See Through Walls with Wi-Fi
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Can Wi-Fi Signals Extend Our Senses?

Wi-Vi uses Wi-Fi signals to see through walls:

- **Detect and track** human motion
- Identify the **number of moving humans** and their relative locations
- Allows humans to **communicate without a transmitting device**
- Through-wall **gesture-based interface**

Applications: law enforcement, gaming, intrusion detection, etc.

Tracking Human Motion

Reflections from Different Moving Humans *Overlap*:
- Correlated: reflections of same signal
- Spatially un-correlated: different angles

- Use **Spatially Smoothed MUSIC** algorithm to distinguish
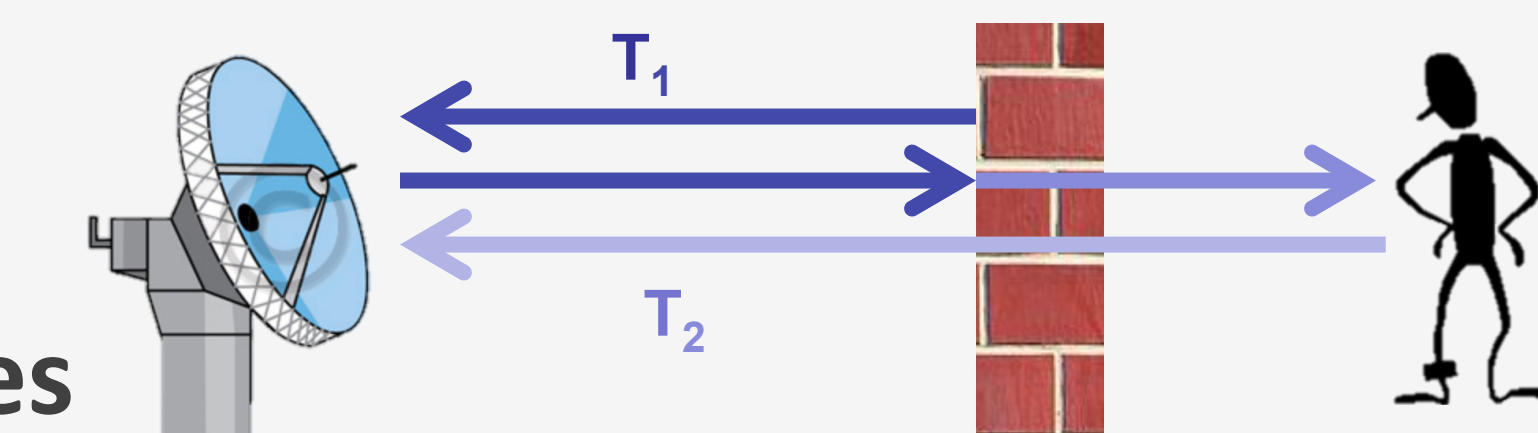- Automatically identify # of moving objects by computing **spatial variance** of output

One Person

DC line (static objects)

Two Persons

Three Persons
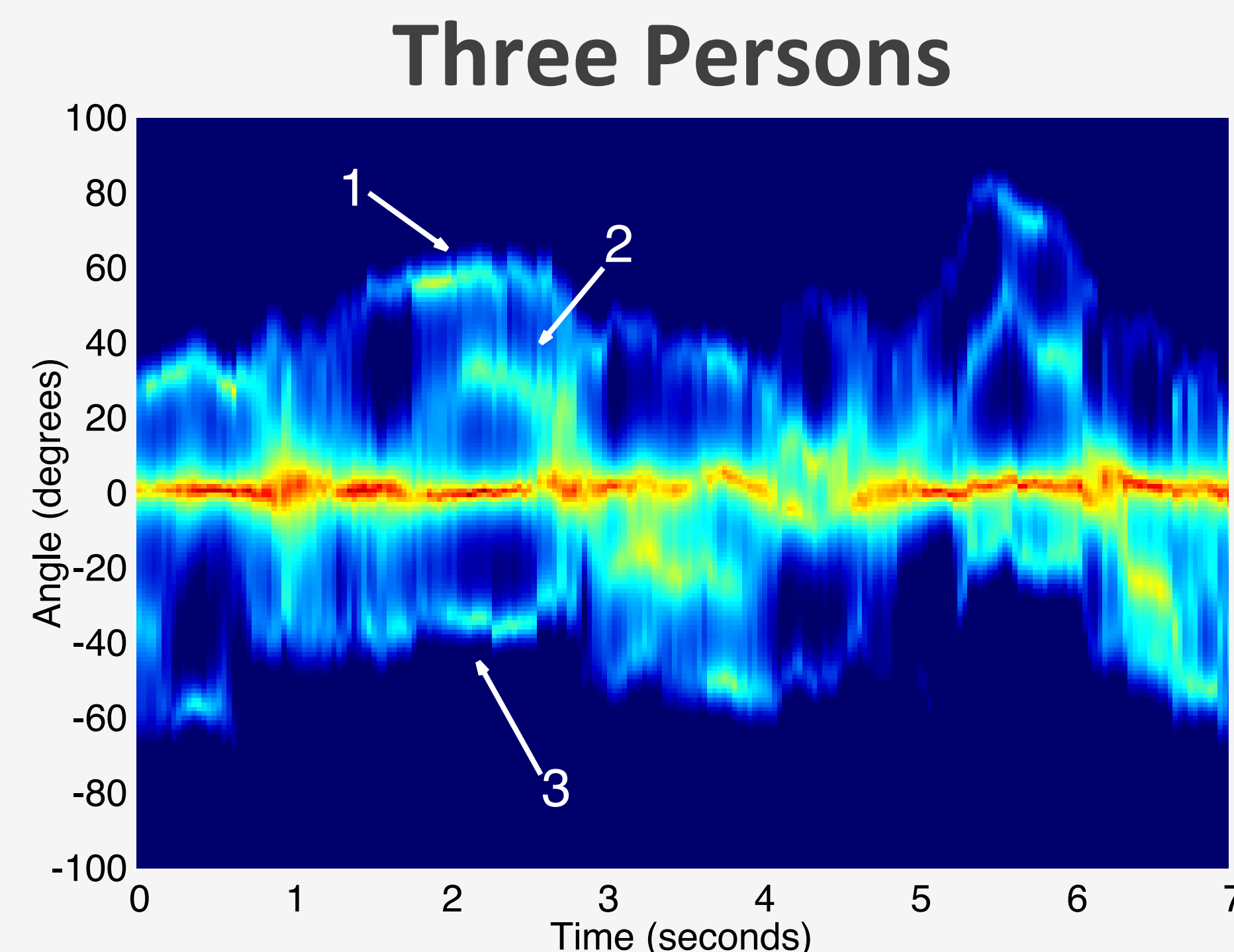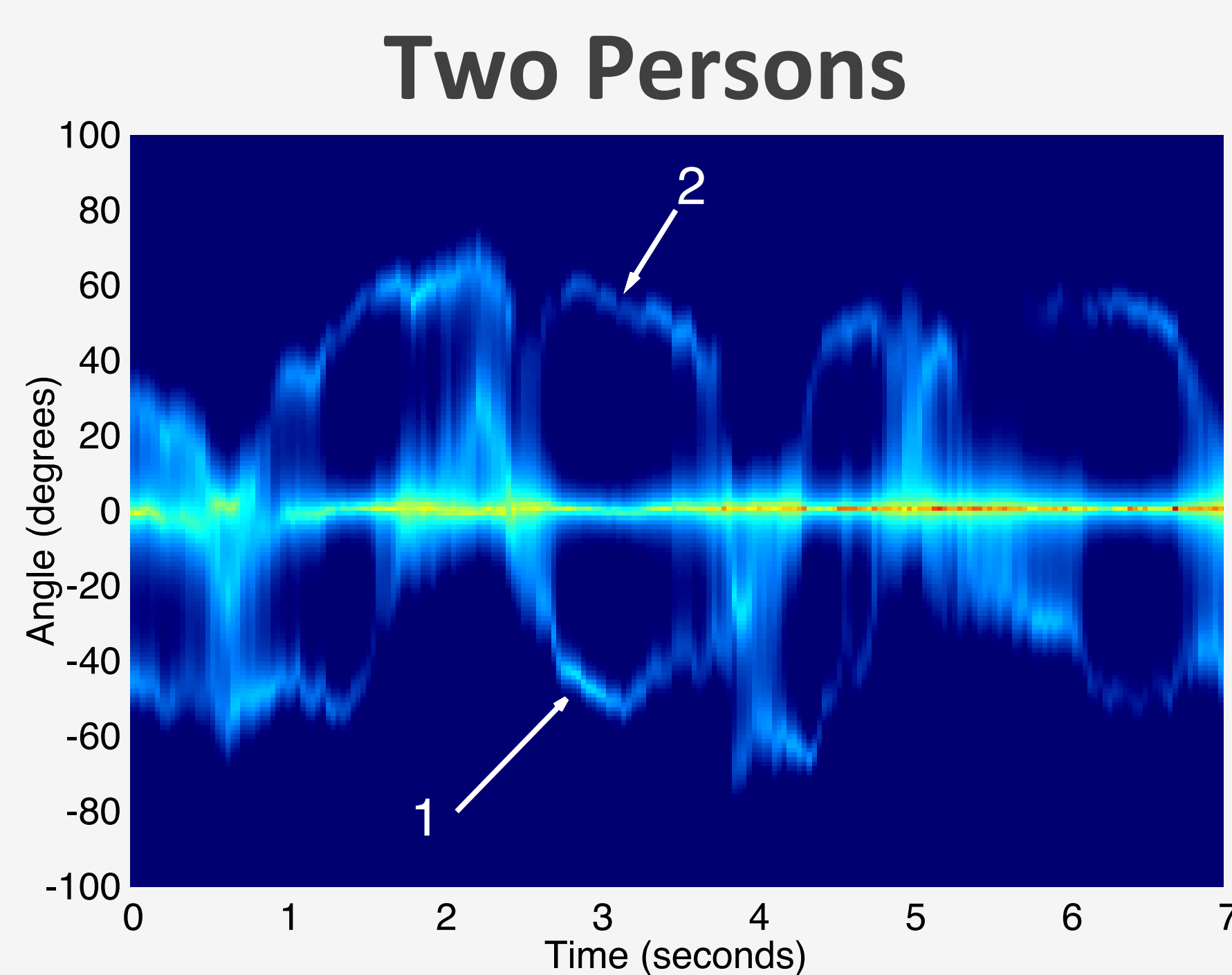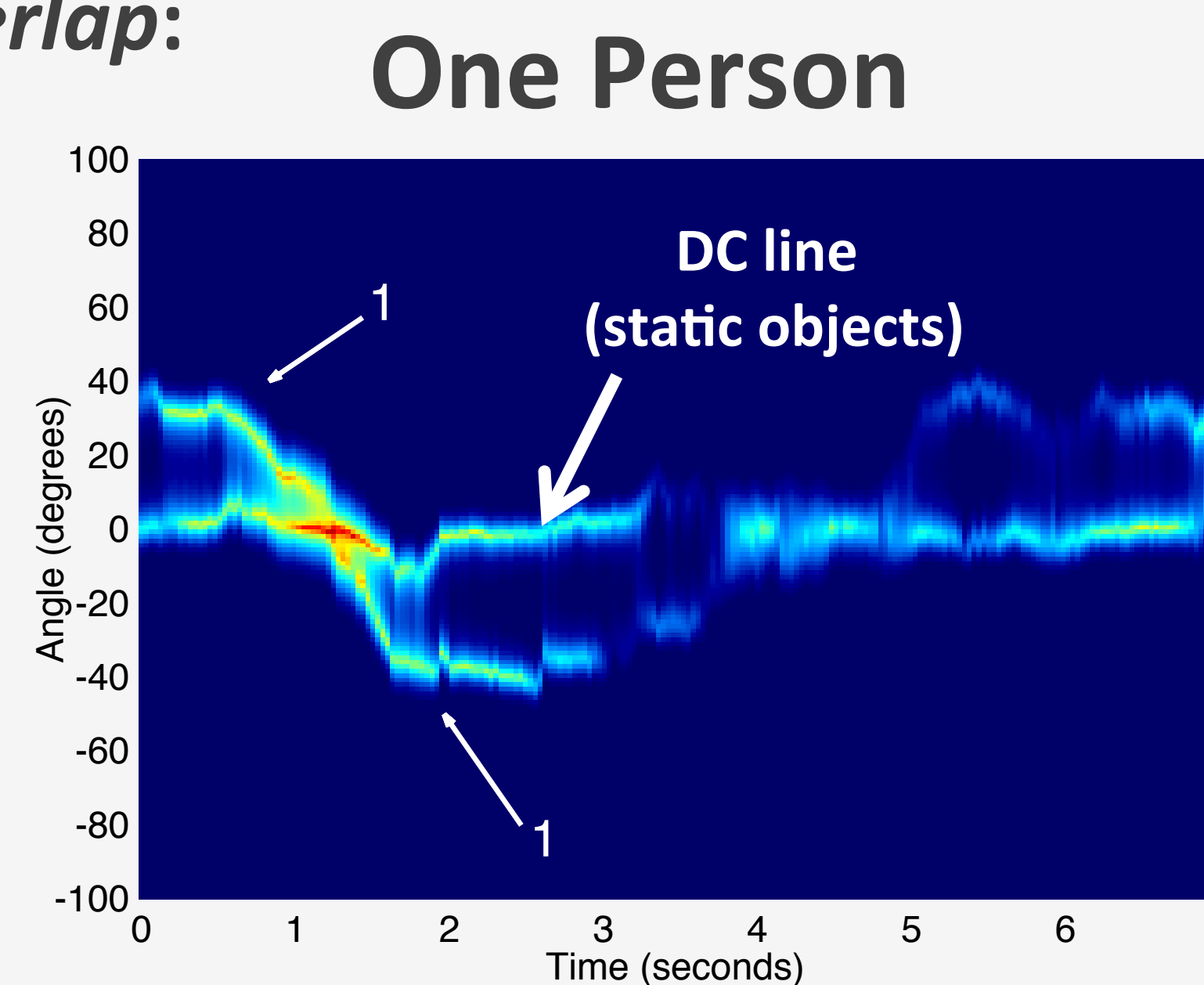
Challenges in Designing Wi-Vi

Challenge #1: "Flash" Effect

RF signals penetrate walls:
- Reflect off objects on other side of wall
- Distinguish reflectors by their arrival times

T_1 T_2

Measure sub-nanosecond delays

Use Multi-GHz bandwidth

At low bandwidth:
- Wall reflection much stronger than reflections coming from behind the wall
- Flash effect: **wall reflection saturates the ADC.**

Wi-Vi overcomes "Flash" by MIMO nulling

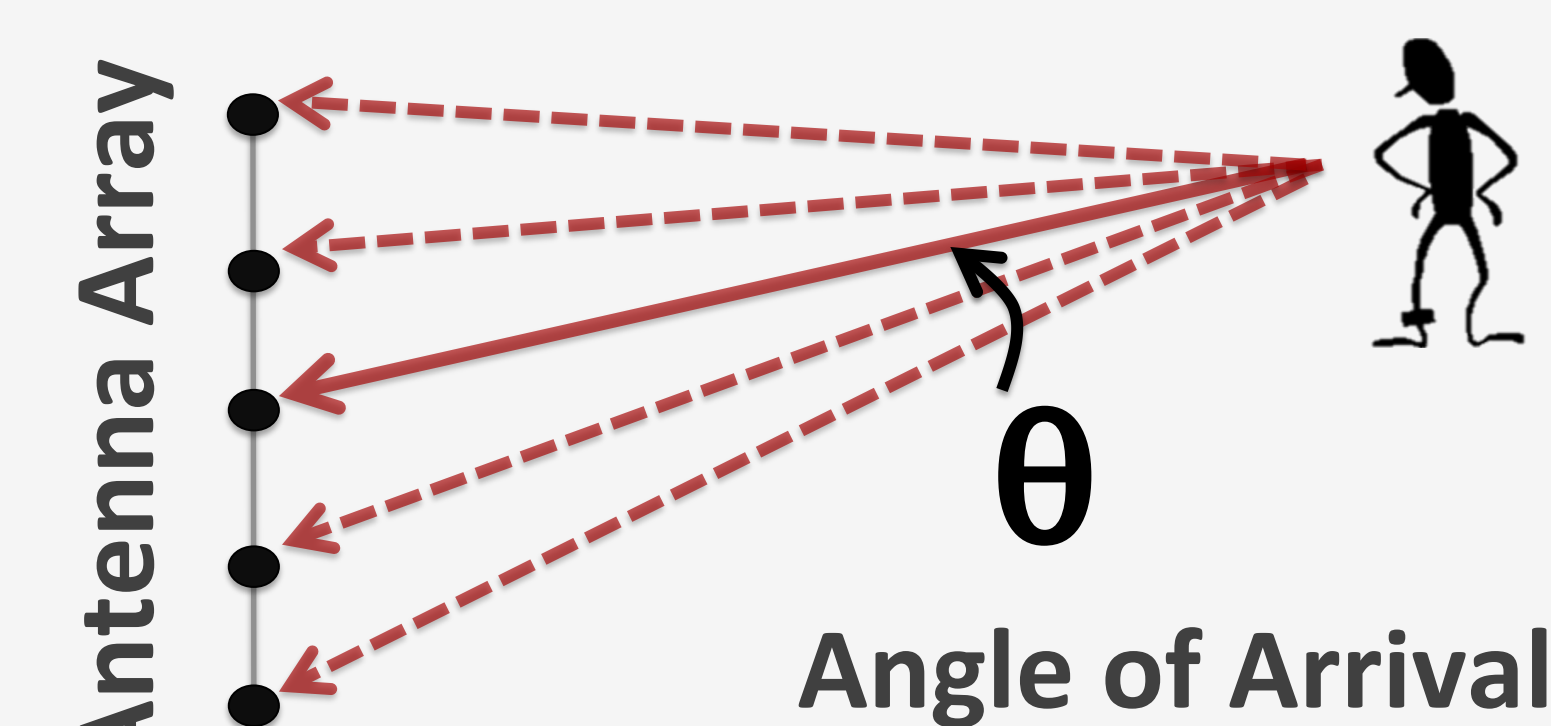Multi-antenna Wi-Fi nodes can pre-code transmitted signal to avoid interference

αx βx Transmitter

h_1 h_2

Desired receiver   Undesired receiver
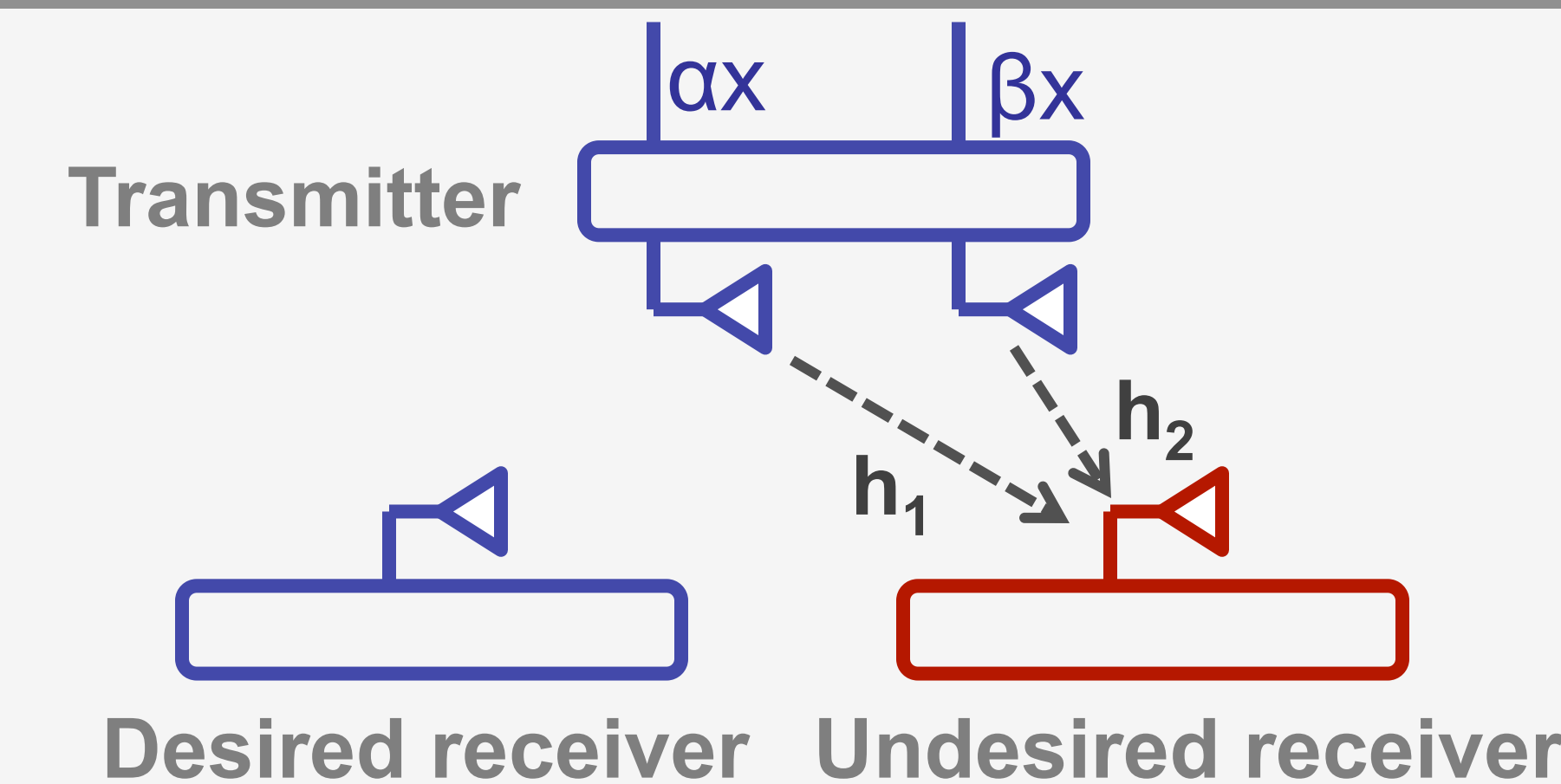
$\alpha = -h_2$ and $\beta = h_1$

Signal is Zero at undesired receiver

- **Flash Effect is Removed**
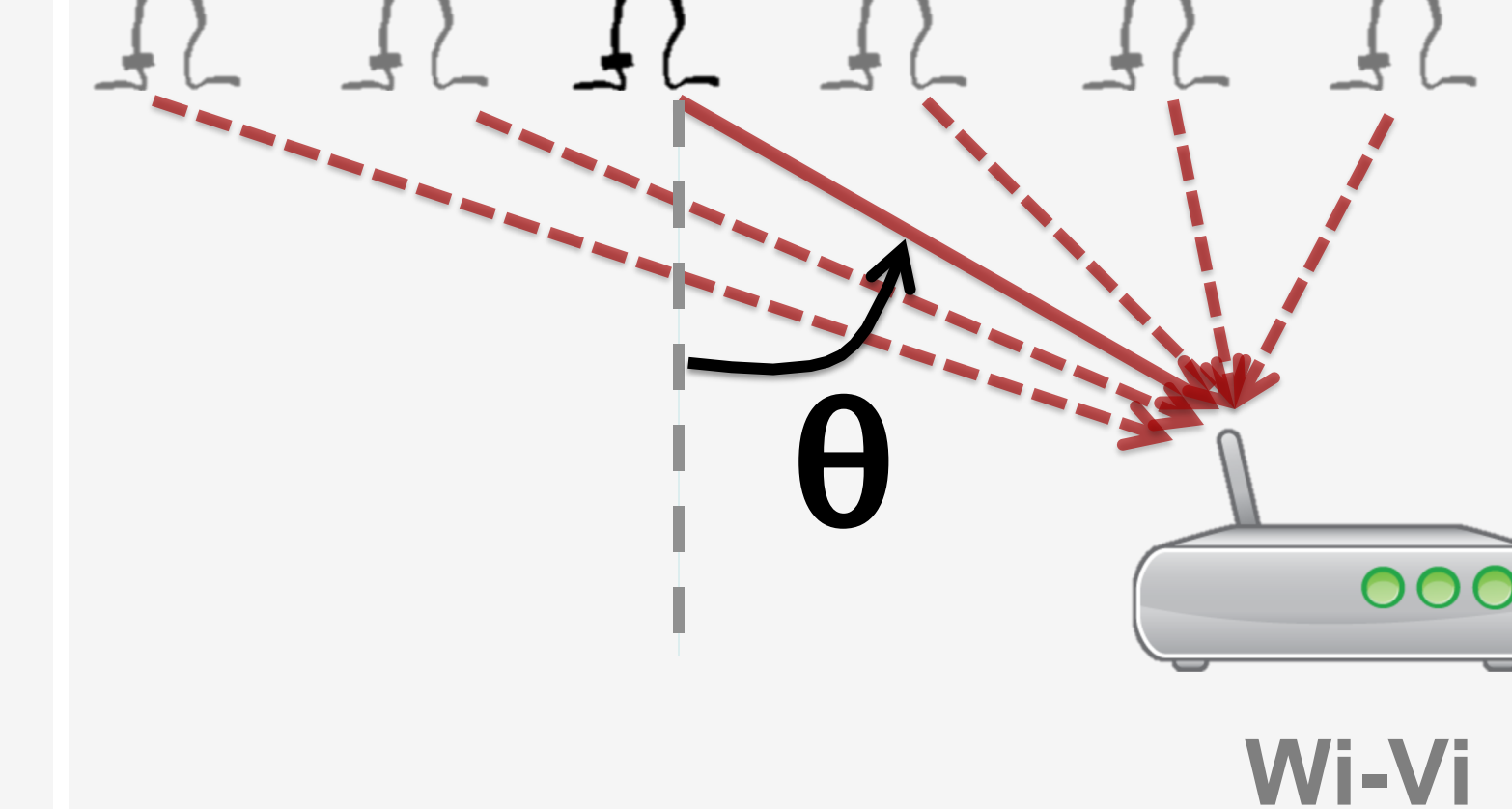- **Non-static reflectors survive**

Challenge #2: Tracking

Traditional systems:

Antenna Array

θ

Angle of Arrival

Bulky antenna arrays (eg. 8 foot long) track angle of arrival of reflection

Wi-Vi uses Inverse Synthetic Aperture

Direction of Motion

θ

Wi-Vi

Treat *time* samples as *spatial* samples of antenna array elements

Apply standard antenna array equations:

Angle of motion

Empirical Results

Human Detection

Actual \ Detected	0	1	2	3
0	100%	0%	0%	0%
1	0%	100%	0%	0%
2	0%	0%	85%	15%
3	0%	0%	10%	90%

Building Materials

	Free Space	Tinted Glass	1.75" Solid Wood Door	6" Hollow Wall	8" Concrete
Accuracy (%)	100	100	100	100	87.5