Relative Localization of RFID Tags using Spatial-temporal Phase Profiling

Longfei Shangguan, Zheng Yang, Alex. X. Liu, Zimu Zhou, and Yunhao Liu

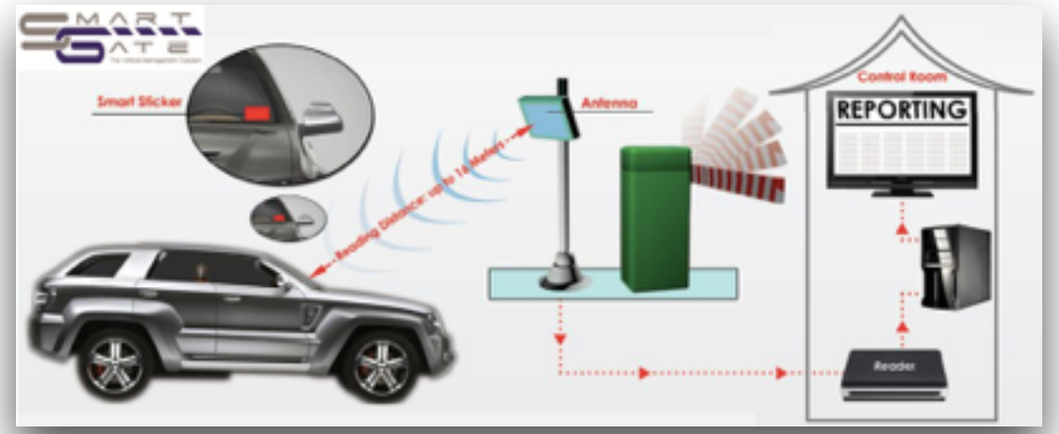
CSE, The Hong Kong University of Science and Technology
School of Software and TNList, Tsinghua University
CSE, Michigan State University







RFID technology revolutionizes human lives in diverse ways



admission control



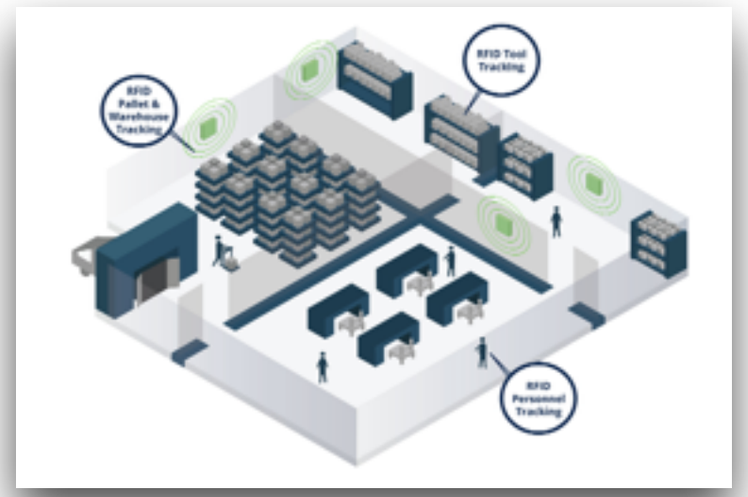
quick payment



anti-counterfeiting



book findings



warehouse management

Location, location, location…



in warehouse
finding the desired object



in library
finding the desired book

significant research efforts in this area:

LANDMARC
Wireless Networks'04

. . . . . .

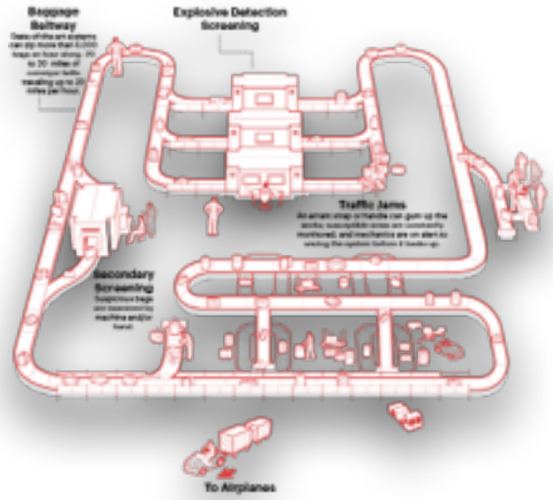
PinIt
SIGCOMM'13

RFIDraw
SIGCOMM'14

Tagoram
MobiCom'14



finding books in the library



baggage sortation



warehouse management

Such emerging applications need the relative location of the tag instead of its absolute location.



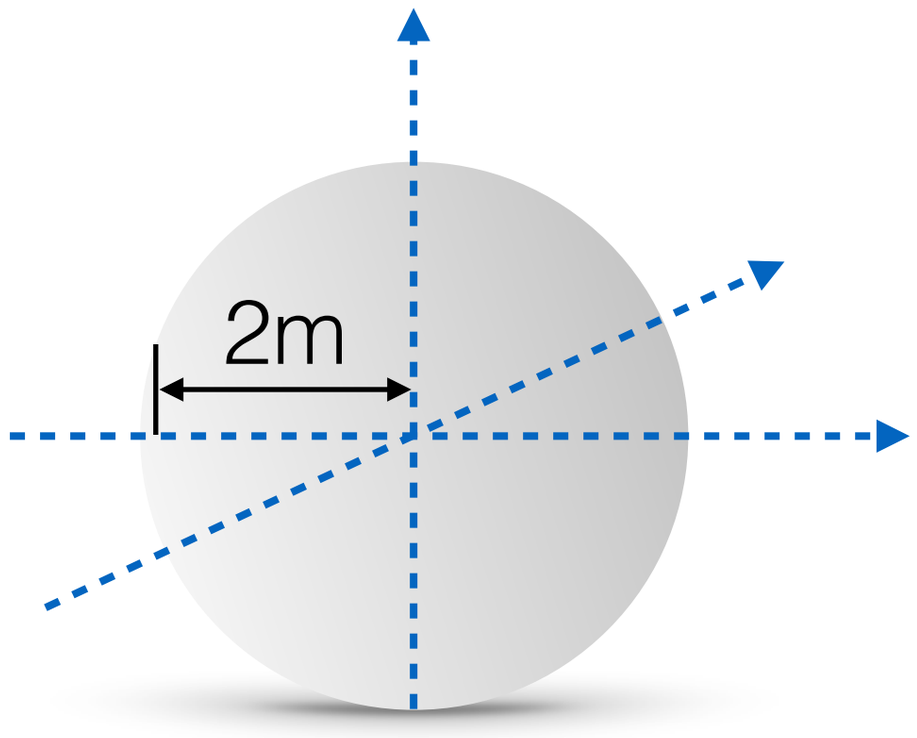


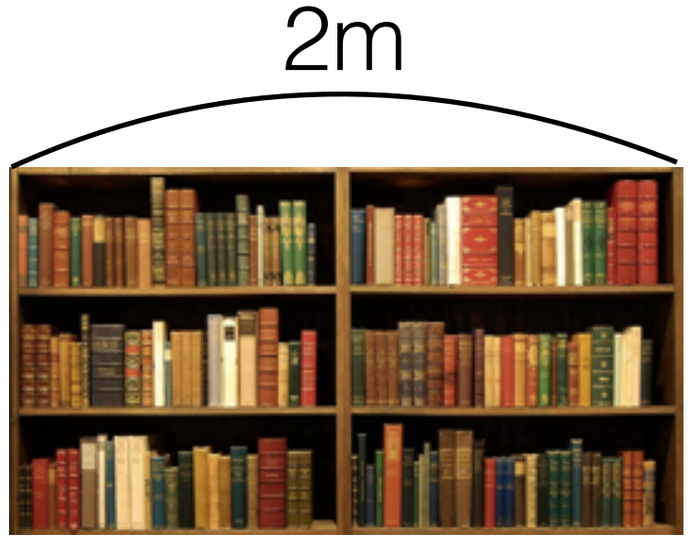
Can we convert from absolute to relative location?

State-of-the-art

LANDMARC
Wireless Networks'04

Error-margin





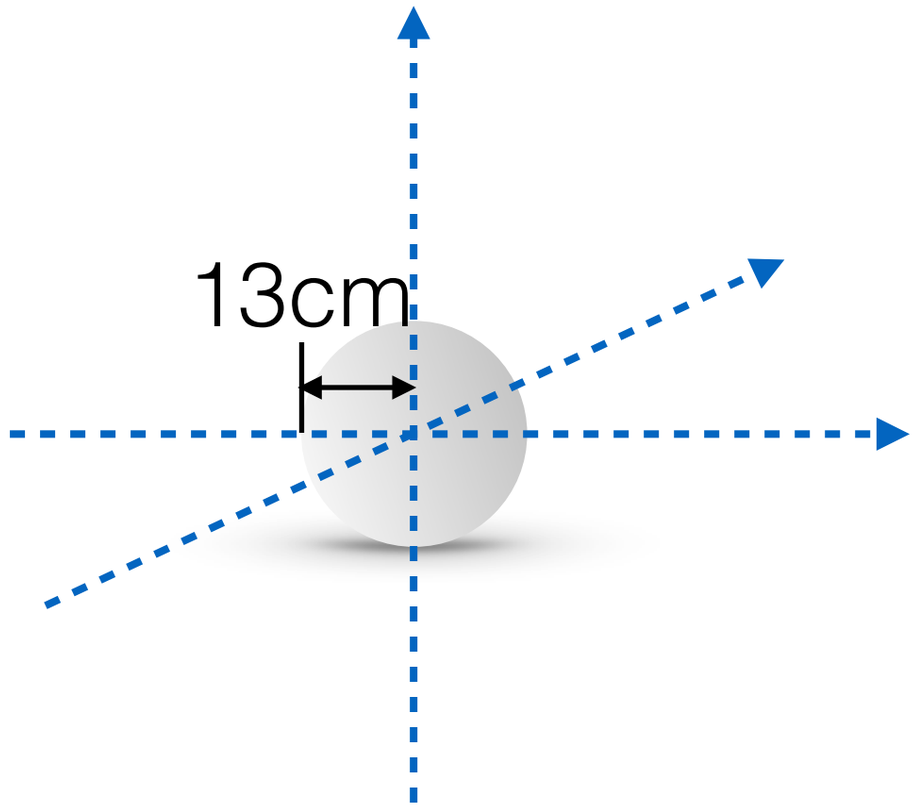
(1): unsatisfying accuracy;
(2): densely deployed anchor tags;

Can we convert the relative location from the absolute location?

State-of-the-art

PinIt
SIGCOMM'13

Error-margin





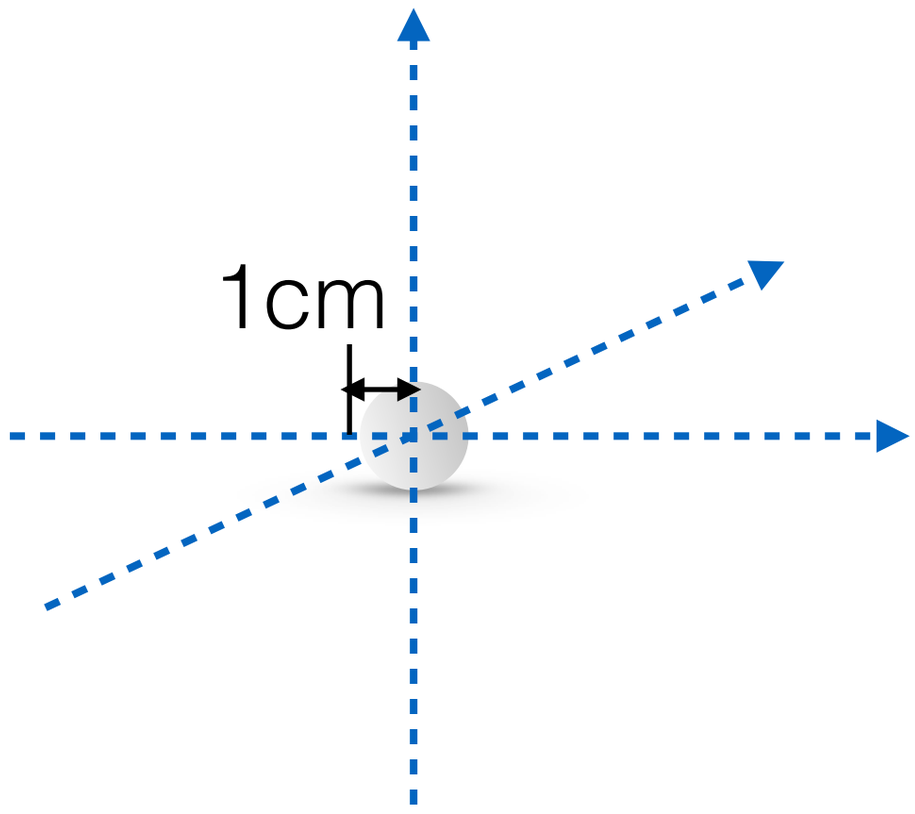
(1): better accuracy;
(2): dedicated hardwares, e.g., USRP;
(3): densely deployed anchor tags;

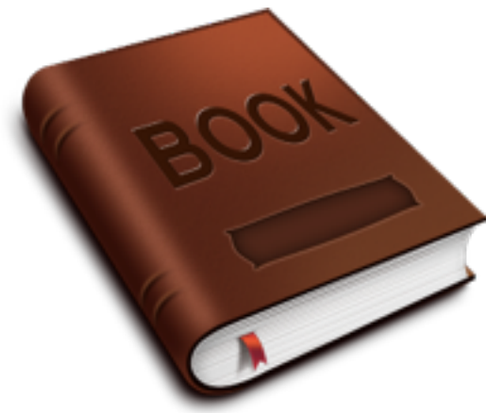
Can we convert the relative location from the absolute location?

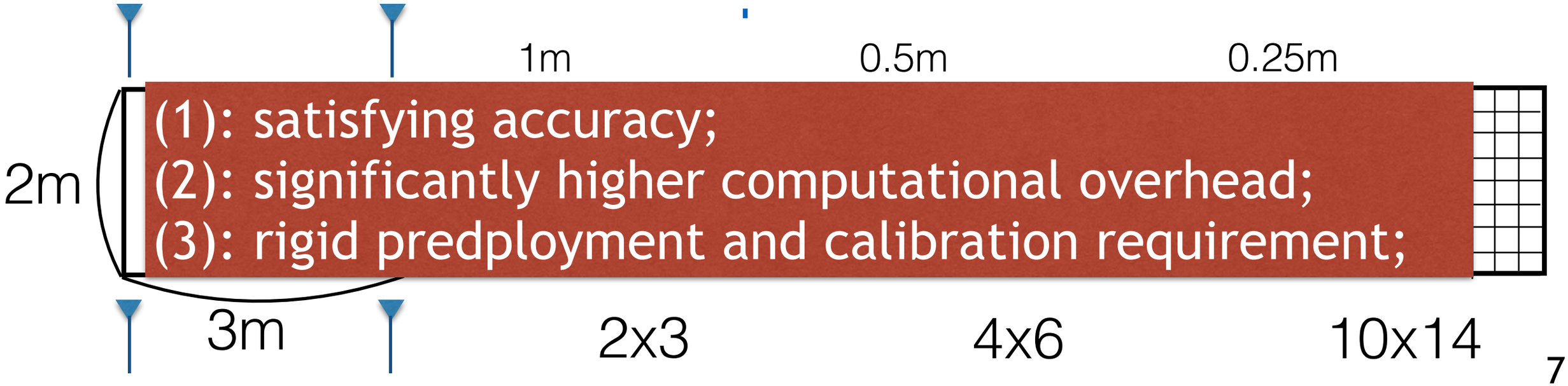
State-of-the-art

Tagoram MobiCom'14

Error-margin



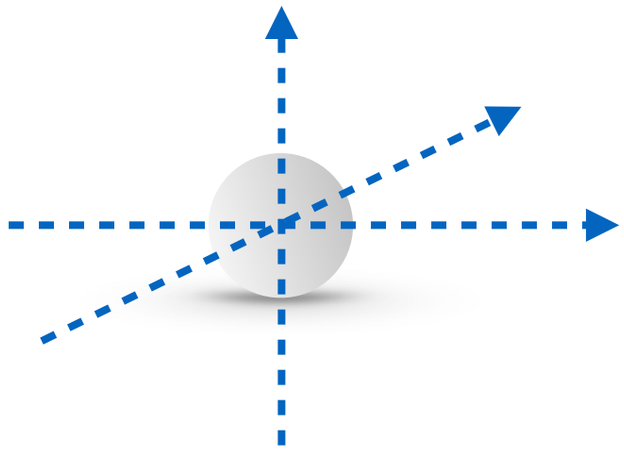




(1): satisfying accuracy;
(2): significantly higher computational overhead;
(3): rigid predployment and calibration requirement;

Design target

Goal: acquiring the relative location in 2D space without detecting tag's absolute location;







1: accurate;

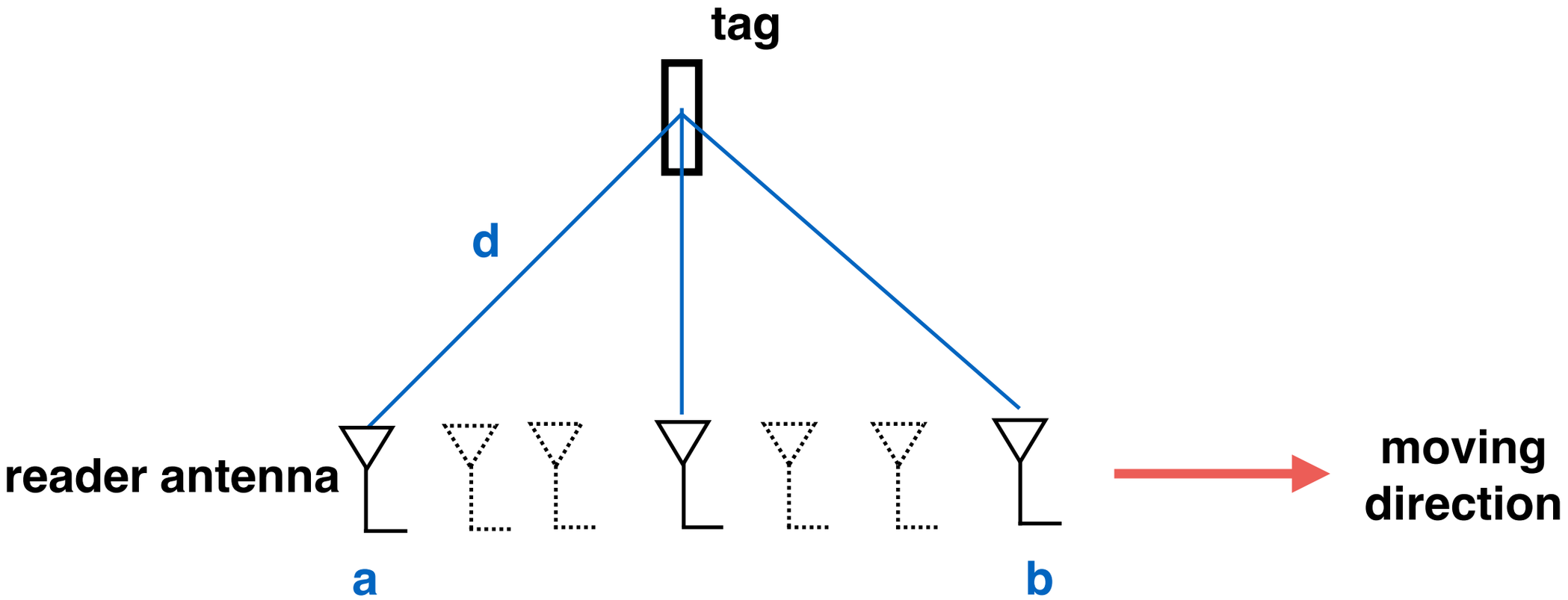
2: low-computational overhead;

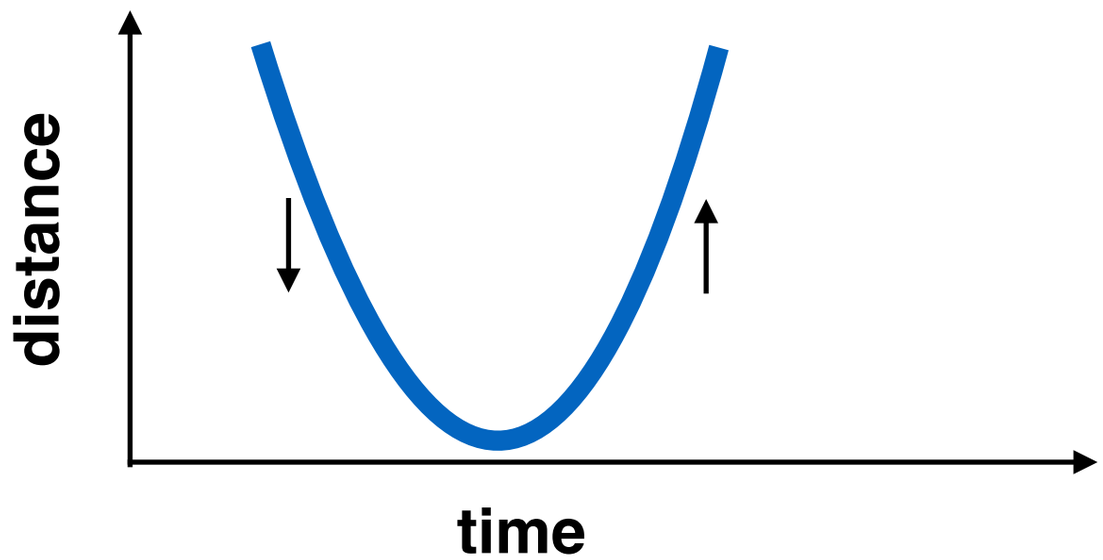
3: using off-the-shelf devices;

We propose STPP to fulfill these requirements

STPP's principle: spatial-temporal correlation of phase profile

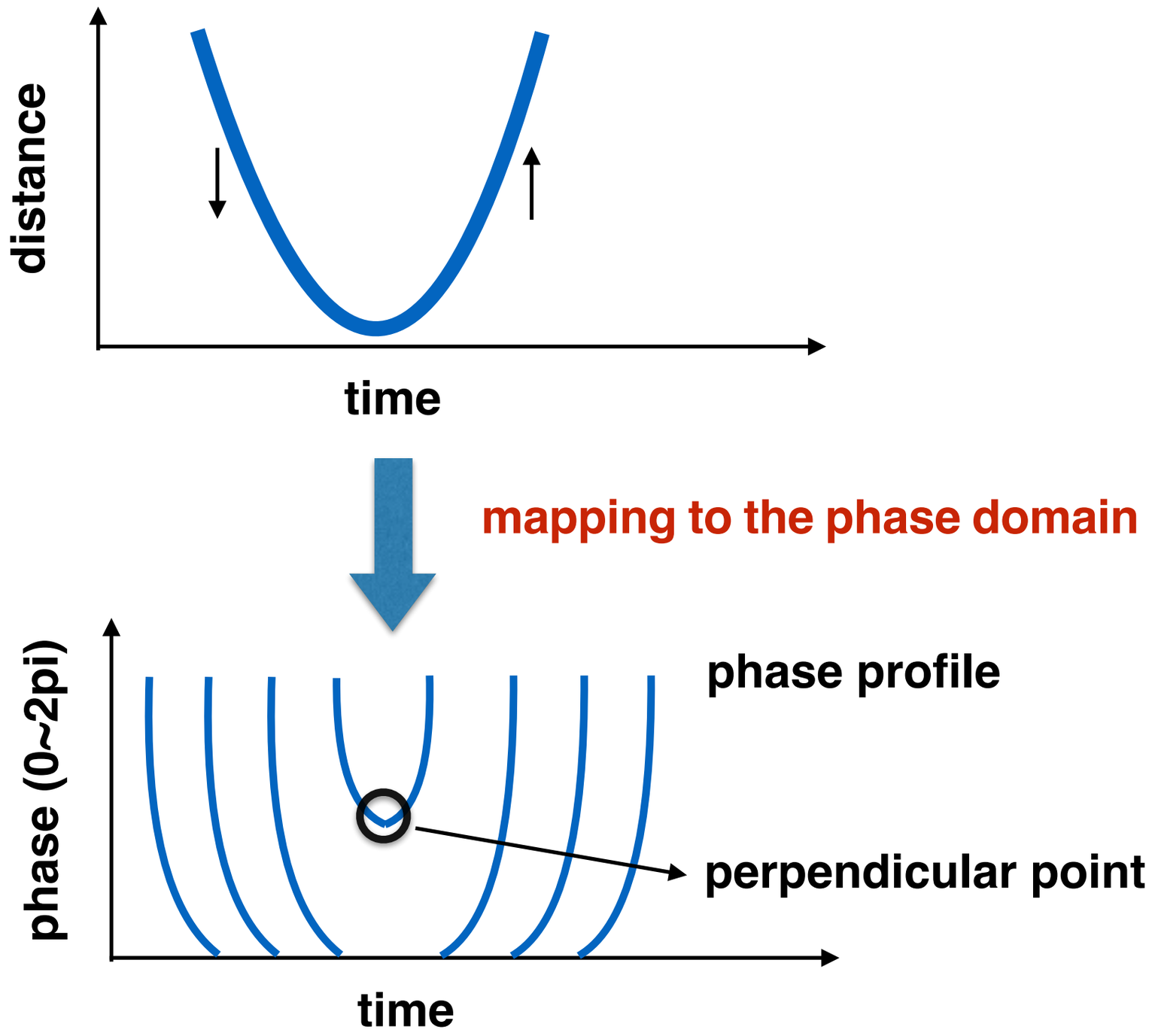
when reader antenna moves from a to b, the tag-to-antenna distance d decreases first and then increases;





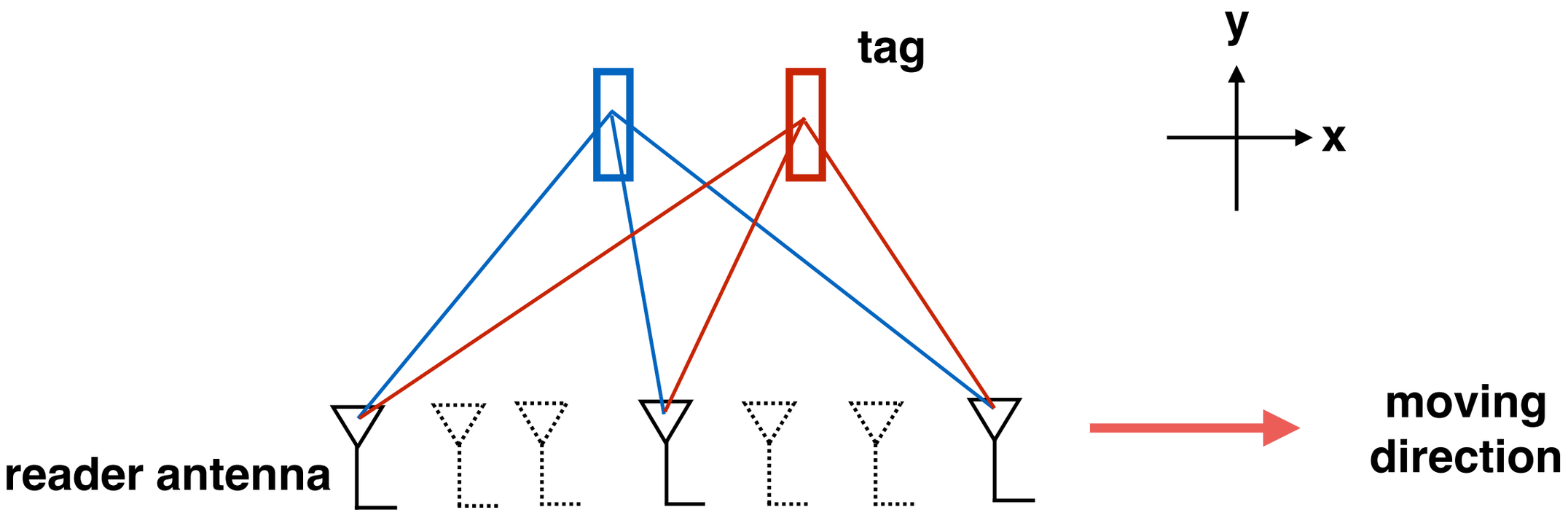
STPP's principle: spatial-temporal correlation of phase profile

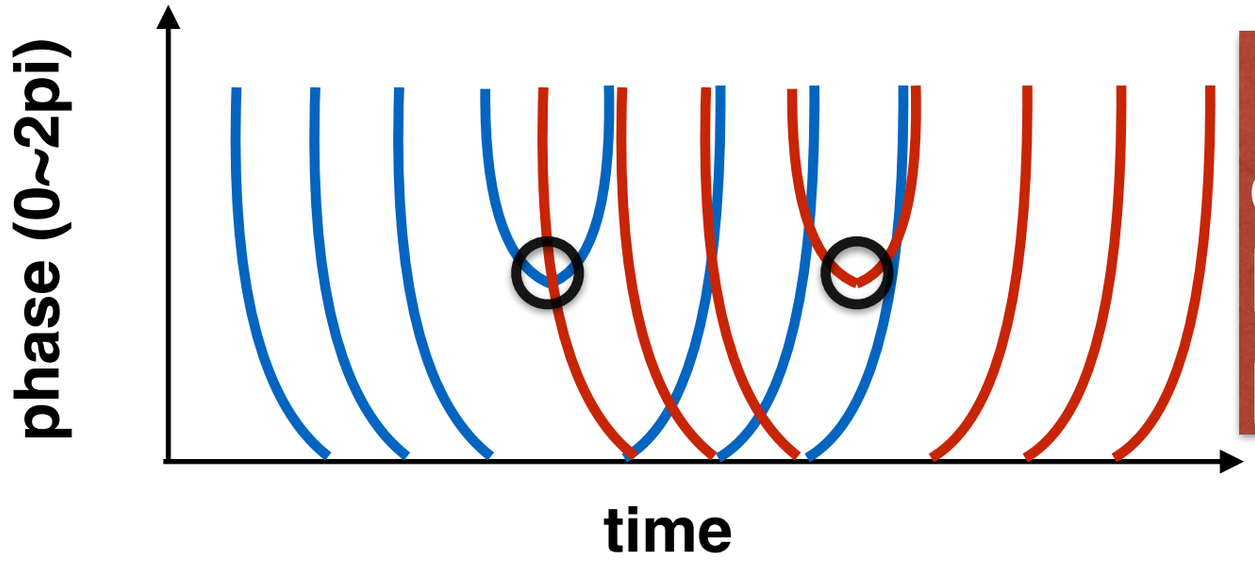
when reader antenna moves to the point in perpendicular to the tag, the phase value achieves a local minimum;



STPP's principle: spatial-temporal correlation of phase profile

Determine the tag order along the X-axis



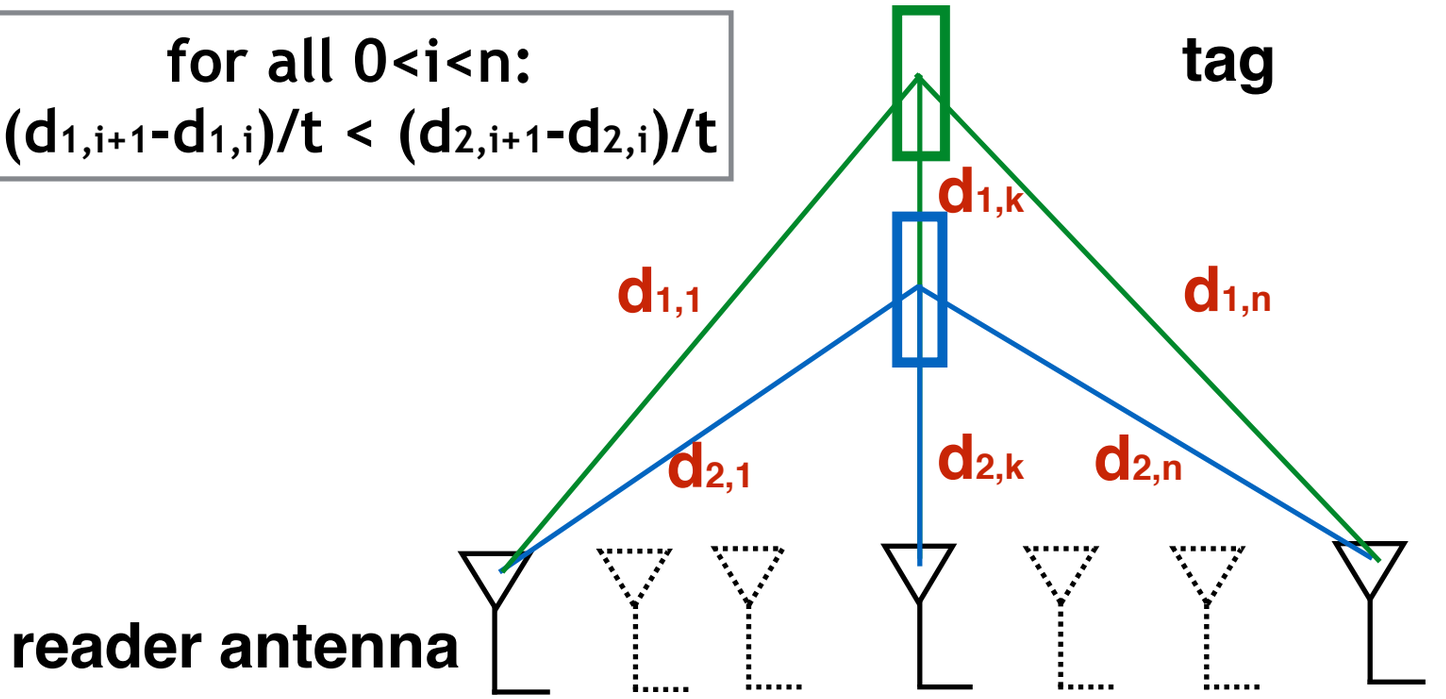


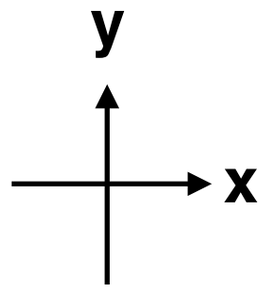
Determine the tag order along the X-axis by referring their perpendicular point;

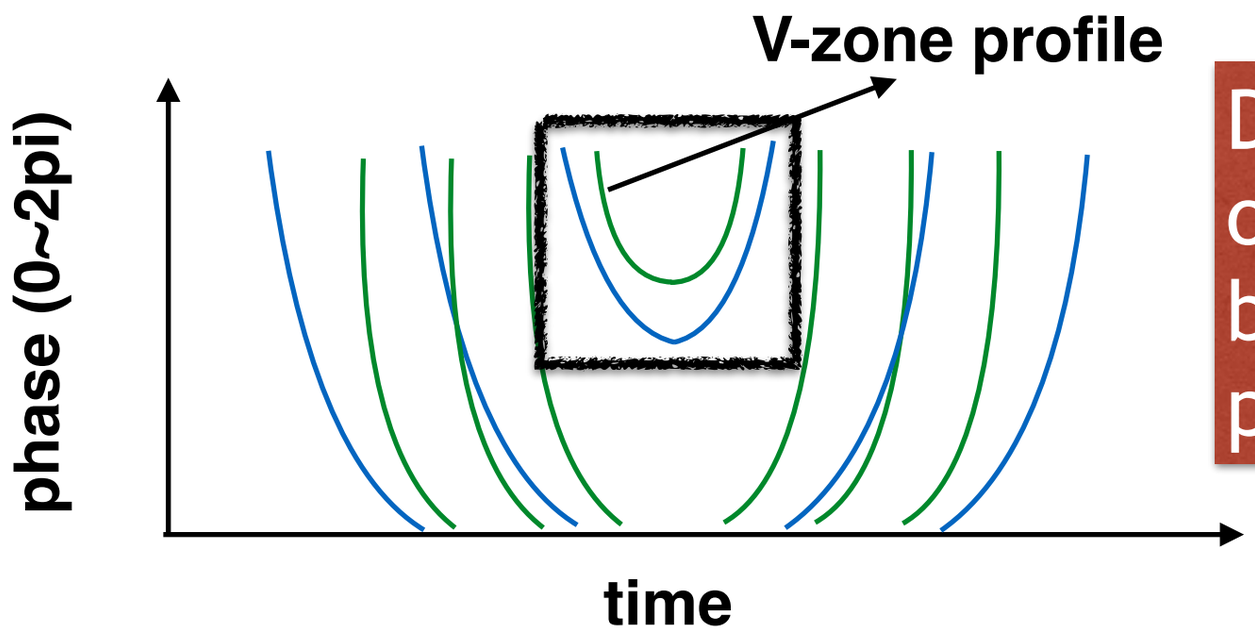
STPP's principle: spatial-temporal correlation of phase profile

Determine the tag order along the Y-axis

for all $0<i<n$:
$(d_{1,i+1}-d_{1,i})/t < (d_{2,i+1}-d_{2,i})/t$







Determine the tag order along the Y-axis by referring their phase changing rate;

STPP's Techniques

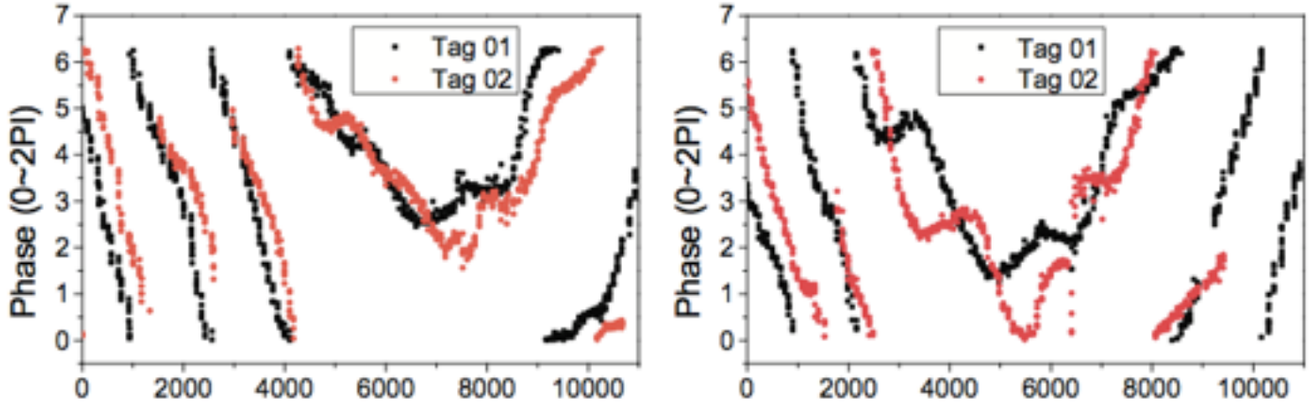
Detecting the V-zone

Detecting the perpendicular point

Comparing the phase changing rate

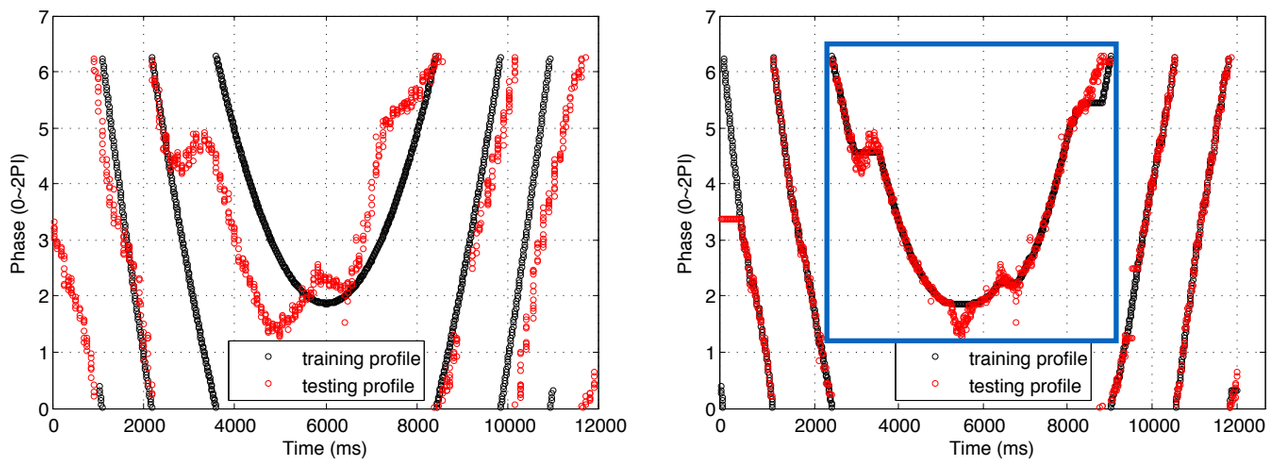
How to detect the V-zone?

full of noises; **disconnected abruptly;** **with different length;**



(a) X dimension spacing = 5cm (b) X dimension spacing = 10cm

idea: matching to the template with dynamic time warping, since each profile is with difference length due to random access nature of ALOHA protocol;

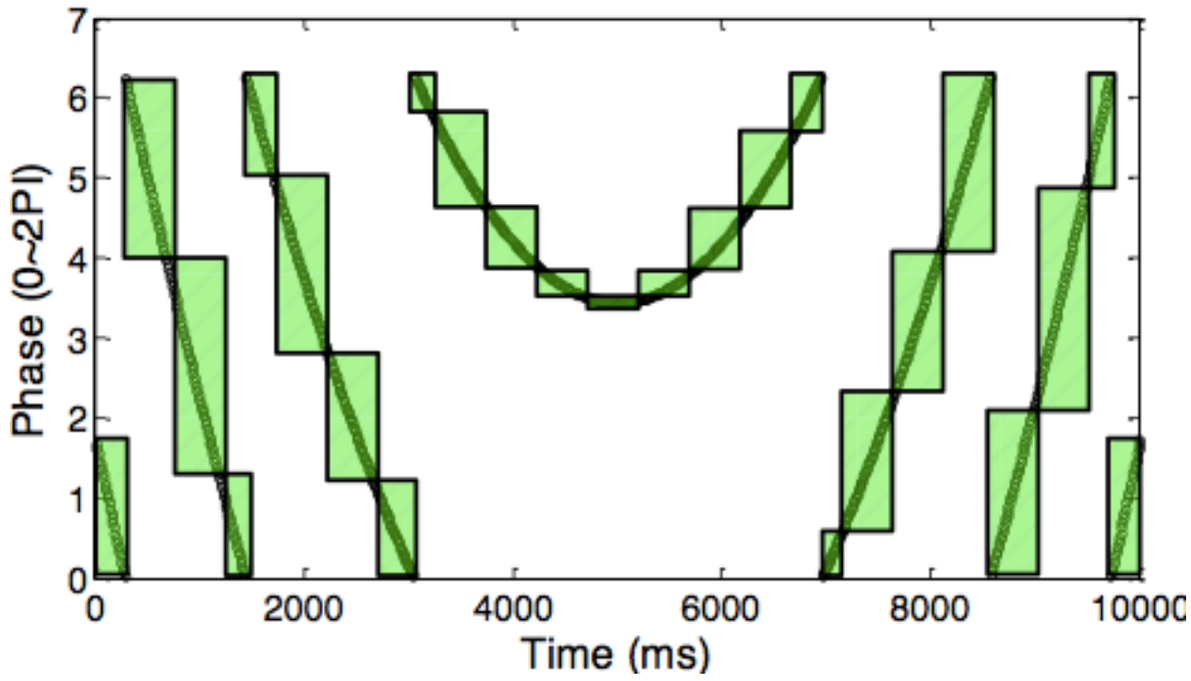


before warping **after warping**

How to detect the V-zone?

Enhancing the efficiency

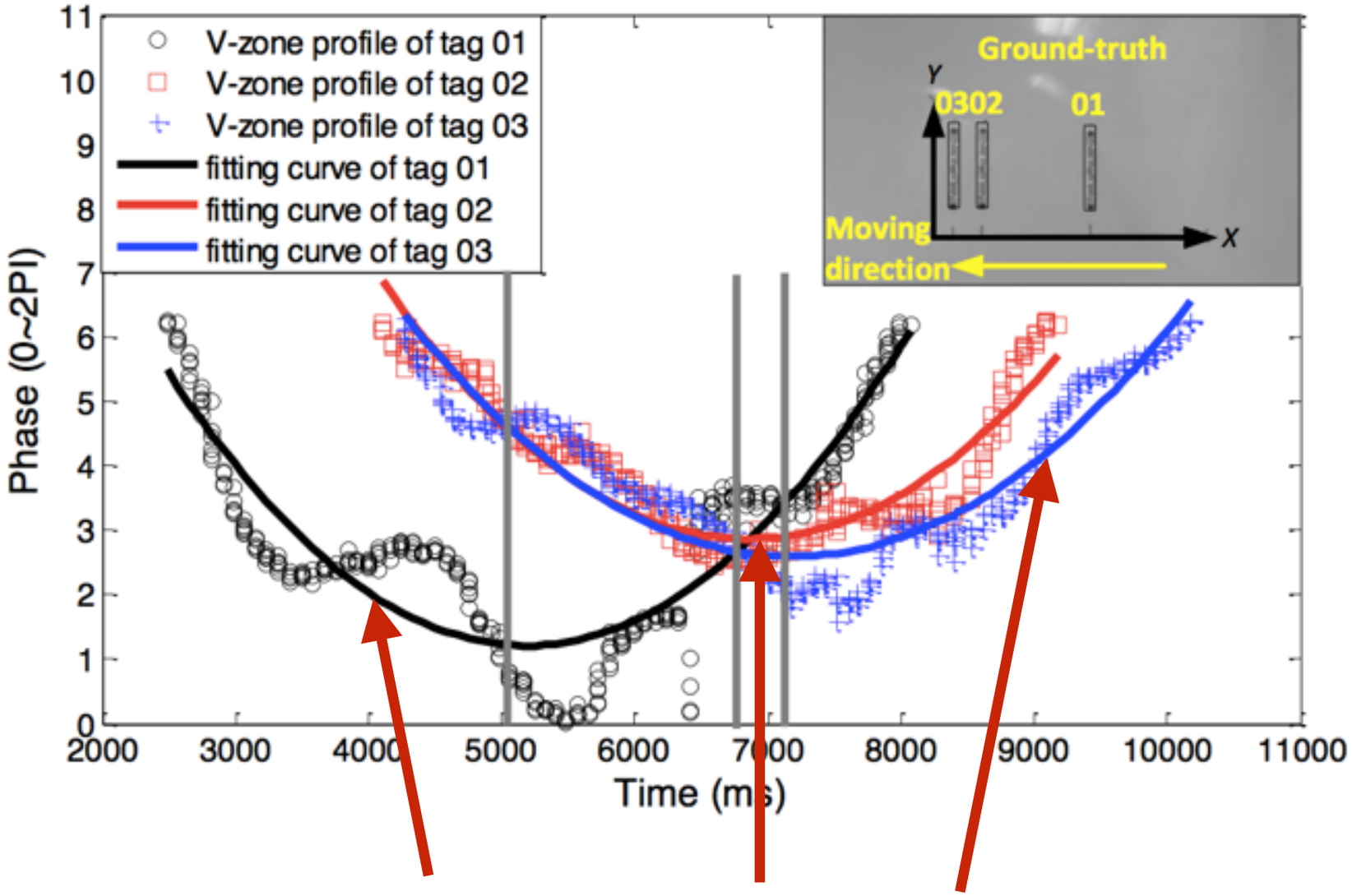
the phase profile may be long due to the high reading rate of commercial RFID readers; e.g., ImpinJ R420 supports up to 340times/second reading rate;



1: splitting the phase profile into pieces, and recording the maximum, minimum, average phase value within each piece;
2: comparing the phase profile on their coarse representations;

How to detect the perpendicular point?

the V-zone is not strictly self-symmetric;

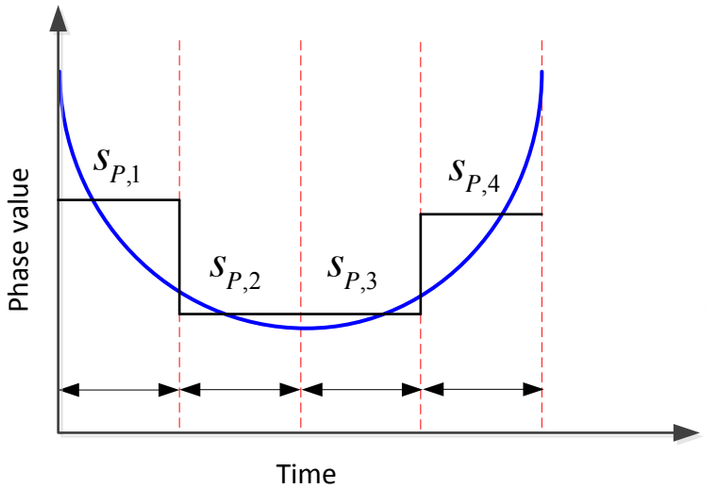


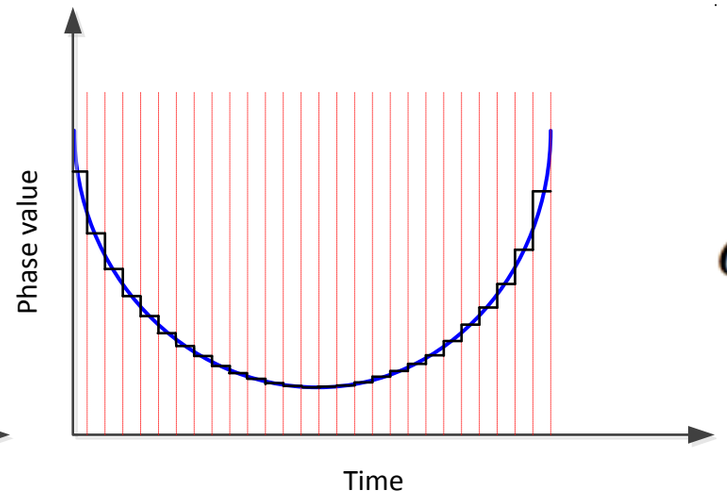
General idea: Curve fitting

1:using quadratic fitting;

2:finding the time point when the phase achieves the minimum;

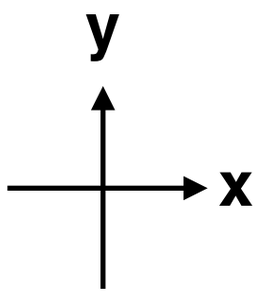
How to compare the phase changing rate?

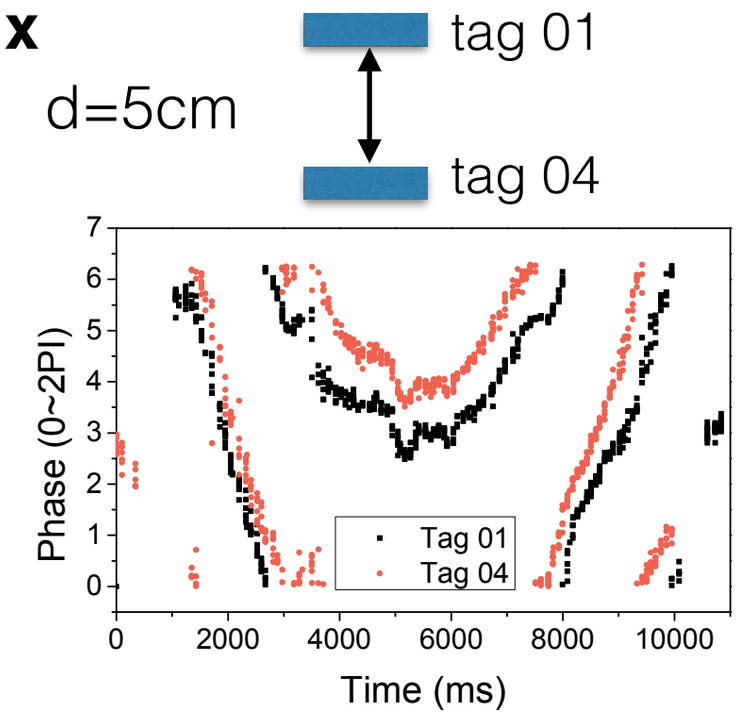


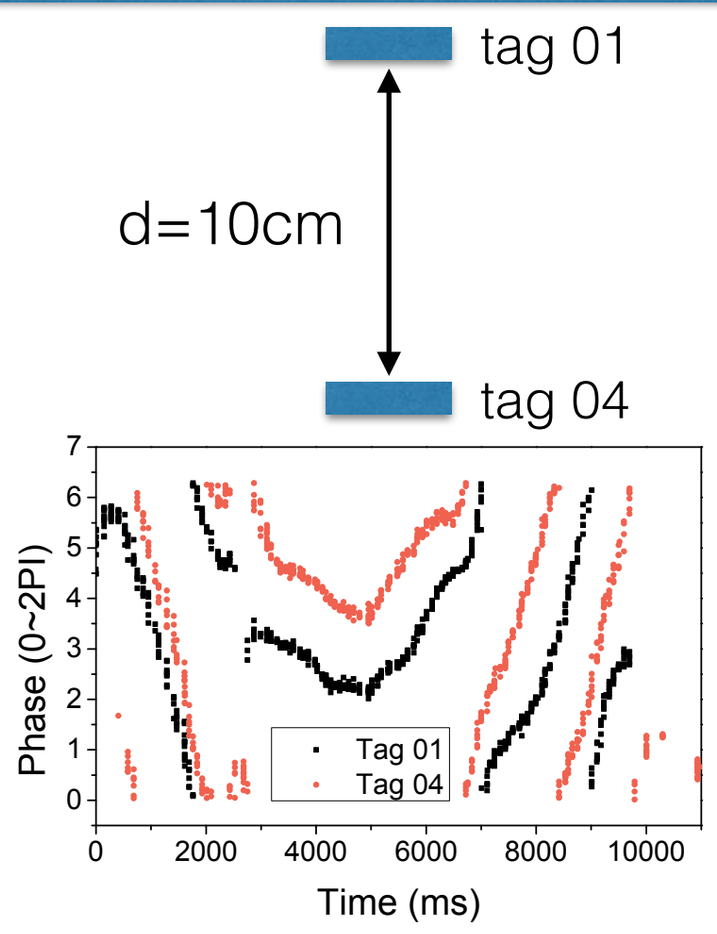


$$O(P,Q) = \sum_{i=1}^{k} \lceil \frac{s_{P,i} - s_{Q,i}}{s_{P,i}} \rceil$$

O(P,Q) closes to k —> phase changing rate of P < that of Q
O(P,Q) closes to 0 —> phase changing rate of P > that of Q

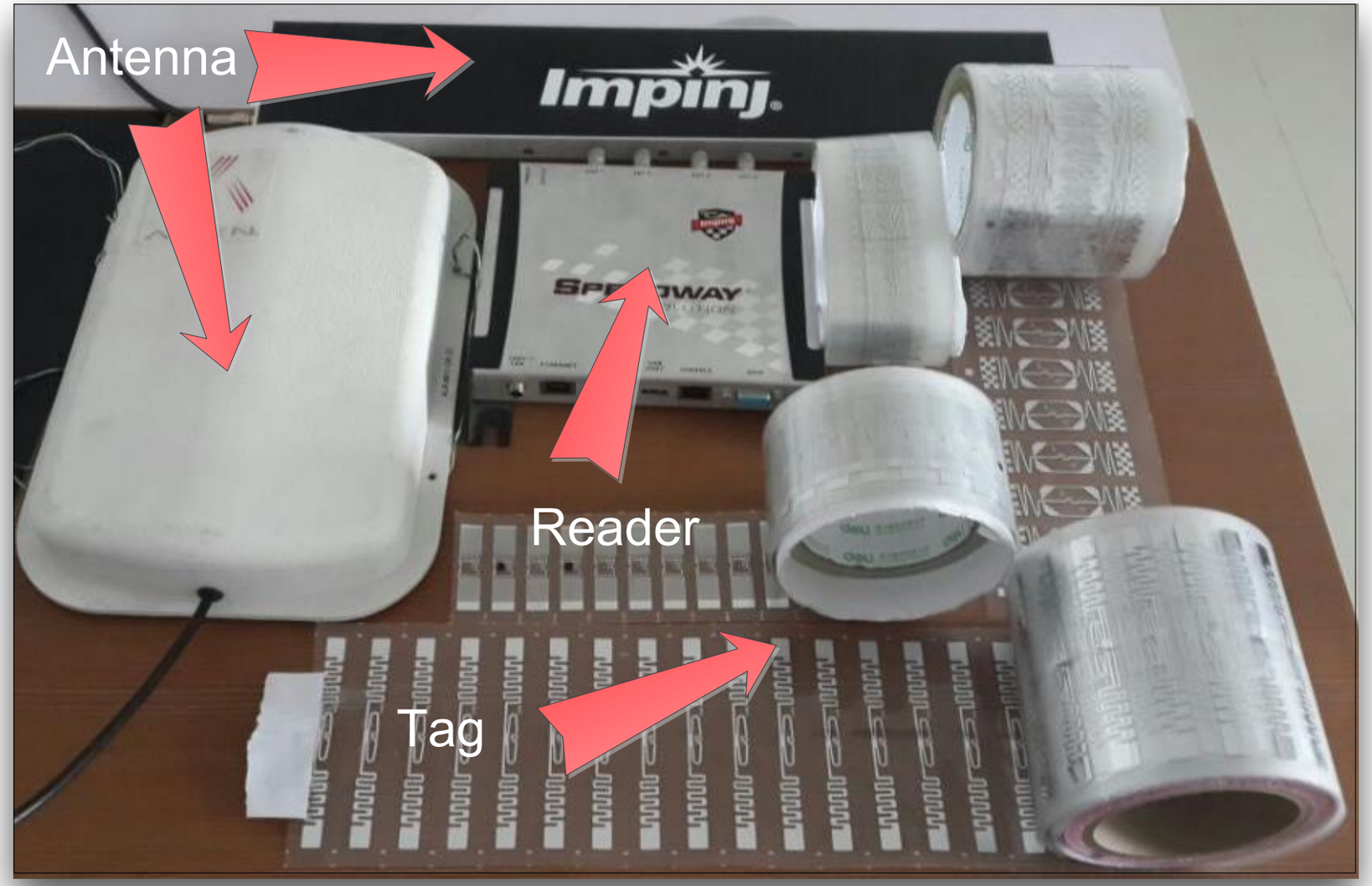






Experiment setups

off-the-shelf hardware component

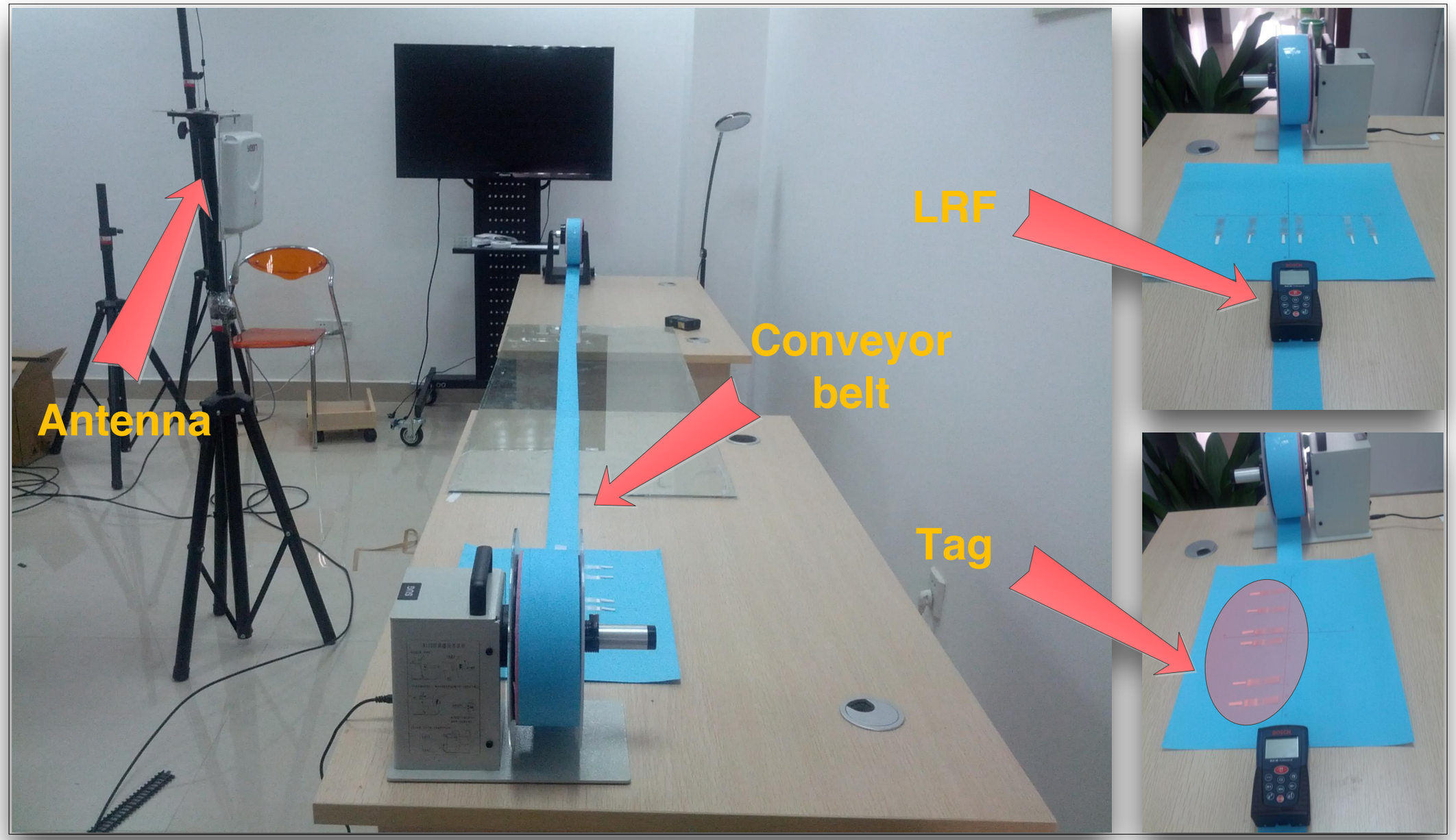


Evaluation metric:

$$Ordering\ Accuracy = \frac{\#\ of\ tags\ ordered\ correctly}{\#\ of\ tags\ in\ total}$$

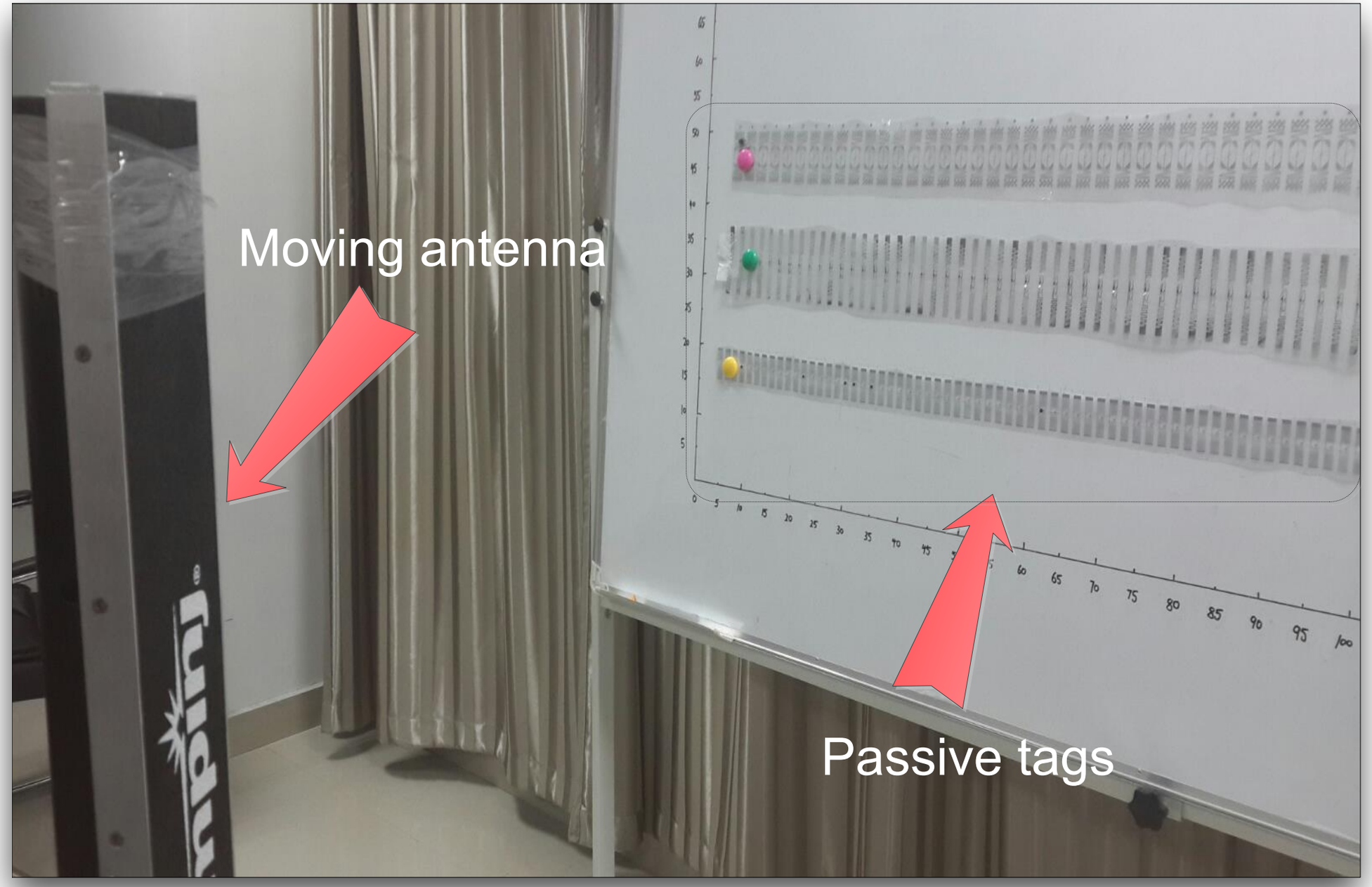
Testing cases

tag moving case



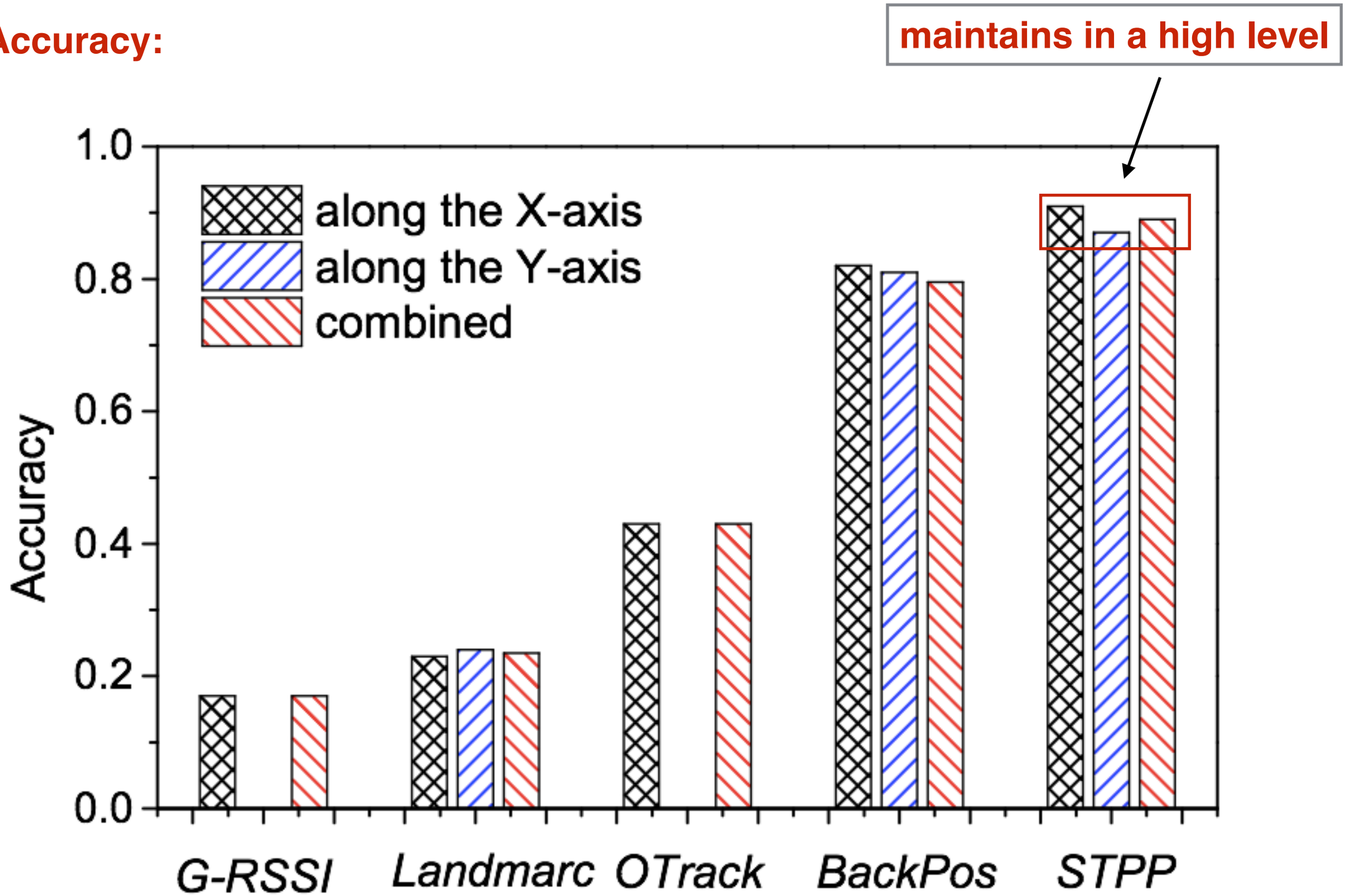
Testing cases

antenna moving case



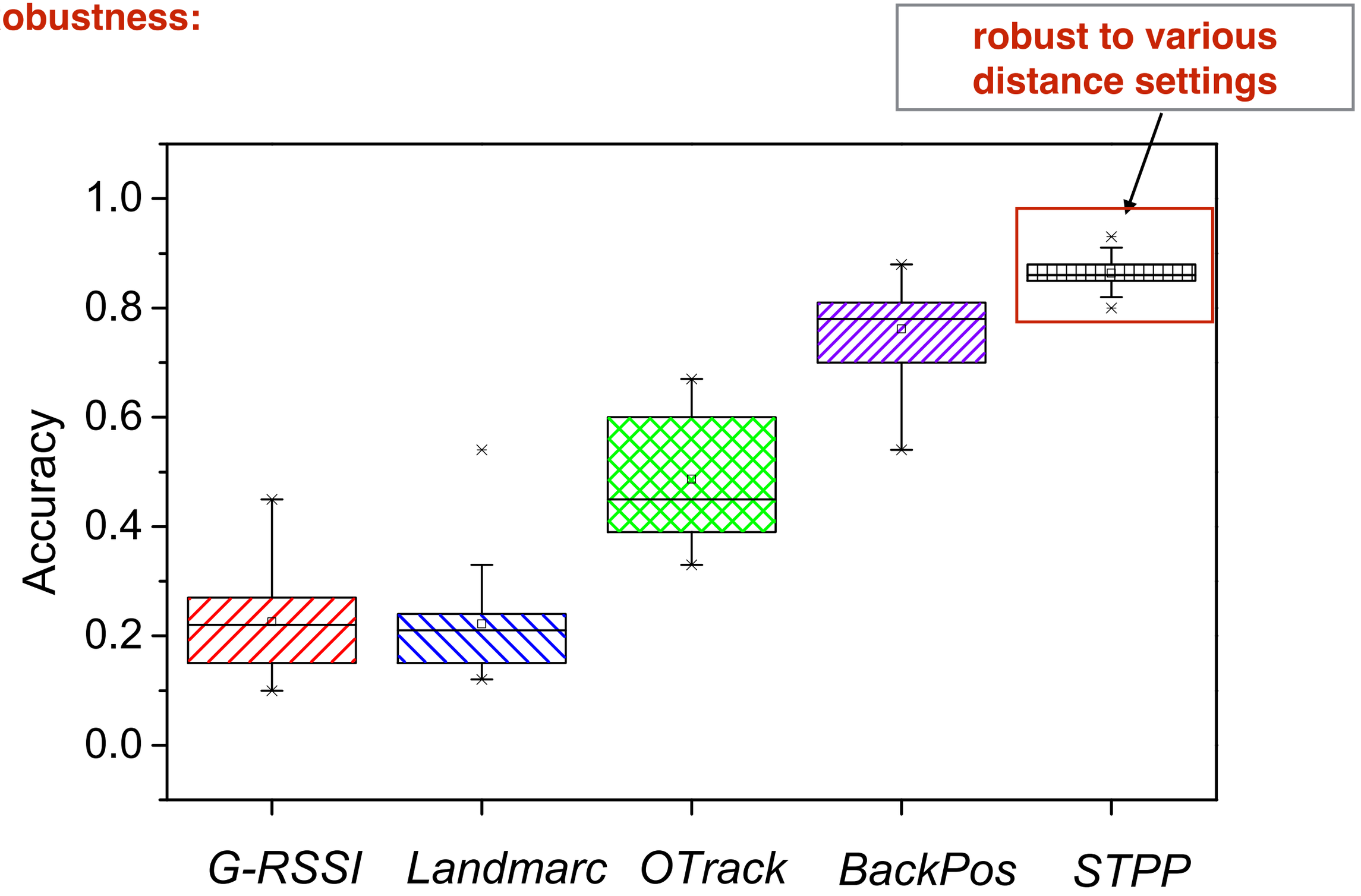
Experimental results

Accuracy:



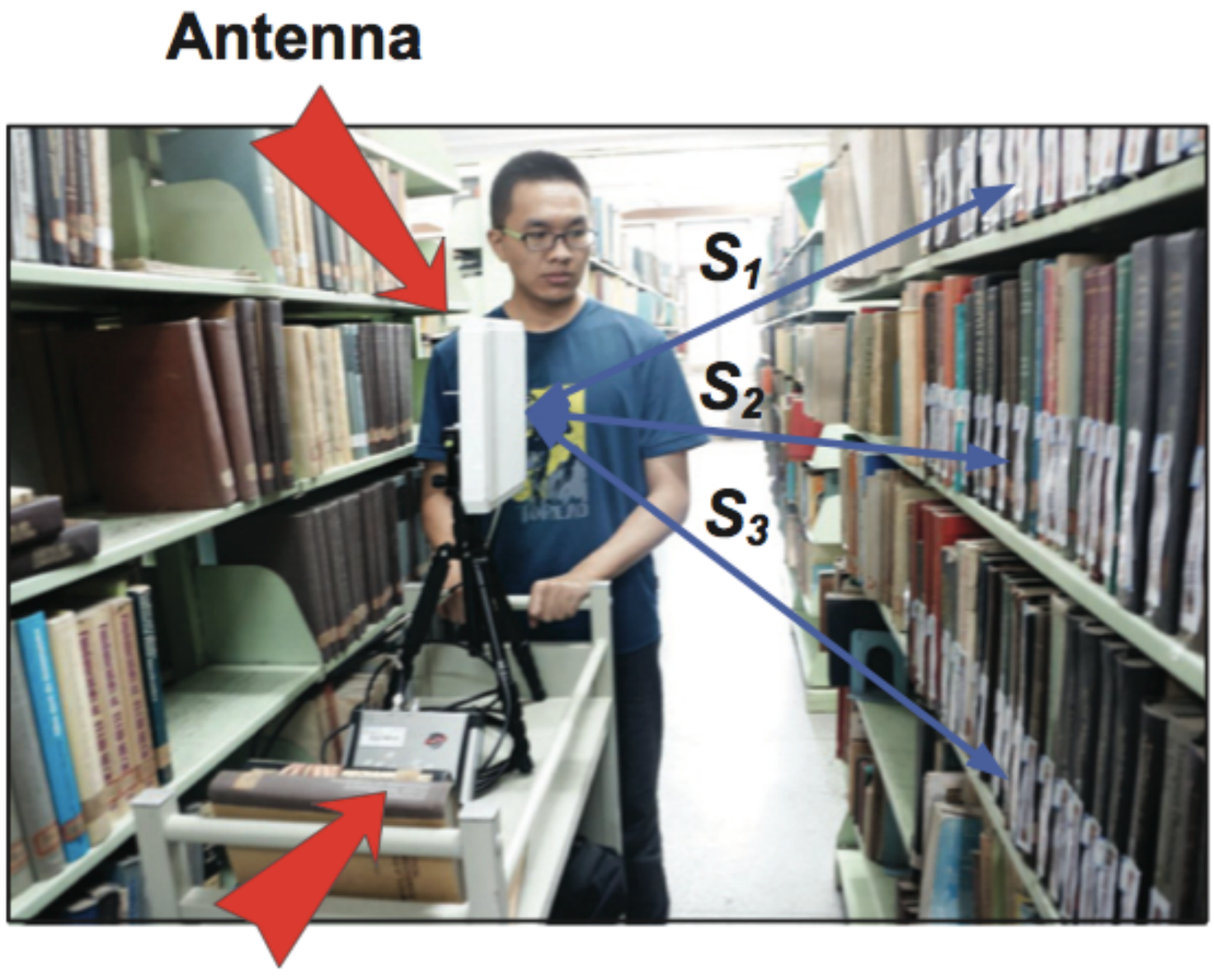
Experimental results

Robustness:



Case study One: finding misplaced books in library

Scenario:

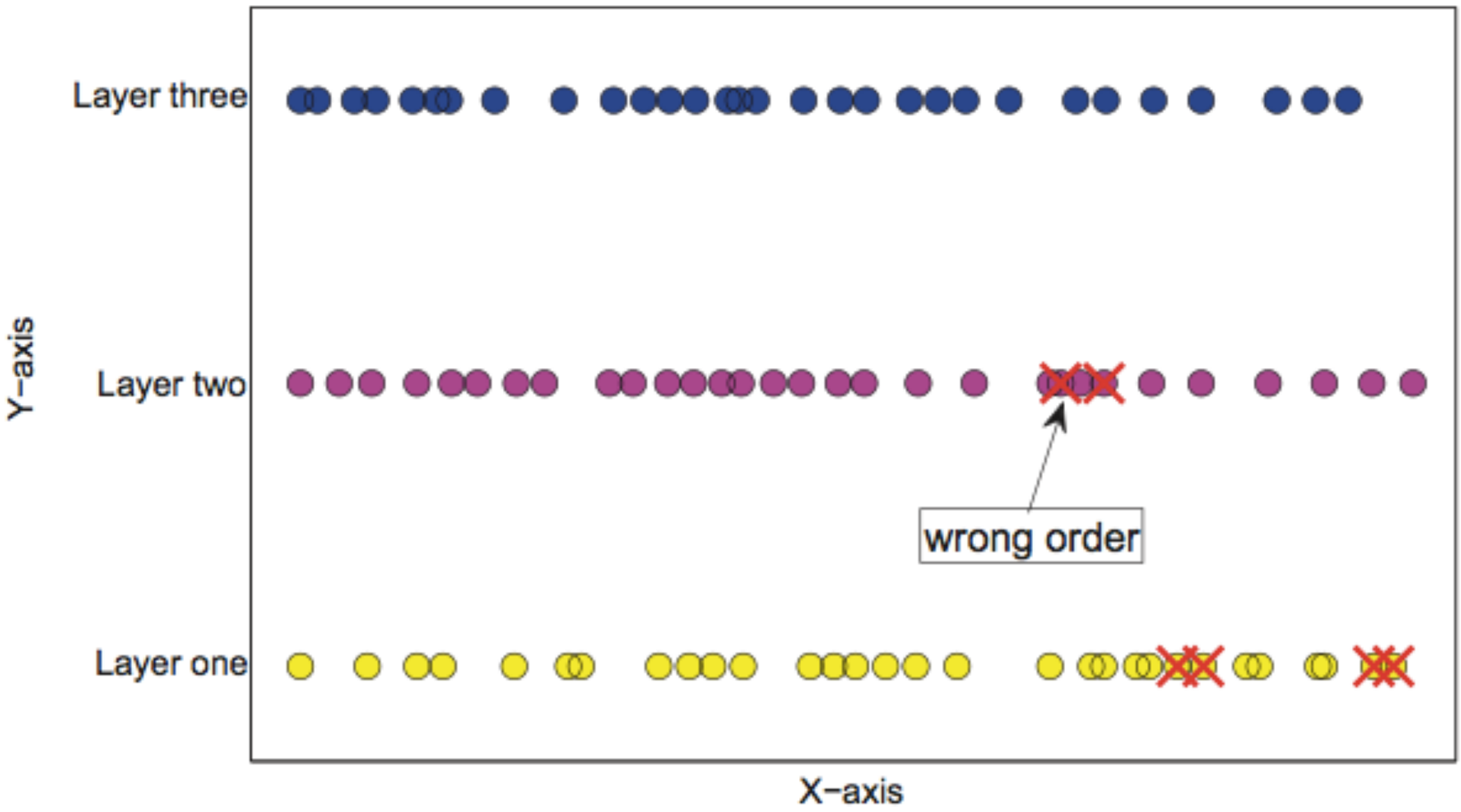




$S_2 < S_1 < S_3$

Case study One: finding misplaced books in library

Detection snapshot:

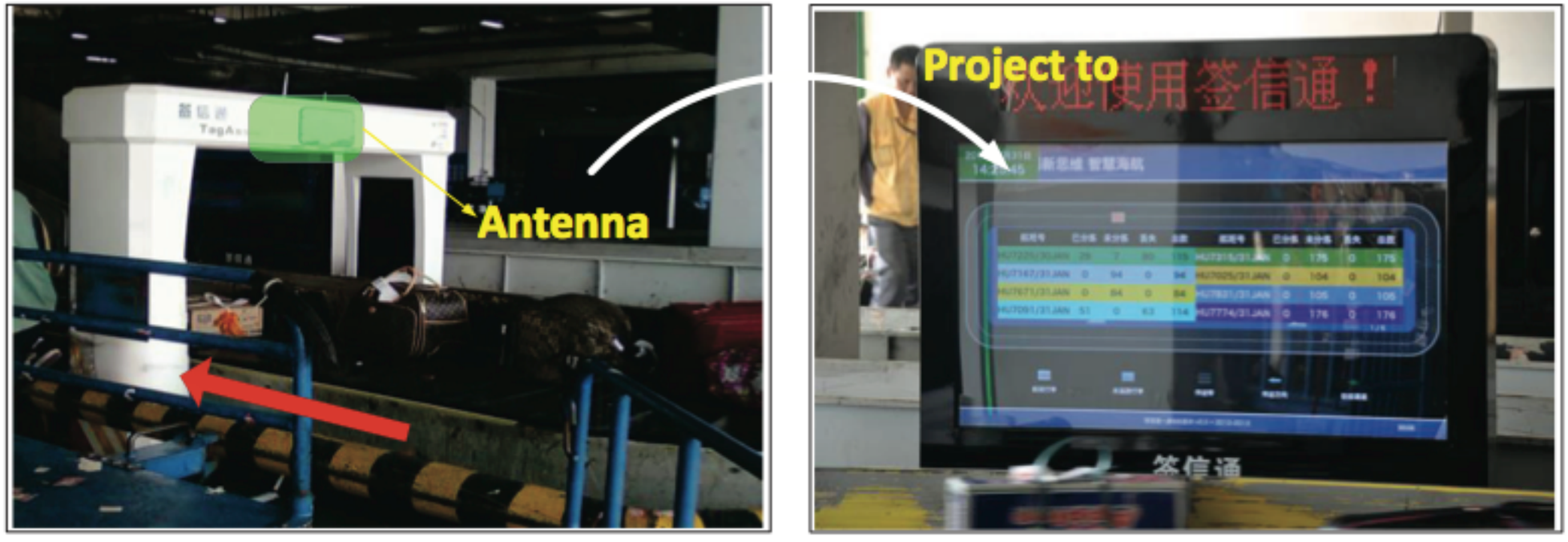


Case study Two: tracking the baggage order in airport

Scenario:



(a) RFID tag for baggage check-in



(b) Baggage handling in Terminal One, Sanya Phoenix airport

Case study Two: tracking the baggage order in airport

Numerical results:

	morning peak		evening peak
	7:00~9:00	13:00~15:00	19:00~21:00
STPP	388/400=97%	224/230=97%	422/440=96%
OTrack	352/400=88%	218/230=95%	388/440=88%
G-RSSI	234/400=59%	166/230=72%	226/440=51%



Conclusion

1: Provide accurate relative RFID localization;

2: Employ the spatial-temporal correlation of phase profiles;

3: Enable a new category of location-based services;

Q & A

Thank you!

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