

RF-IDraw: Virtual Touch Screen in the Air

Deepak Vasisht

Jue Wang, Dina Katabi



How Do We Get Virtual Touch Screens?



How Do We Get Virtual Touch Screens?



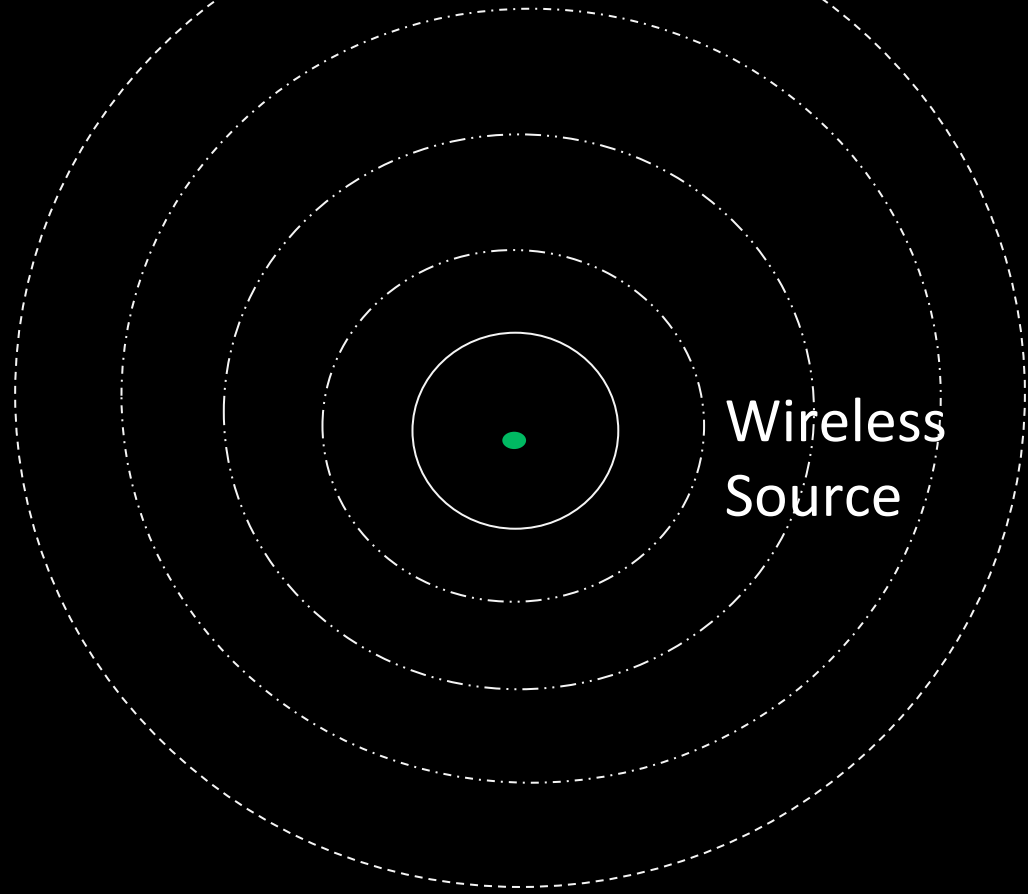
But ... accuracy is not enough ...

How Do We Get Virtual Touch Screens?



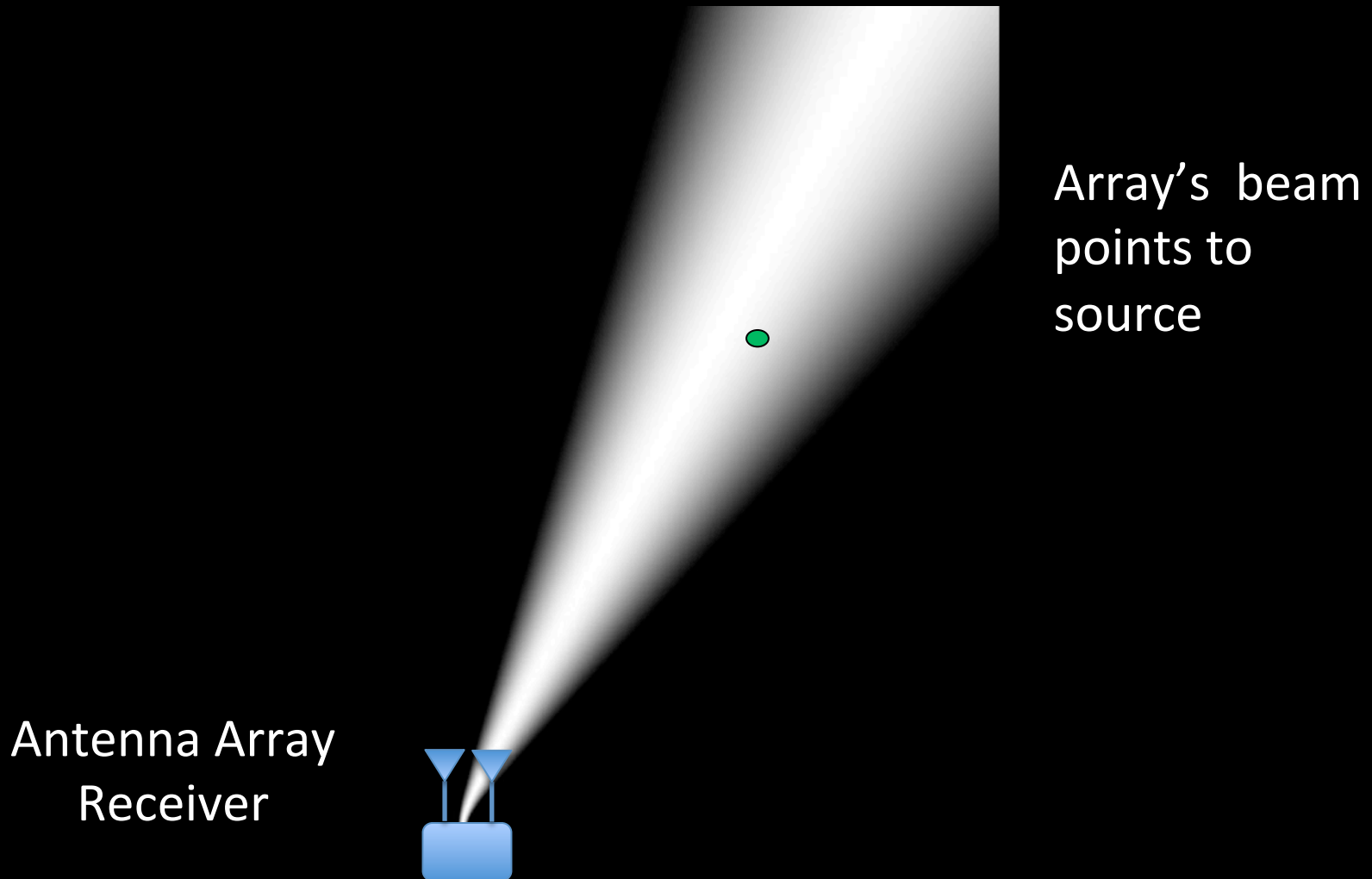
Localization with Antenna Arrays

Antenna Array
Receiver

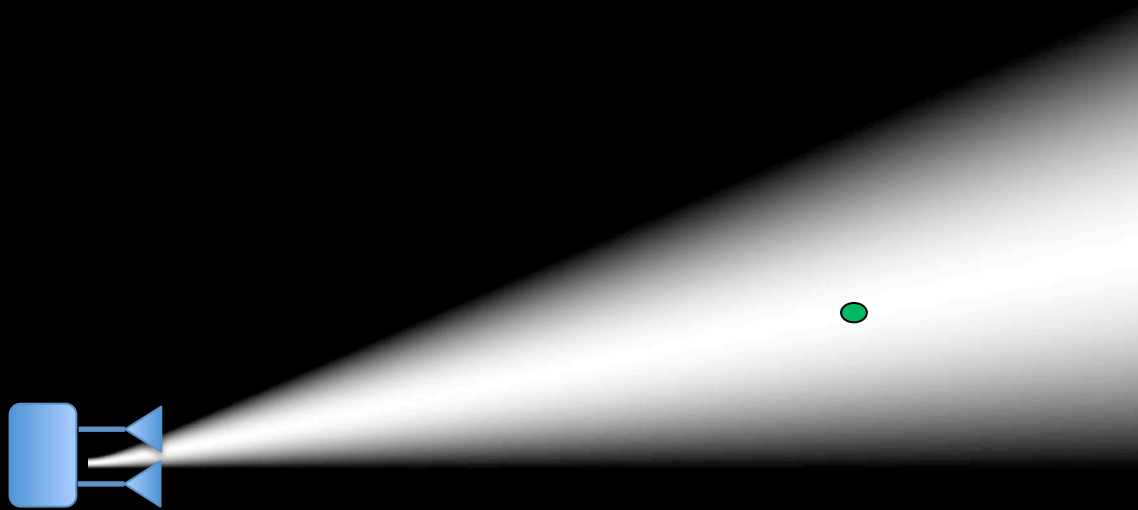


Wireless
Source

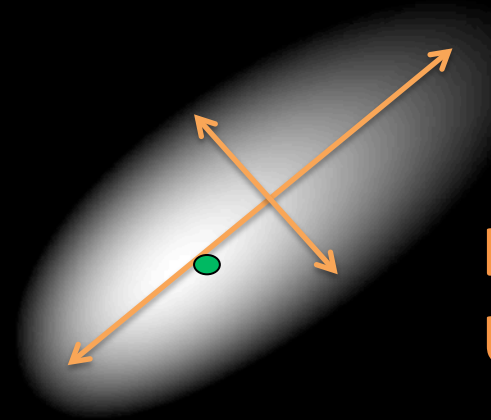
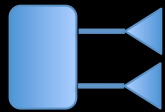
Localization with Antenna Arrays



Localization with Antenna Arrays



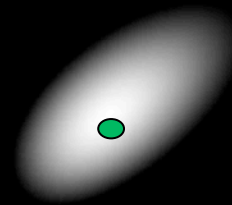
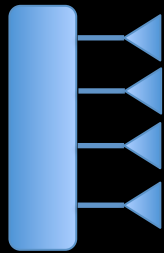
Localization with Antenna Arrays



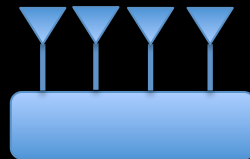
**Location
Uncertainty**



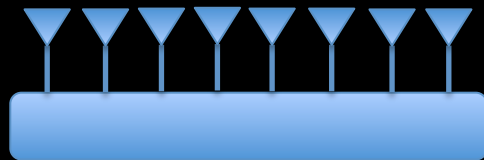
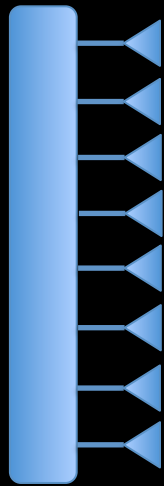
Localization with Antenna Arrays



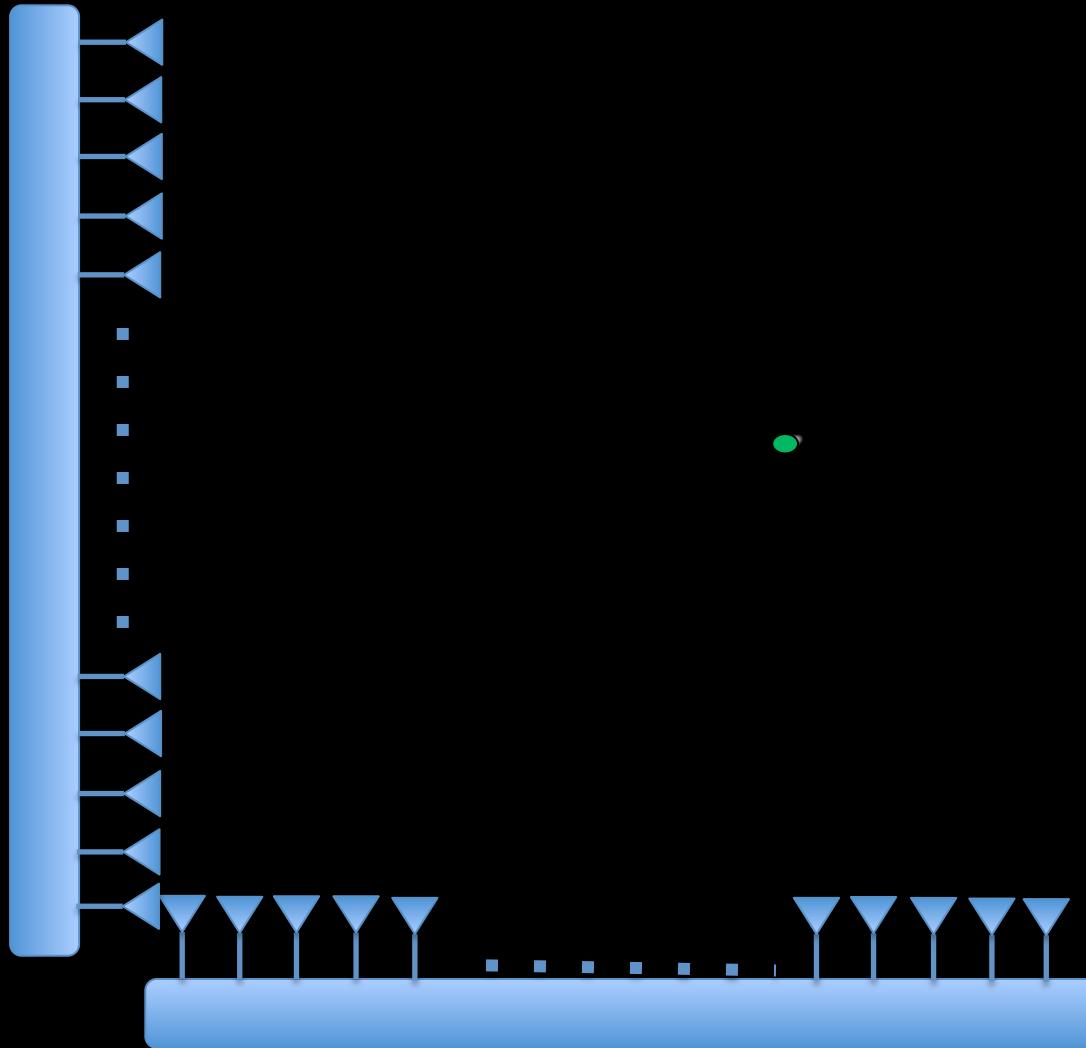
More Antennas
→ Less uncertainty



Localization with Antenna Arrays



Not practical!



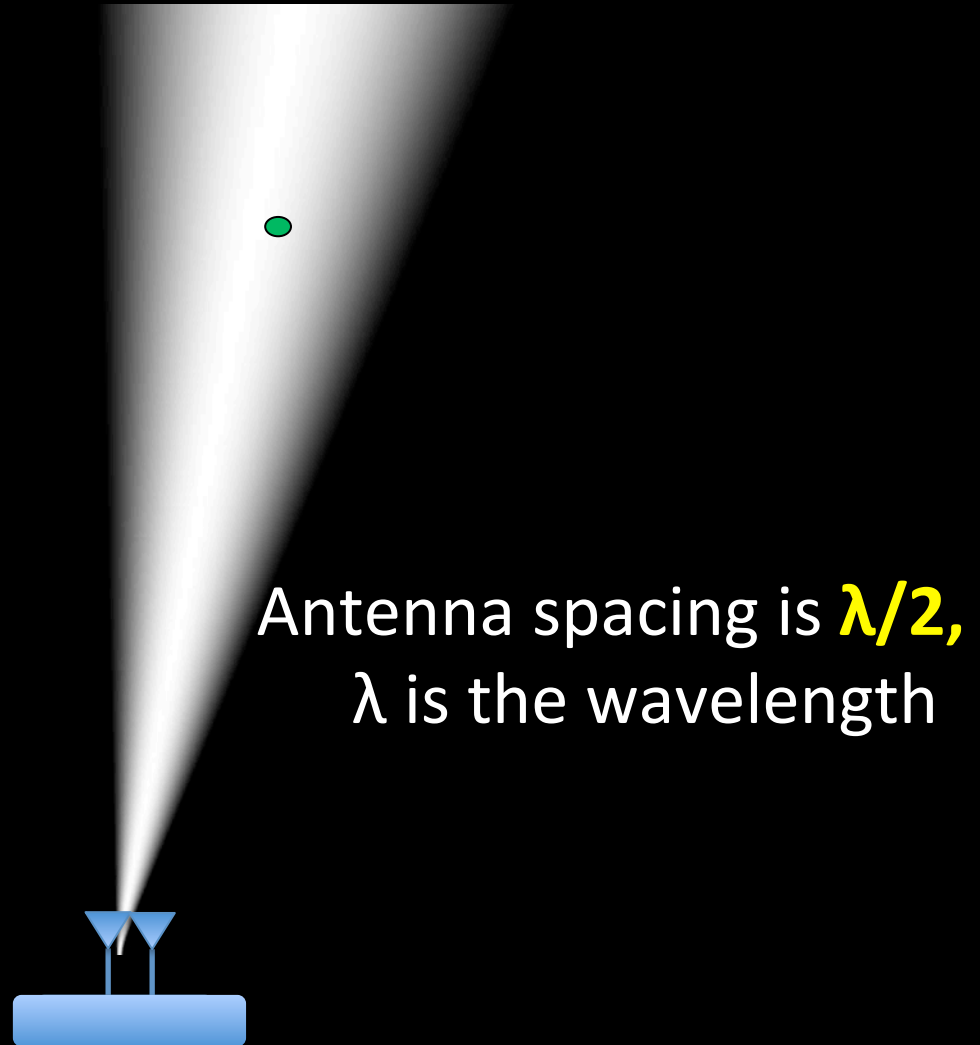
RF-IDraw

- Enables virtual touch screens in the air
- Motion tracking to within 3.7cm
- Rich interface that recognizes words written in the air
- Works with standard RFIDs and RFID readers

How Does it Work?

Ambiguity-Resolution Tradeoff

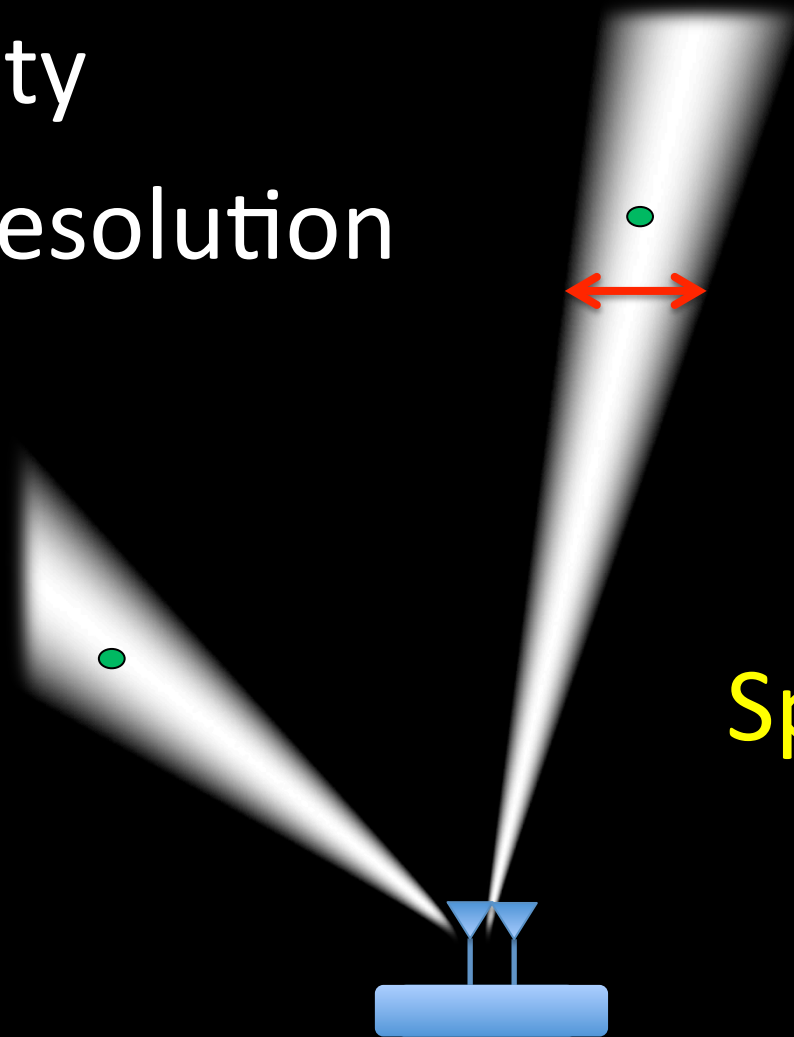
Ambiguity-Resolution Tradeoff



Ambiguity-Resolution Tradeoff

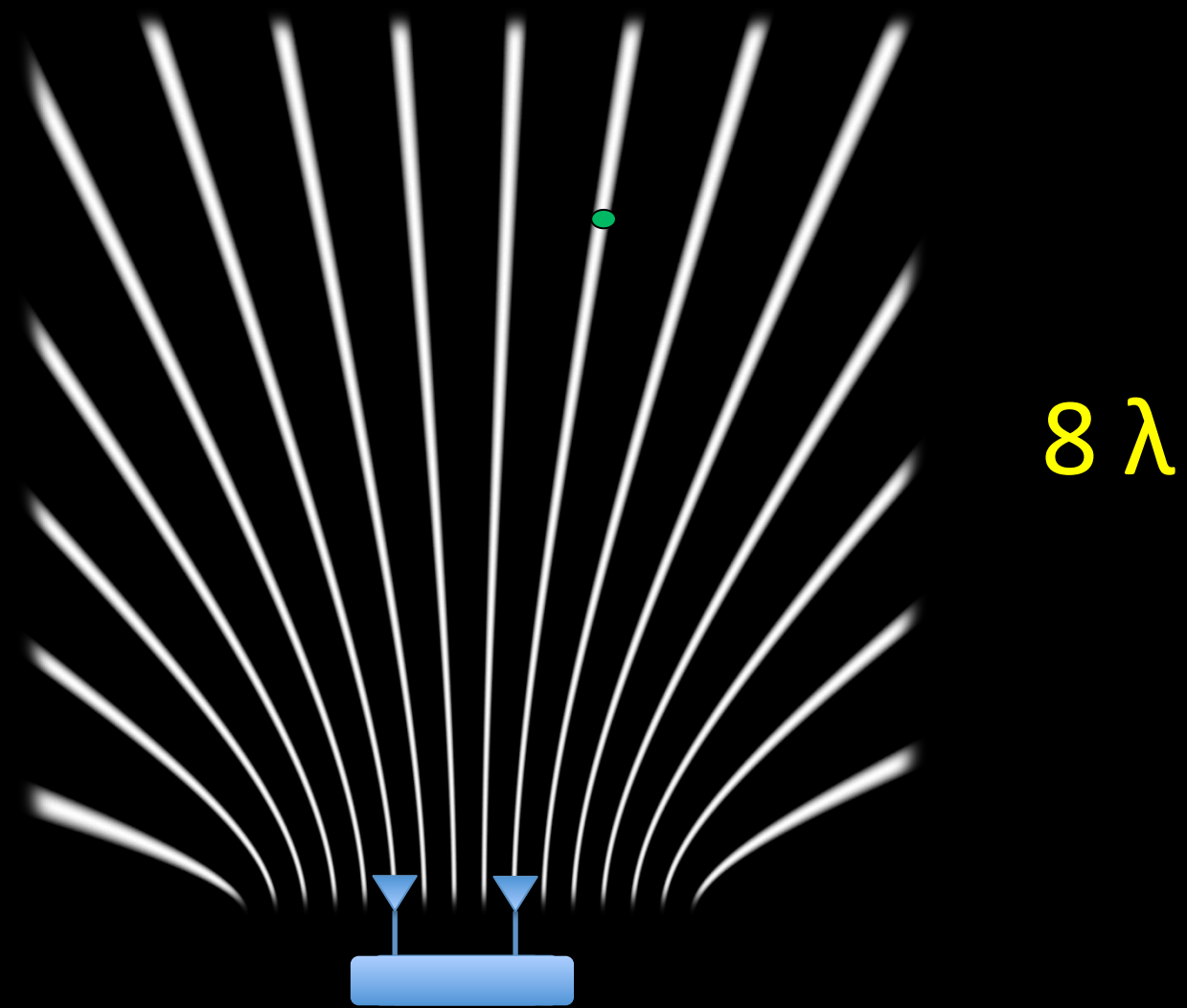
Ambiguity

Higher resolution



Spacing is λ

Ambiguity-Resolution Tradeoff

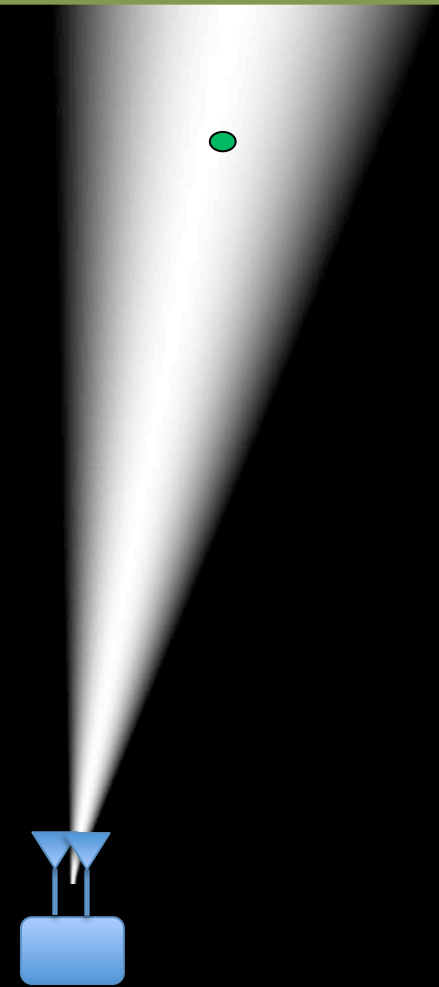
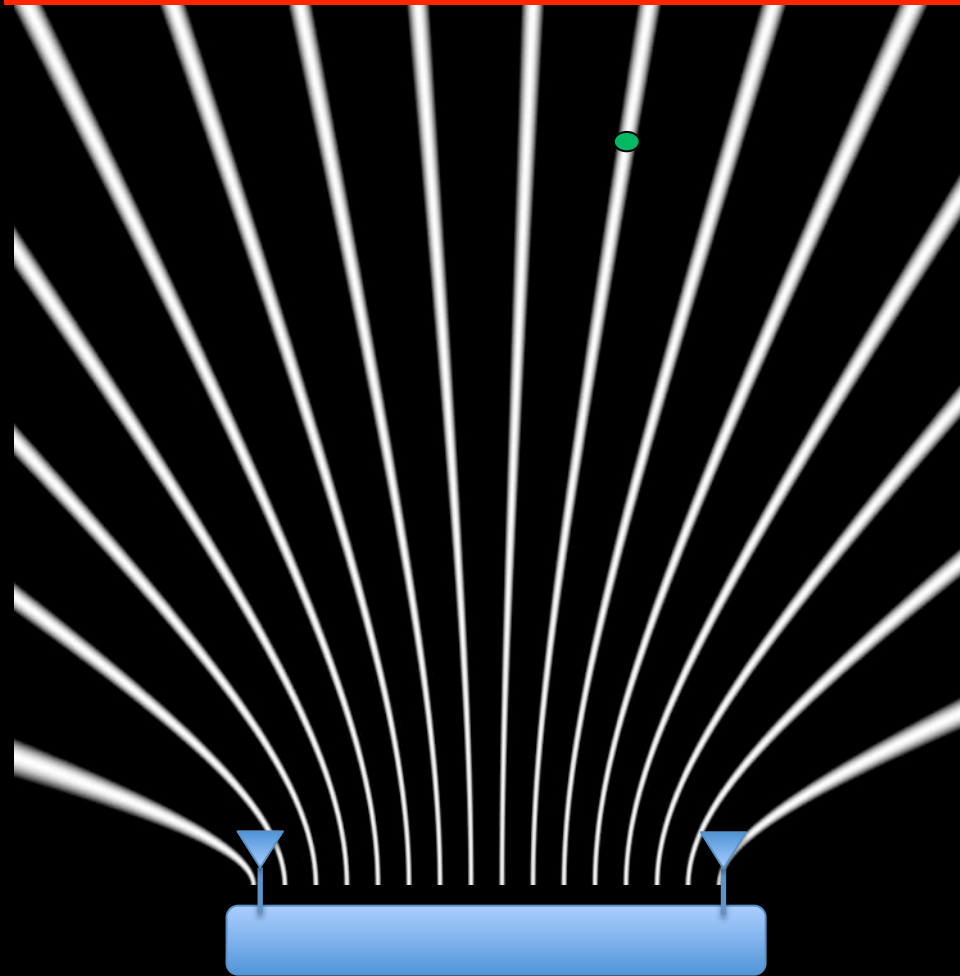


High resolution

Ambiguity in position

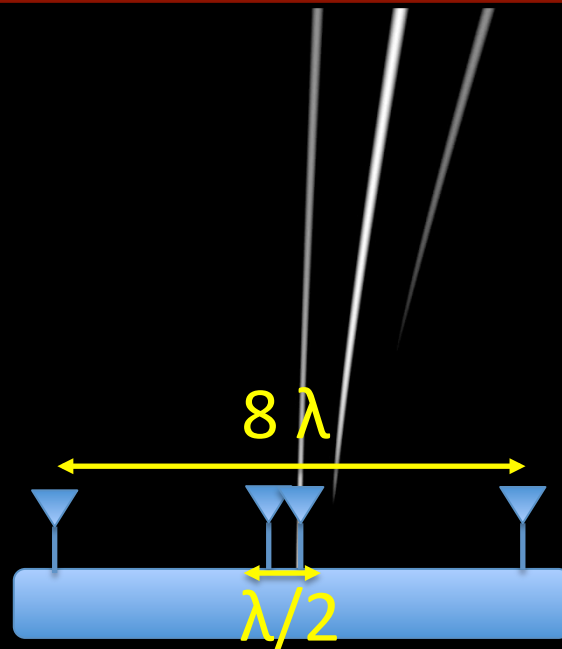
Low resolution

No ambiguity

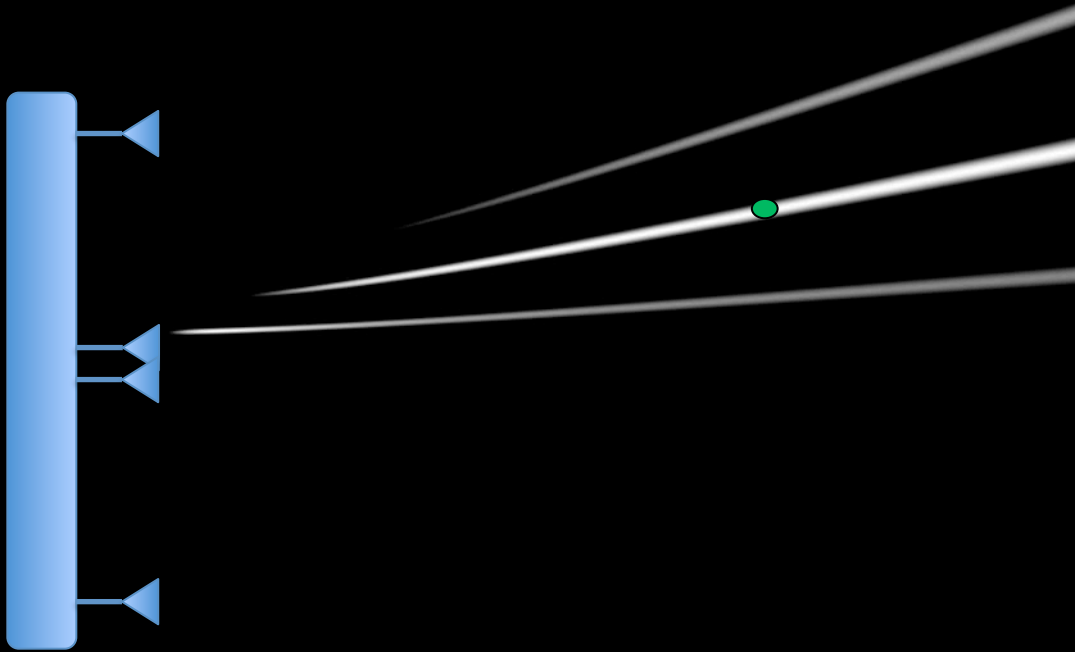


Narrowly spaced and widely spaced antennas create an overlay of multi-resolution beams.

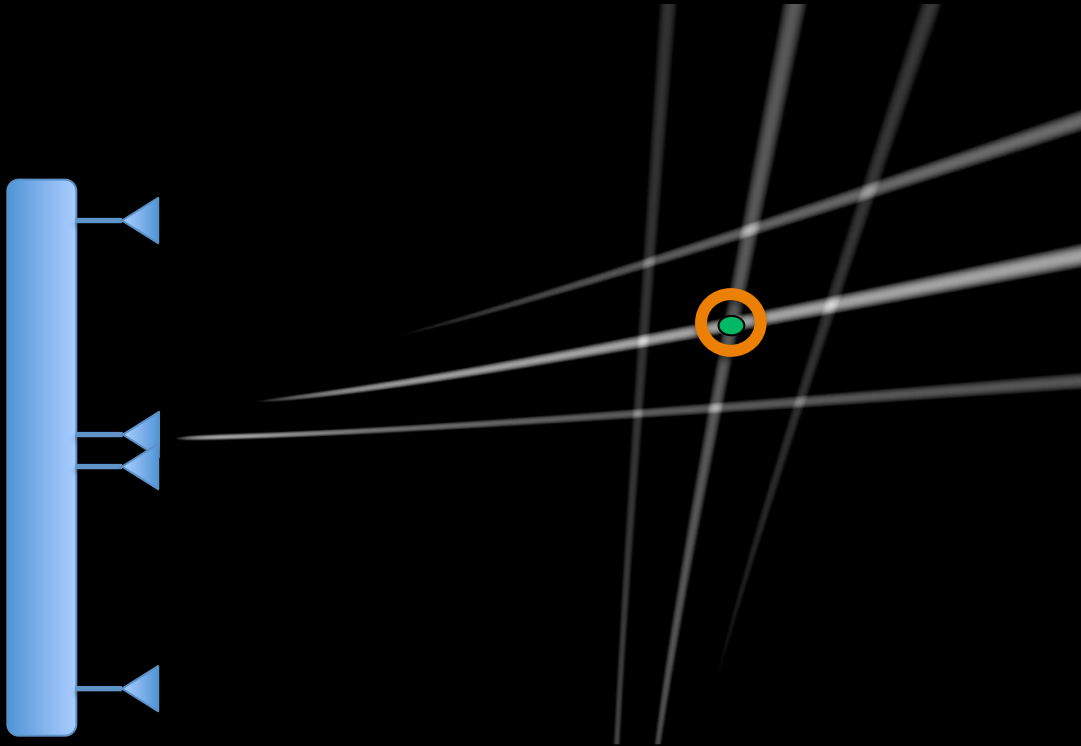
Use fewer antennas, but place them smartly



Localization

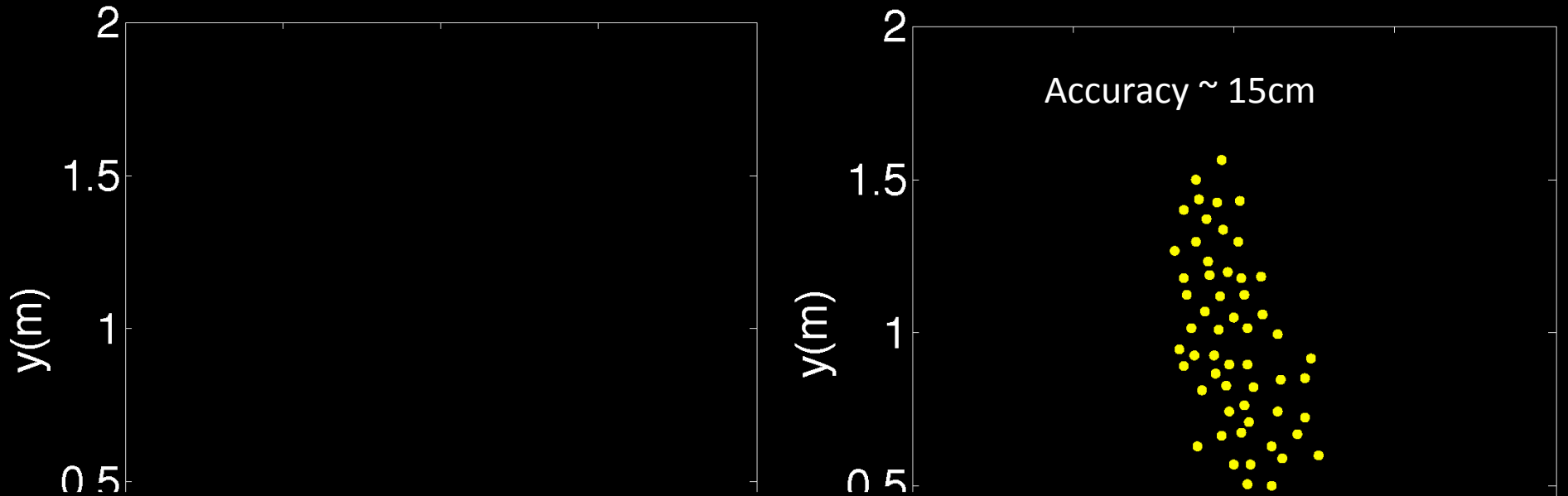


Localization



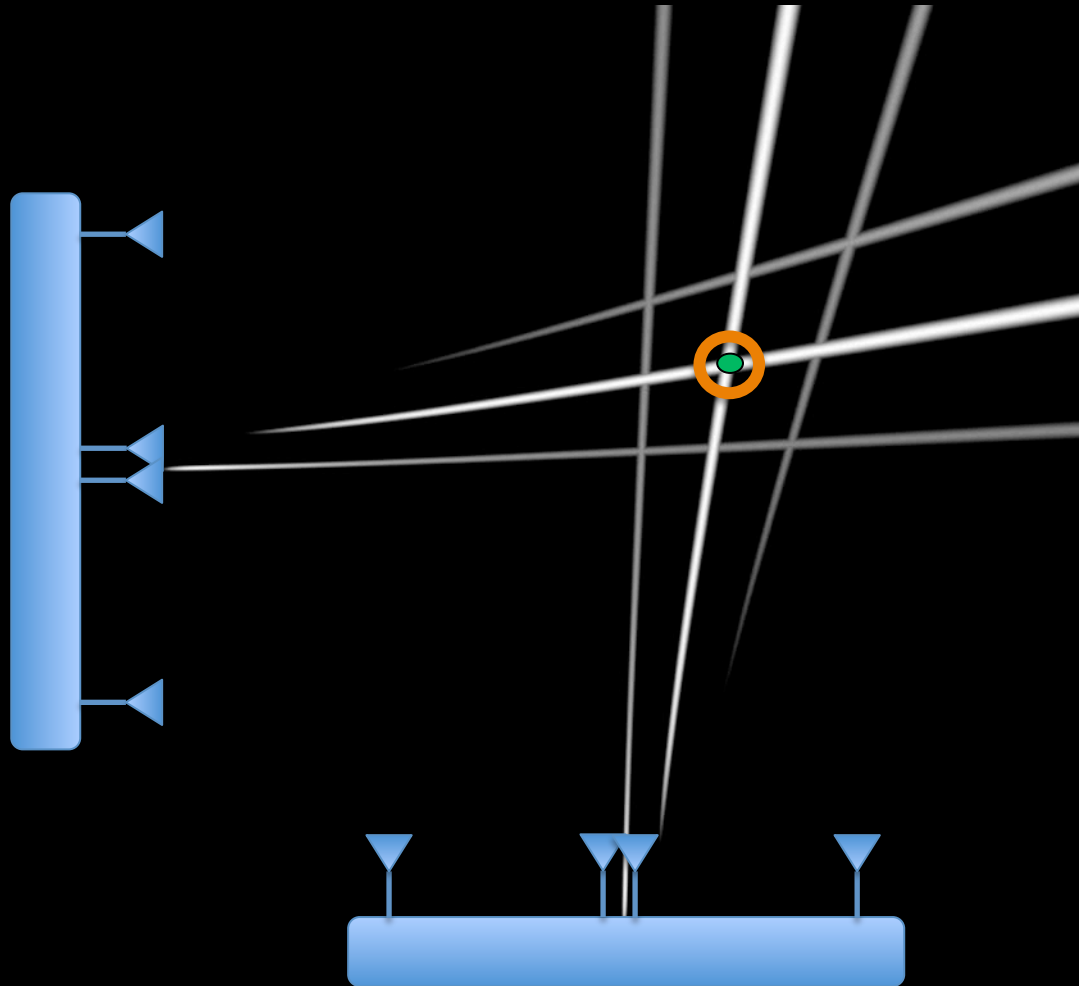
Are we done?

Let's Try

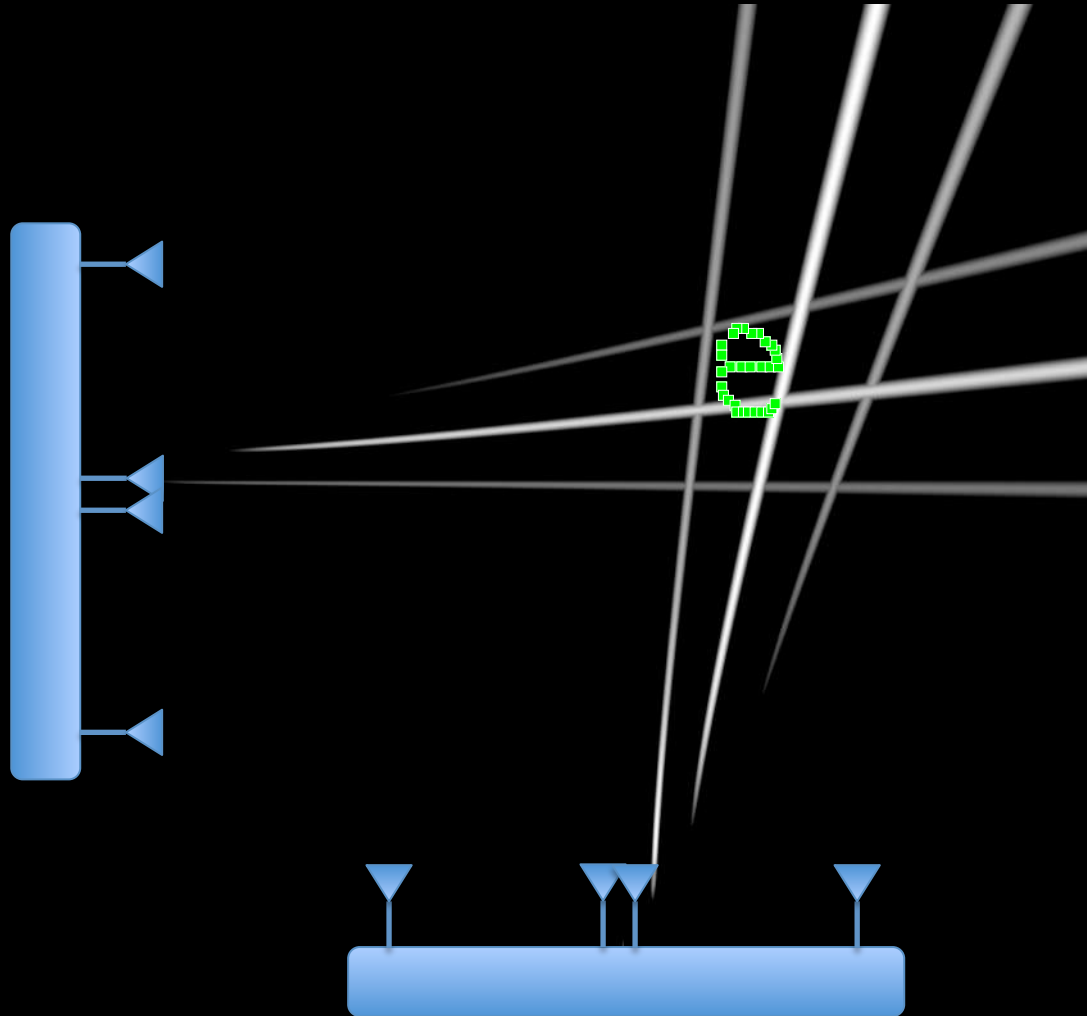


Errors are random and don't preserve the shape of the trajectory.

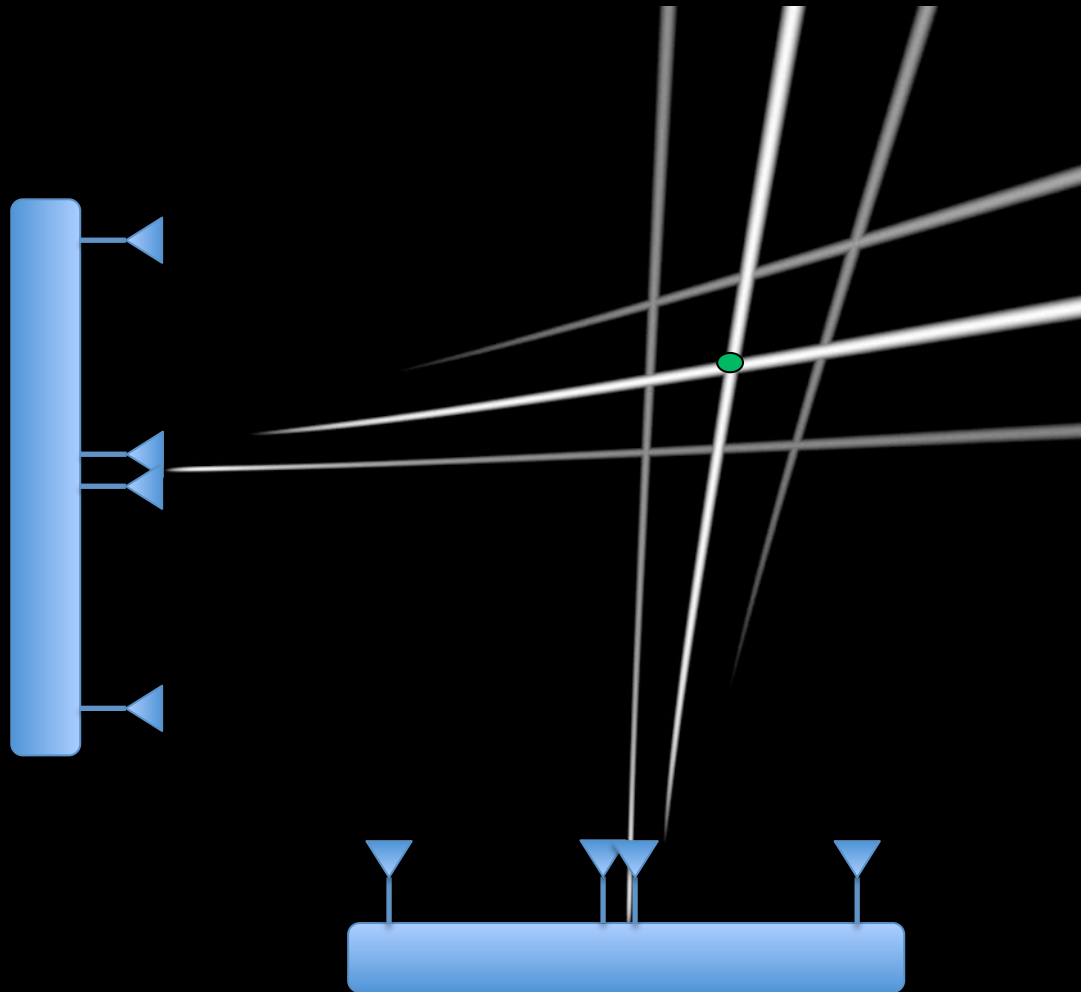
Noiseless Scenario



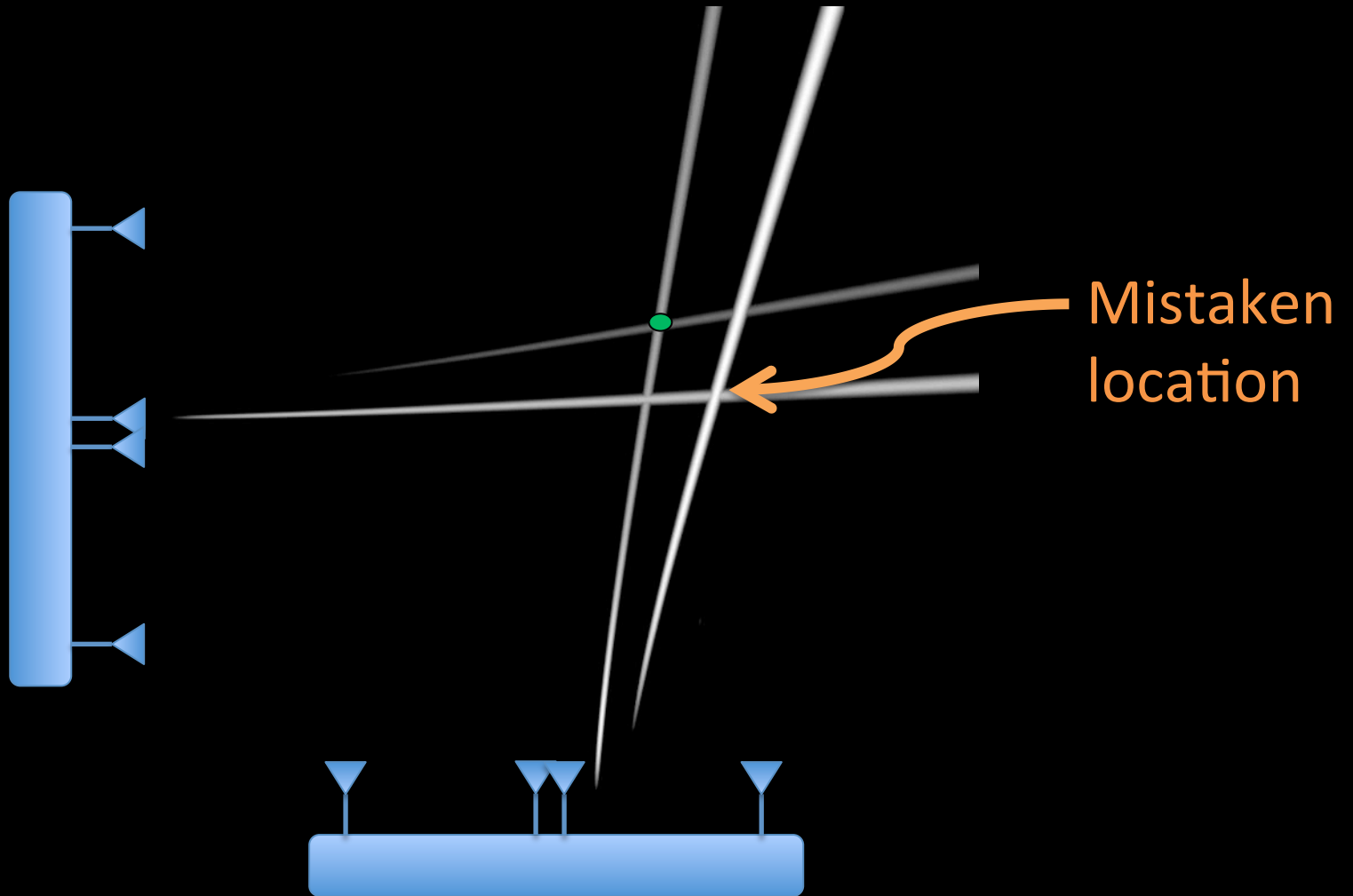
Noiseless Scenario



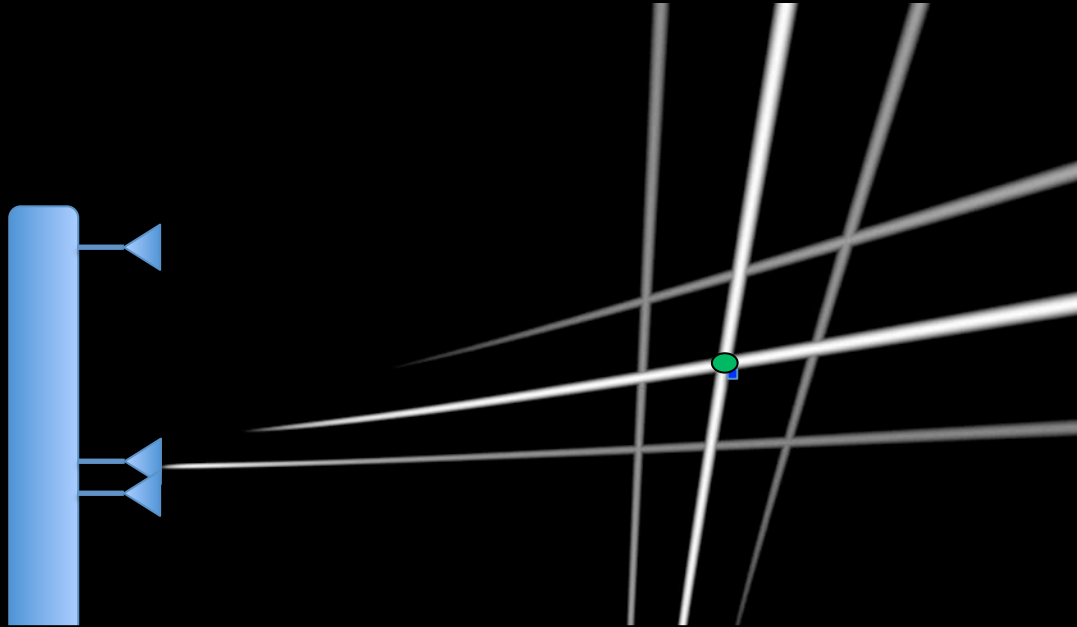
Noiseless Scenario



Impact of Noise



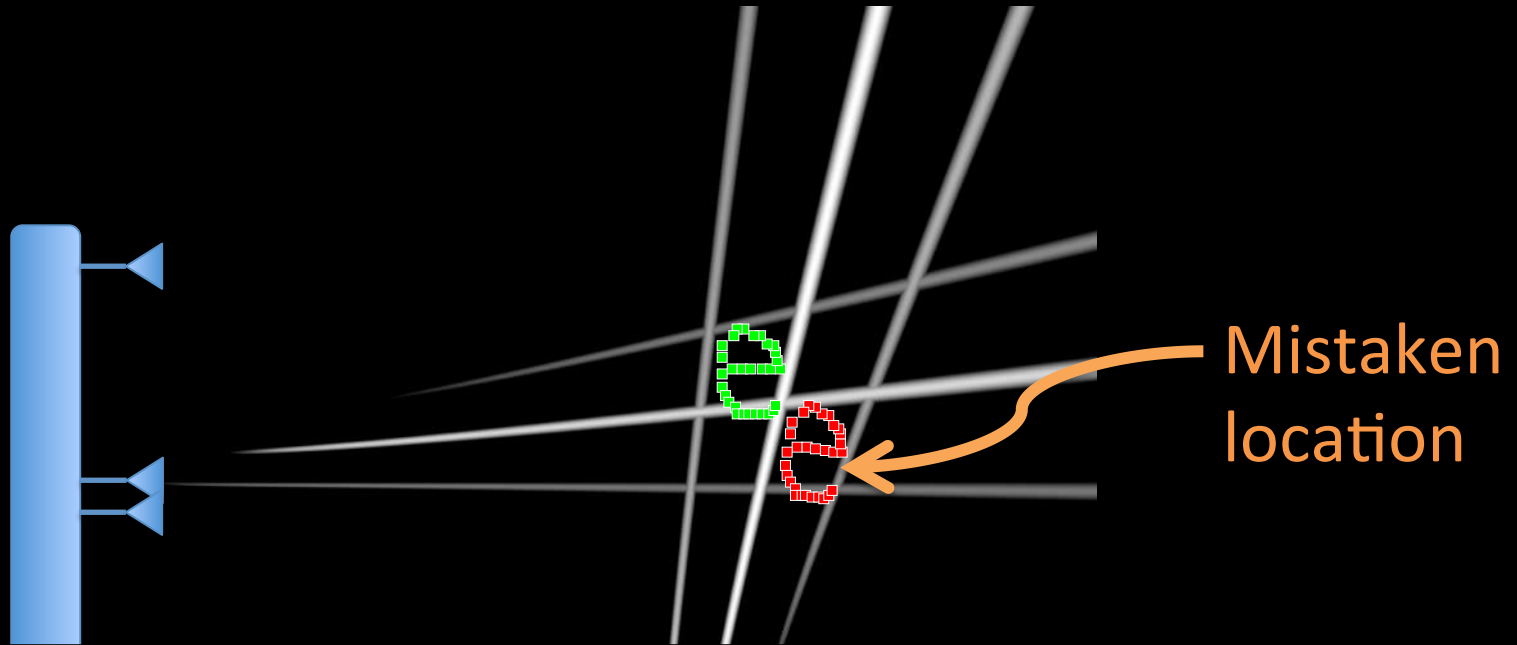
Impact of Noise



Want errors to be systematic –i.e., they may move the trajectory but preserve its shape

Idea: Stick with your choices

Idea: Stick with your choices



Sticking with a beam, even if it is not in the exact location, causes systematic errors

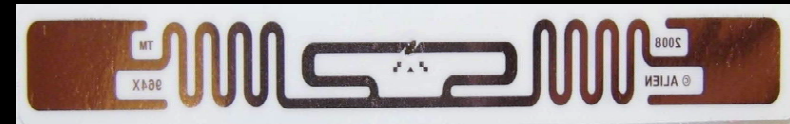
Performance Results

Implementation

- ThingMagic RFID Readers
 - Reader has 4 antennas
 - Used two readers



- Alien Squiggle RFID Tags



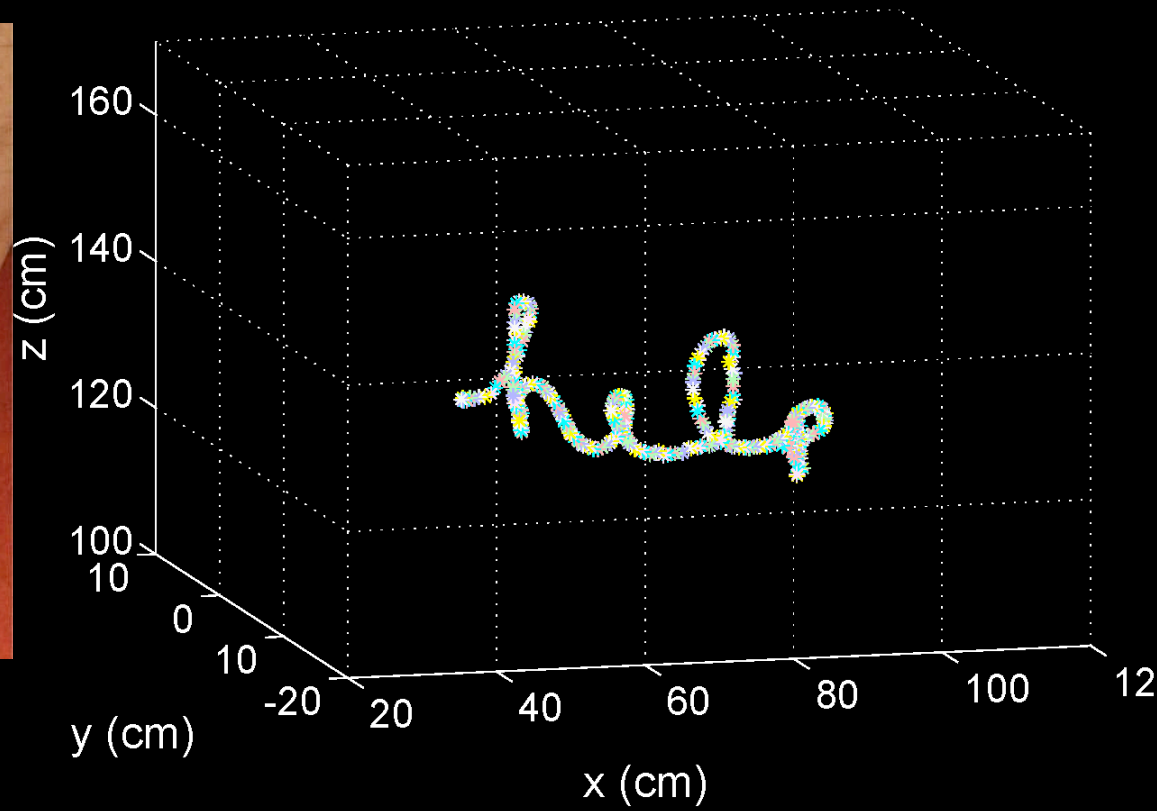
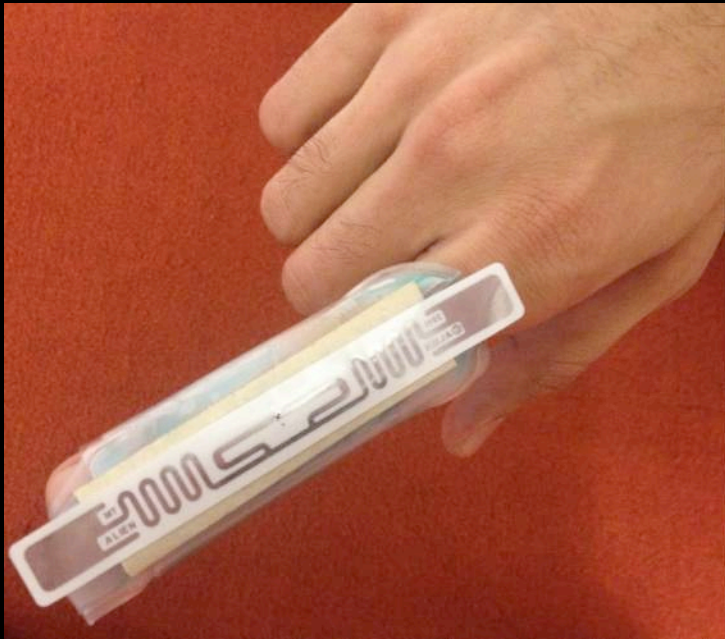
- Baseline: 2 Antenna arrays with 4 antennas each

Setup

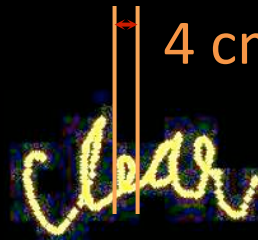
- Ground Truth: VICON motion capture system



Example



Examples



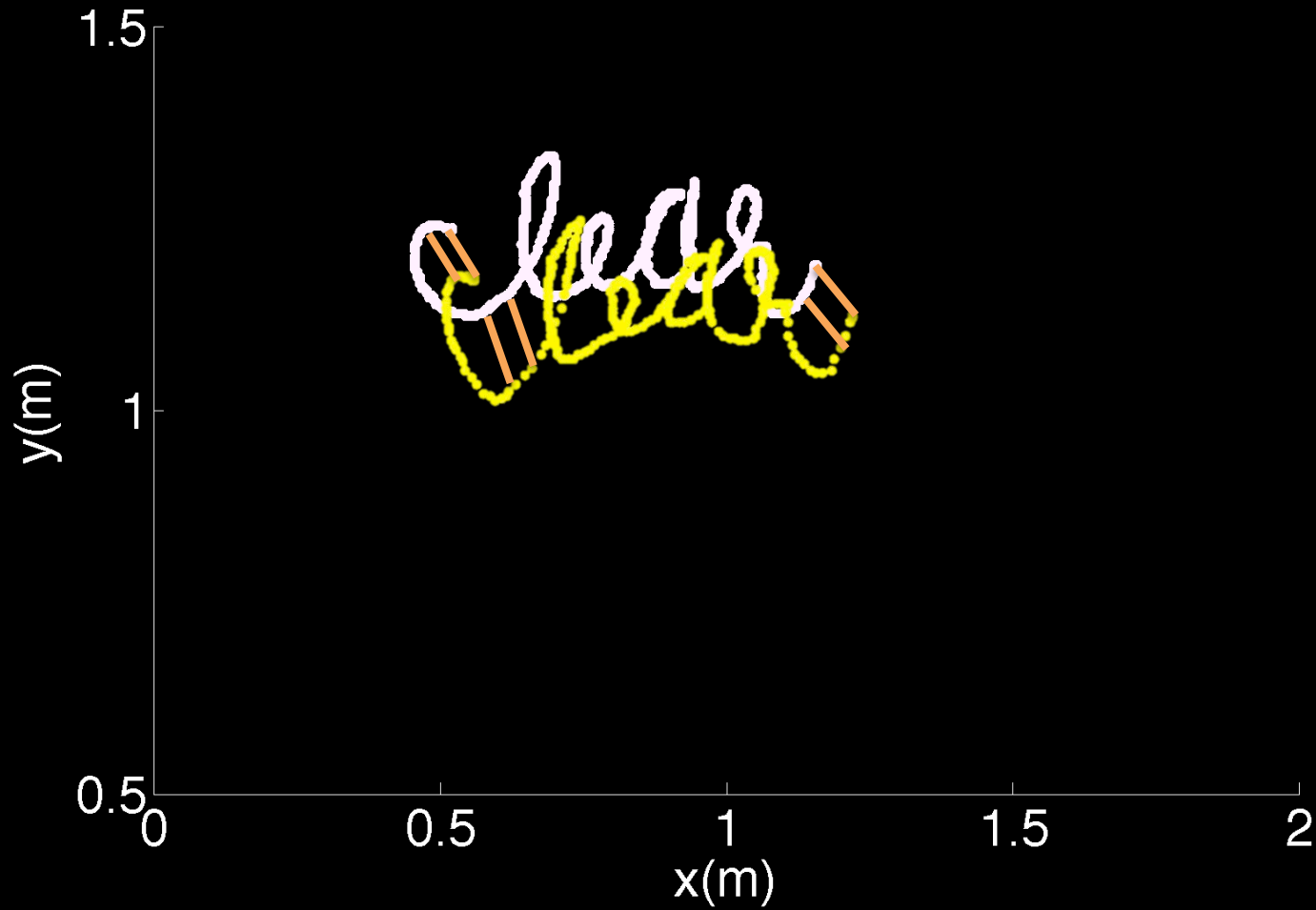
4 cm wide

“Clear”

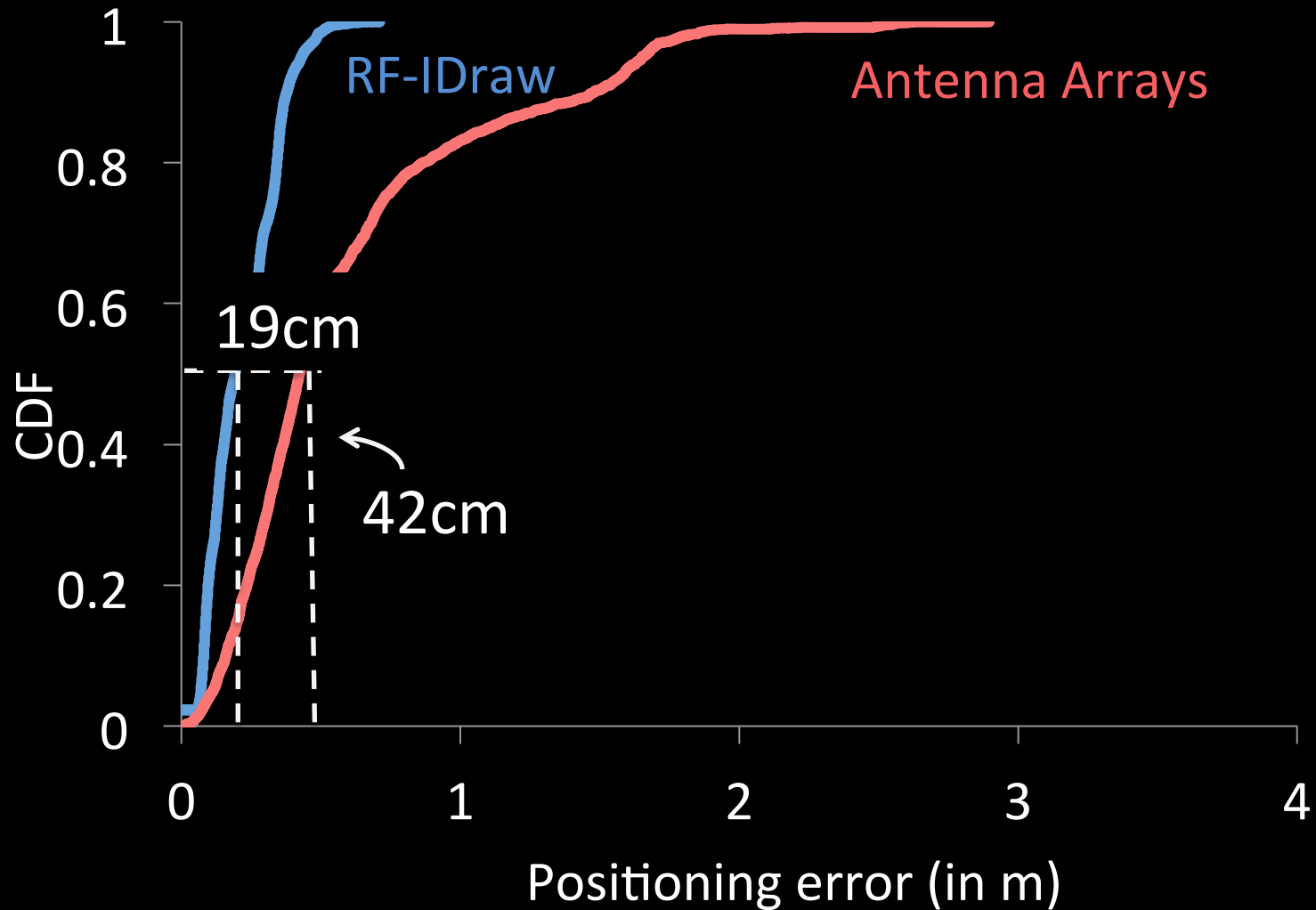


“Jue”

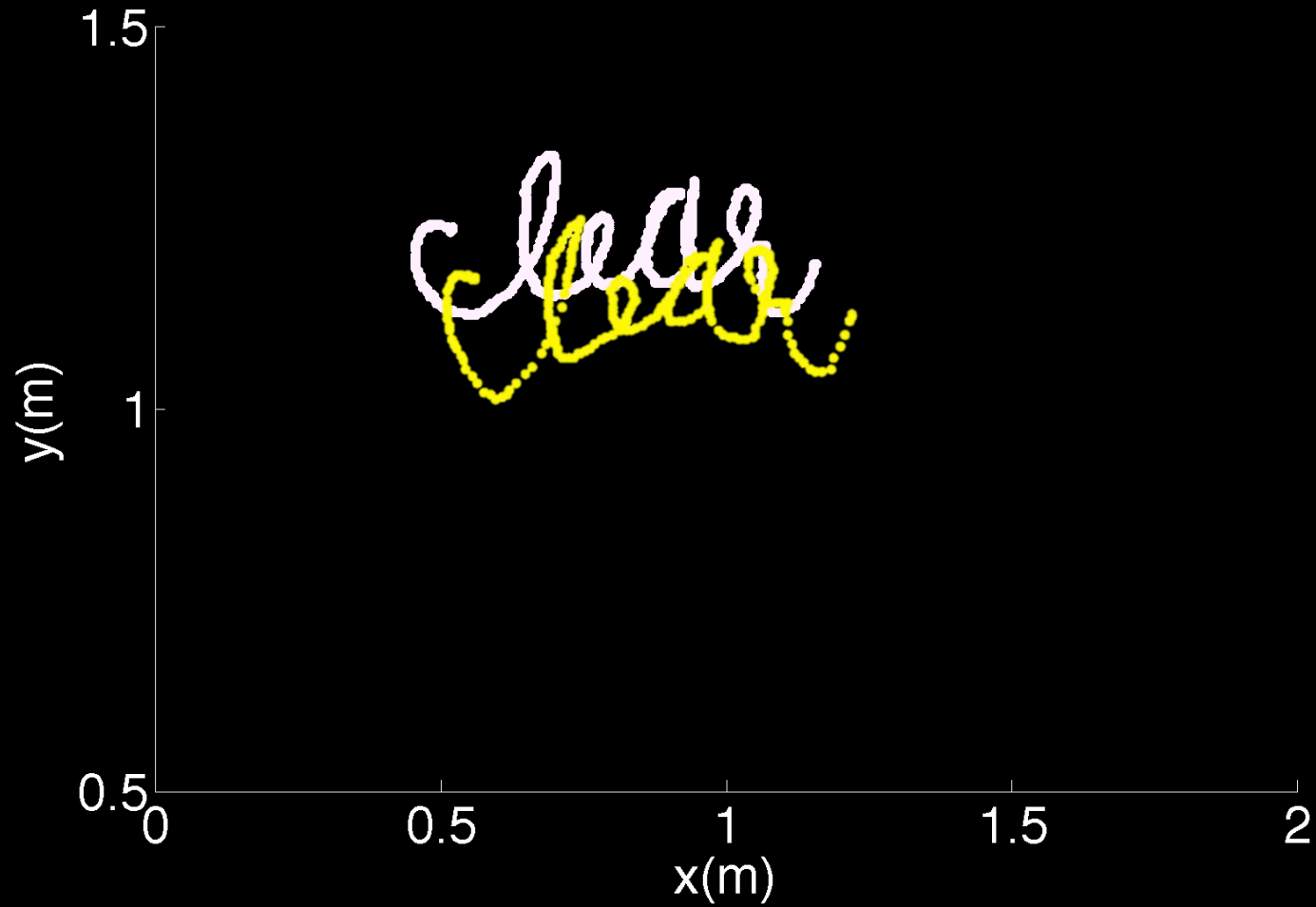
Metric: Absolute Positioning Error



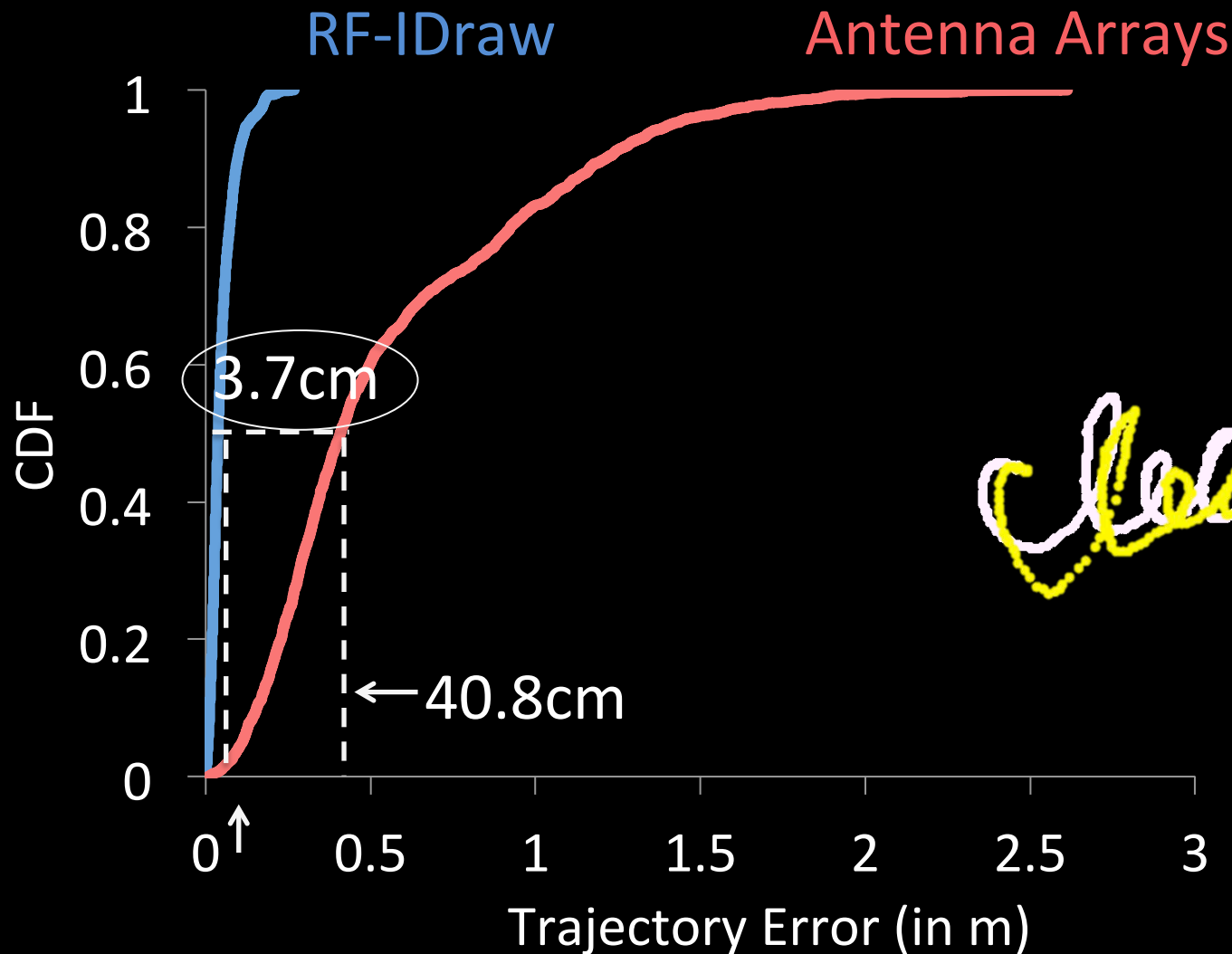
Absolute Positioning Error



Metric: Trajectory Error



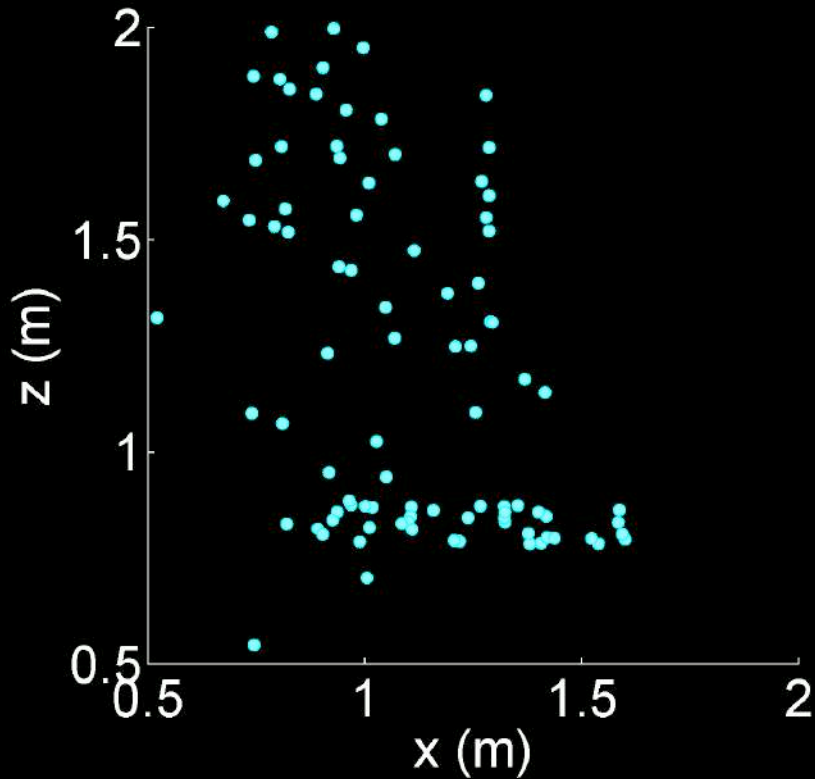
Trajectory Error



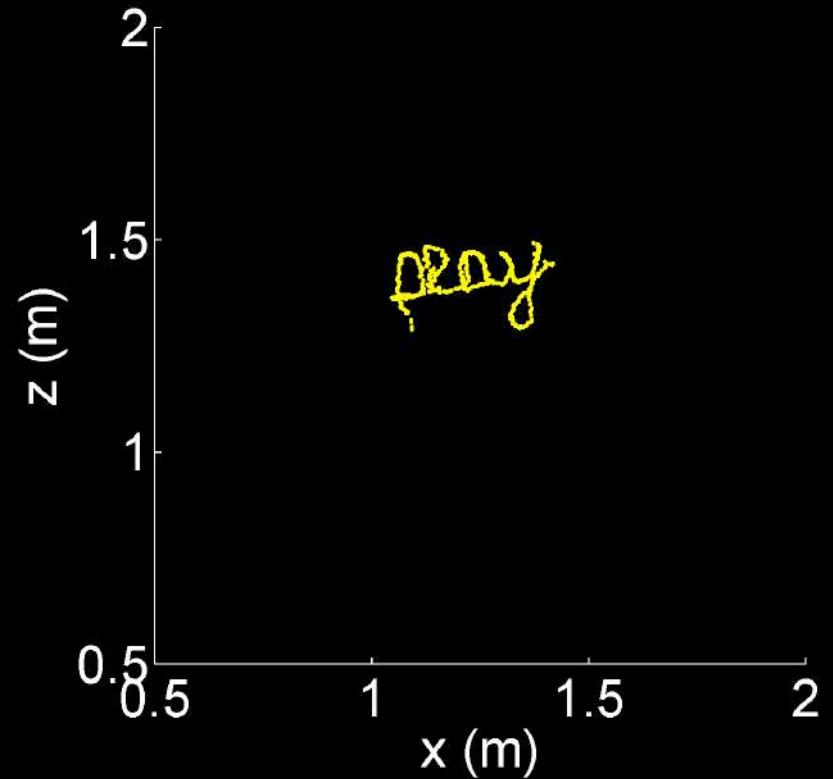
Virtual Touch Screen Application

- 5 users wrote 150 words
- Words used as touch gestures on Android using MonkeyRunner API
- Word recognition using MyScript Stylus app

Example

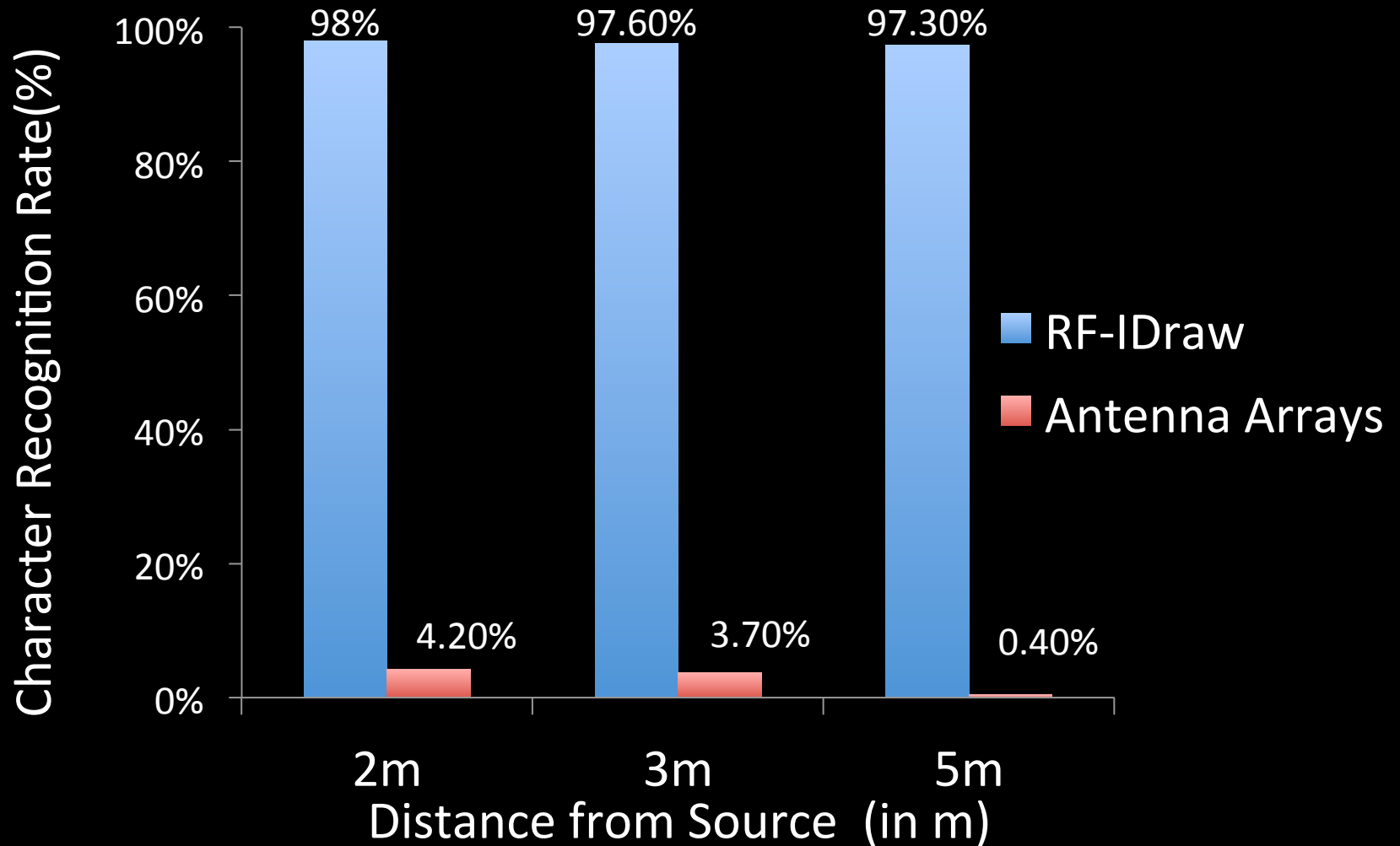


Antenna Arrays



RF-IDraw

RF-IDraw delivers accurate virtual touch screens



Related Work

- **RF-based localization**

- Witrack [NSDI,14], WiSee [Mobicom'14], ArrayTrack [NSDI'13], PinPoint [NSDI'13], PinIt [SIGCOMM'13], Zee [MobiCom'12], PinLoc [MobySys'12], FM-based [MobySys'12], EZ [MobiCom'10],

- **Kinect and vision-based gesture recognition**

- Zhang et al [IEEE Multimedia'13], Murata et al [IJDSN'14] , Yin et al [IEEE VL/HCC'14]

Conclusion

- RF-IDraw the first wireless system that enables virtual touch screens on the air
- It focuses on trajectory tracking as opposed to point-by-point localization
- It introduces the concept of multi-resolution arrays
- Its design applies beyond RFIDs to other wireless technologies – e.g., WiFi