WiTrack

Motion Tracking via Radio Reflections off the Body

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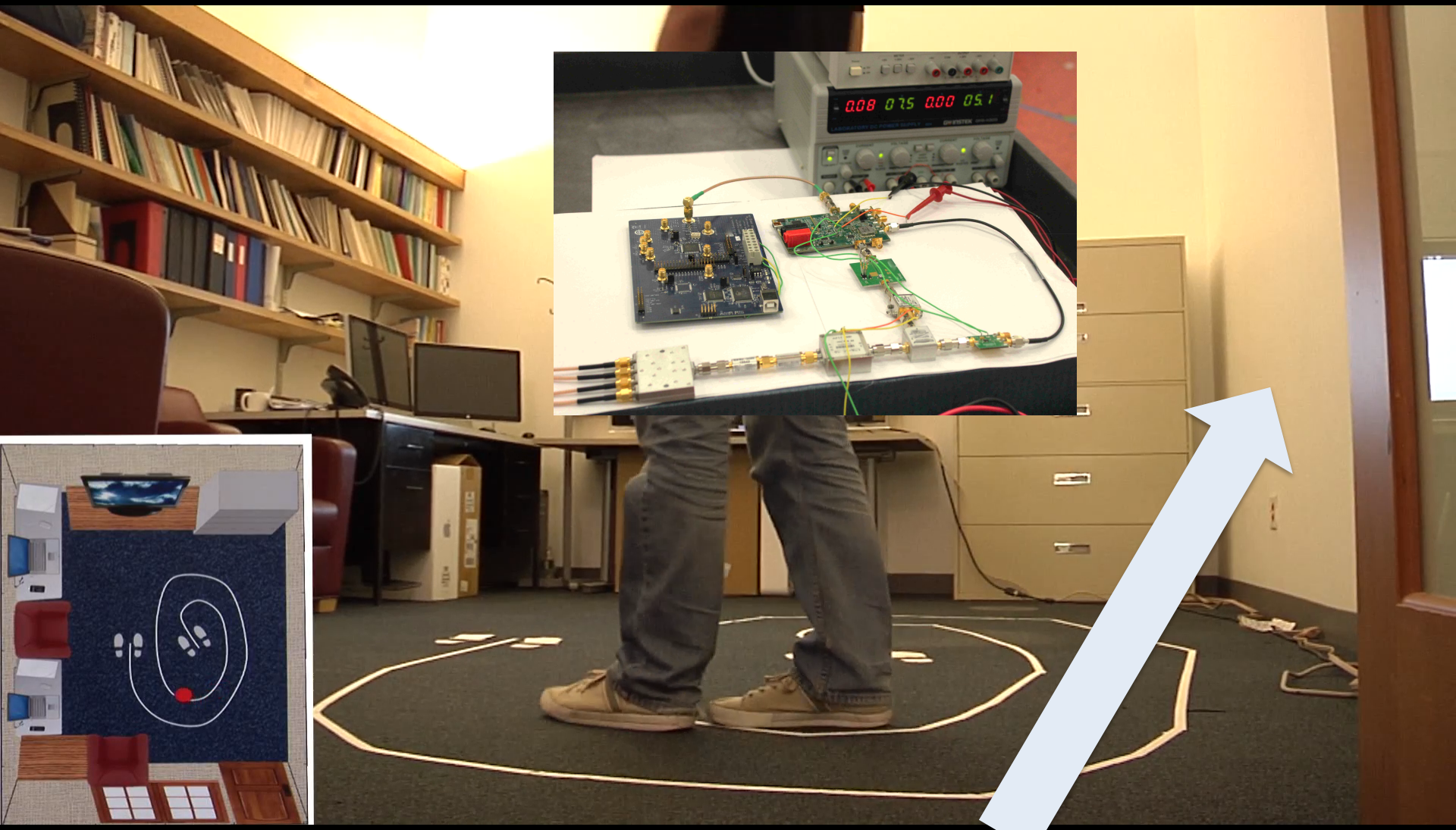
Can we see through walls with wireless signals?



WiTrack behind wall

WiTrack

- Centimeter-scale motion tracking using only radio reflections off the human body

- Works behind walls and does not require person to hold any device

Applications

Gaming

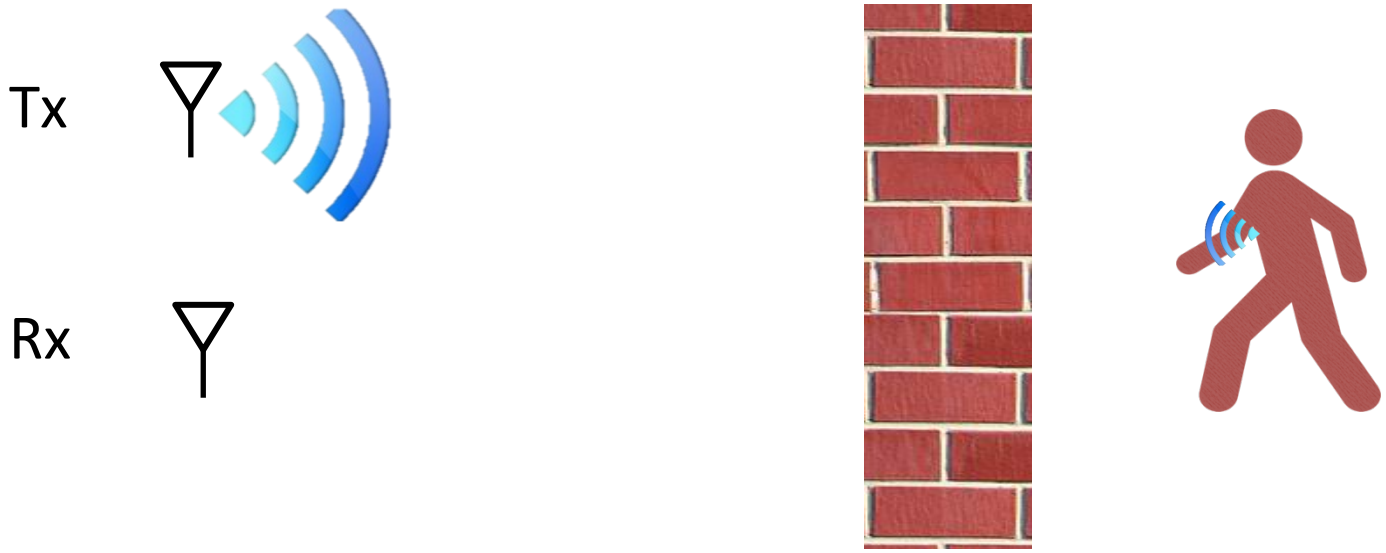
Gesture Control

First Responders

Elderly Monitoring

How WiTrack Works

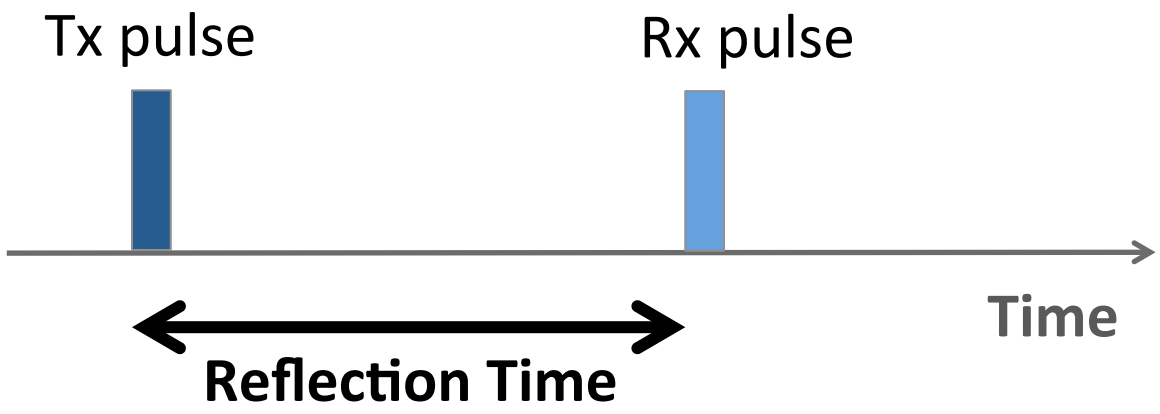
Measuring Distances



Distance = Reflection time x speed of light

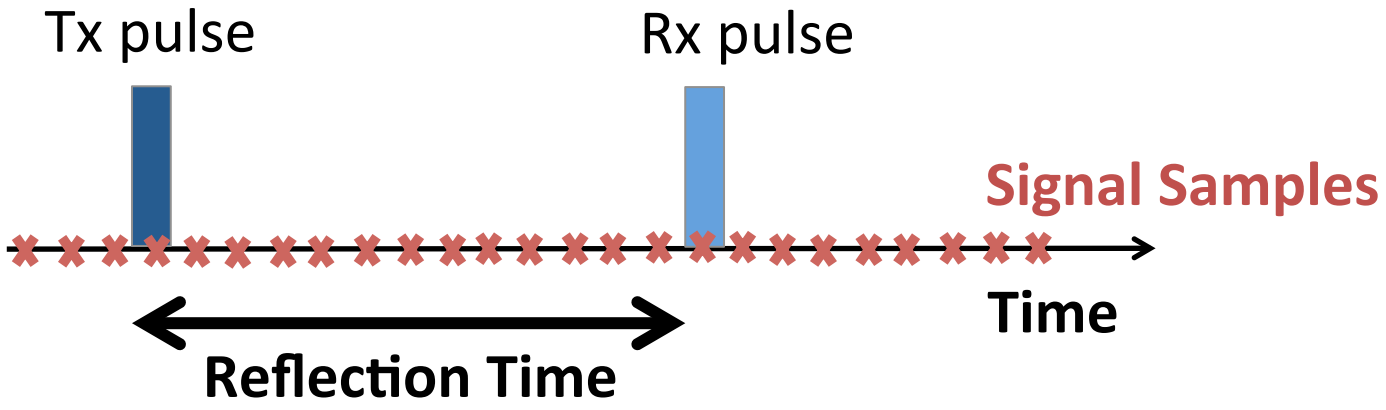
Measuring Reflection Time

Option1: Transmit short pulse and listen for echo



Measuring Reflection Time

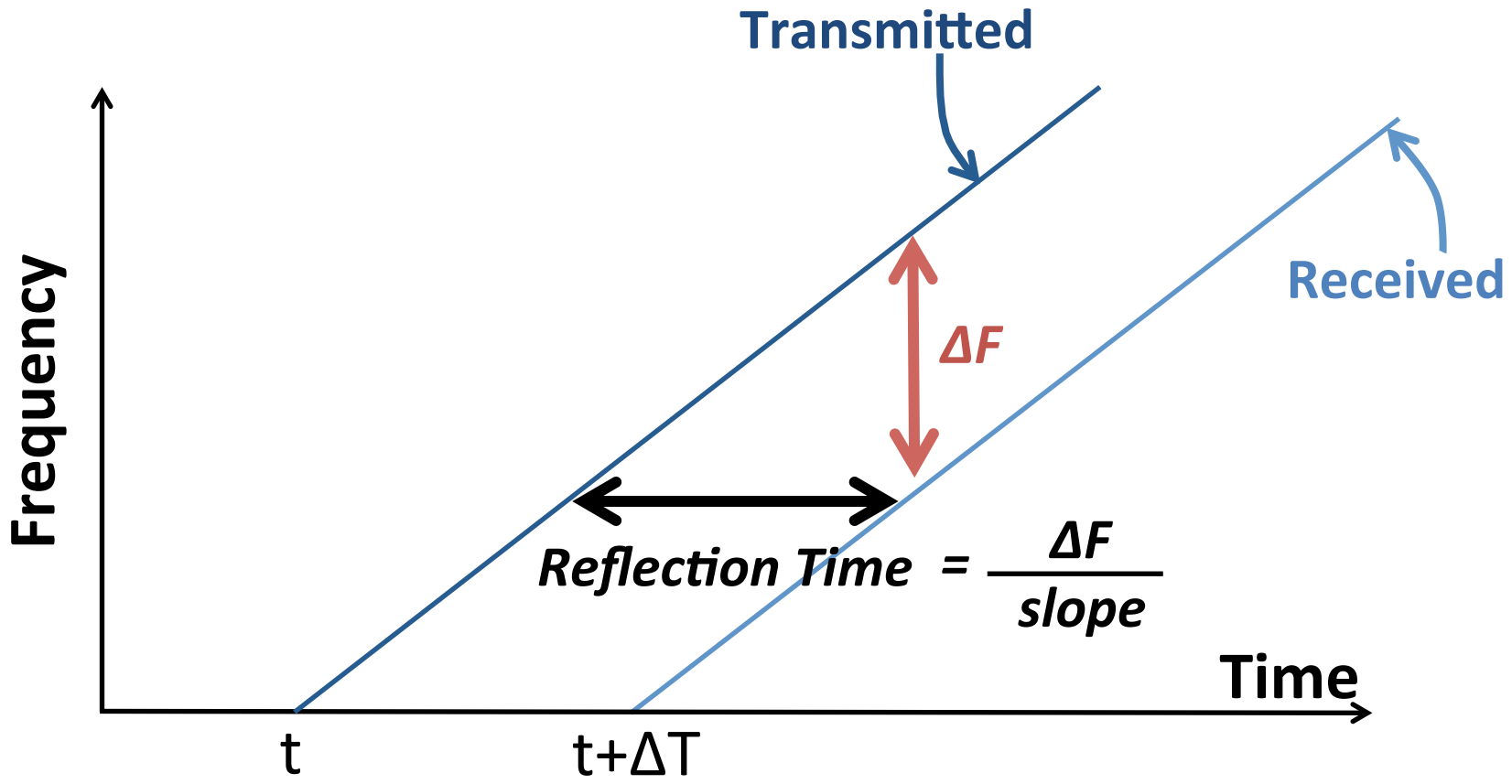
Option1: Transmit short pulse and listen for echo



Capturing the pulse needs sub-nanosecond sampling

Multi-GHz samplers are expensive and have high noise → Impractical for our app

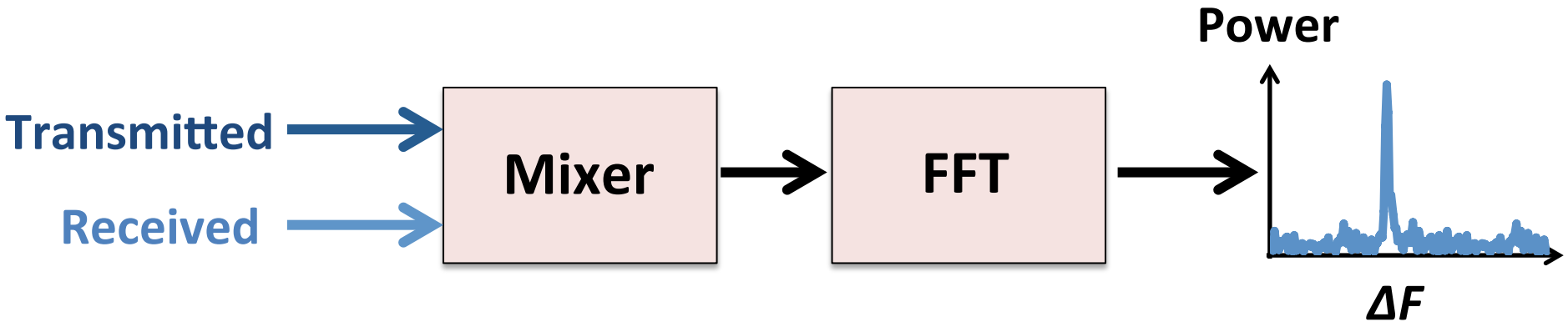
Frequency Modulated Carrier Wave (FMCW)



How do we measure ΔF?

Measuring ΔF

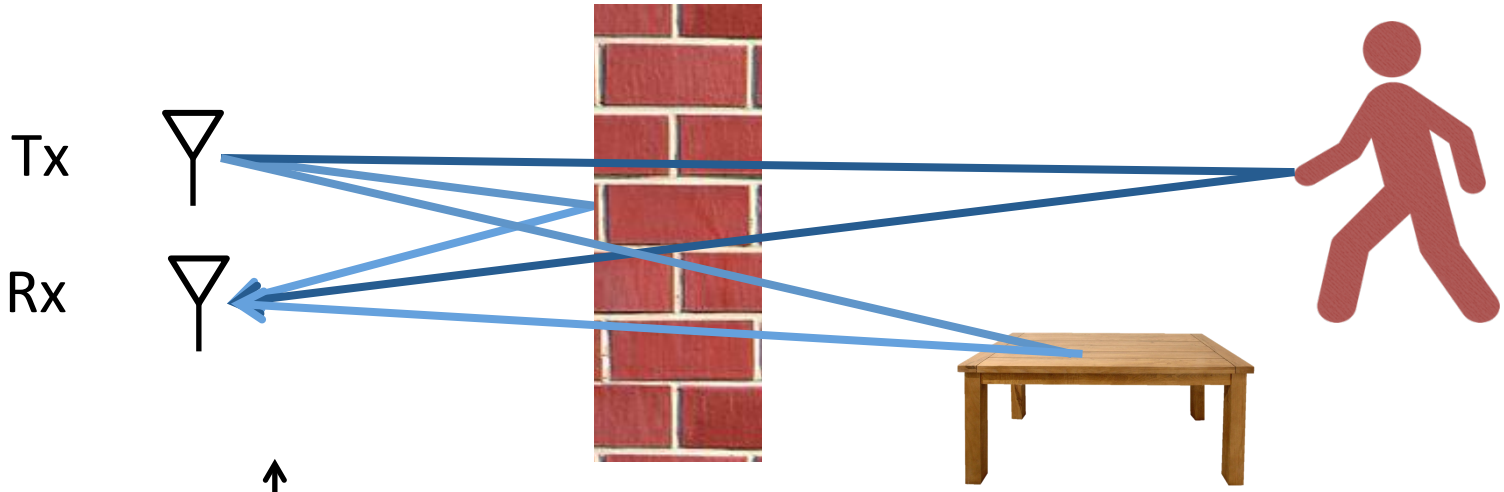
- Subtracting frequencies is easy (e.g., removing carrier in WiFi)
- Done using a mixer (low-power; cheap)

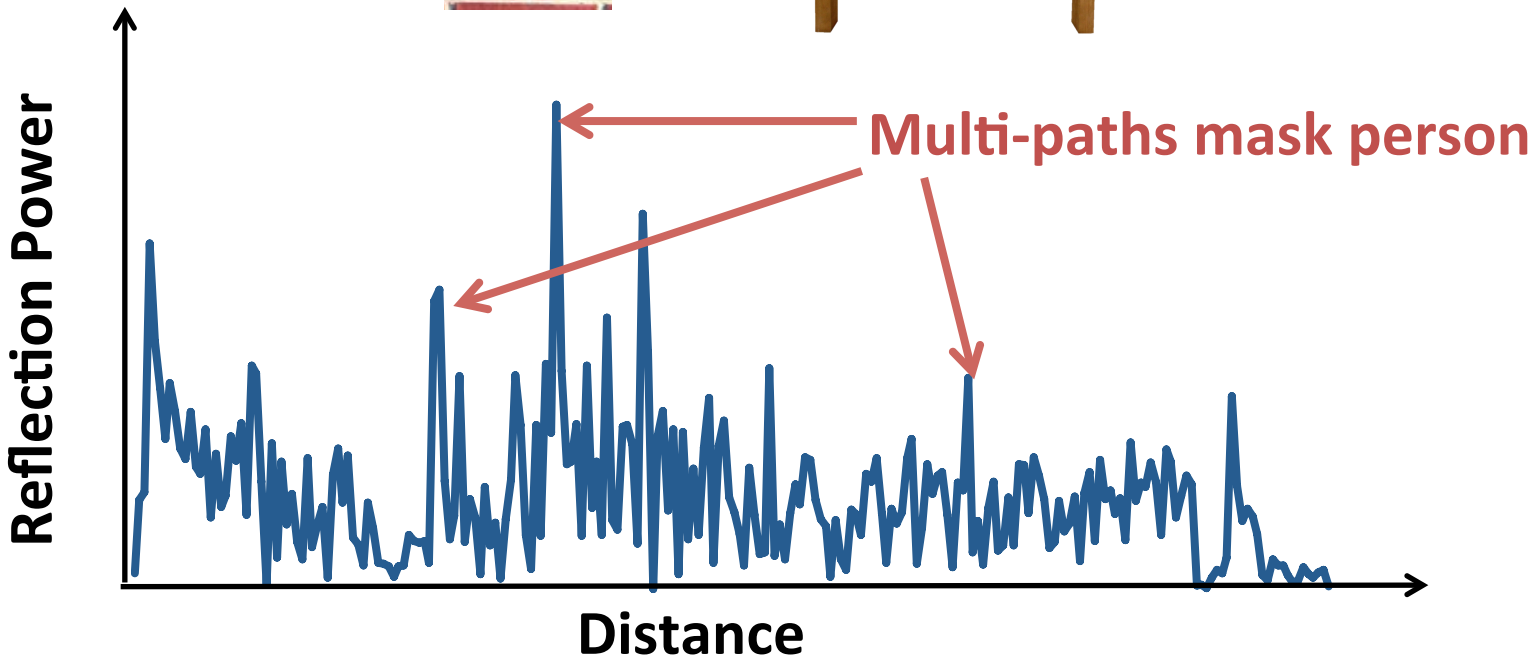


Signal whose frequency is *ΔF*

ΔF → Reflection Time → Distance

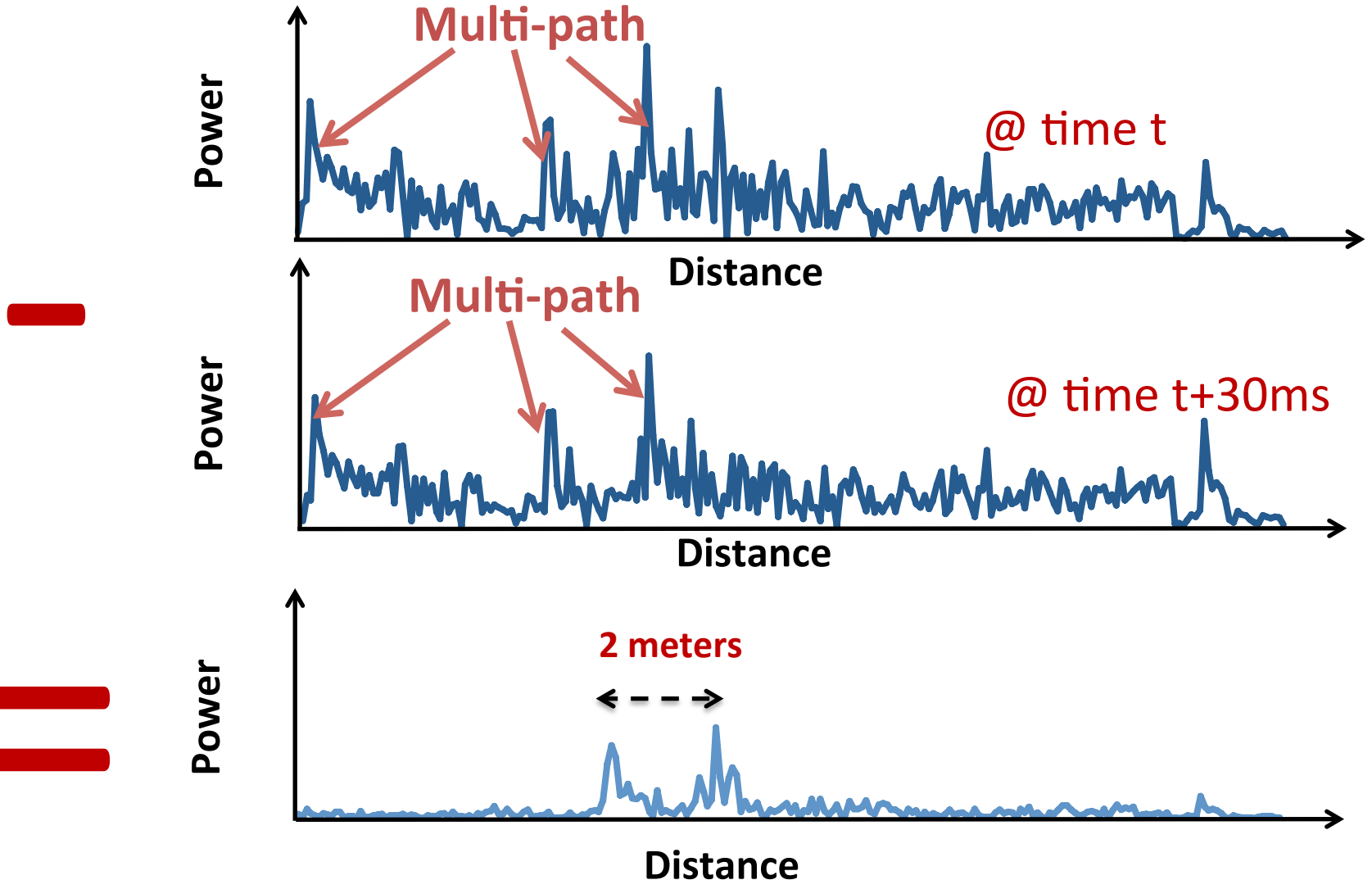
Challenge: Multipath → Many Reflections





Static objects don't move

➔ Eliminate by subtracting consecutive measurements



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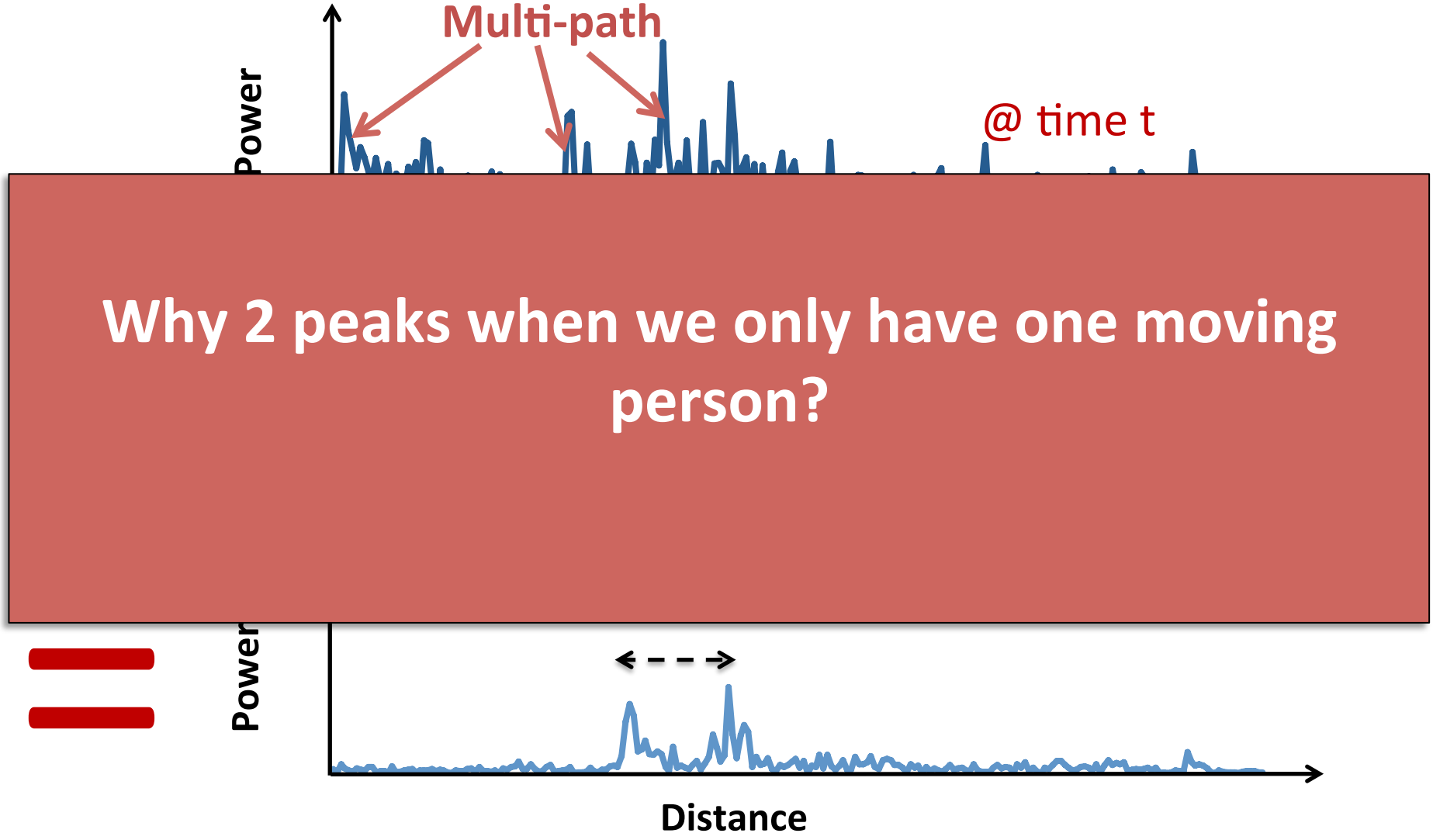
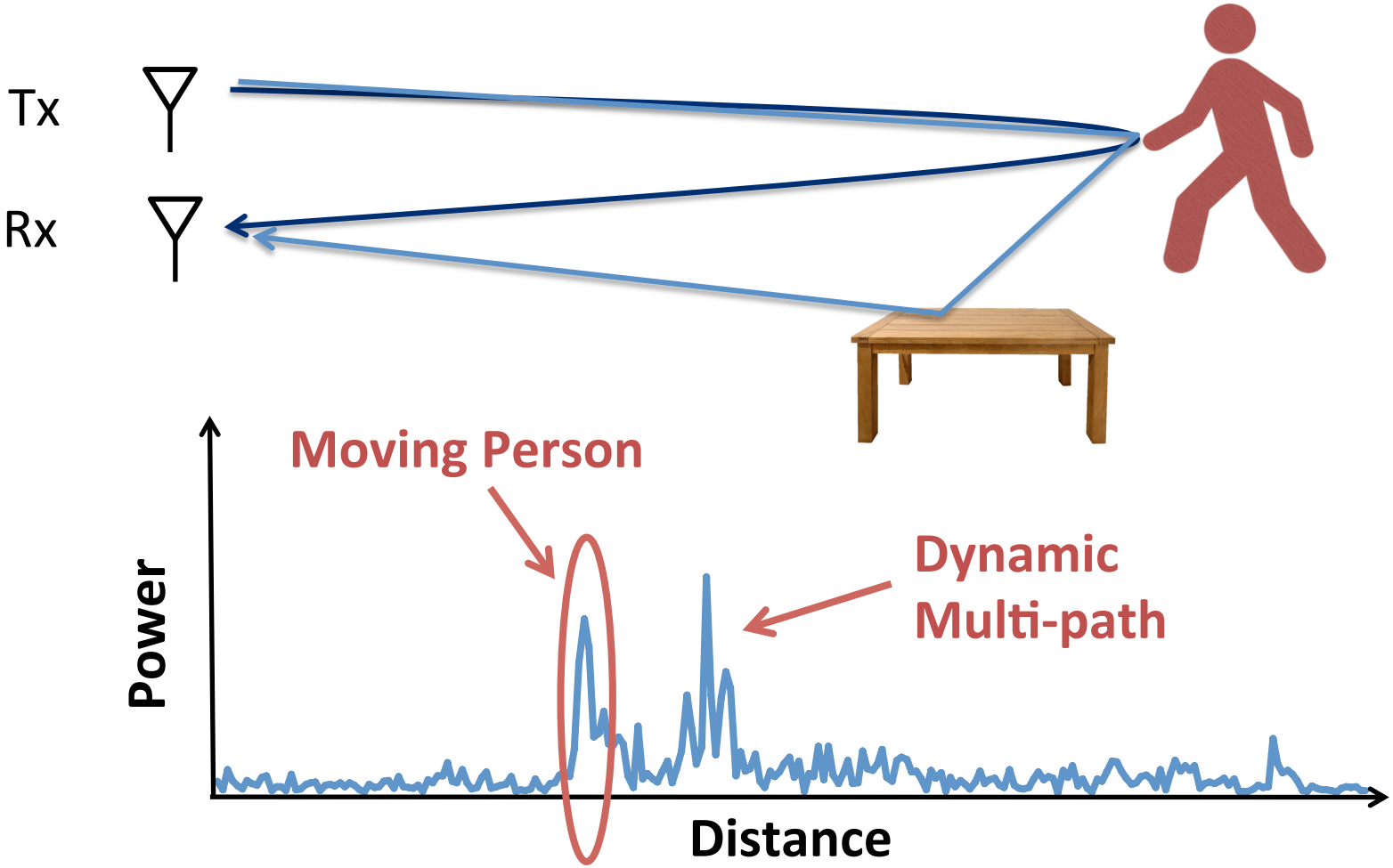
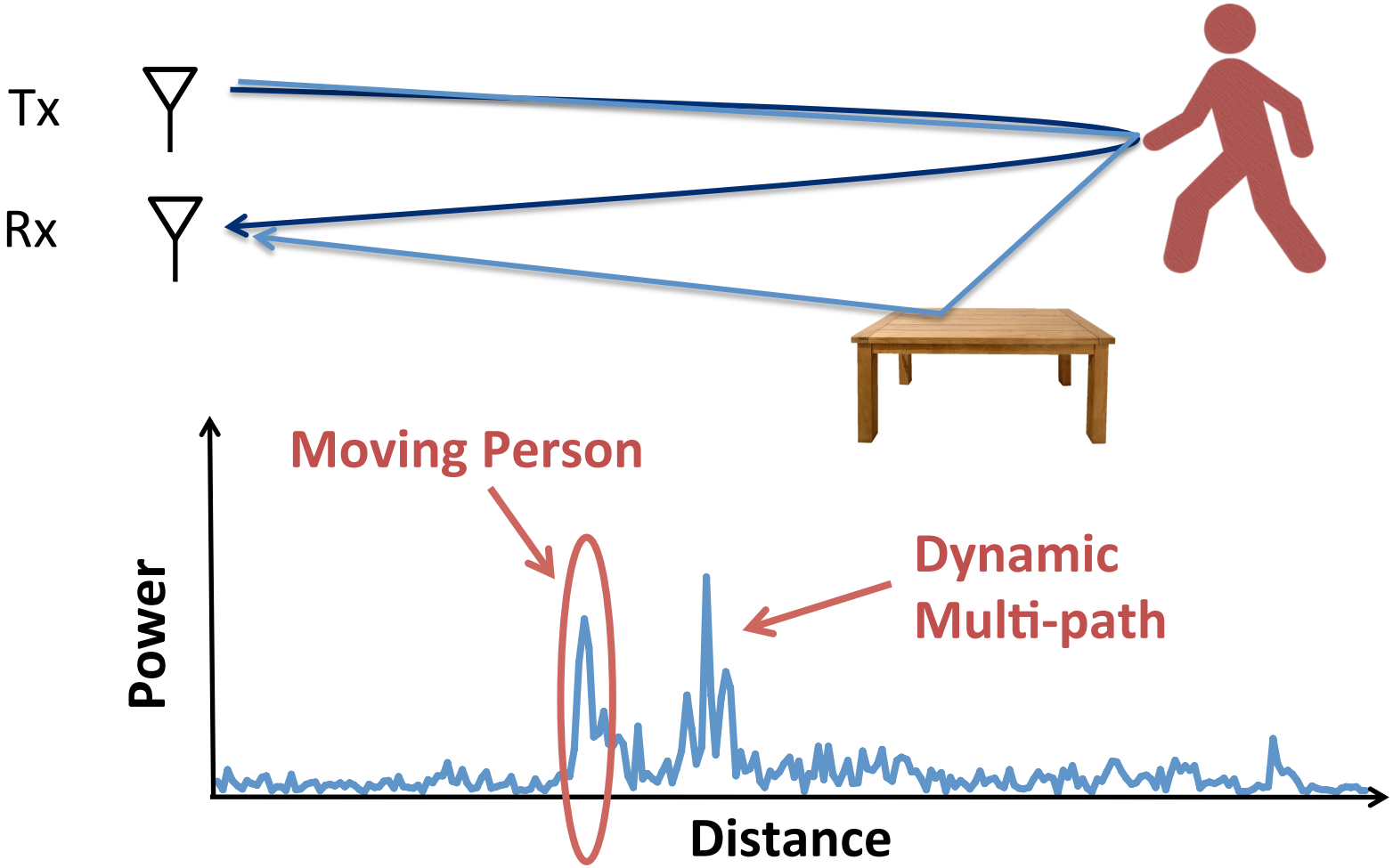


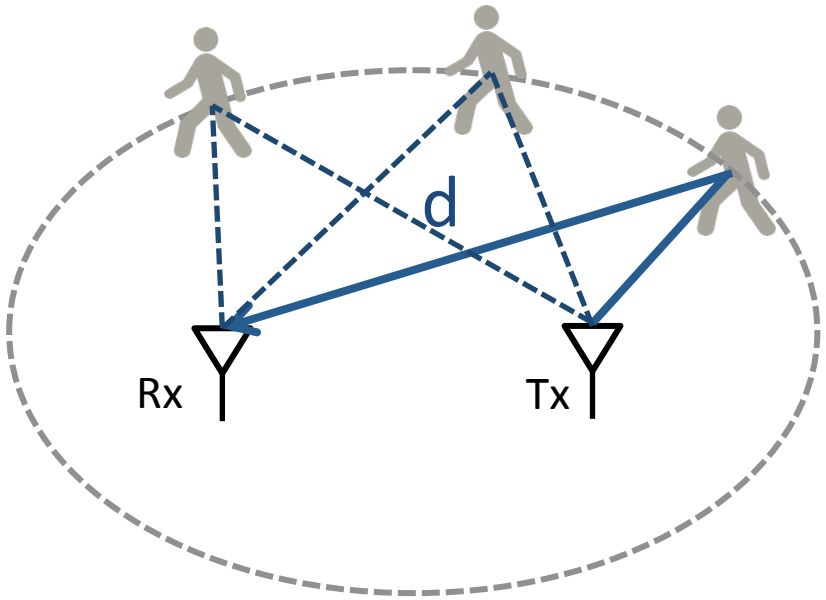
Dynamic Multipath



The direct reflection arrives before dynamic multipath!



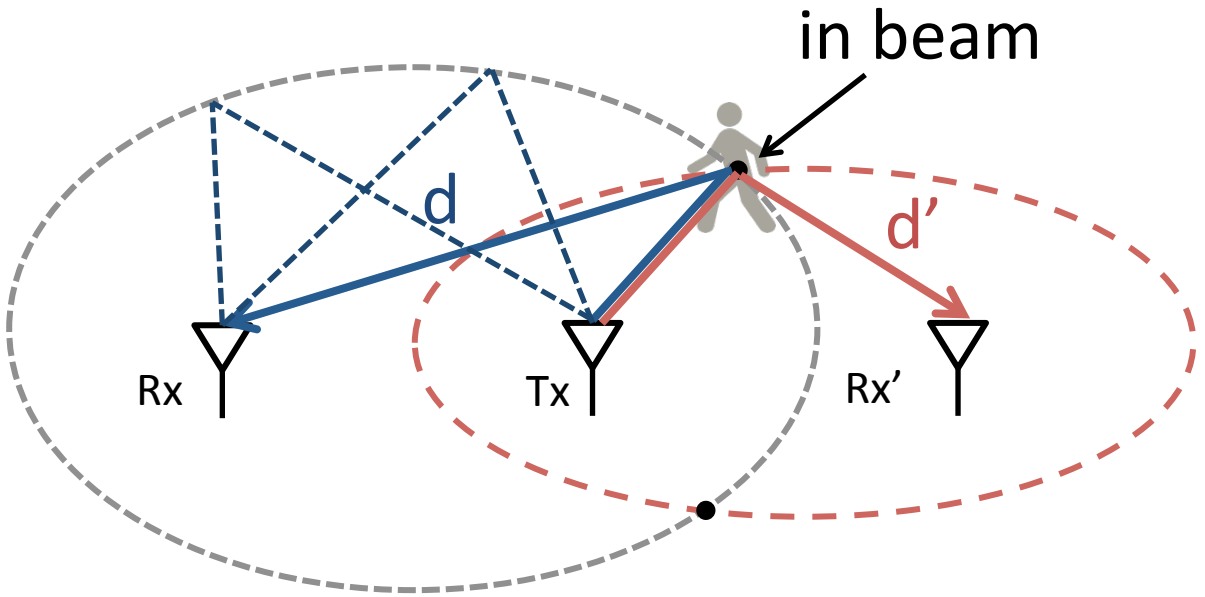
From Distances to Localization



Person can be anywhere on an ellipse whose foci are (Tx,Rx)

One ellipse is not enough to localize!

From Distances to Localization



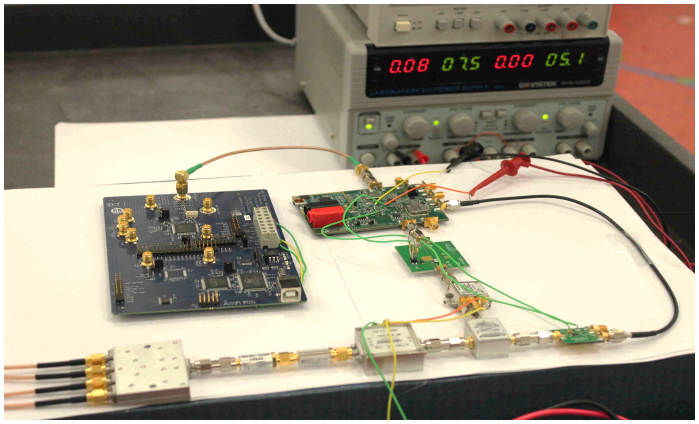
WiTrack uses directional antennas so only one point is in-beam

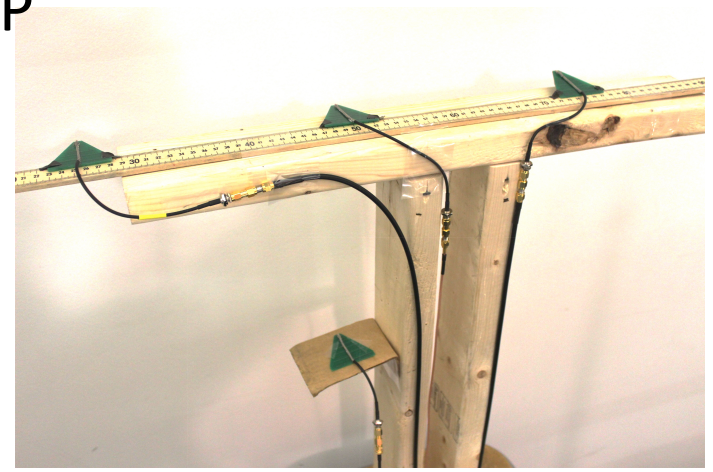
Extend to 3D by using 3 Rx antennas and taking the intersection of ellipsoids

Performance

Implementation

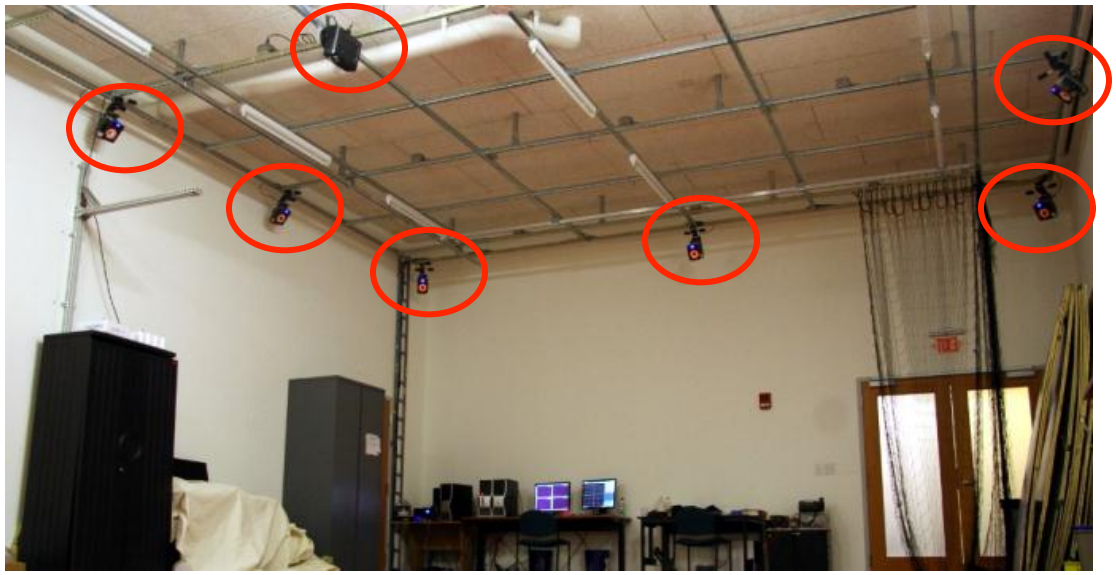
- Built FMCW front-end
  - Connected to USRP
- Band: 5.5-7.2GHz
- Transmit 0.75mW
  - 100x lower power than WiFi AP
- 1 Tx, 3 Rx antennas



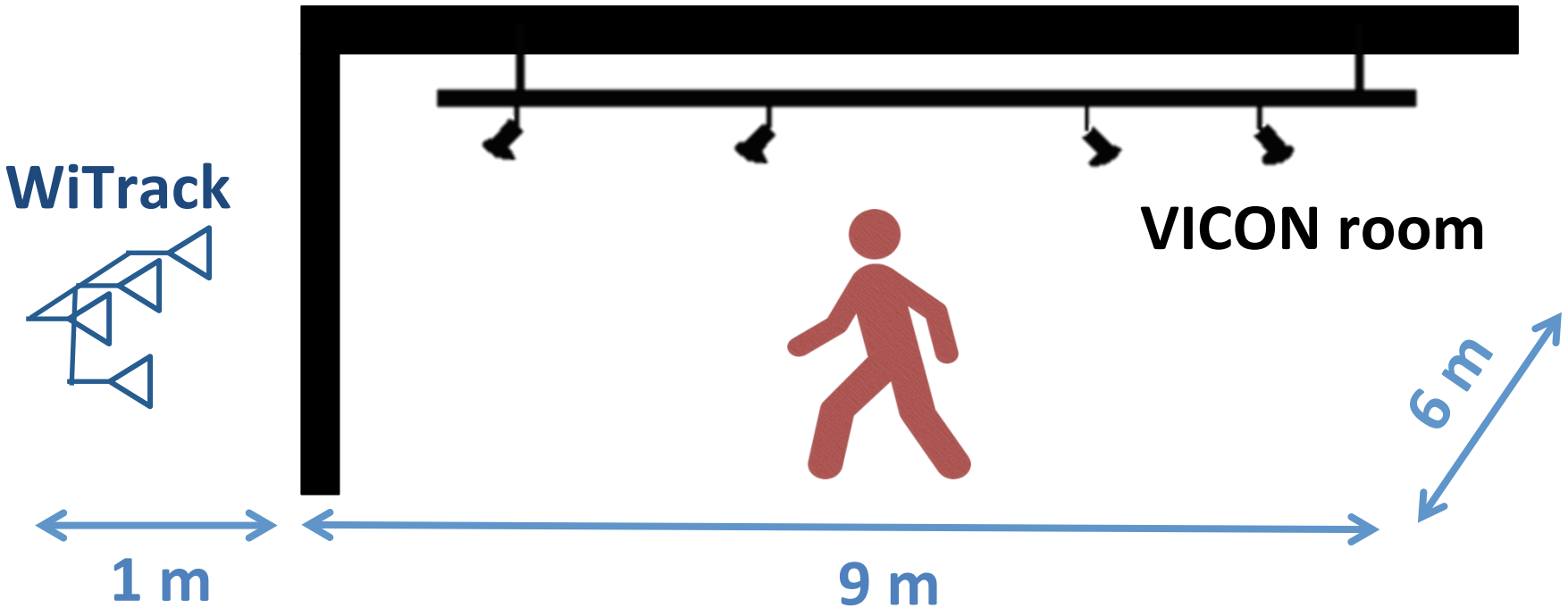


Ground Truth via VICON

- Array of infrared cameras
- Provides sub-cm accuracy
- Instruments the person with IR markers



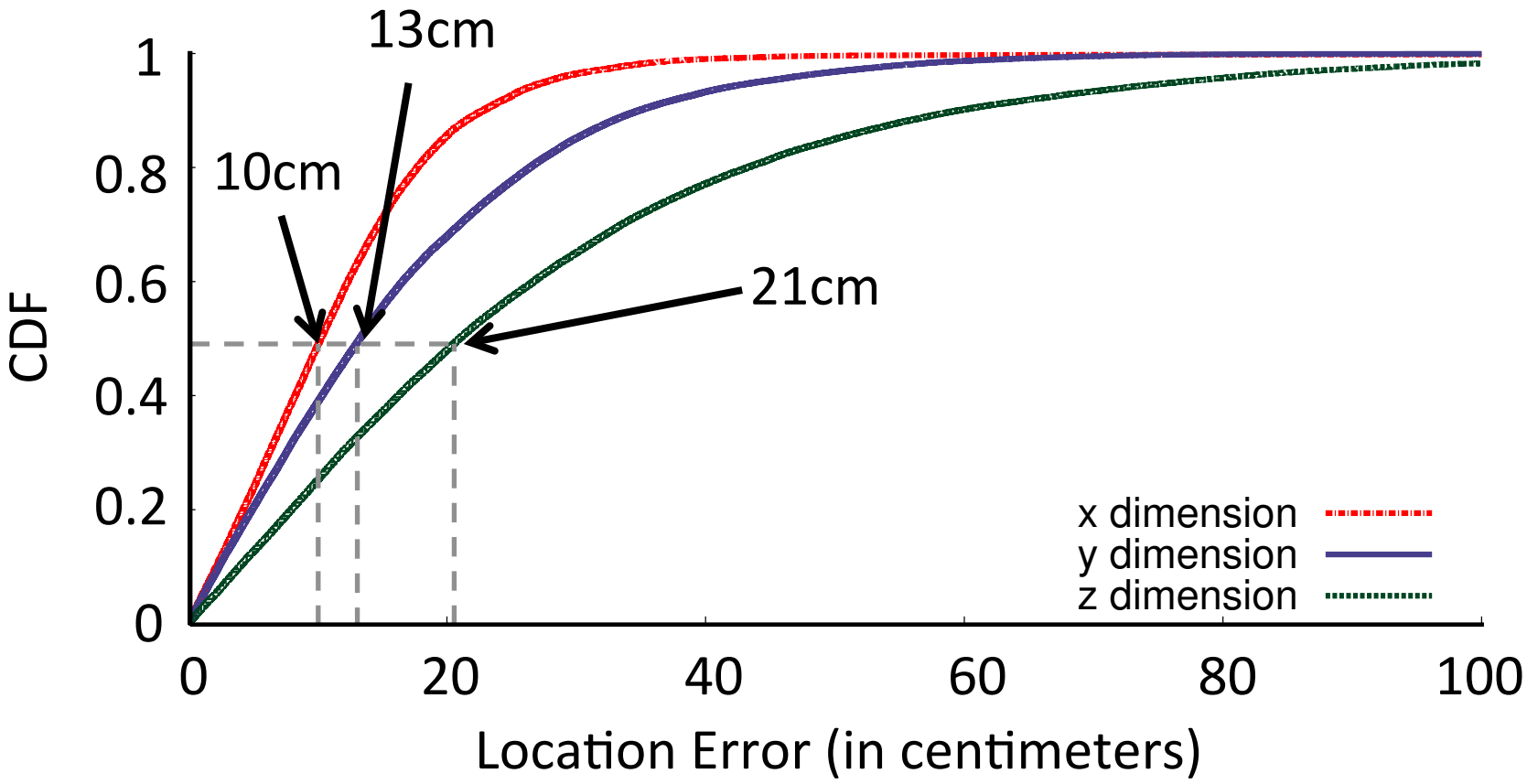
Evaluation



- VICON creates 3D model of human and computes closest reflection point to WiTrack
- Localization error: difference between WiTrack-estimated location and VICON-computed point

Through-Wall Localization Accuracy

100 experiments: ½ million location measurements



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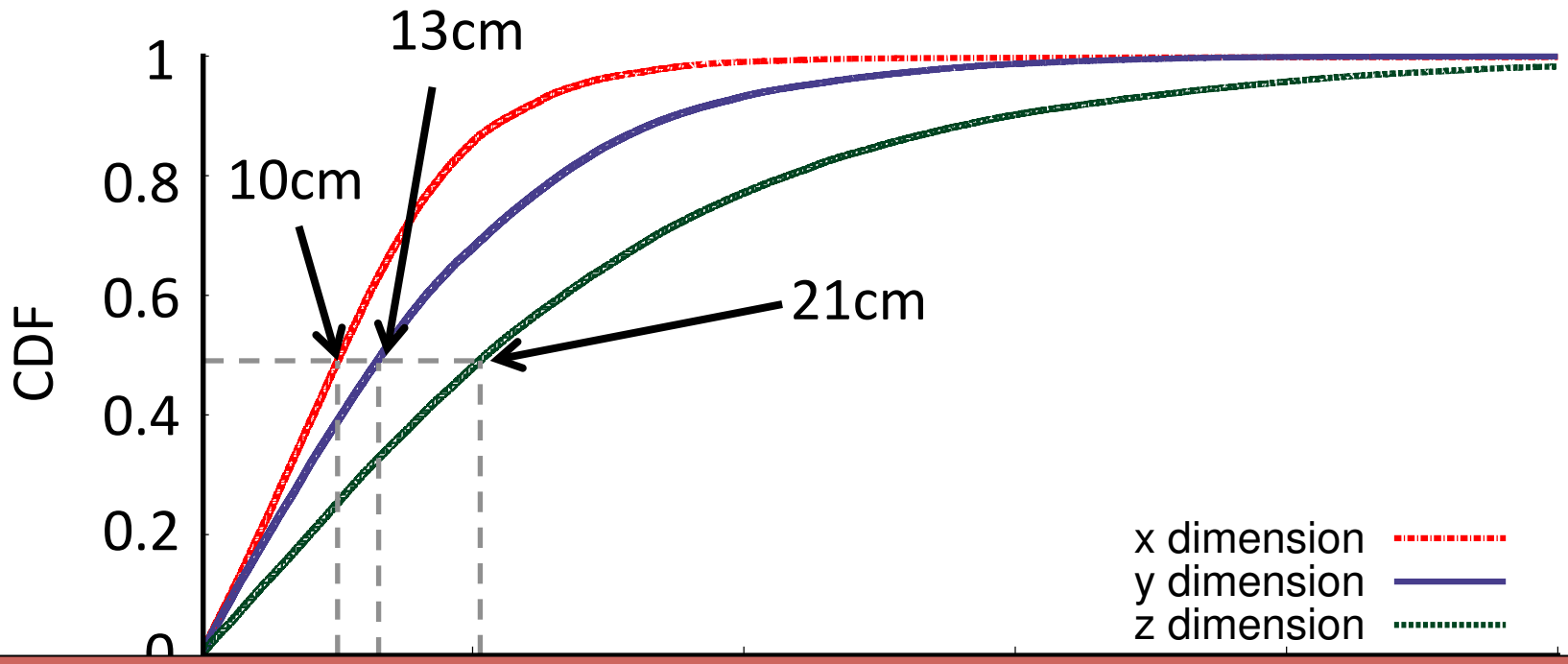
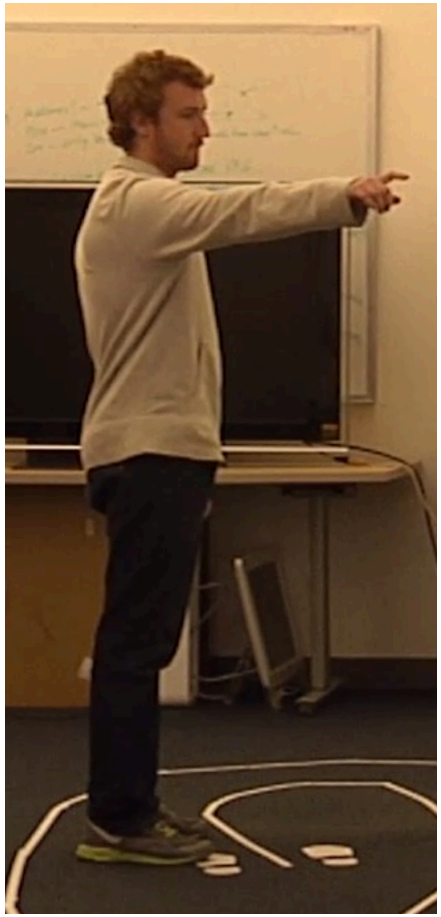
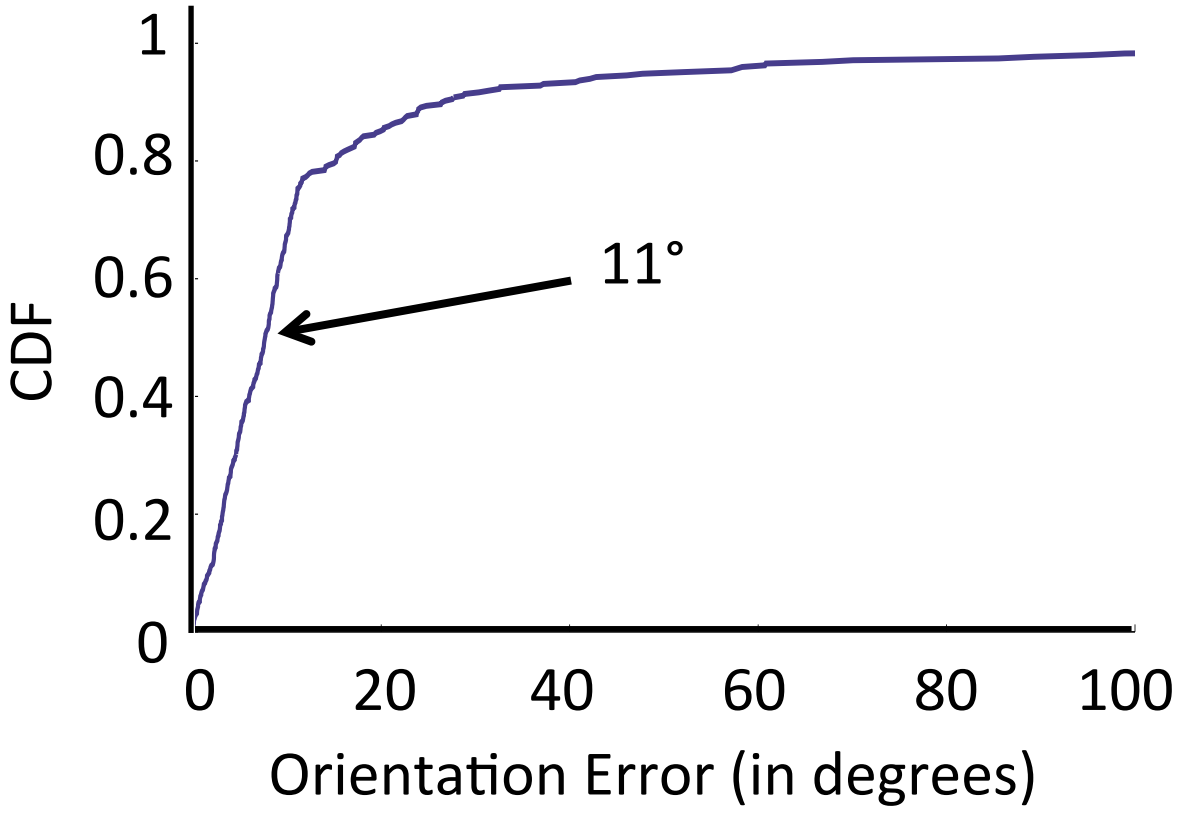


Centimeter-scale localization without requiring the user to carry a wireless device

Accuracy of Pointing Gesture

Experiment: person points in a random direction

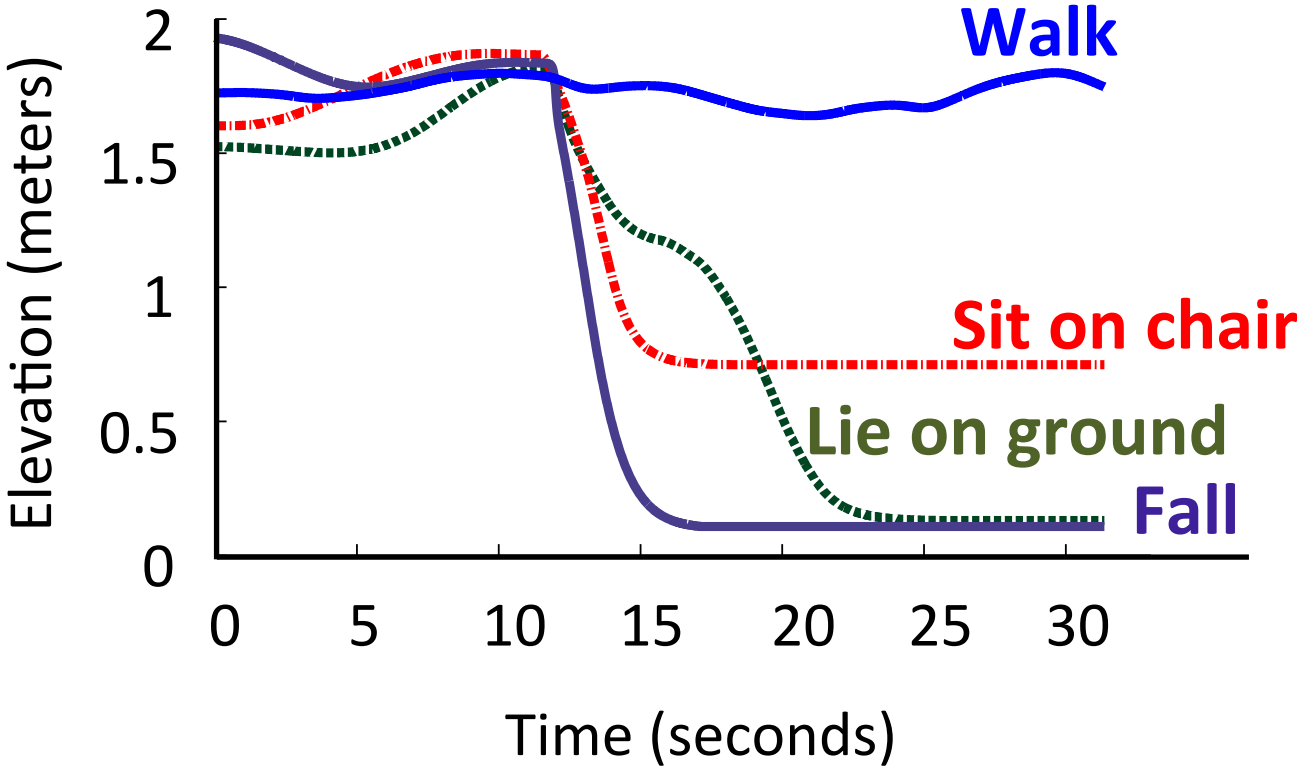




Fall Detection

Goal: Elderly monitoring to detect falls

Experiment: Person simulates falling, sitting, lying on the floor. Check if WiTrack detects falls



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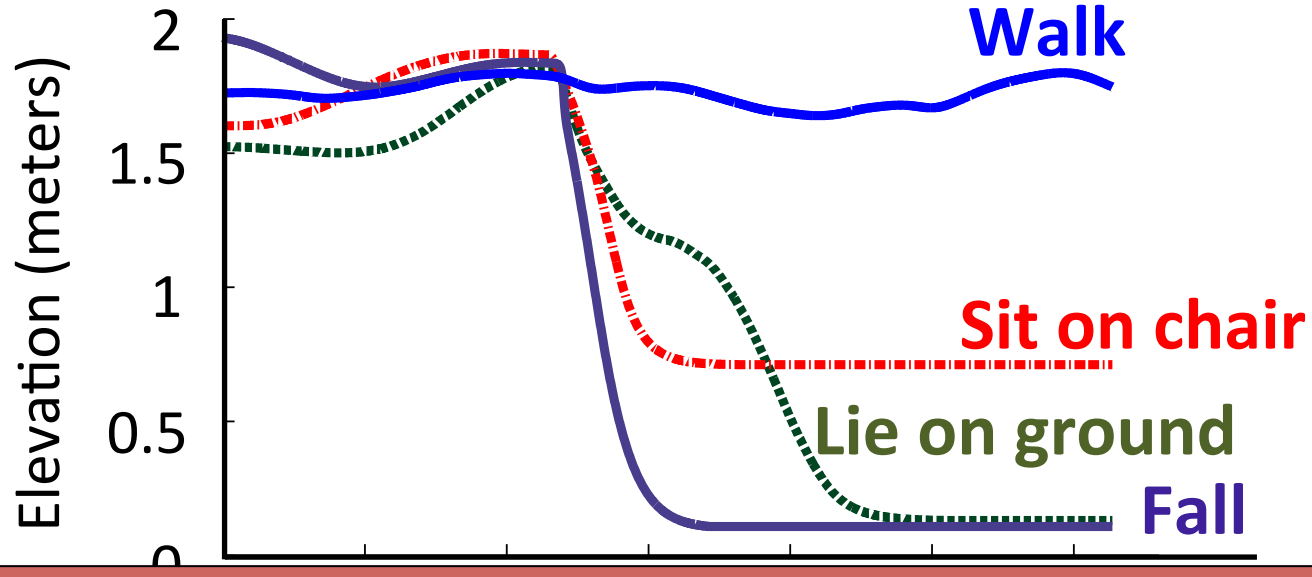

Fall Detection Accuracy: 97%

Related Work

- **Emerging area uses body radio reflections for motion and gesture detection**
  - WiVi [SIGCOMM'13], WiSee [MobiCom'13], Full Duplex Backscatter [HotNets'13], AllSee [NSDI'14], Electronic Frog Eye [INFOCOM'14]

- **RF-based localization: localizes an RF transceiver**
  - ArrayTrack [NSDI'13], PinPoint [NSDI'13], PinIt [SIGCOMM'13], Zee [MobiCom'12], PinLoc [MobySys'12], FM-based [MobySys'12], EZ [MobiCom'10], Link Signatures [MobiCom'07], Bayesian [INFOCOM'05], VOR [MobiCom'04], APS [INFOCOM'03], AHLoS [MobiCom'01], Cricket [MobiCom'00], RADAR [INFOCOM'00], …

Limitations

- Can only detect a moving person
- Cannot concurrently track multiple people

Ongoing Work: Unpublished

To lift WiTrack's limitations (requiring motion)

Our device can also monitor breathing remotely

It uses radio signals that are hundreds of times lower power than WiFi.

More information

(Videos and animated slides)

http://witrack.csail.mit.edu