6.829: Computer Networks and Mobile Systems

Lecture 6: Device-Free Localization

Previous Lecture: Device-based Localization

This Lecture: Using radio signals to track humans without any sensors on their bodies

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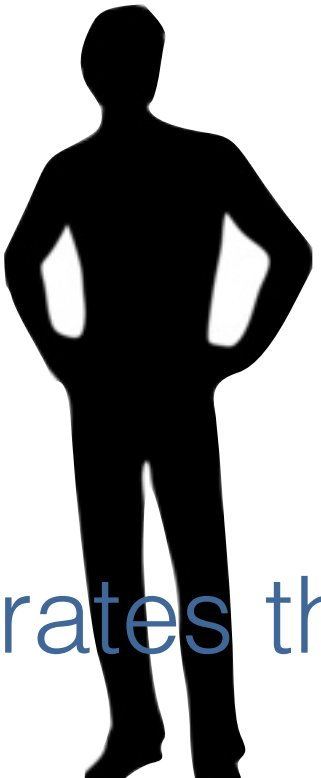
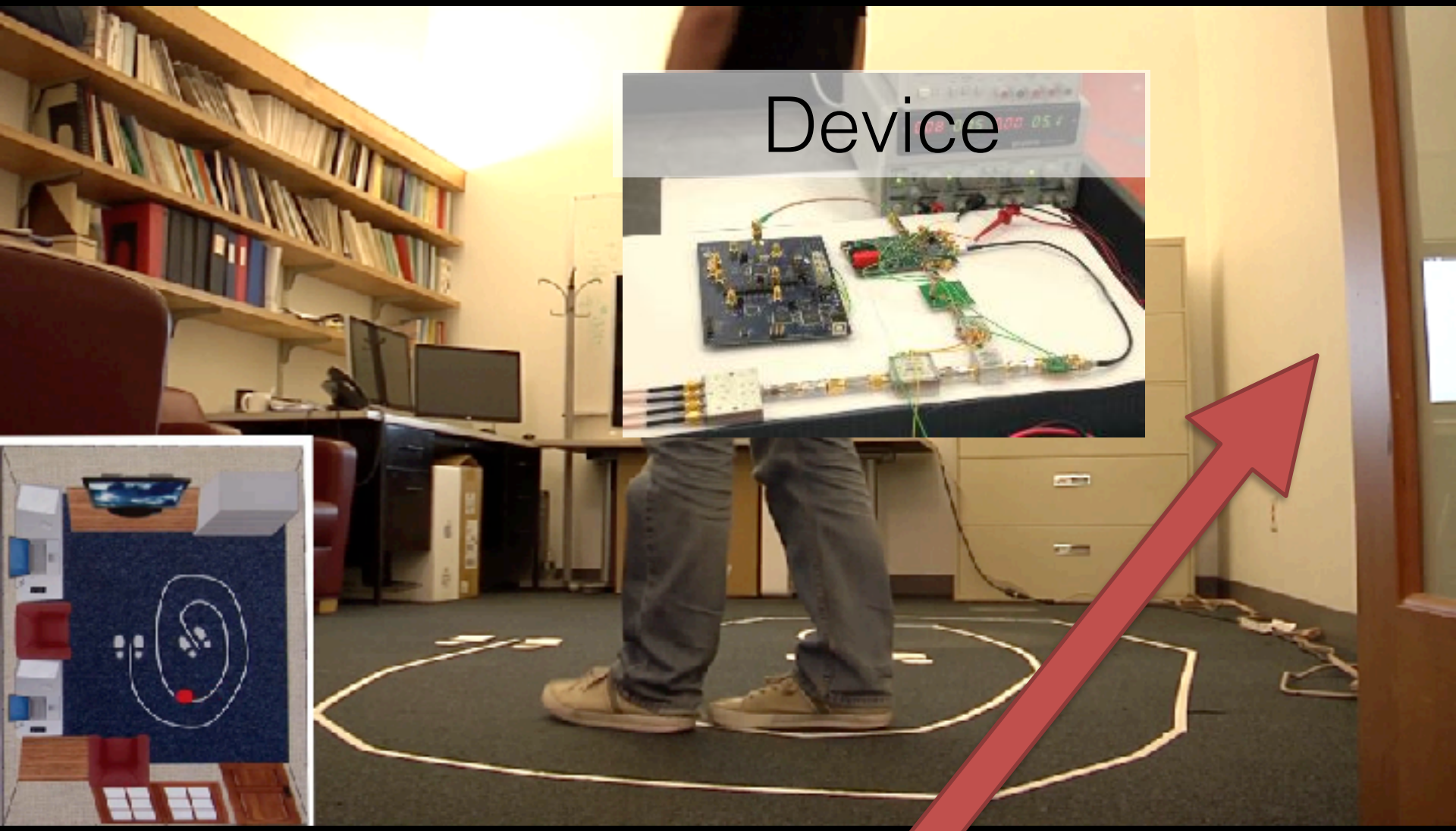


- Location
- Vital Signs
- Gestures

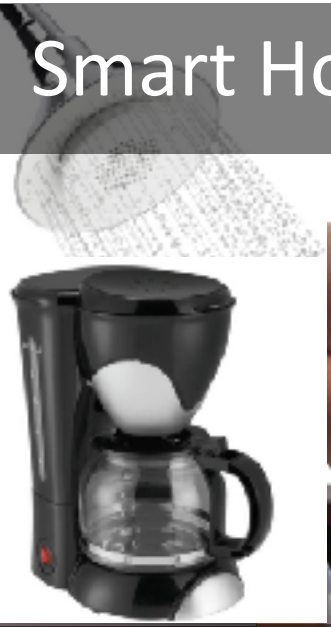
Operates through occlusions

Example: WiTrack


Device
Device in another room

Applications

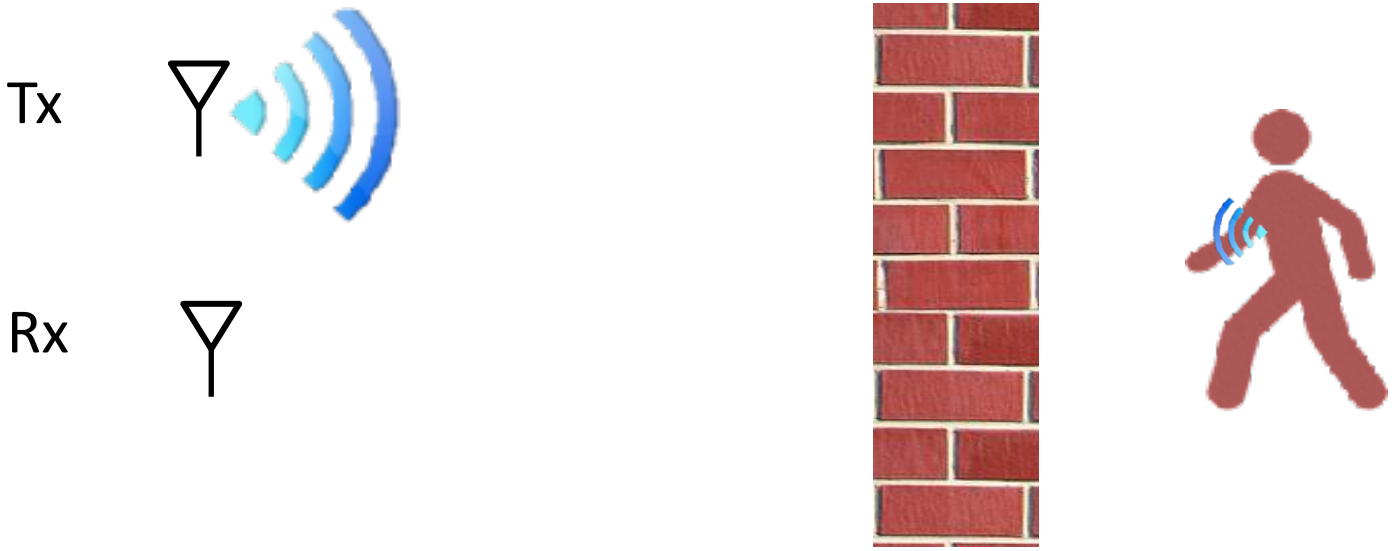
Smart Homes



Energy Saving

Gaming & Virtual Reality

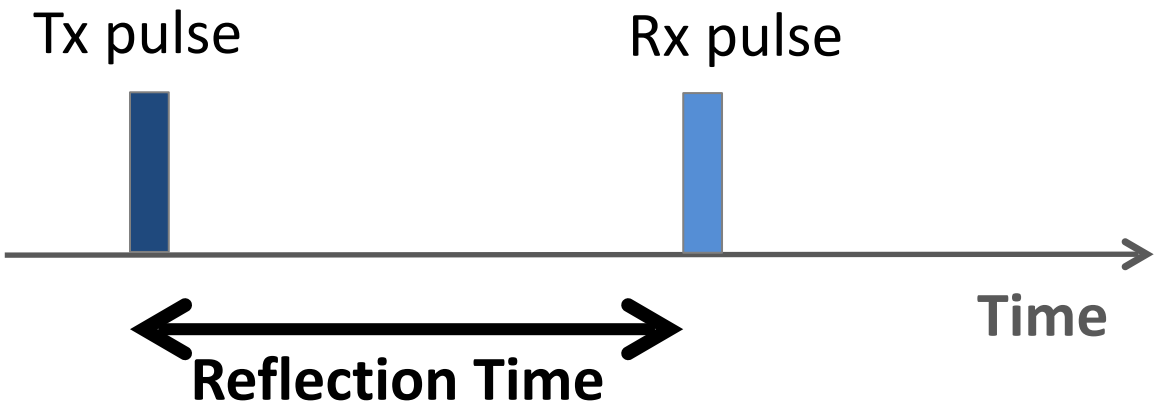
Measuring Distances



Distance = Reflection time x speed of light

Measuring Reflection Time

Option1: Transmit short pulse and listen for echo



Measuring Reflection Time

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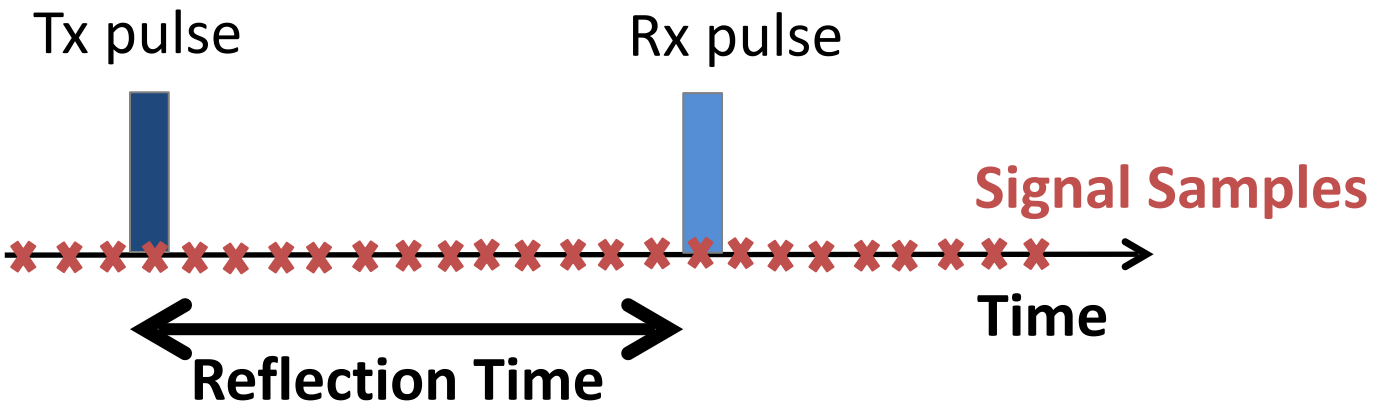
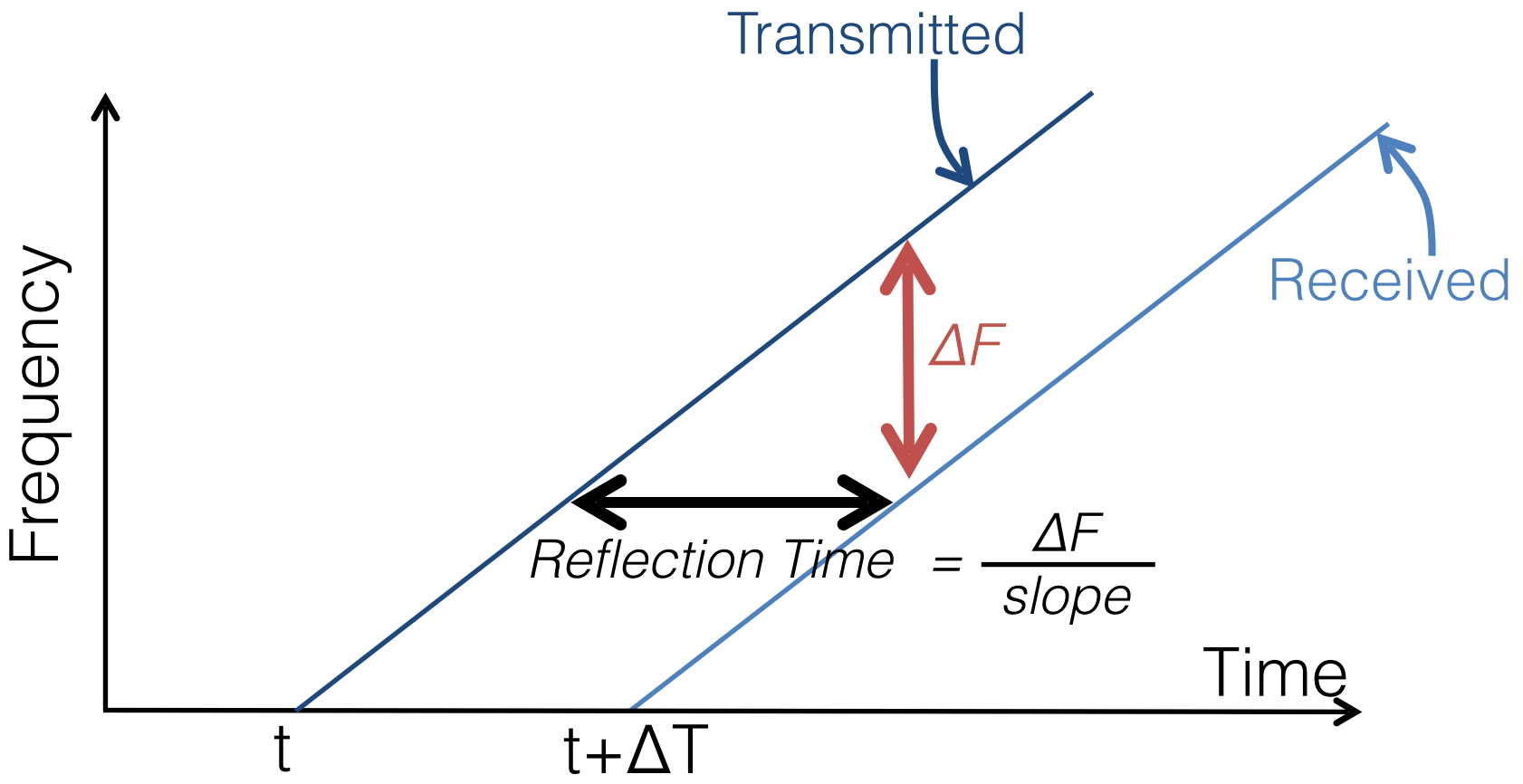


Capturing the pulse needs sub-nanosecond sampling

Multi-GHz samplers are expensive, have high noise, and create large I/O problem

What is the resolution direct time sampling?

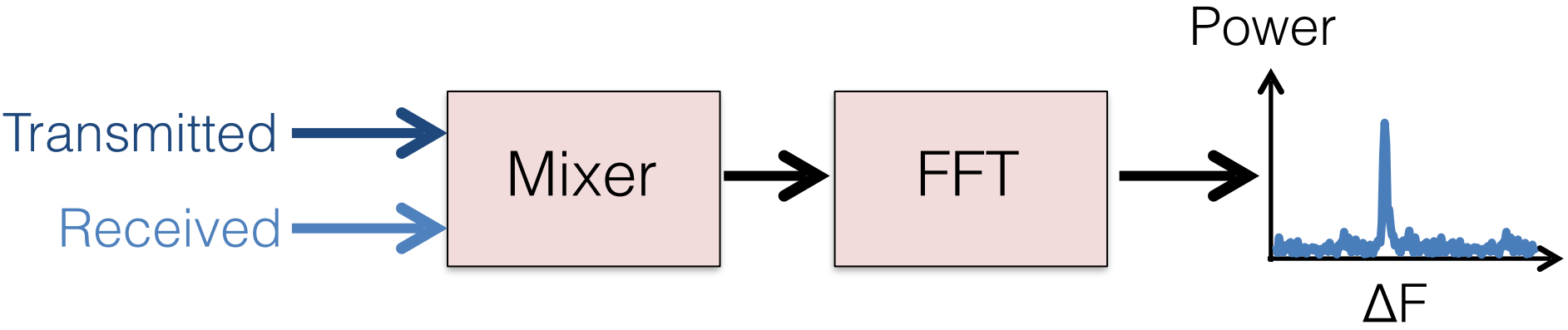
FMCW: Measure time by measuring frequency



How do we measure ΔF?

Measuring ΔF

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

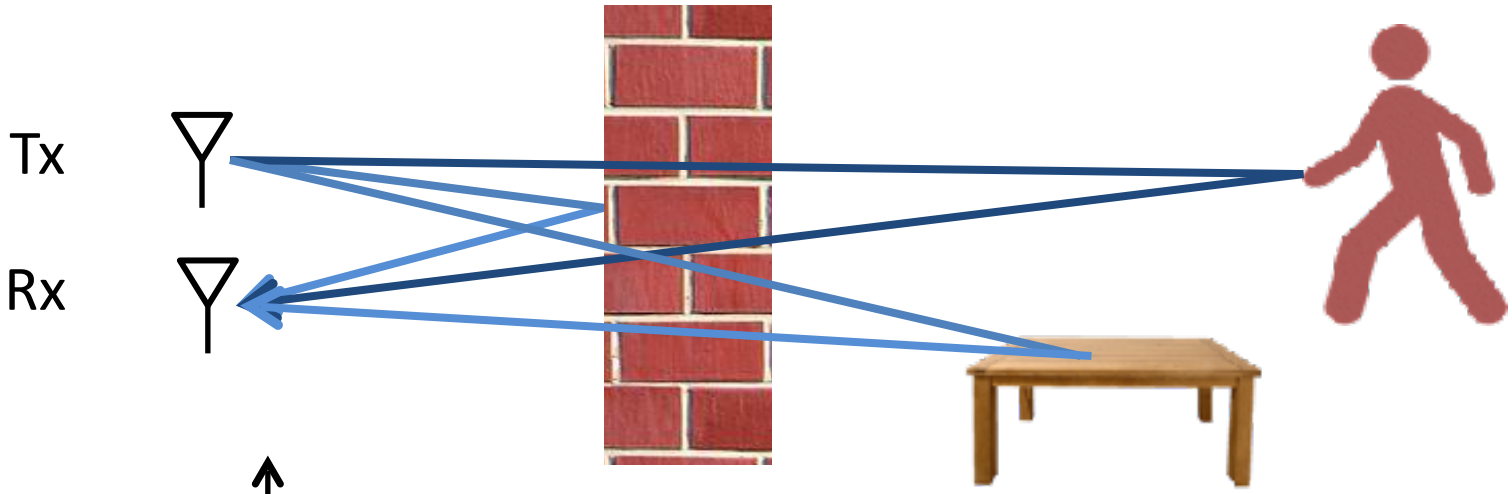


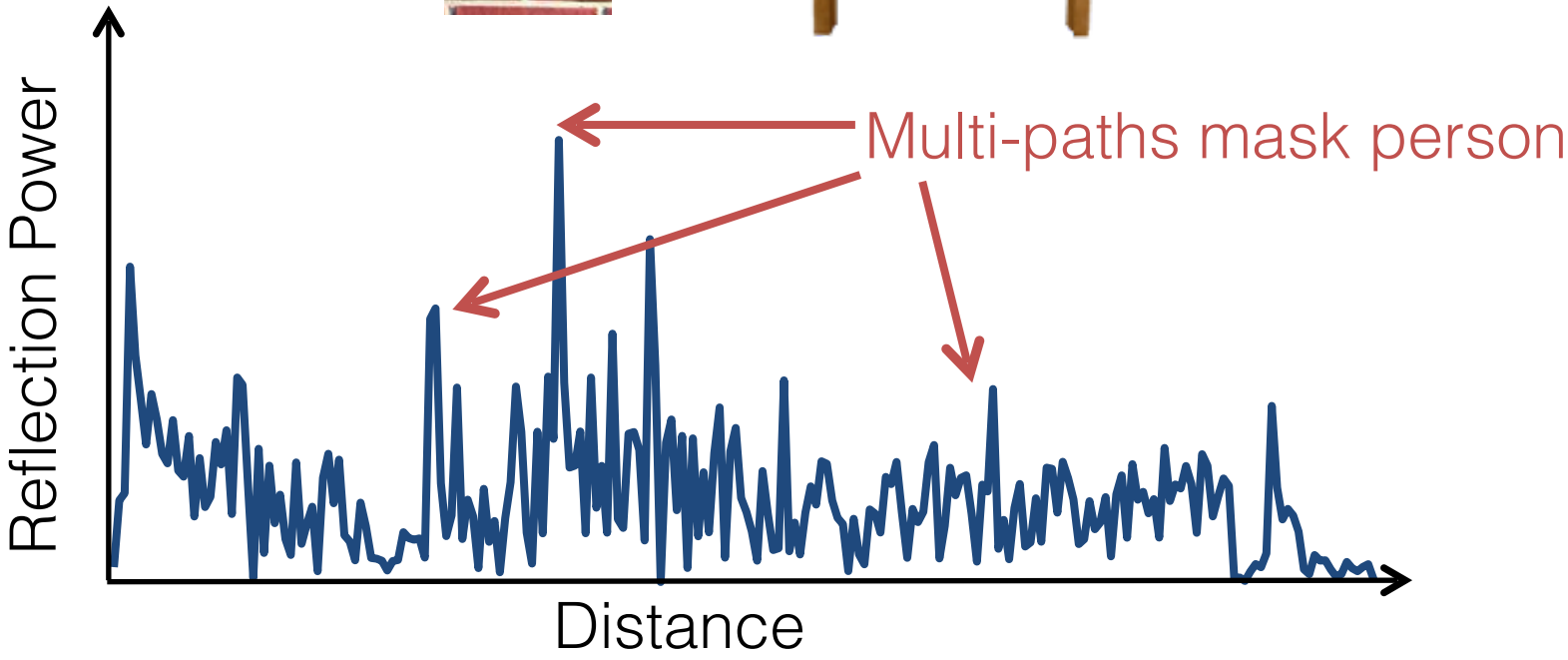
Signal whose frequency is ΔF

ΔF →Reflection Time → Distance

What is the resolution of FMCW?

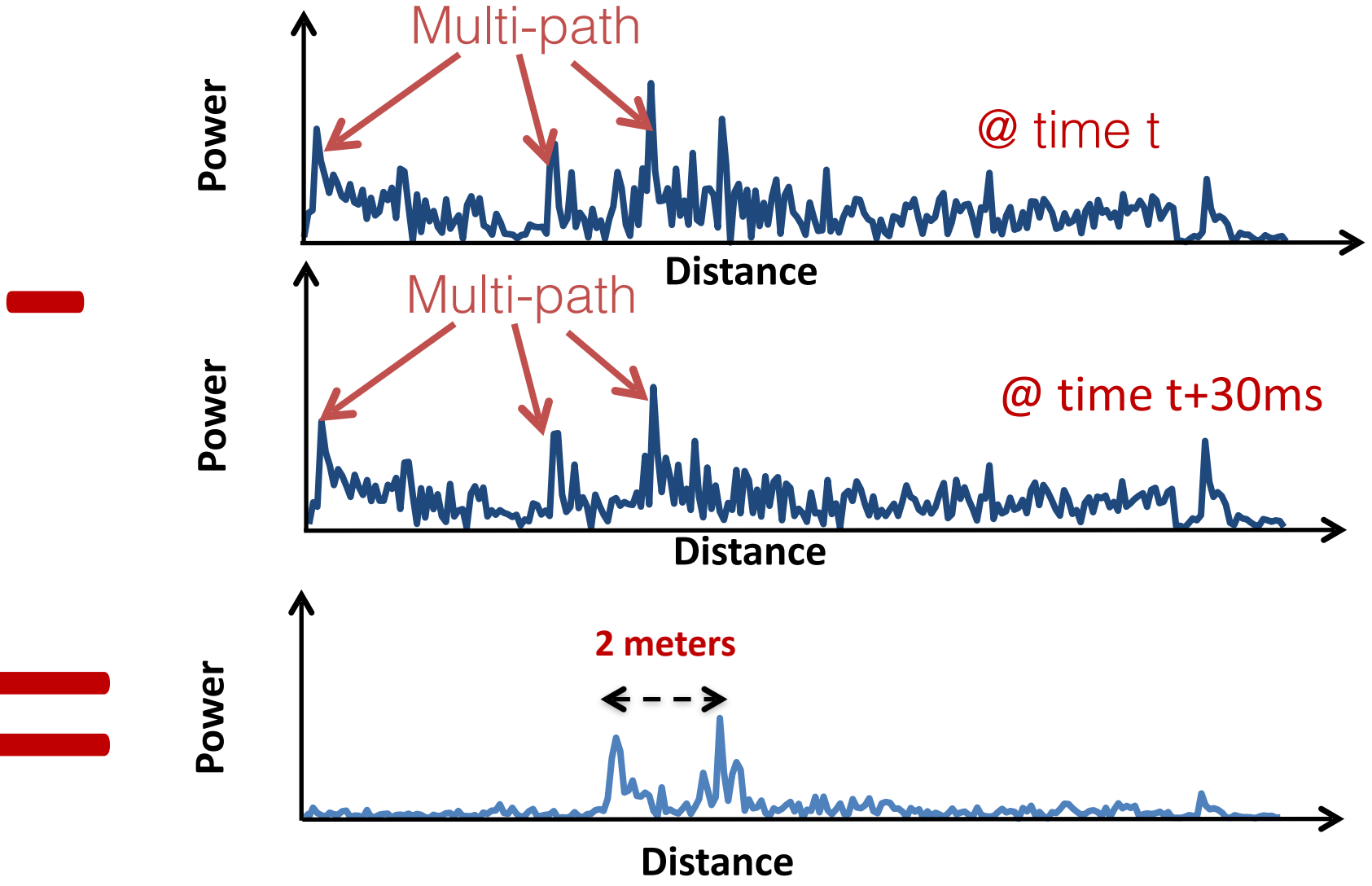
Challenge: Multipath➔ Many Reflections





Static objects don't move

➔ Eliminate by subtracting consecutive measurements



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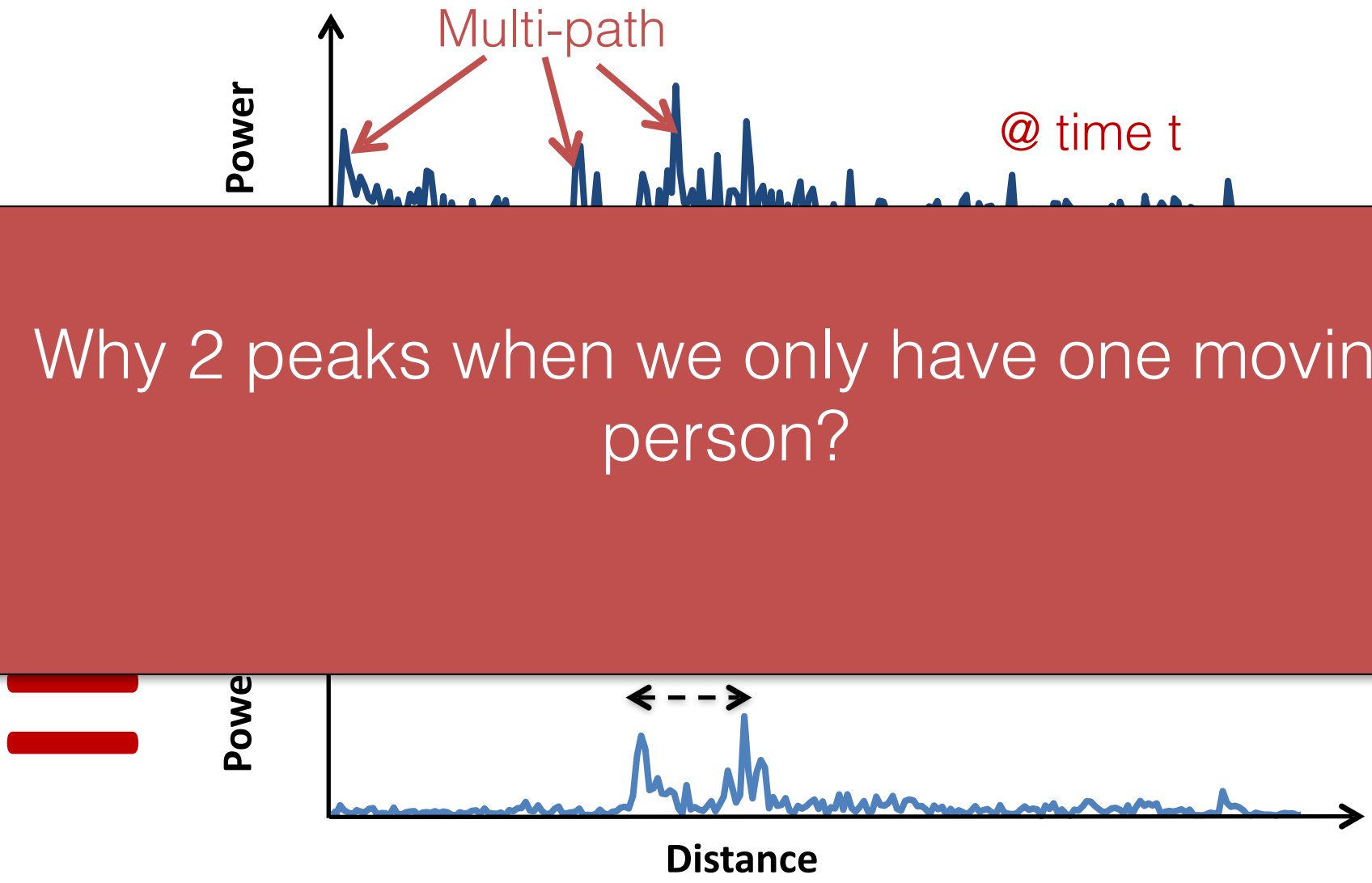
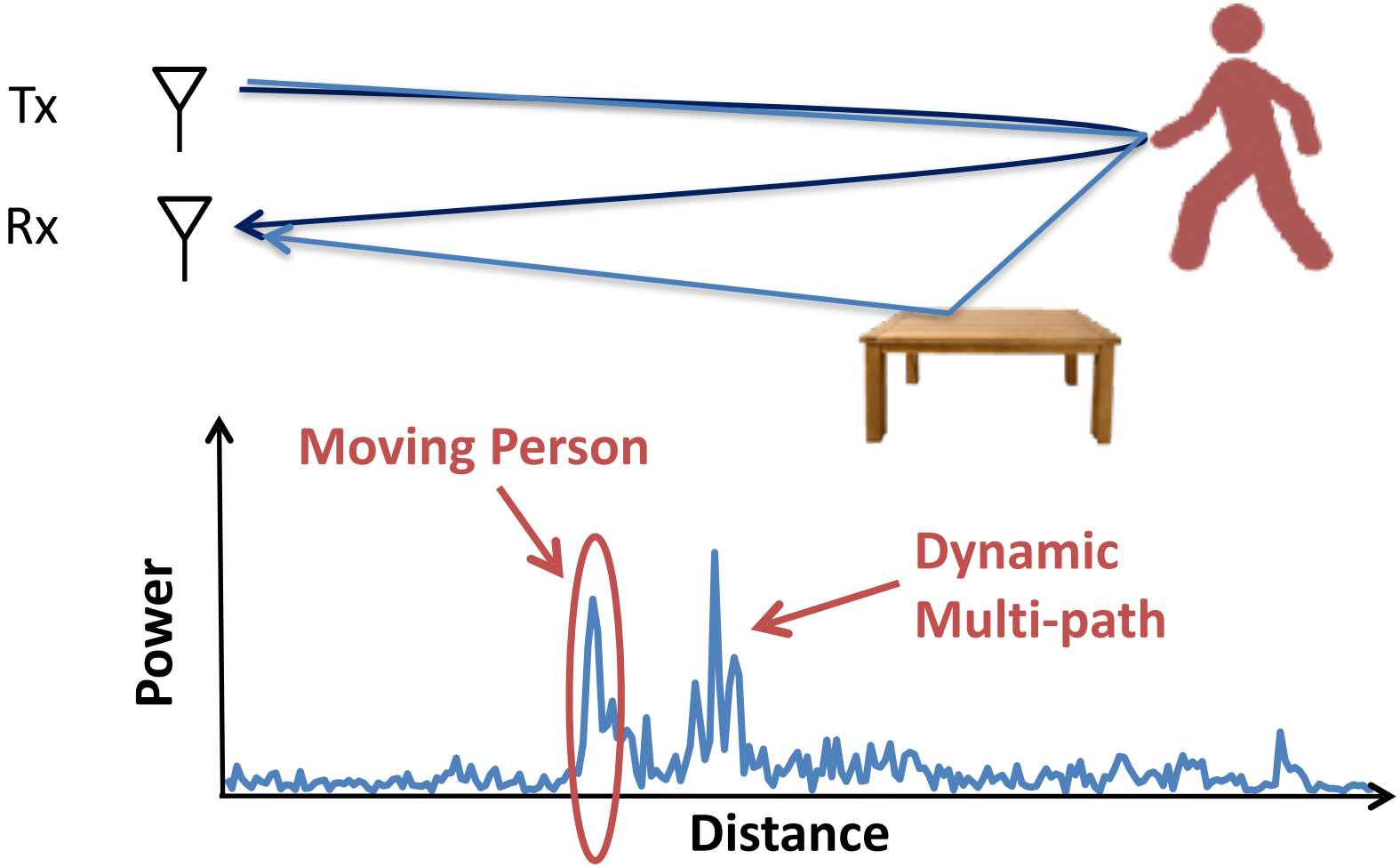
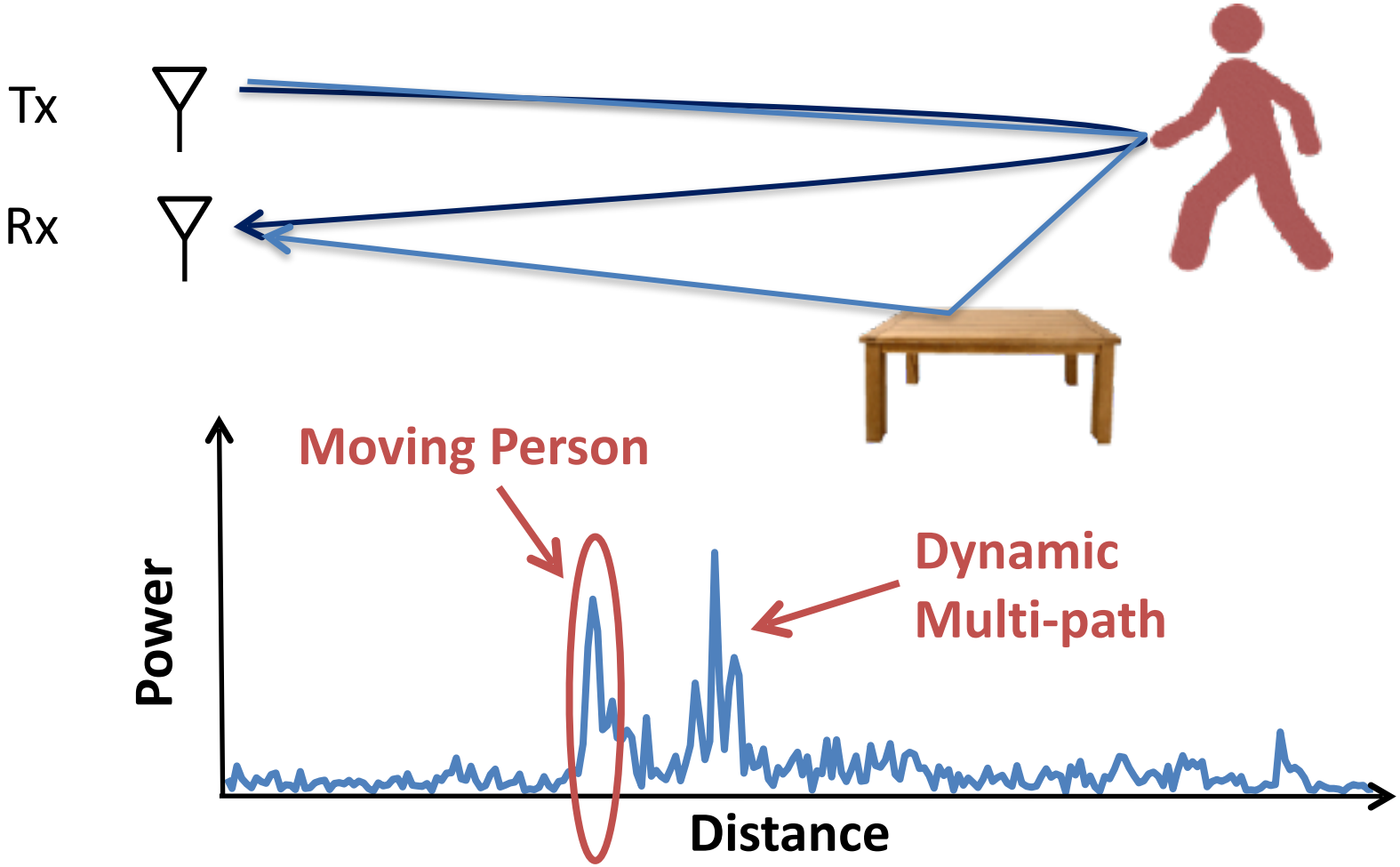


Why 2 peaks when we only have one moving person?

Challenge: Dynamic Multipath

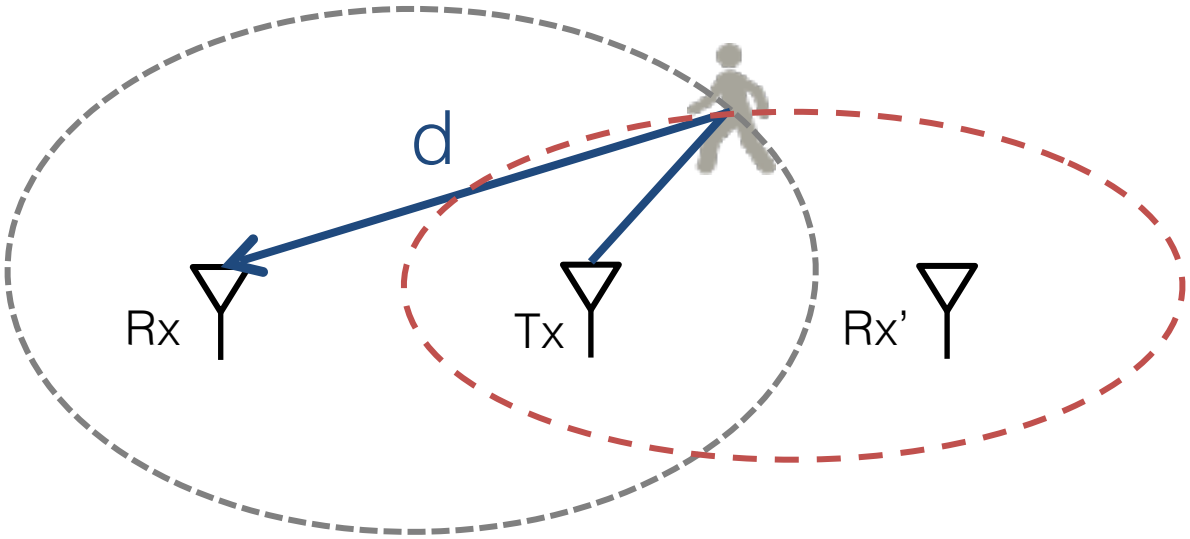


The direct reflection arrives before dynamic multipath!



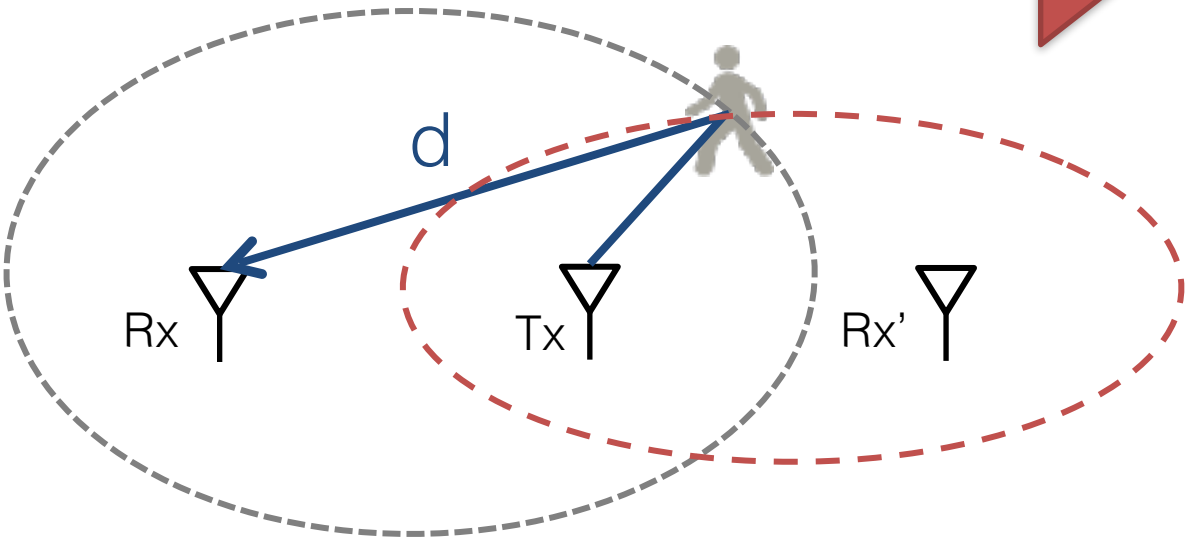
Mapping Distance to Location

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

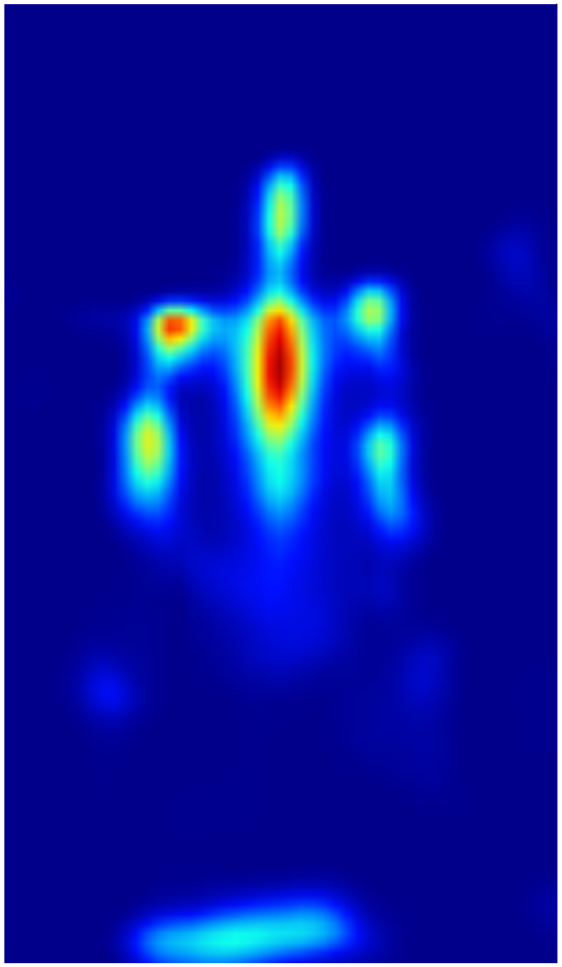


By adding another antenna and intersecting the ellipses, we can localize the person

People are points

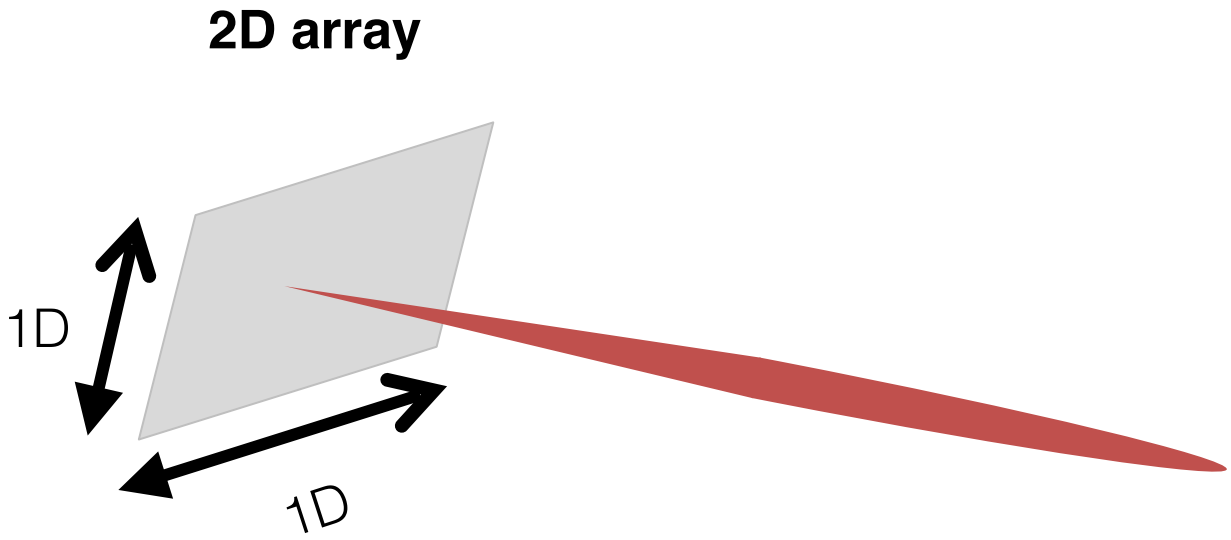


Want a silhouette



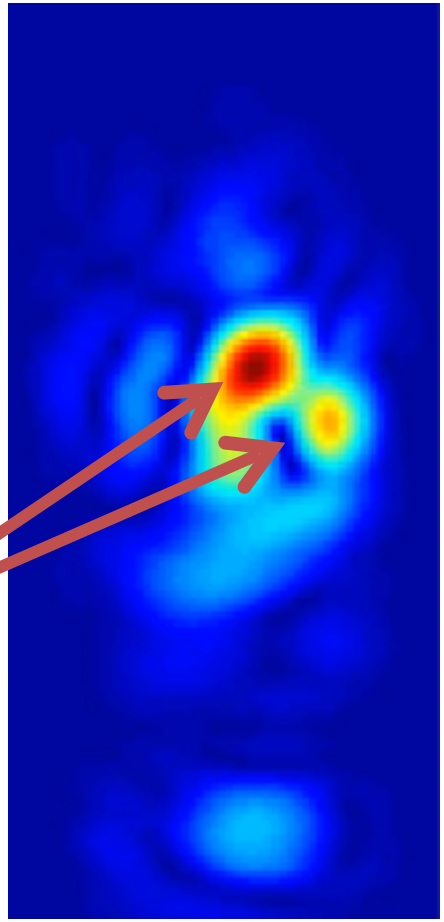
Approach: Combine antenna arrays with FMCW to get 3D image

- 2D Antenna array gives 2 angles
- FMCW gives depth (1D)



Challenge: We only obtain blobs in space

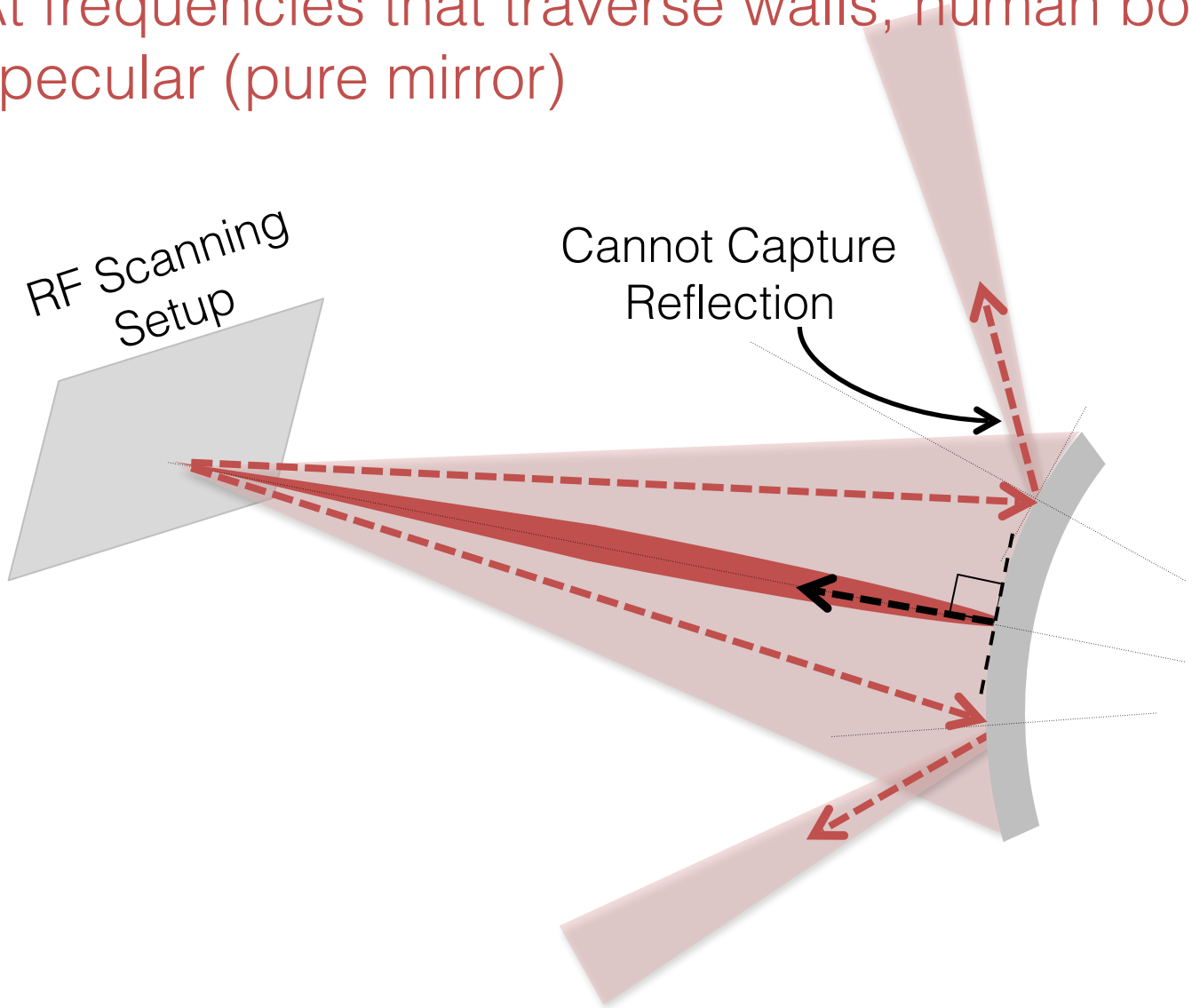
Output of 3D RF Scan



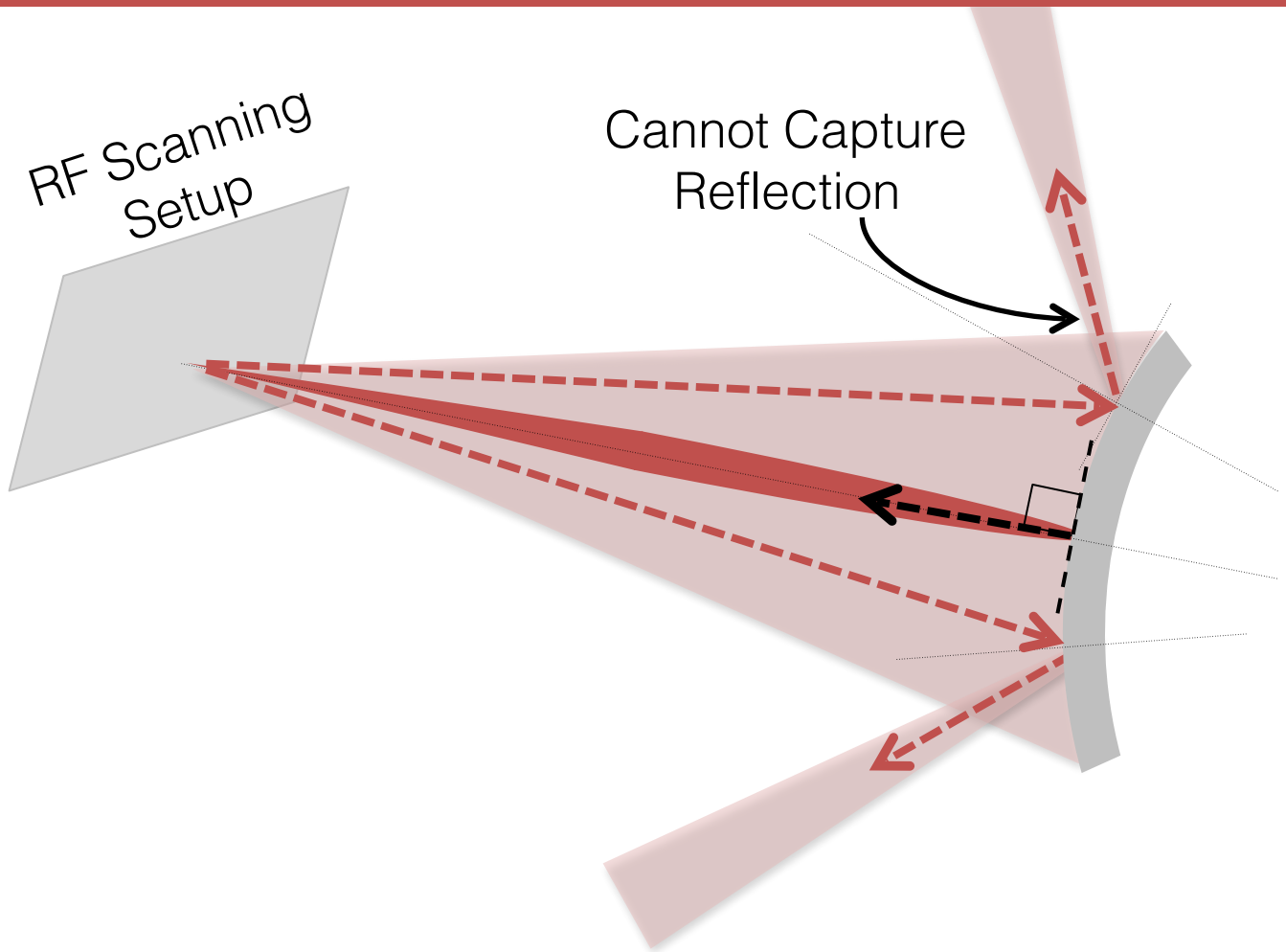
Blobs of reflection power

Challenge: We only obtain blob in space

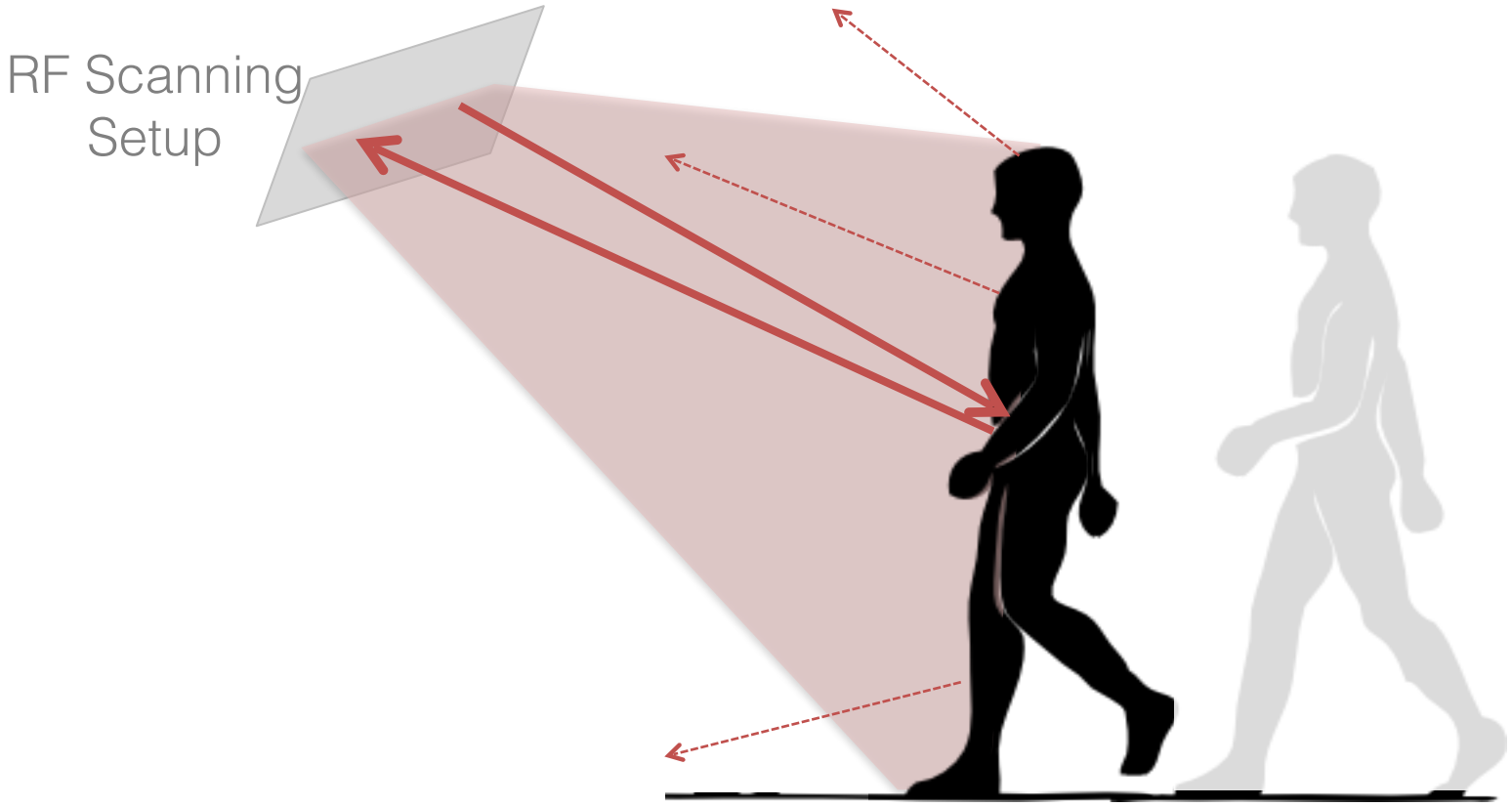
At frequencies that traverse walls, human body parts are specular (pure mirror)



At every point in time, we get reflections from only a subset of body parts.



Solution Idea: Exploit Human Motion and Aggregate over Time



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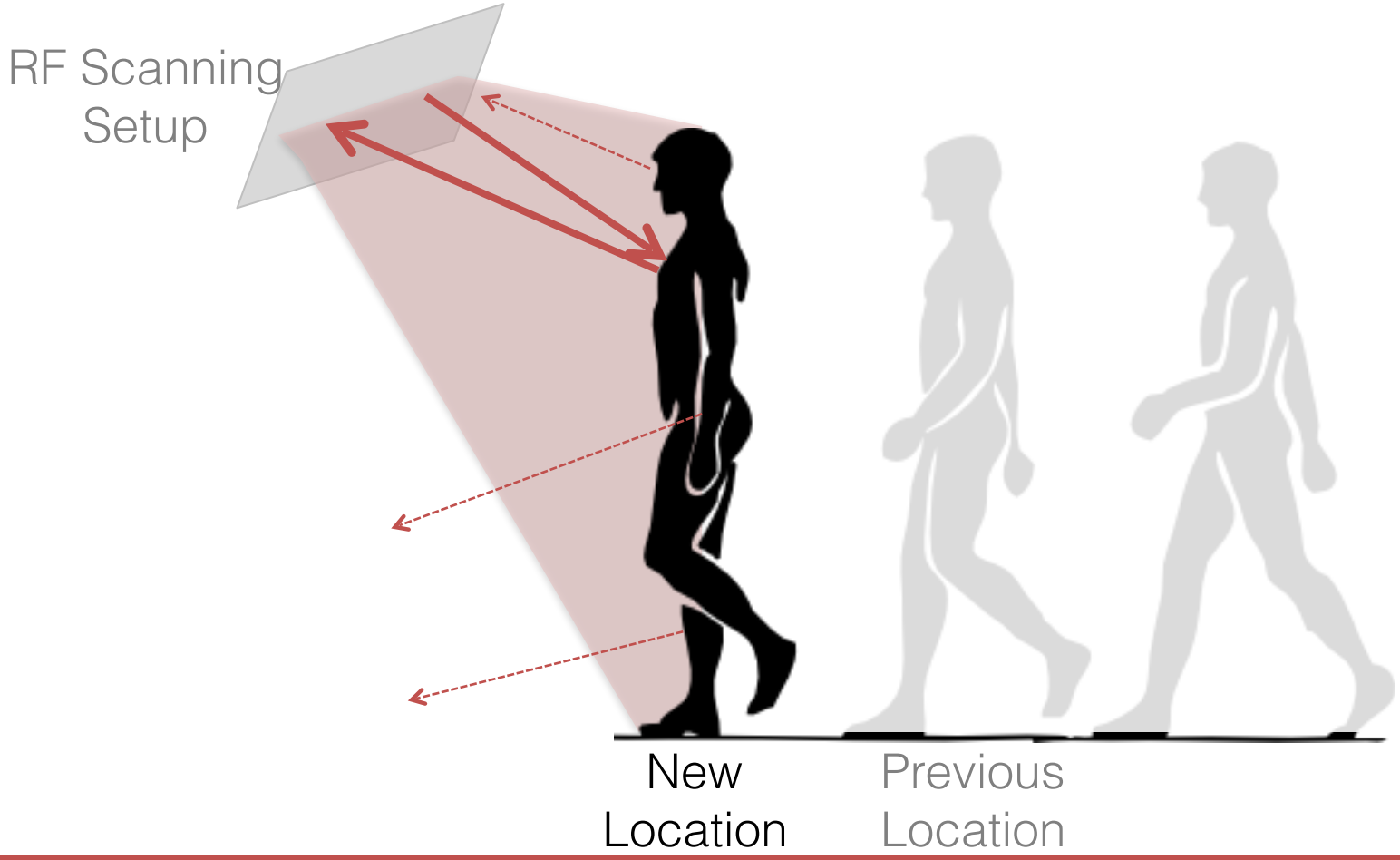
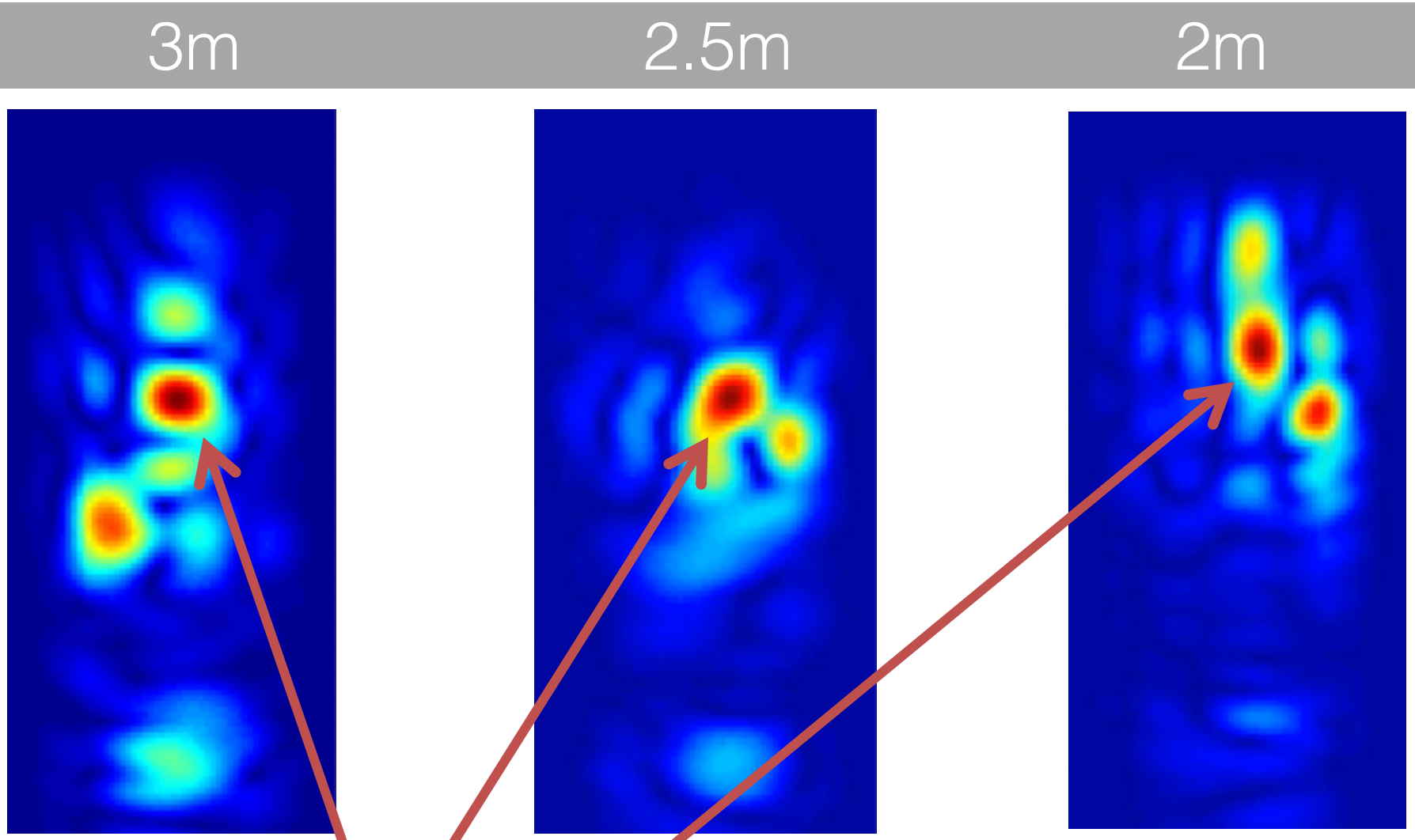
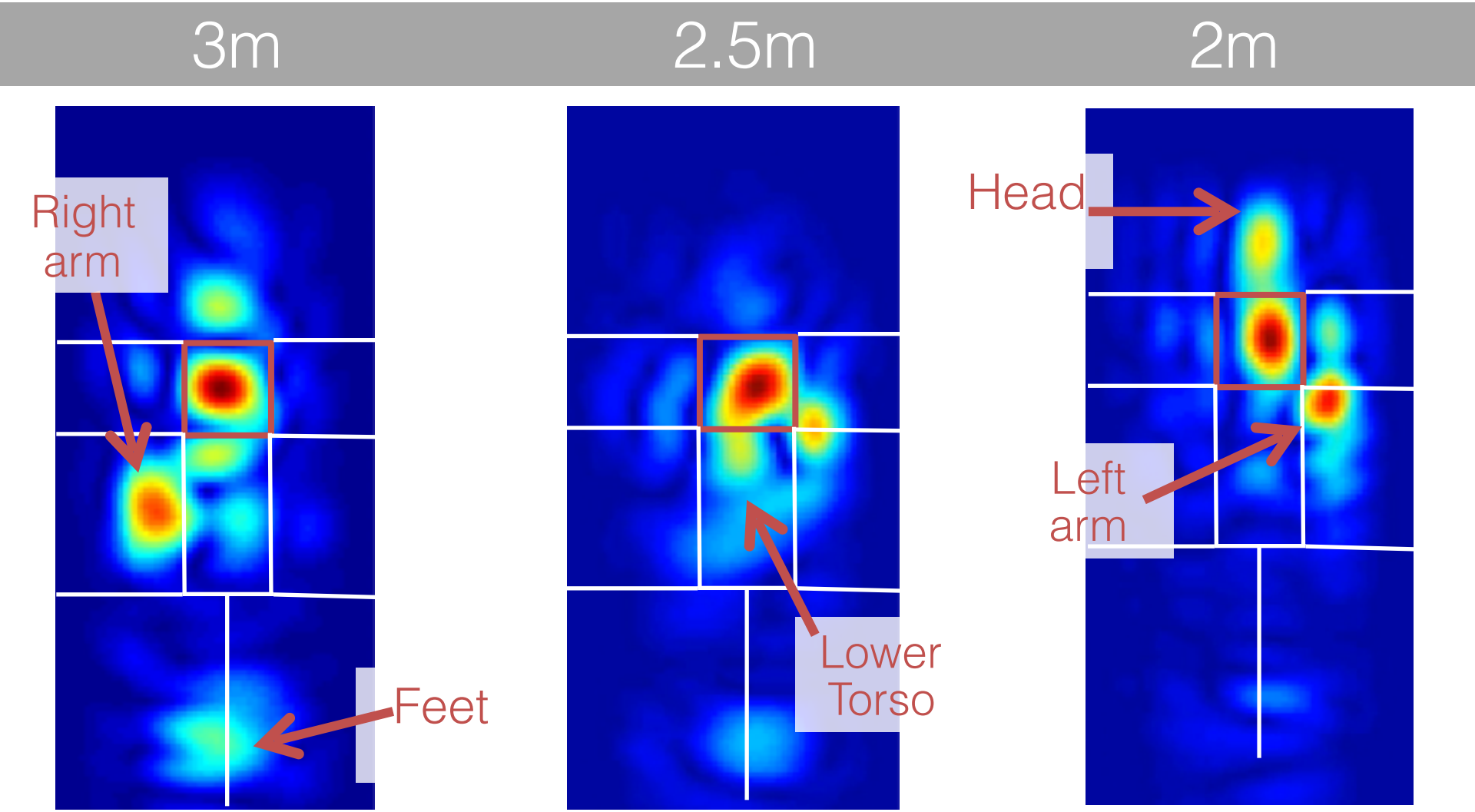


Combine the various snapshots

Human Walks toward Sensor



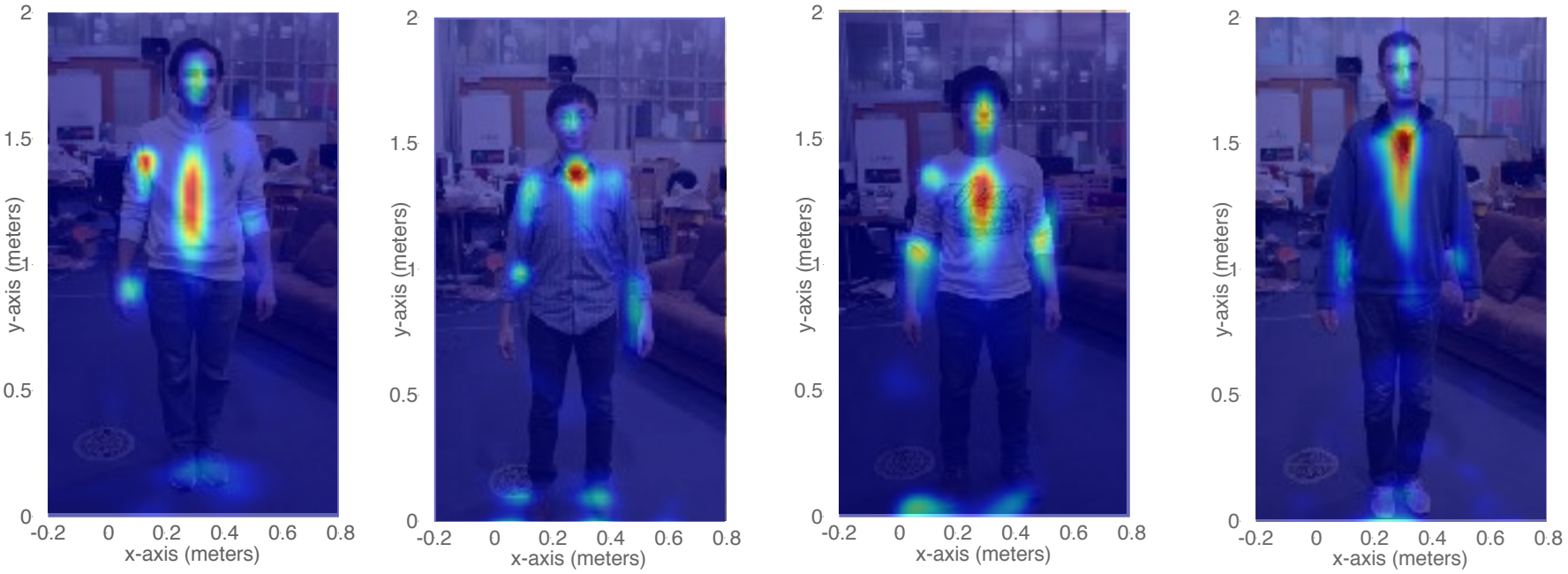
Human Walks toward Sensor



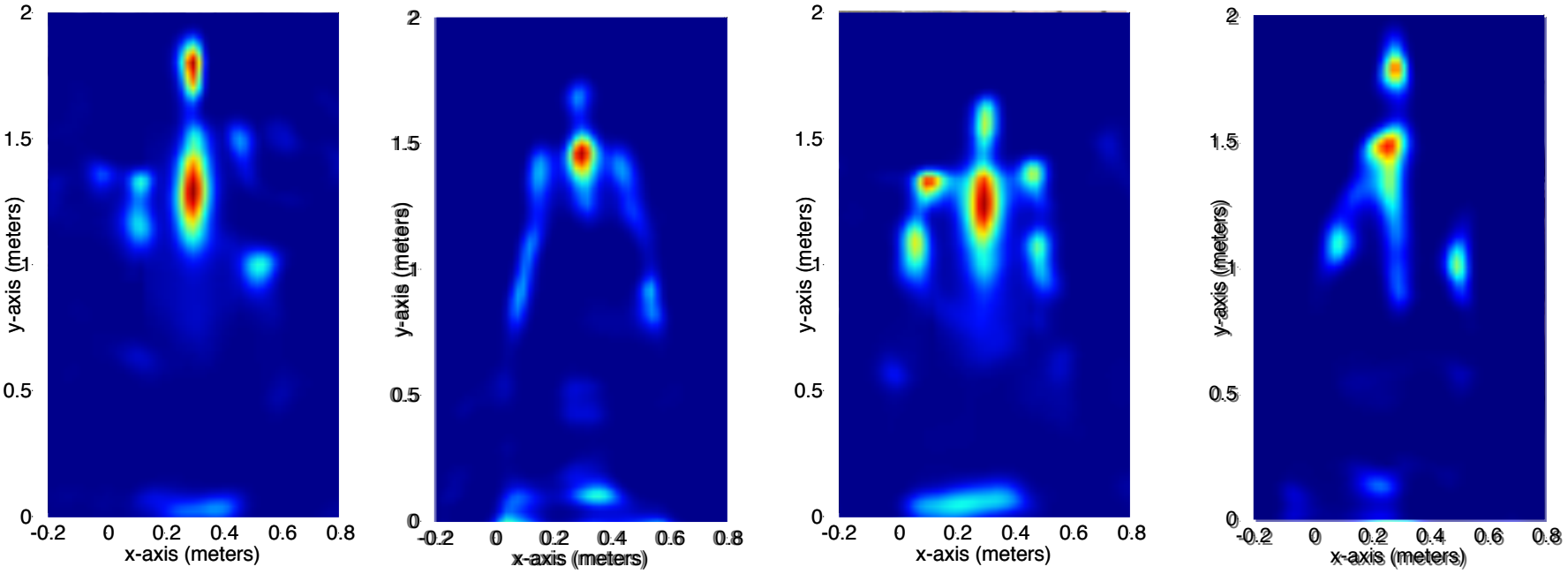
Combine the various snapshots

Human Walks toward Sensor

Sample Captured Figures through Walls



Through-wall classification accuracy of 90% among 13 users



Wireless Comm (Cont'd)

- Packet Detection (sliding window)
- Wireless Channel
- Carrier Frequency Offset (CFO)