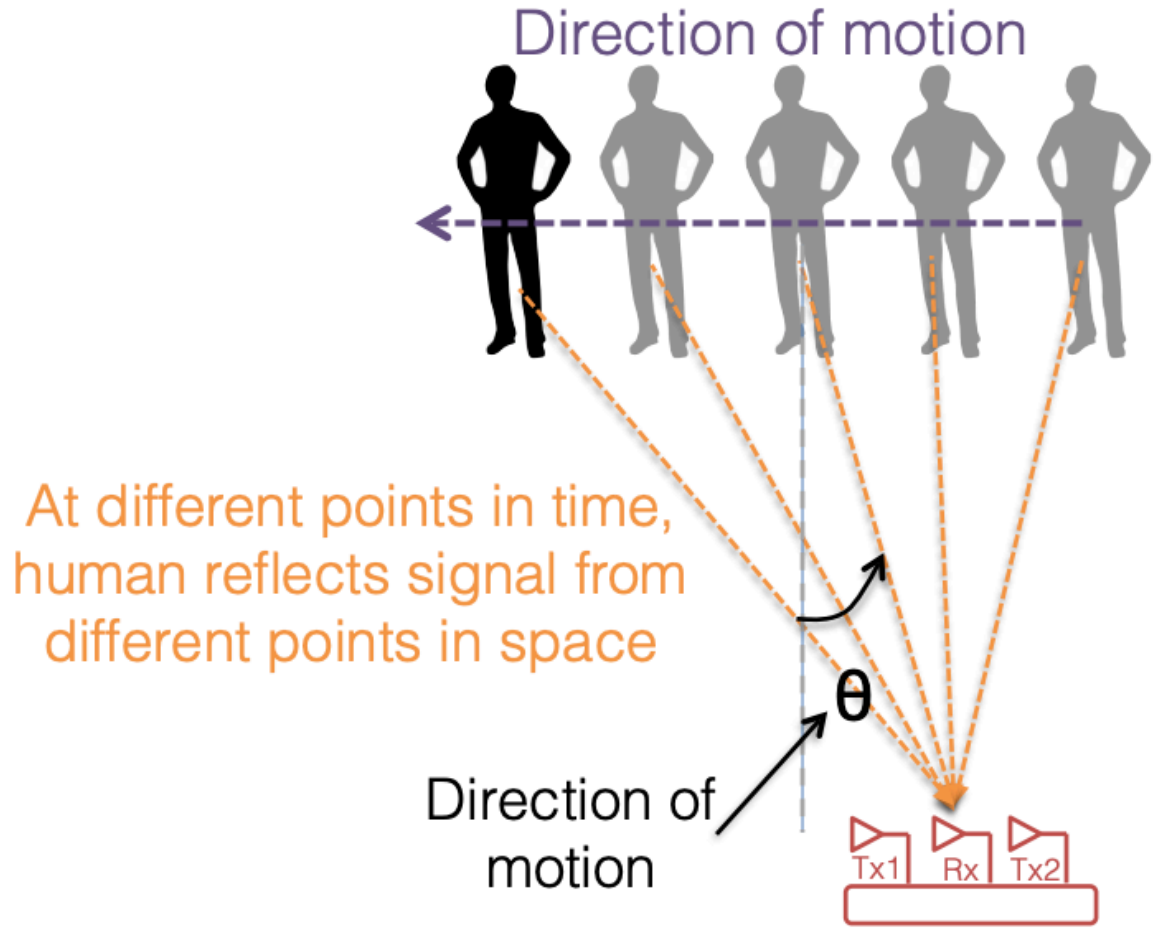


But people are moving. Therefore, the channel could not cancel out -> human signal will stay
Why not subtract the range profile?
-> Dynamic Range of Rx
-> WiFi-based system: CFO/SFO

How can we track using Reflections?

Track Motion

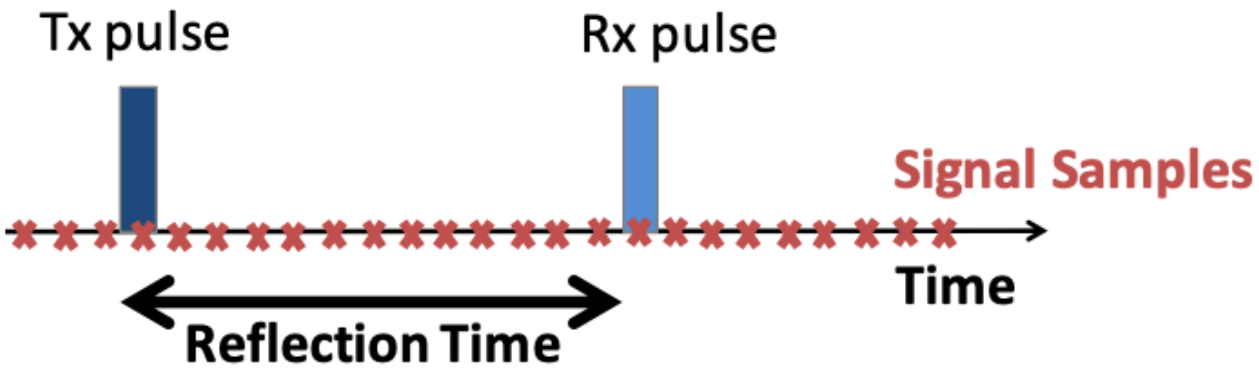
Phase change over time



WiTrack:

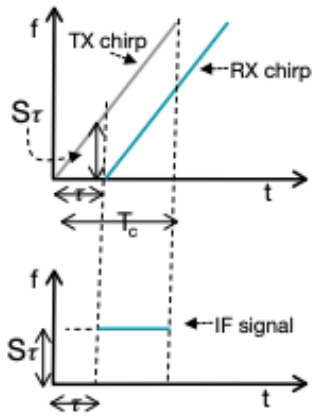
Distance = Reflection time * speed of light

O1: Transmit short pulse (accurate not enough) - need to sample at very high rate -> UWB

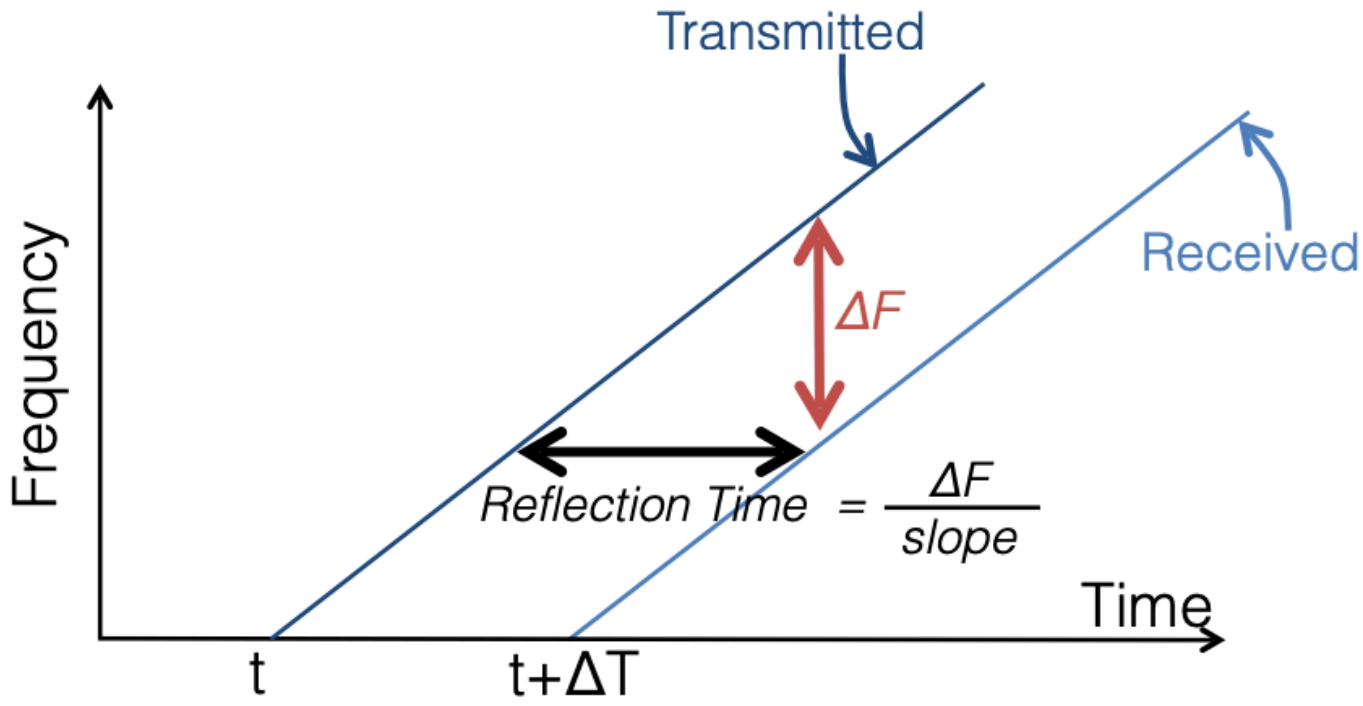


O2: FMCW: measure time by measuring frequency

- FMCW (Frequency modulated Continuous Wave)
- This is achieved by continuously varying the frequency of the transmitted signal by a modulating signal at a known rate over a fixed time period.

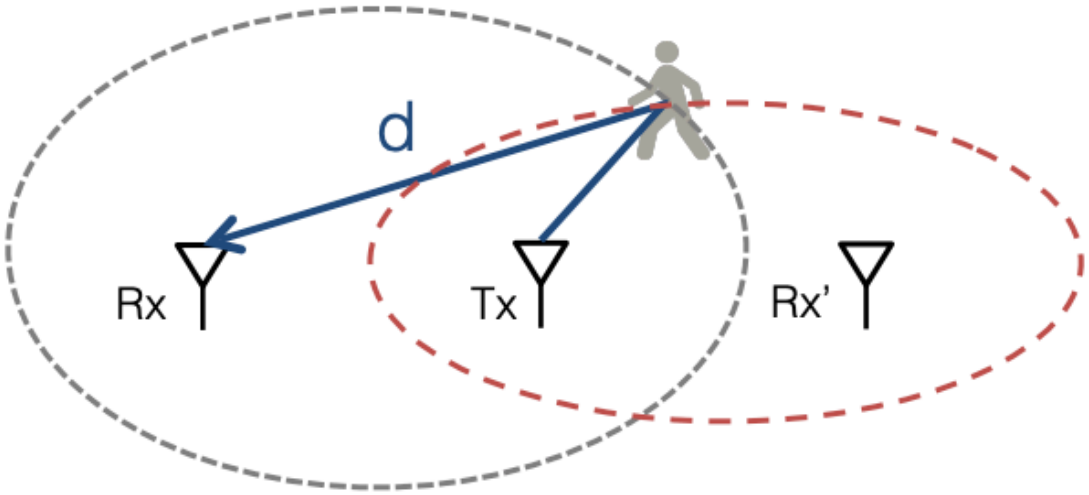


How do we measure δ F -> Reflection Time -> Distance?



Mapping Distance to Location

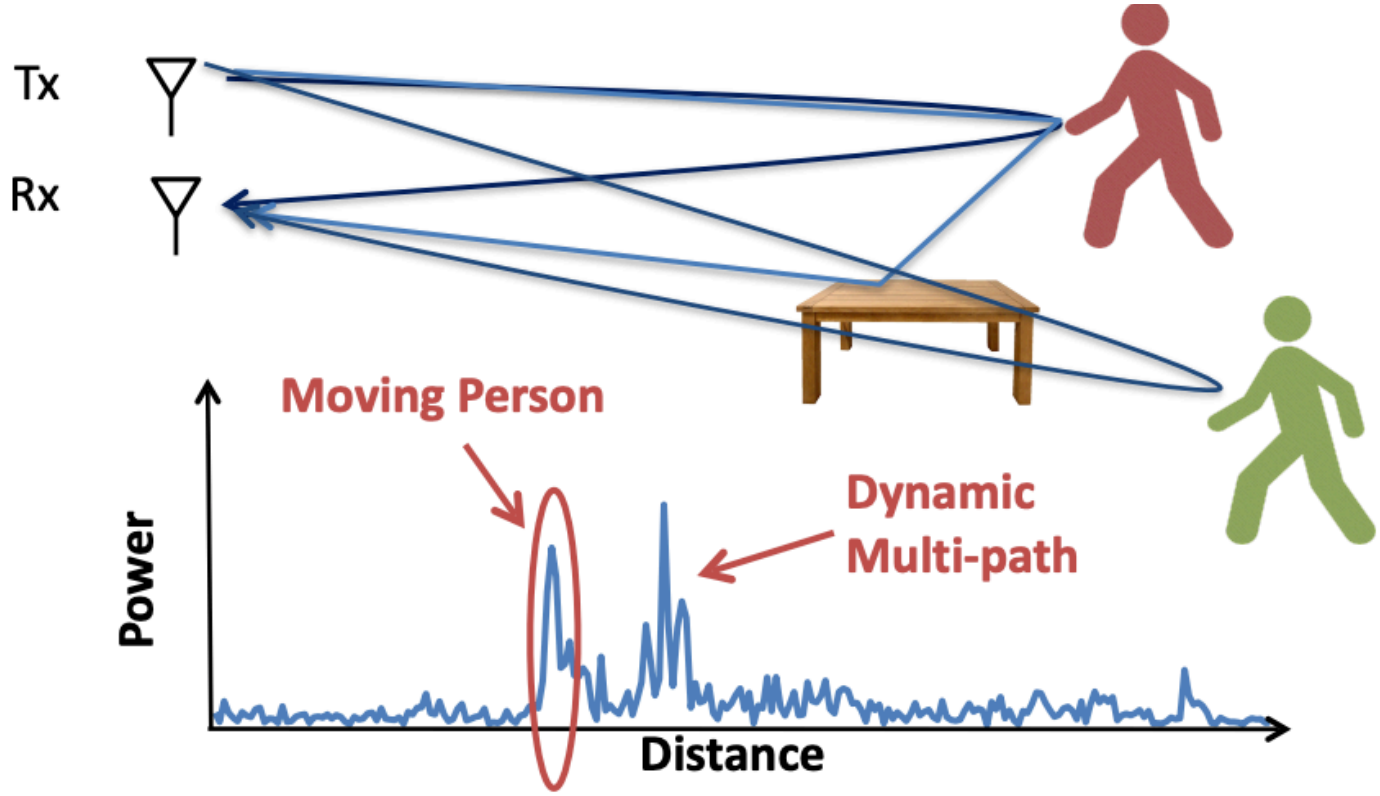
People on Ellipses



Dealing with multi-path - Dynamic Multipath

Humans reflect on static objects than on the receiver

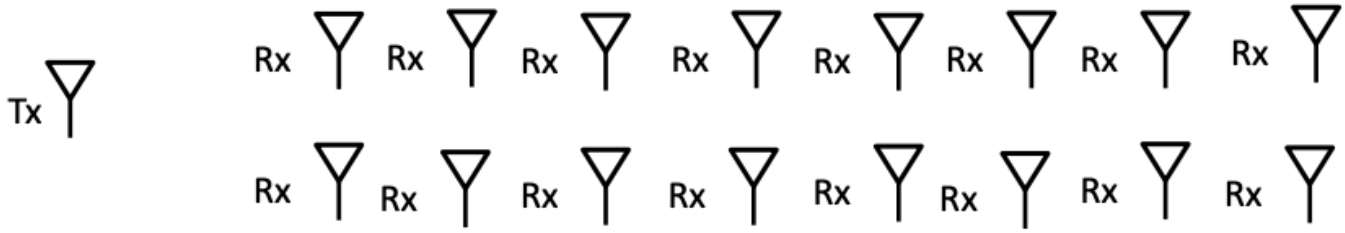
- The shortest path should be the correct direct path



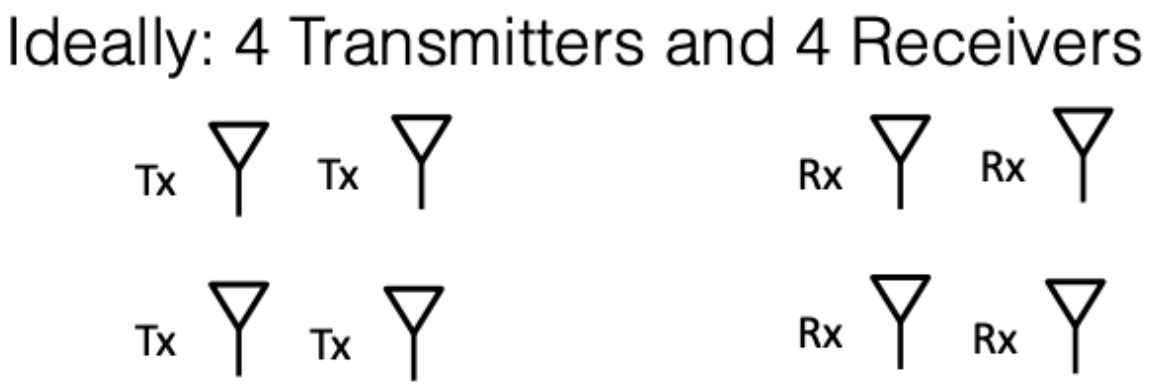
How can we deal with multi-path with multiple people?
Idea: Person is consistent across different vantage points, while multi-path is different from different vantage points

Combing across multiple vantage points (independent transmitter-receiver pairs)

How can we obtain 16 vantage points?
Naive -> 1 transmitter -> 16 Receiver



-> 4 Transmitter and 4 Receiver (need some time shift)



Same frequency band

Multi-User Localization (SNR getting worse if multiple people are present)

How can we localize the static user?

- Breathing and walking happen at different time scales

Problem: How do we use OFDM to do this? Since Wi-Fi normally does not do FMCW