Canon: Exploiting Channel Diversity for Reliable Parallel Decoding in Backscatter Communication

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清華大學
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Low Cost

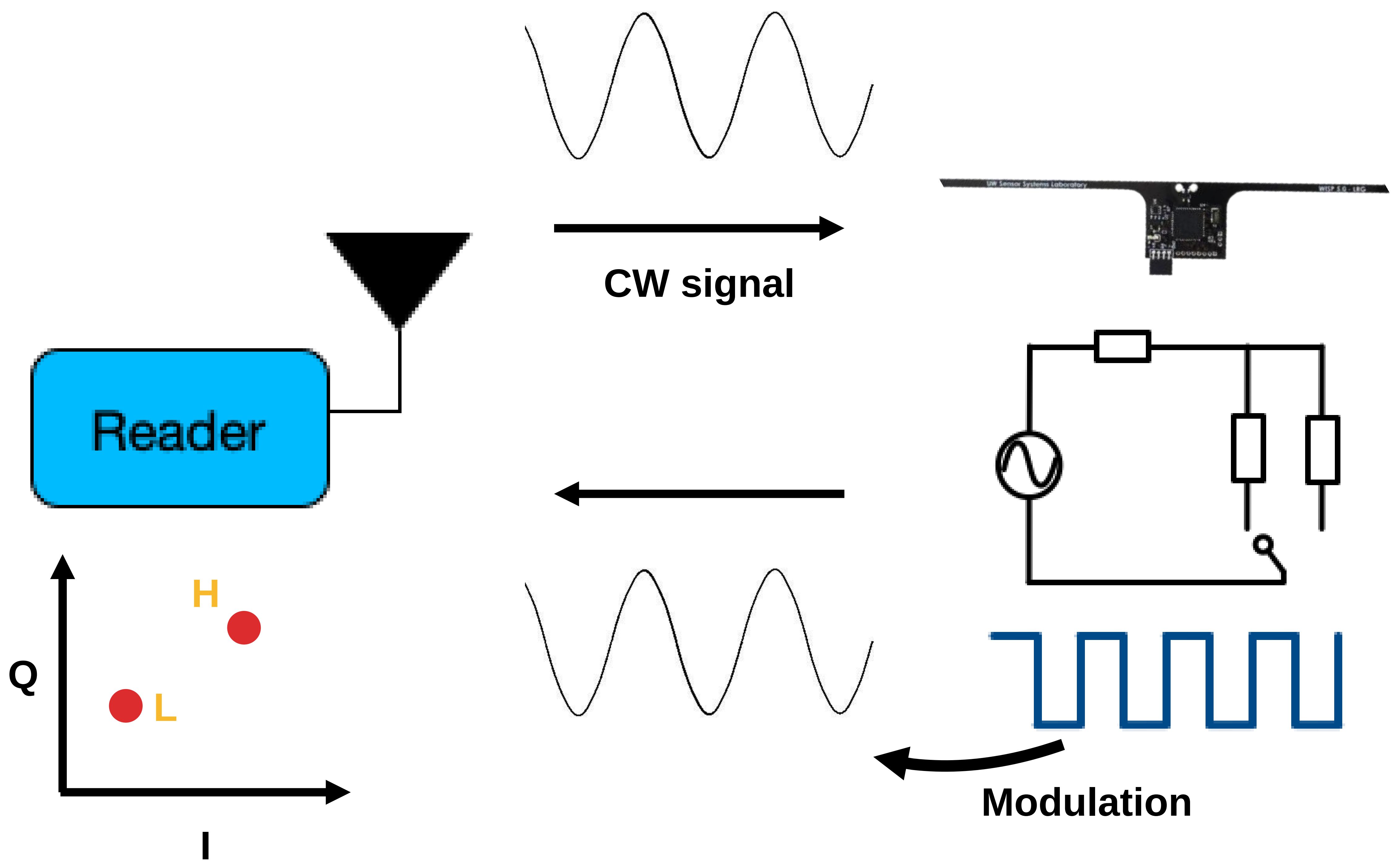
Easy to Deploy

Low Energy Consumption

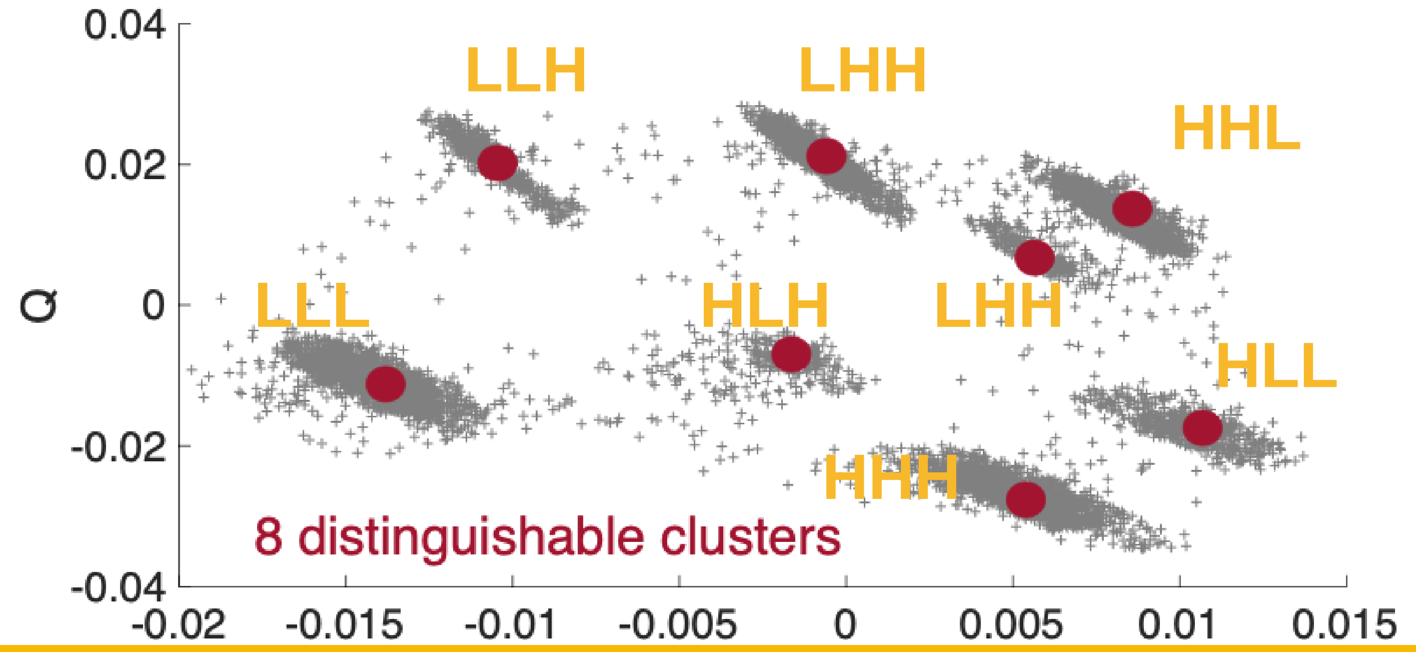
Densely-deployed tags generate large volume of data

Parallel Decoding of Multiple Tags

Backscatter Communication

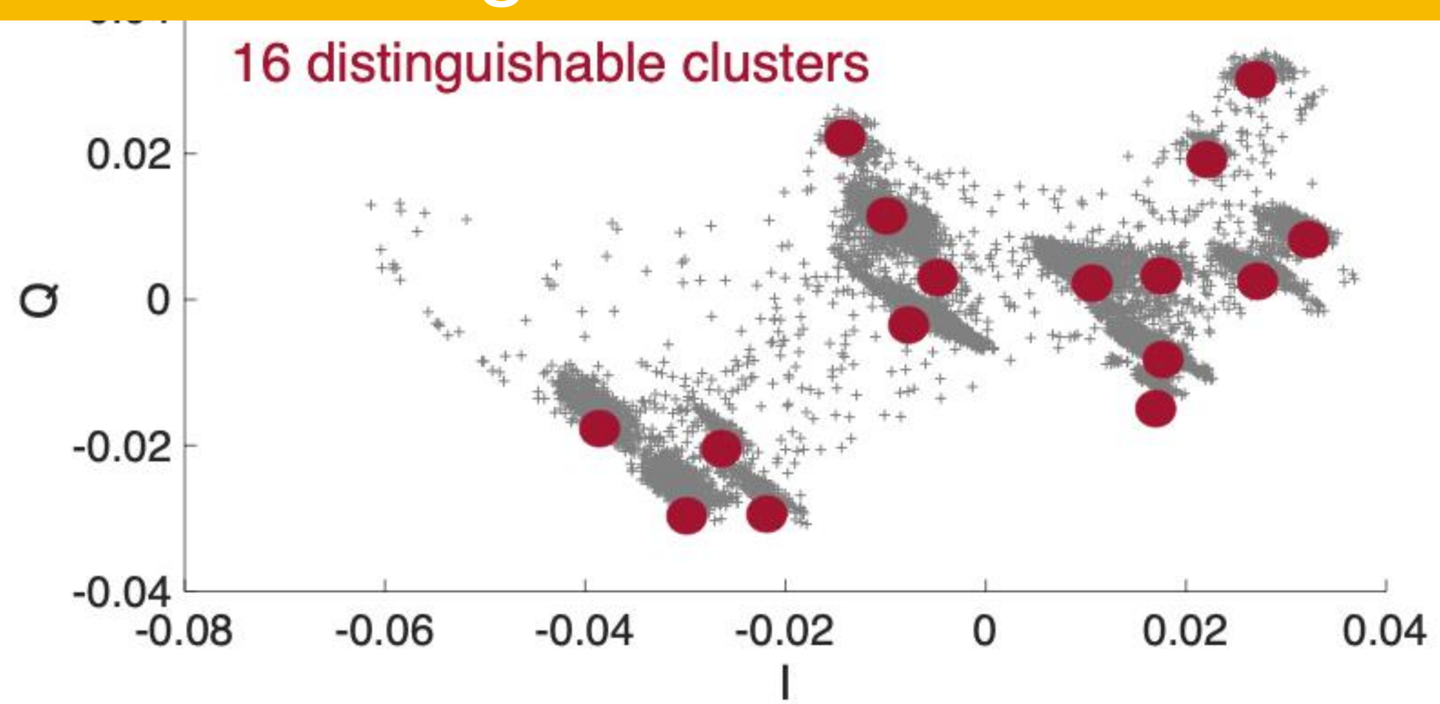


The Transmission of Multiple Tags



3 Tags

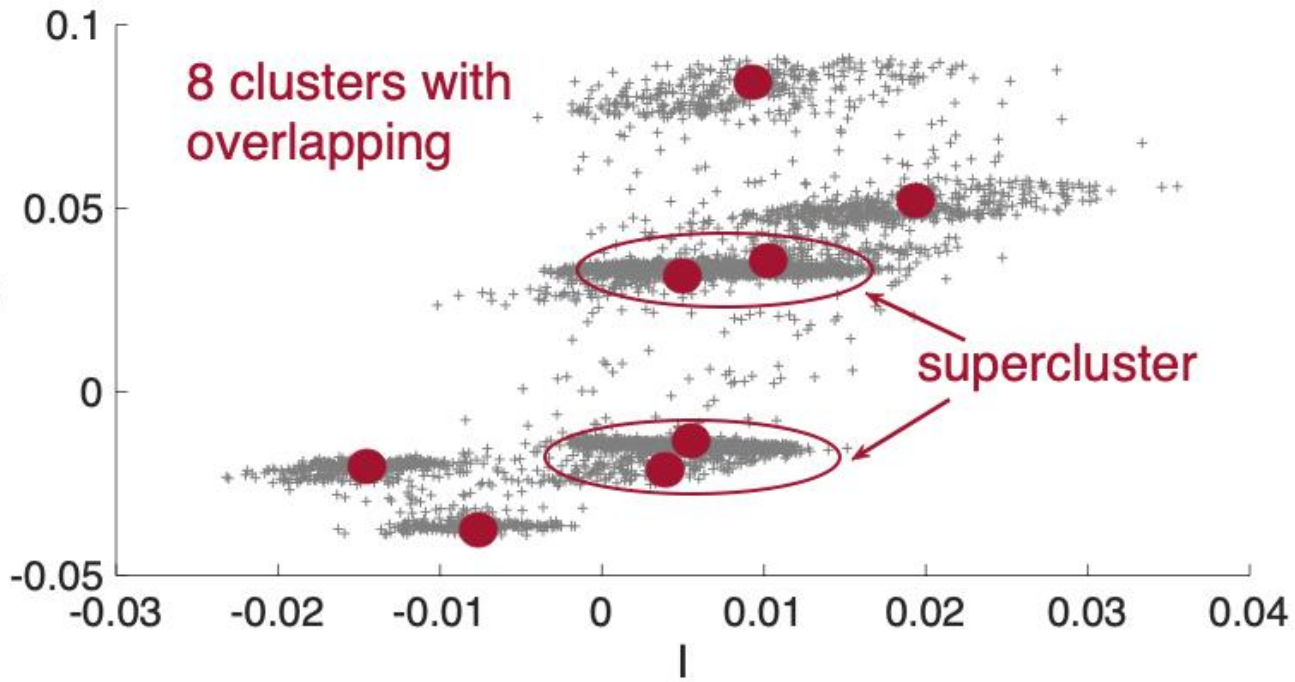
Distinguishable clusters?



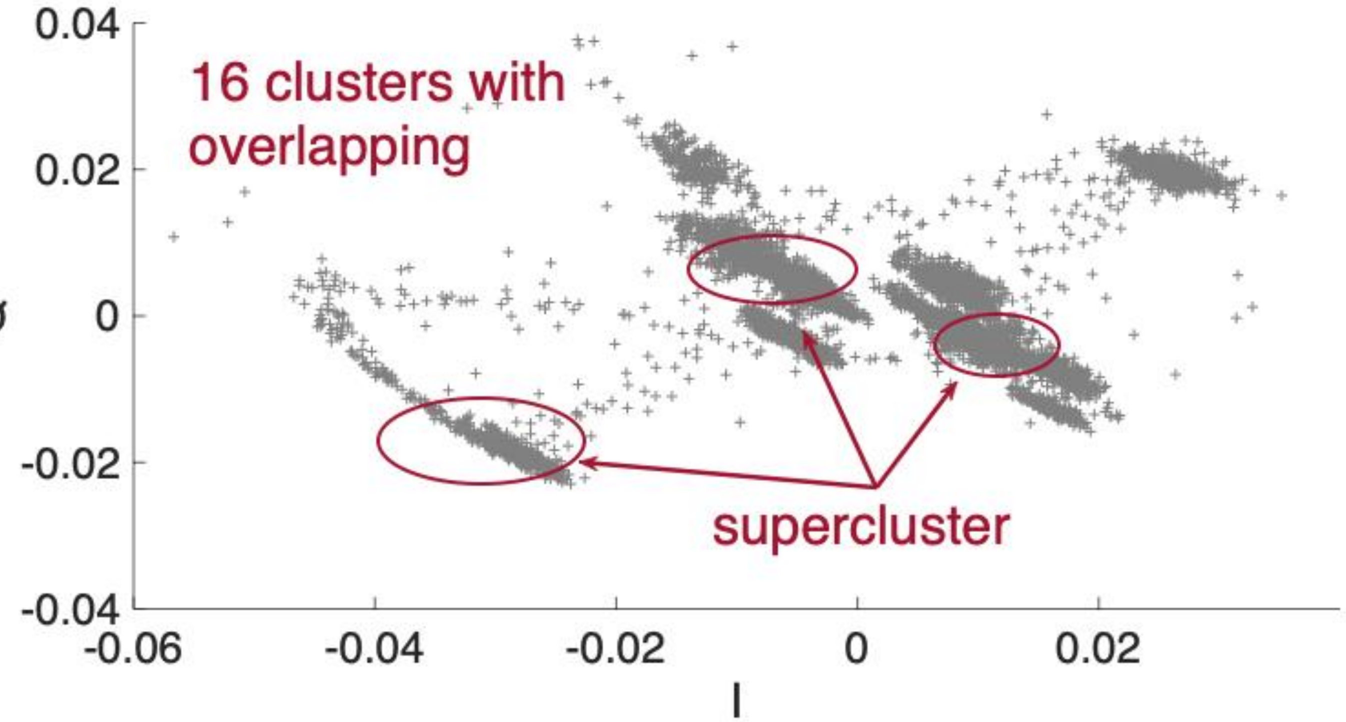
4 Tags

Using the symbol transition to decode the tags

The Transmission of Multiple Tags



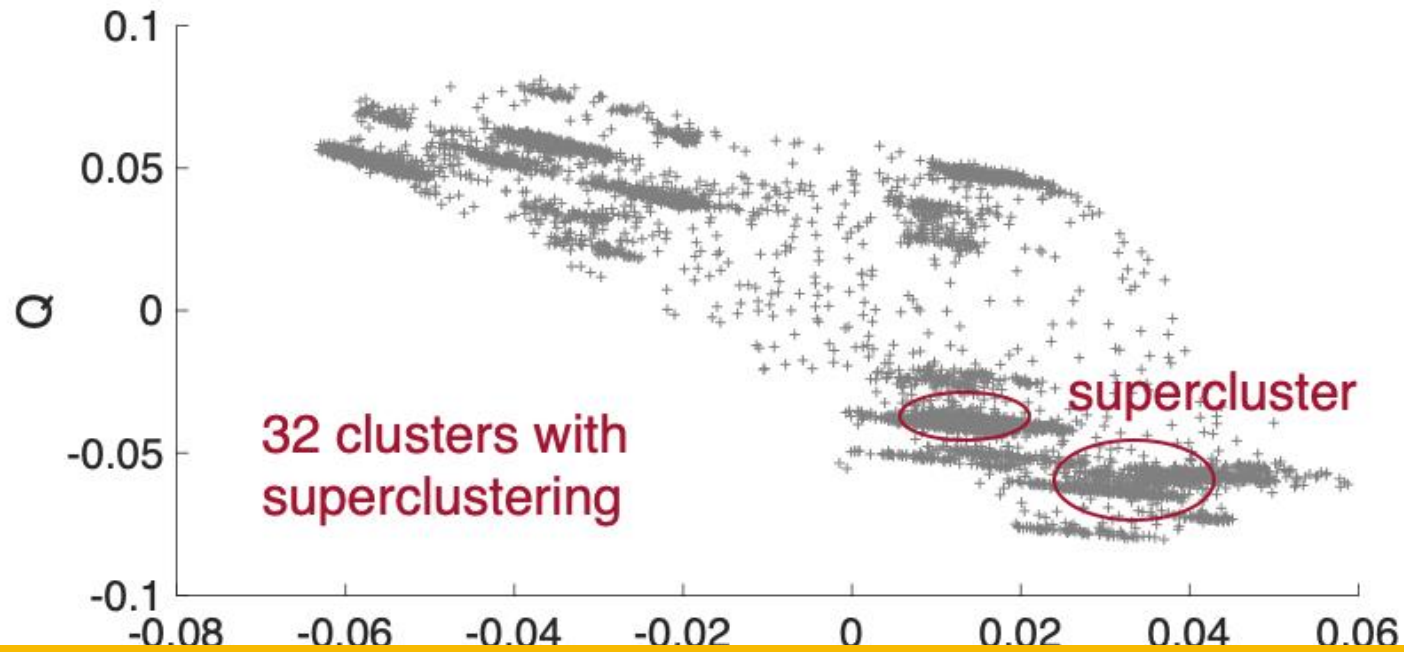
3 Tags



4 Tags

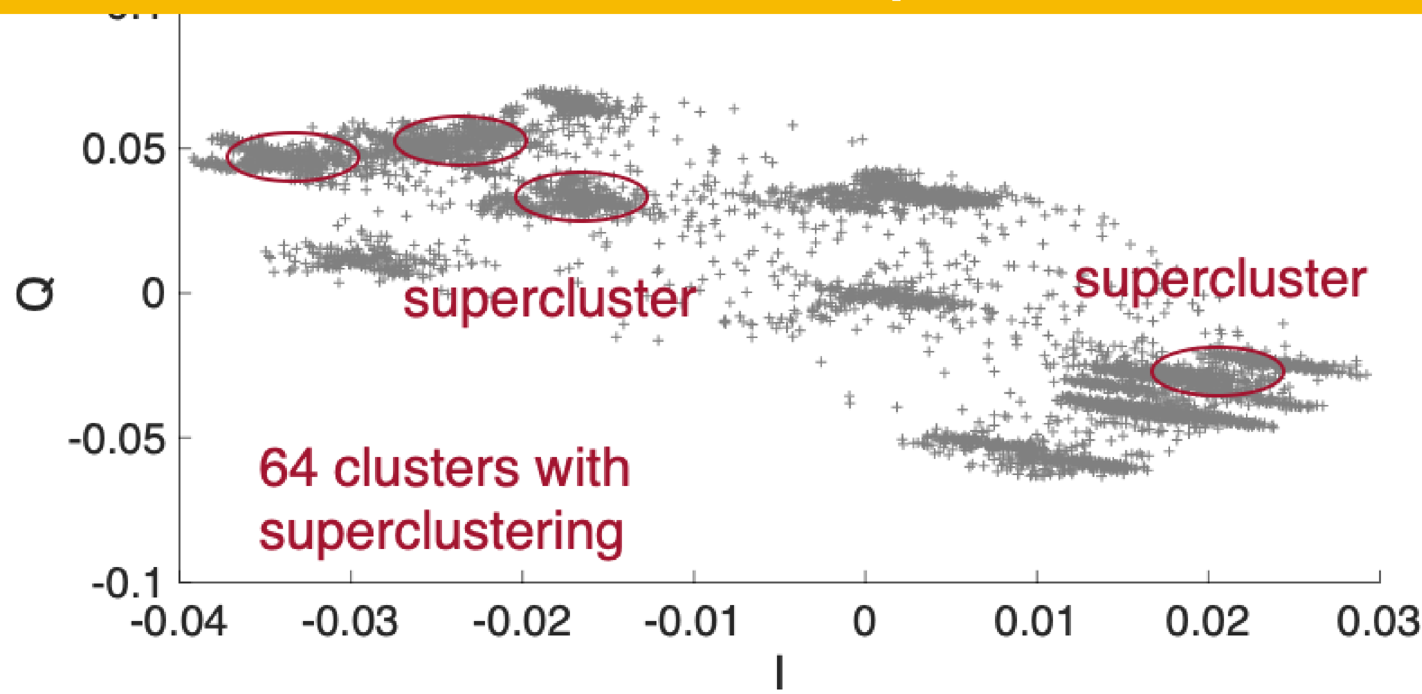
The superclusters caused by the noise and the low SNR

The Transmission of Multiple Tags



5 Tags

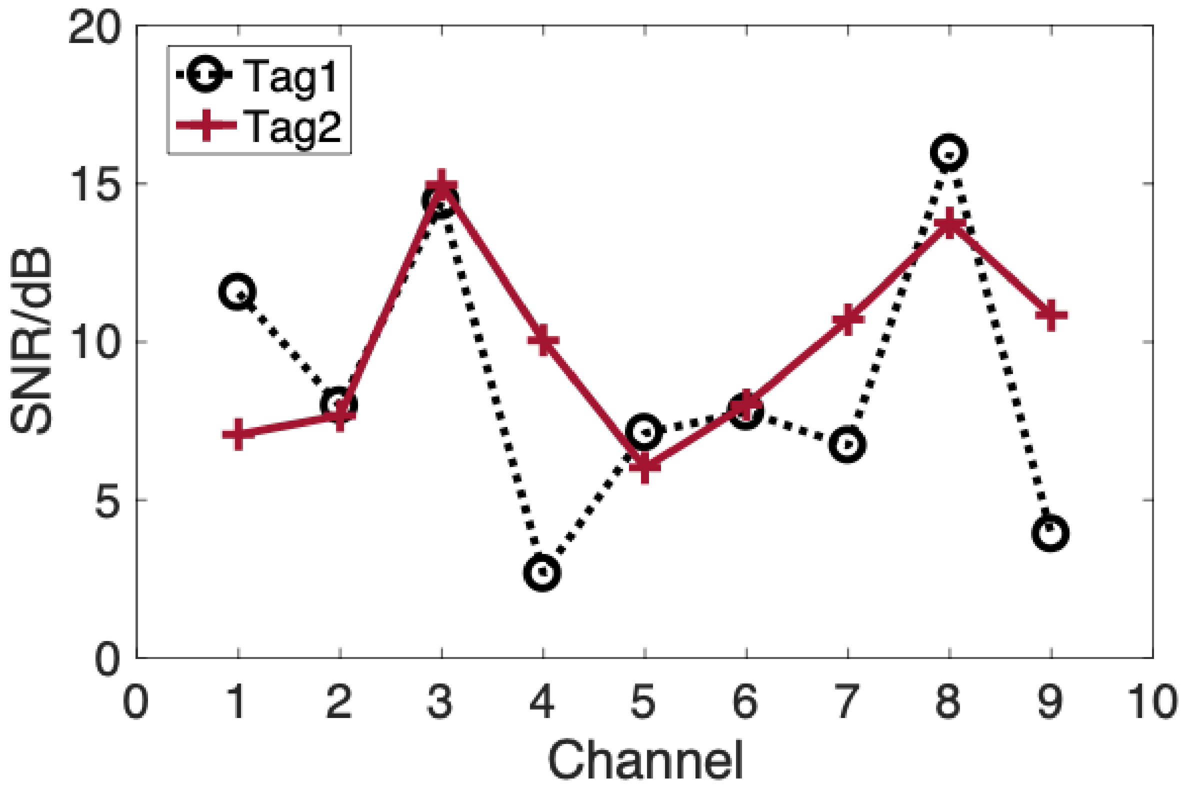
How to realize a reliable parallel decoding?

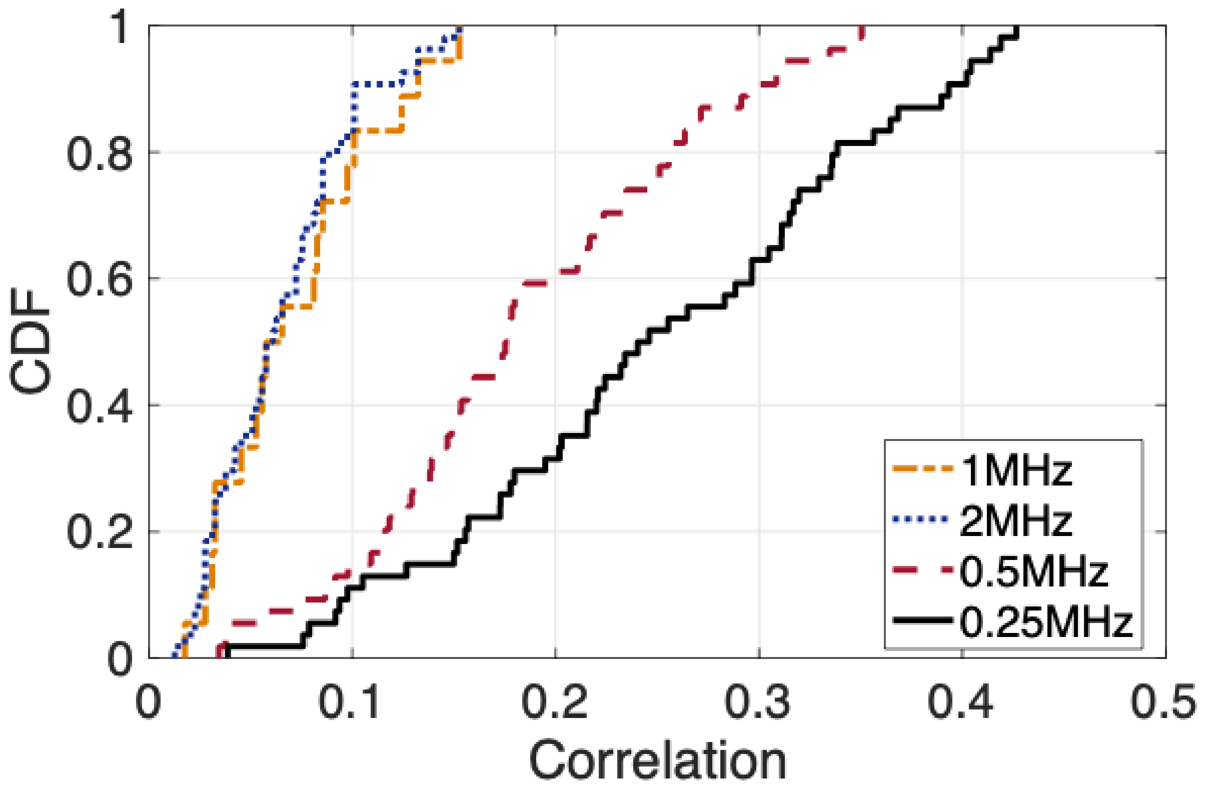


6
Tags

The superclusters caused by too many parallel tags

Observations





Different changing pattern of the SNRs

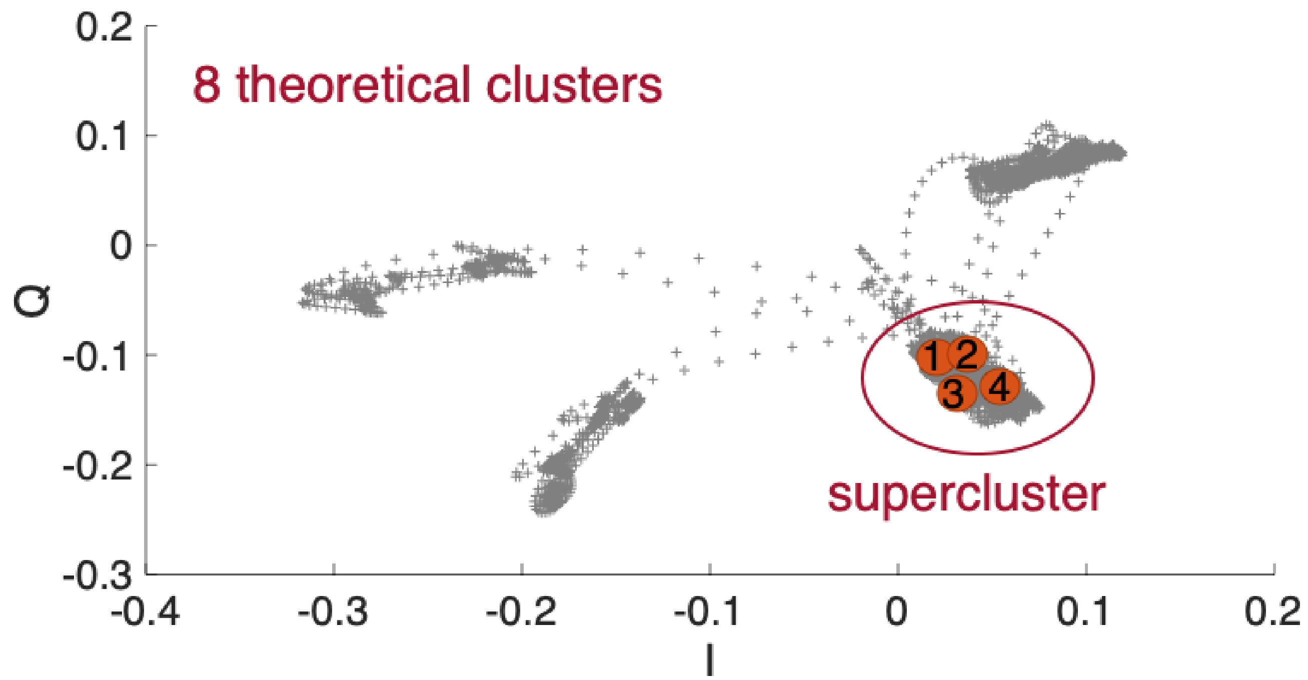
$$\rho(X,Y) = \frac{E[(X-E(X))(Y-E(Y))]}{\sigma_x \sigma_y}$$

The channel diversity of the backscatter signal

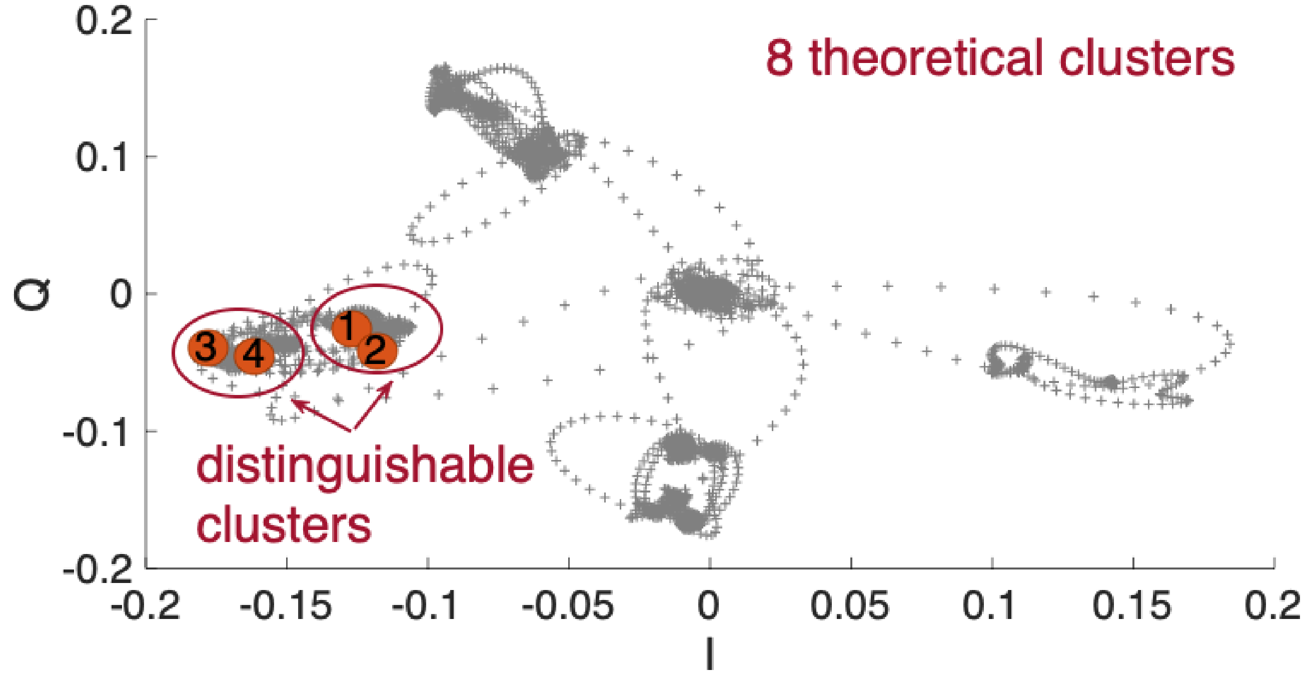
Observations

Channel Diversity

Overlapping Clusters can be separated in other channels



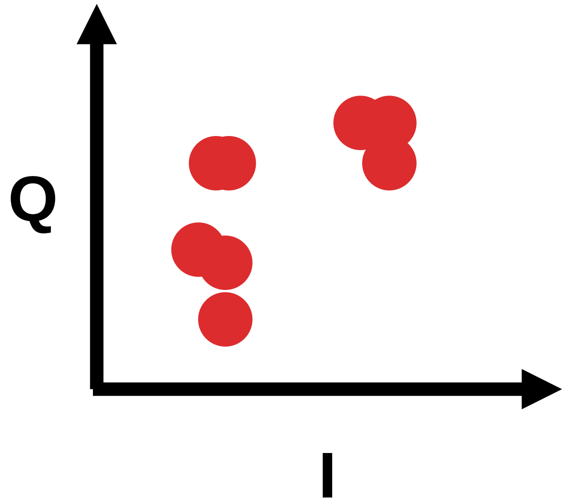
Channel-910MHz

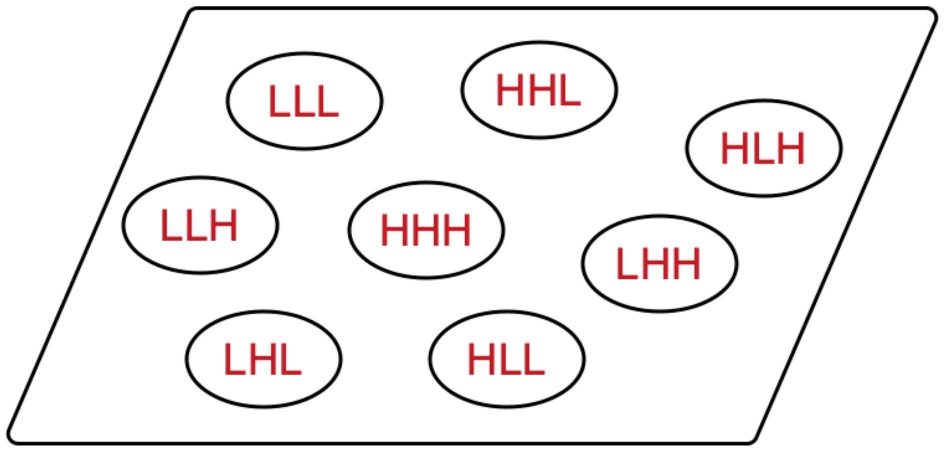


Channel-912MHz

Our Goal

Channel Diversity



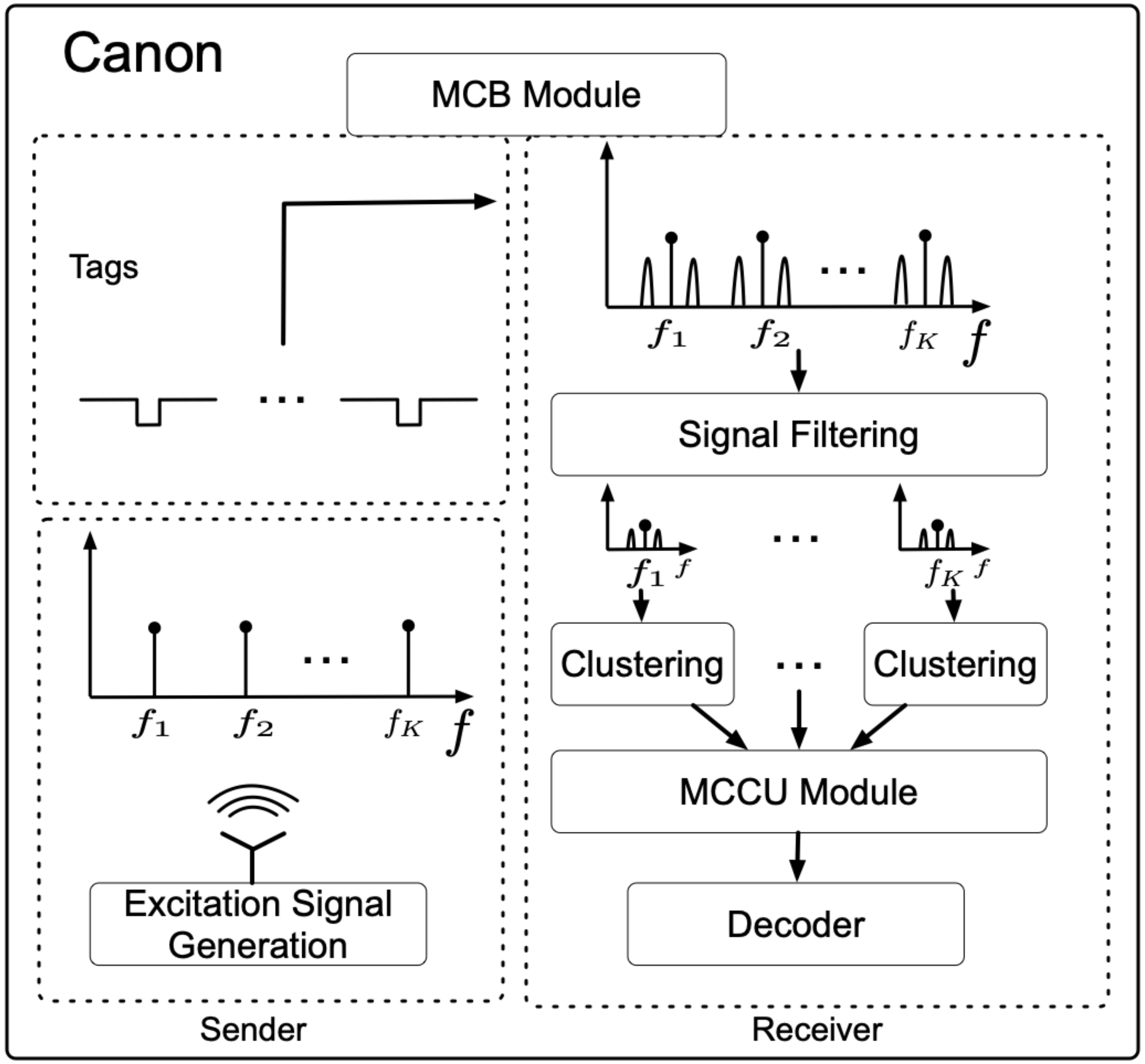


Indistinguishable Superclusters

Distinguishable Clusters for Parallel Decoding

Exploiting the Channel Diversity for Reliable Parallel Decoding of the Tags

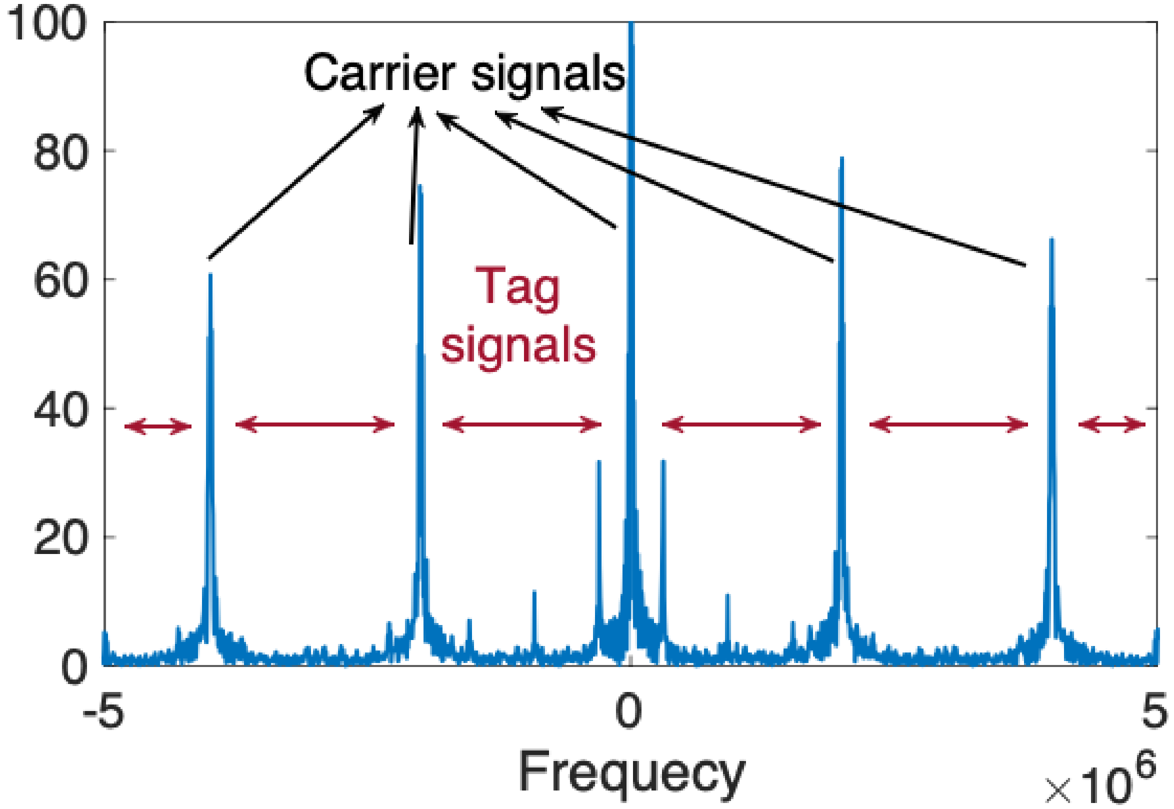
Canon

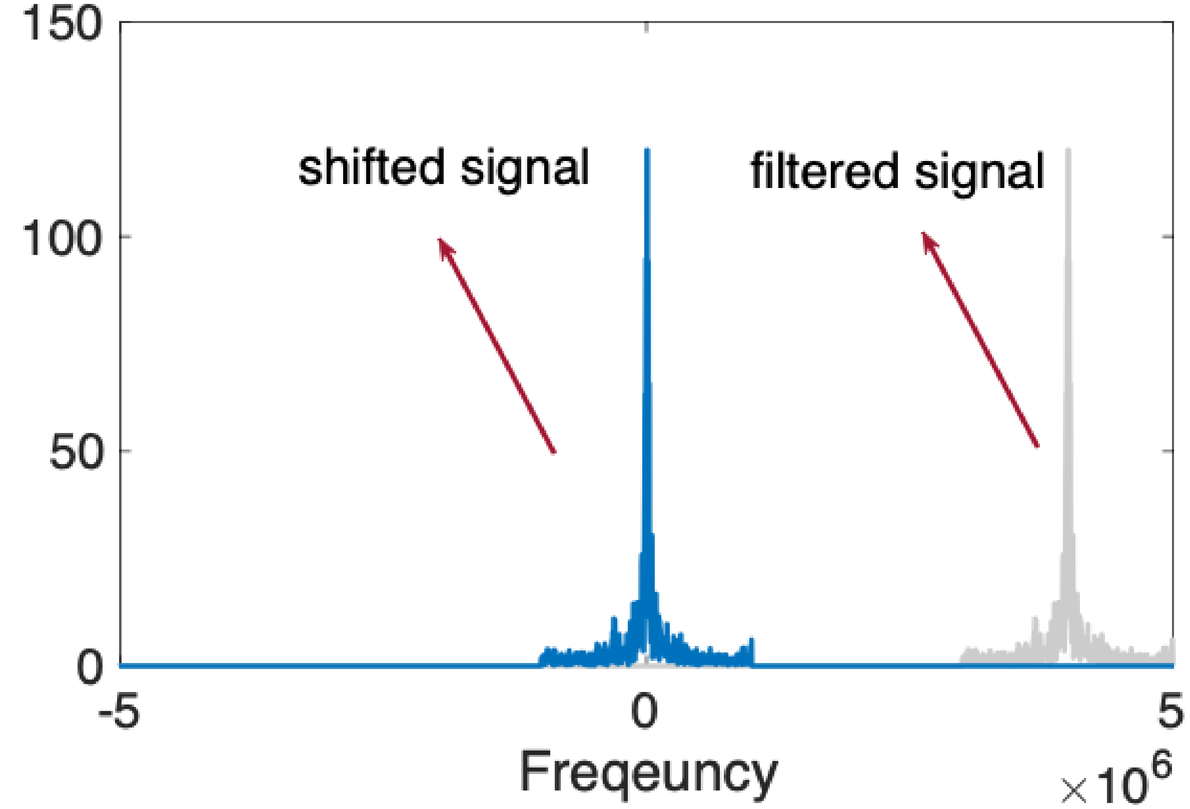


The overview of Canon

- **Multi-Carrier Backscatter (MCB)**
- **Multi-Channel Cluster Union (MCCU)**

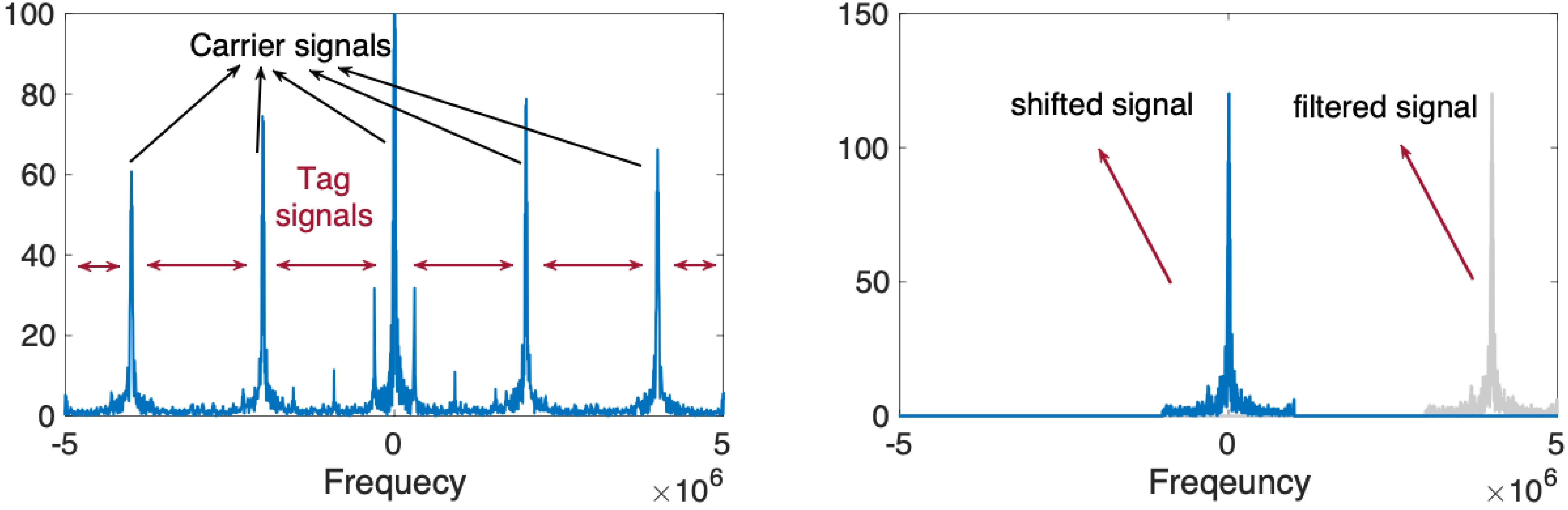
How to Generate Multi-Carrier Backscatter





$$S(t) = (e^{j2\pi f_1 t} + e^{j2\pi f_2 t} + \ldots + e^{j2\pi f_K t})e^{j2\pi f_c t}$$
$$= \sum_{i=1}^{K} e^{j2\pi (f_i + f_c)t}$$

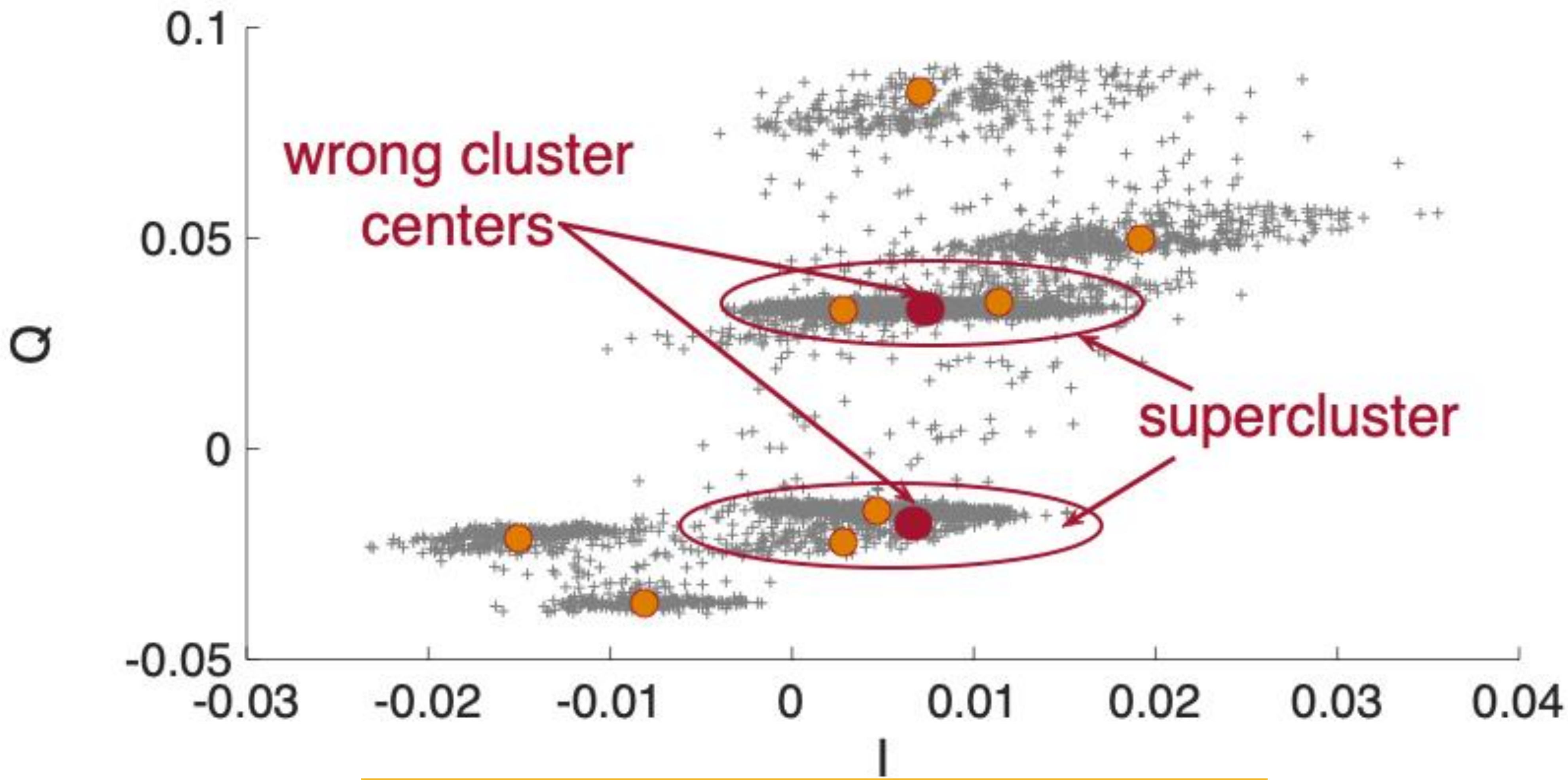
How to Generate Multi-Carrier Backscatter



- Filtering the wanted frequency band
- Shifting the frequency to the origin
- Clustering the IQ symbols

IQ Symbol Clustering

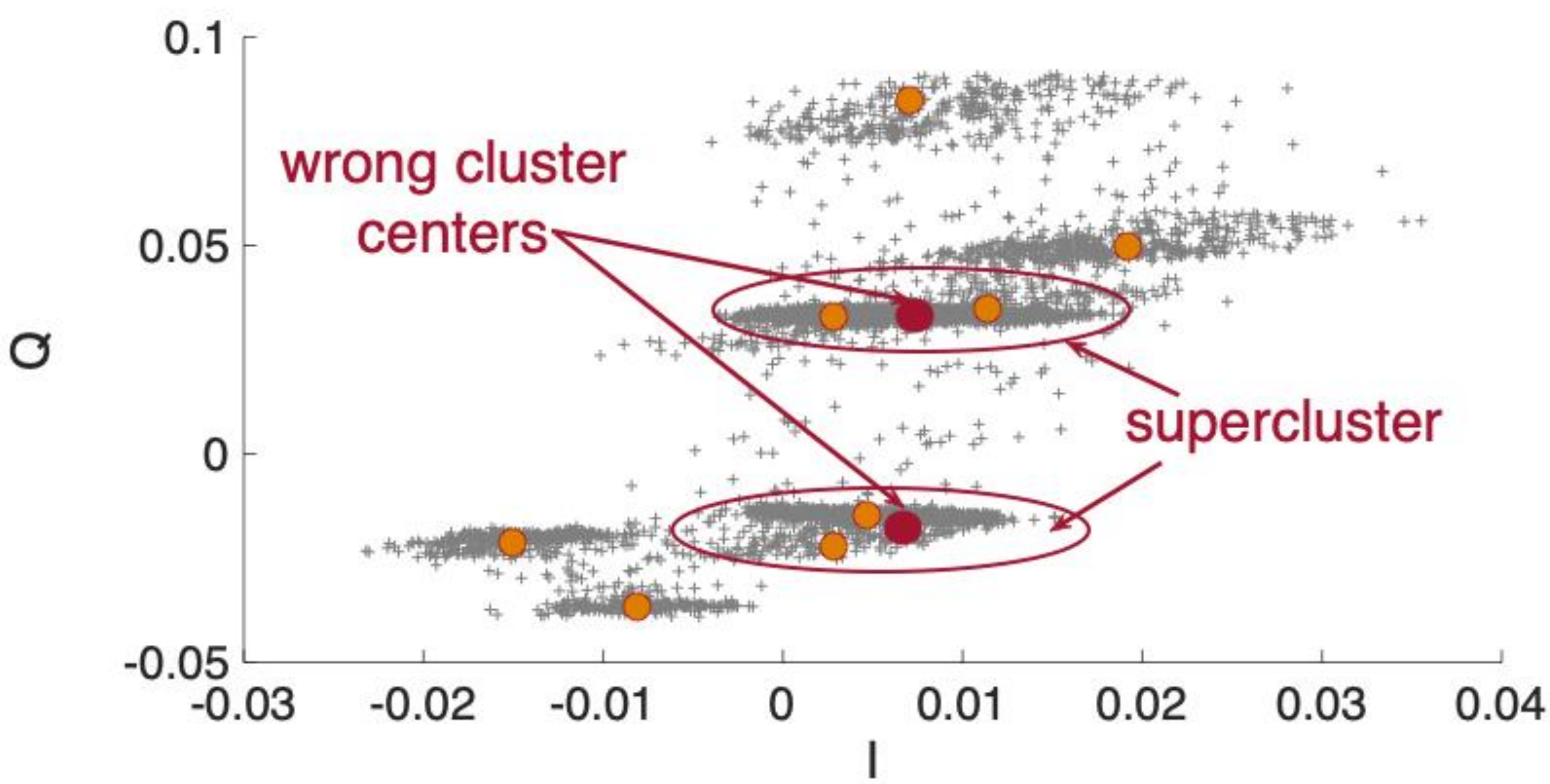
~~Only rely on the density?~~



Temporal Features of the IQ symbols

IQ Symbol Clustering

Only rely on the density?



Spatial Feature:

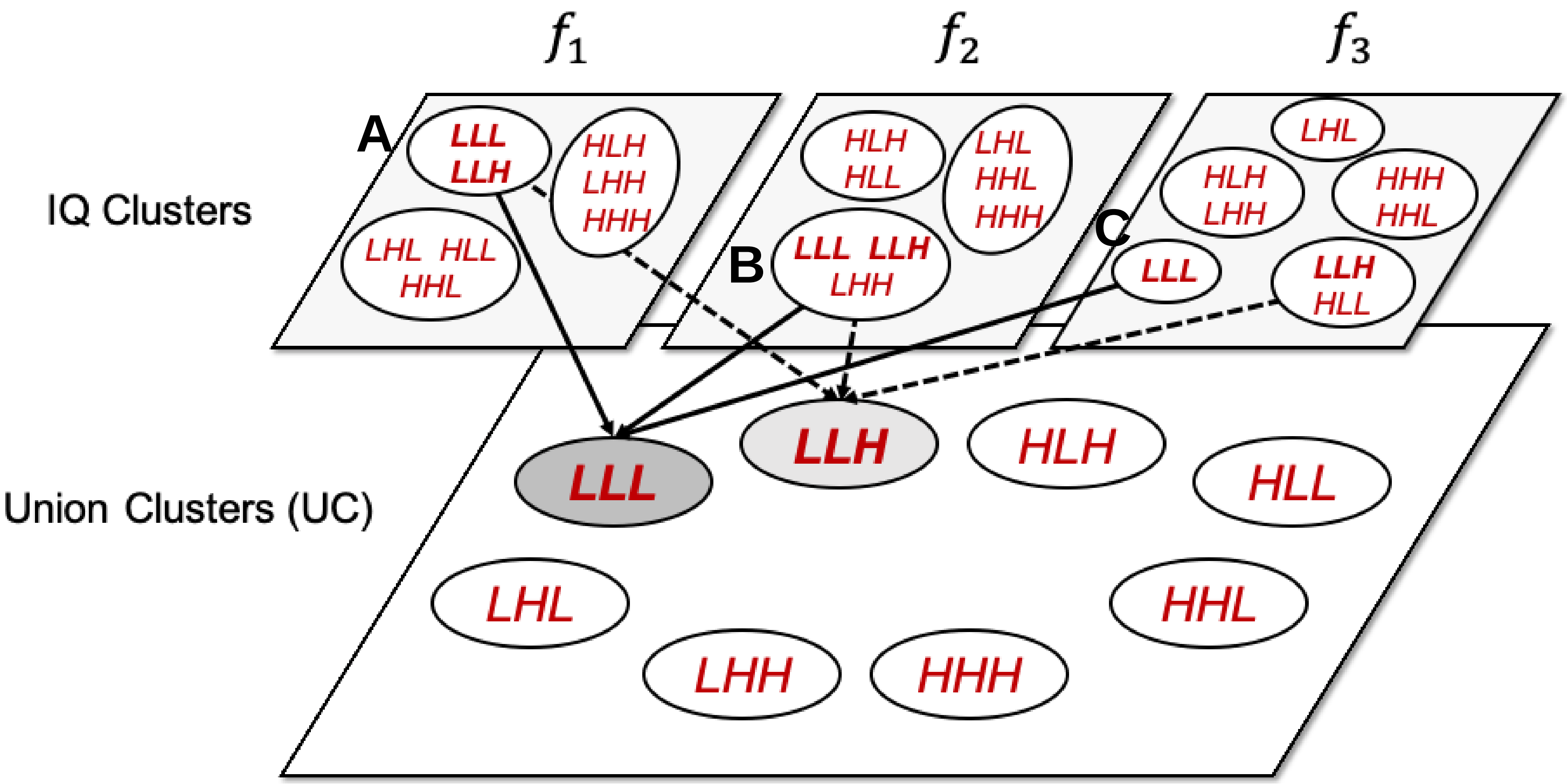
$$Td(i) = \sum_{j \in W(i)} e^{-(\frac{d_{ij}}{d_c})^2}$$

Temporal Feature:

$$Sd(i) = \sum_{j \in I_s \setminus \{i\}} e^{-(\frac{d_{ij}}{d_c})^2}$$

Multi-Channel Cluster Union

We still can't separate all clusters corresponding to each tags' state



Union Cluster (UC) ⟷ State of the tags' signals

Multi-Channel Cluster Union

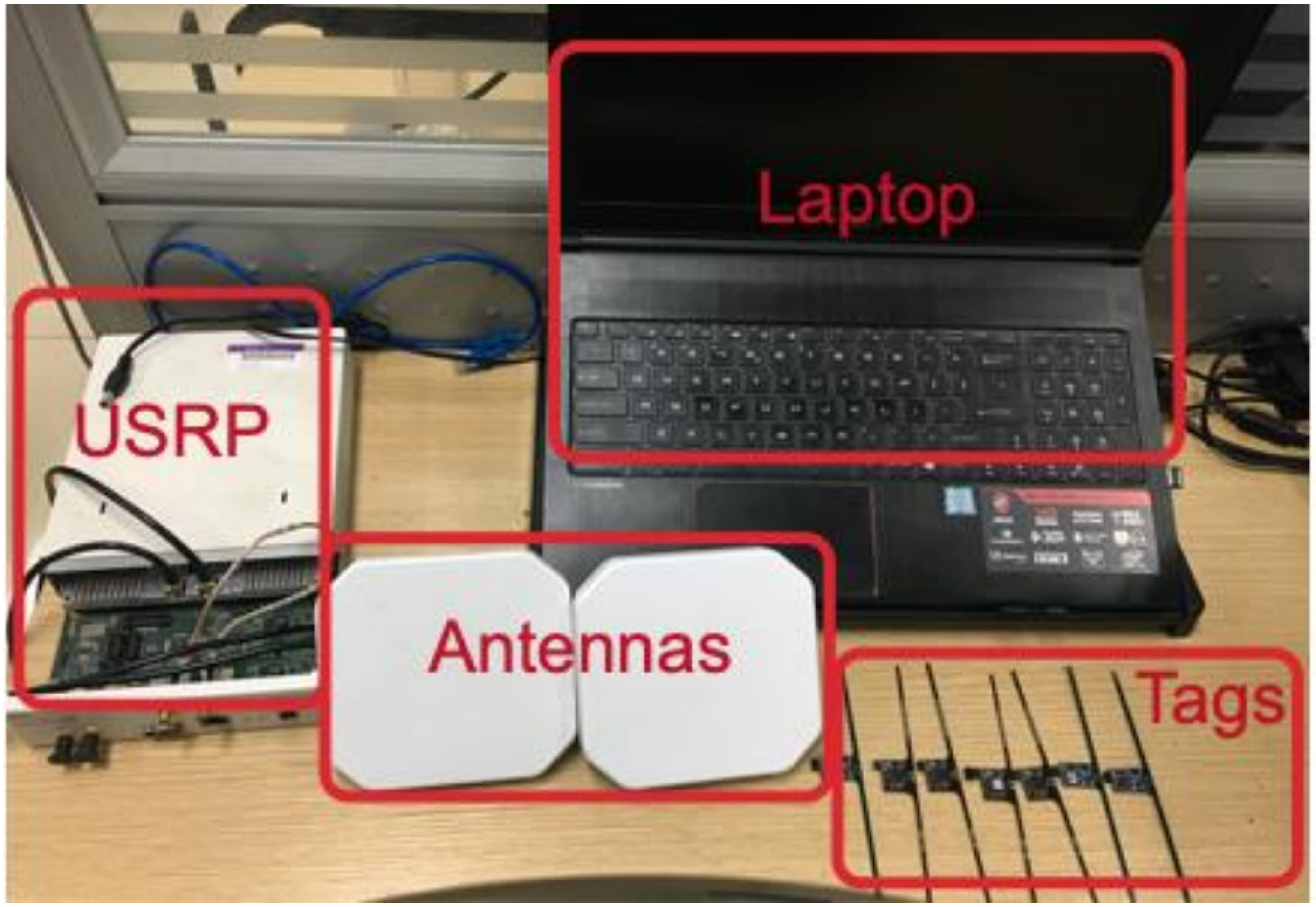
Labeling the Union Clusters

Transition Probability	LLL	LLH	LHL	HLL	LHH	HLH	HHL	HHH
LLL	0	X	X	X	X	X	X	X
LLH		0	X	X	X	X	X	X
LHL			0	X	X	X	X	X
HLL				0	X	X	X	X
LHH					0	X	X	X
HLH						0	X	X
HHL							0	X
HHH								0

The transition probability between neighbor states is much higher

Experiment Setup

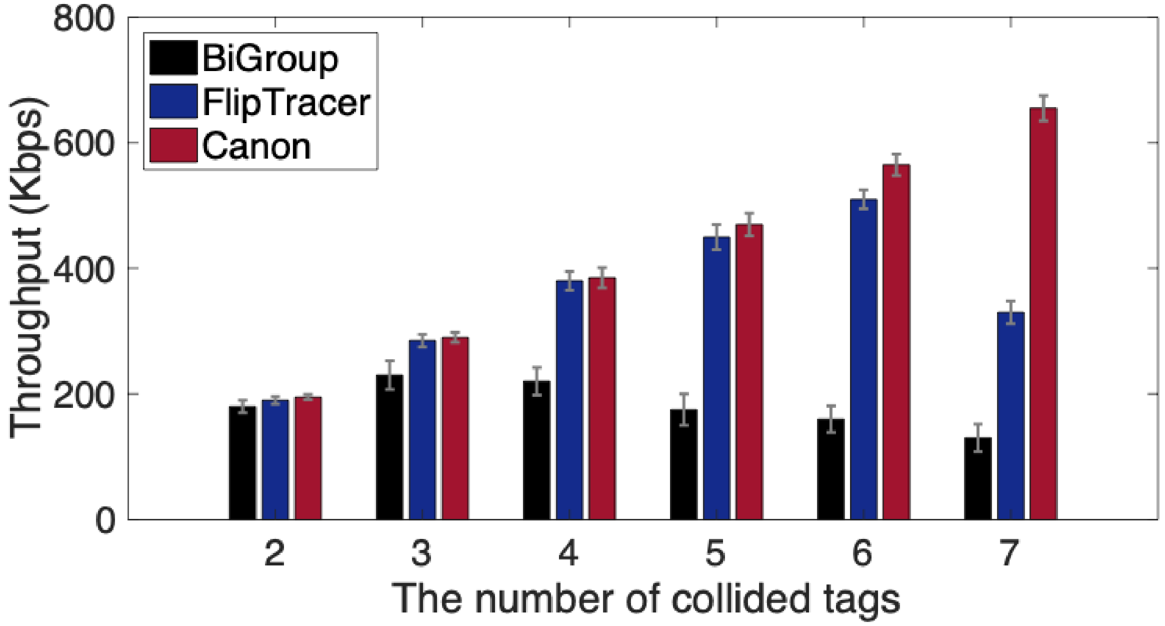
- **NI USRP N210**
- **WISP 4.1 & WISP 5.0 Tags**
- **Tx & Rx Antennas**



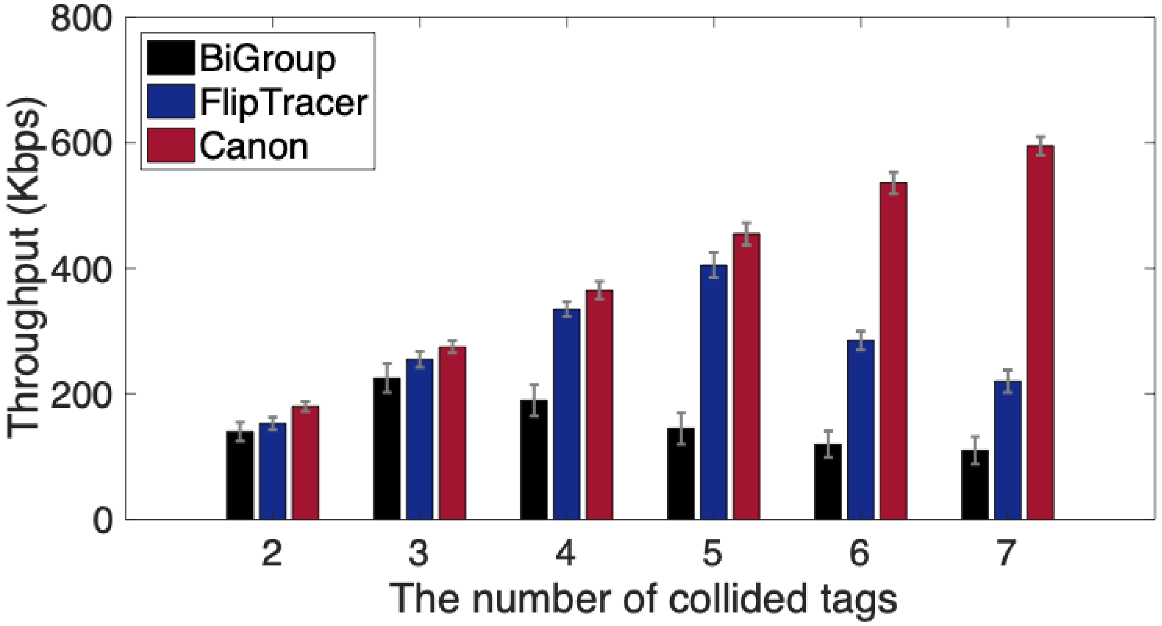
Comparison

- **BiGroup**
- **FlipTracer**
- **Canon**

Evaluation

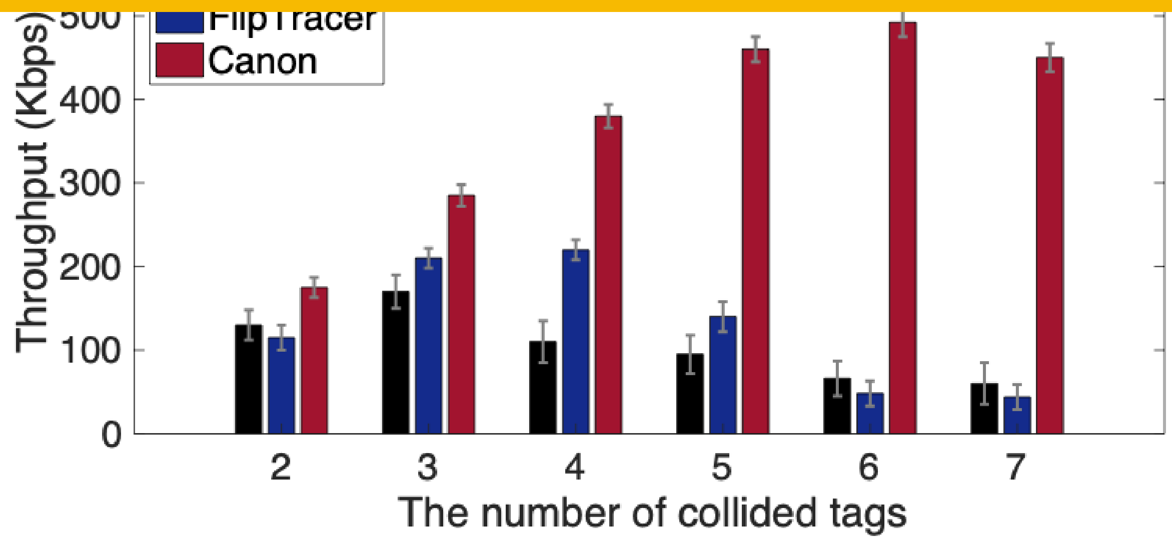


SNR = 20dB



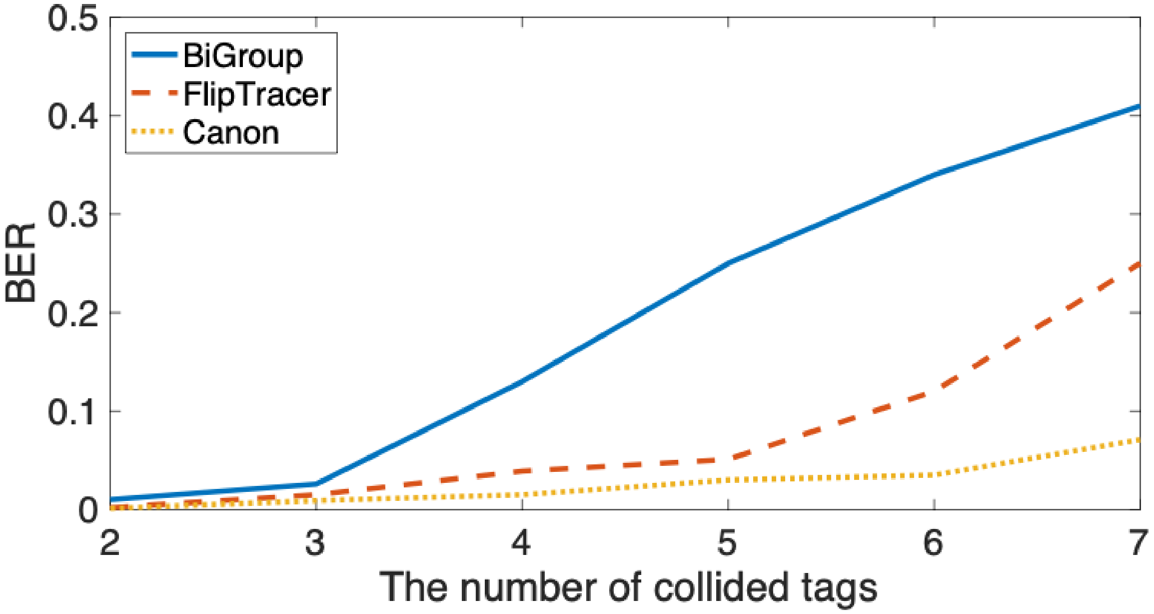
SNR = 15dB

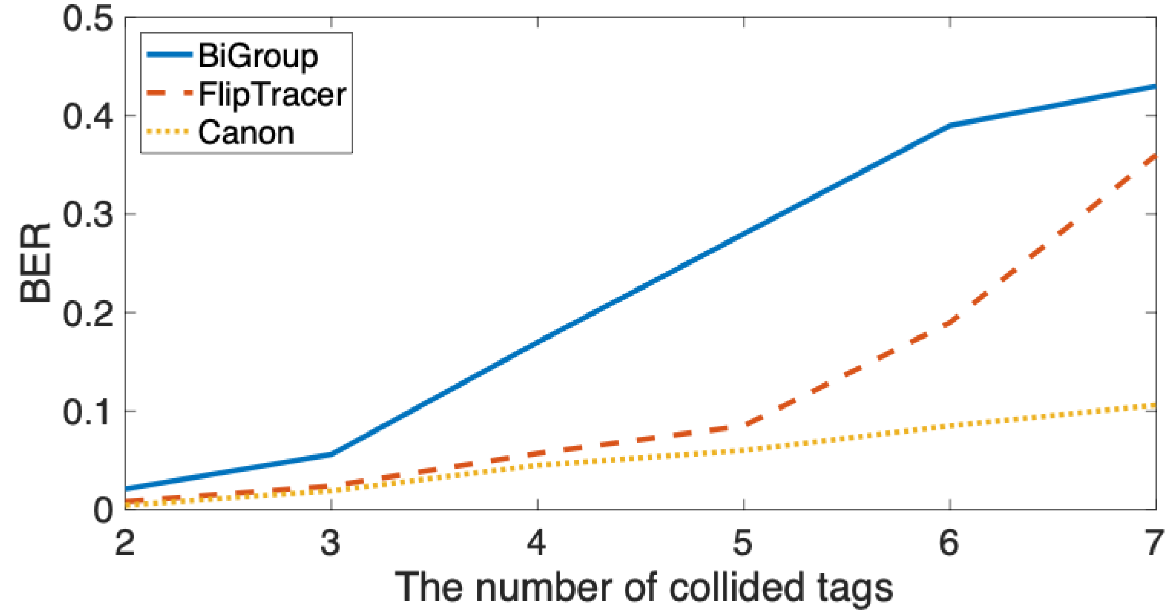
Canon has a better performance with low SNR and more collided tags



SNR = 11dB

Evaluation

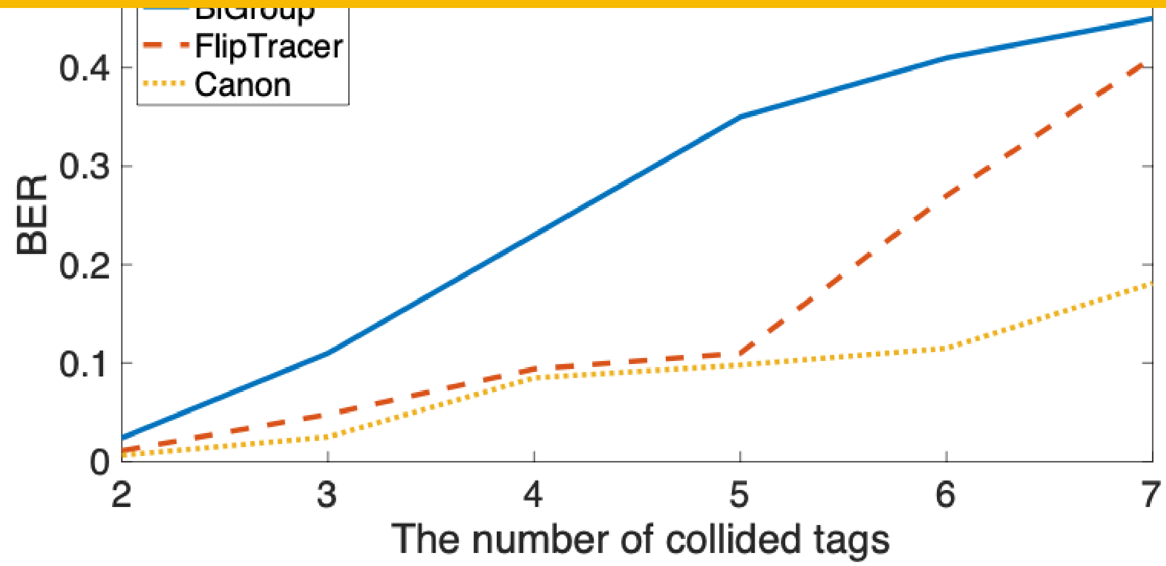




SNR = 20dB

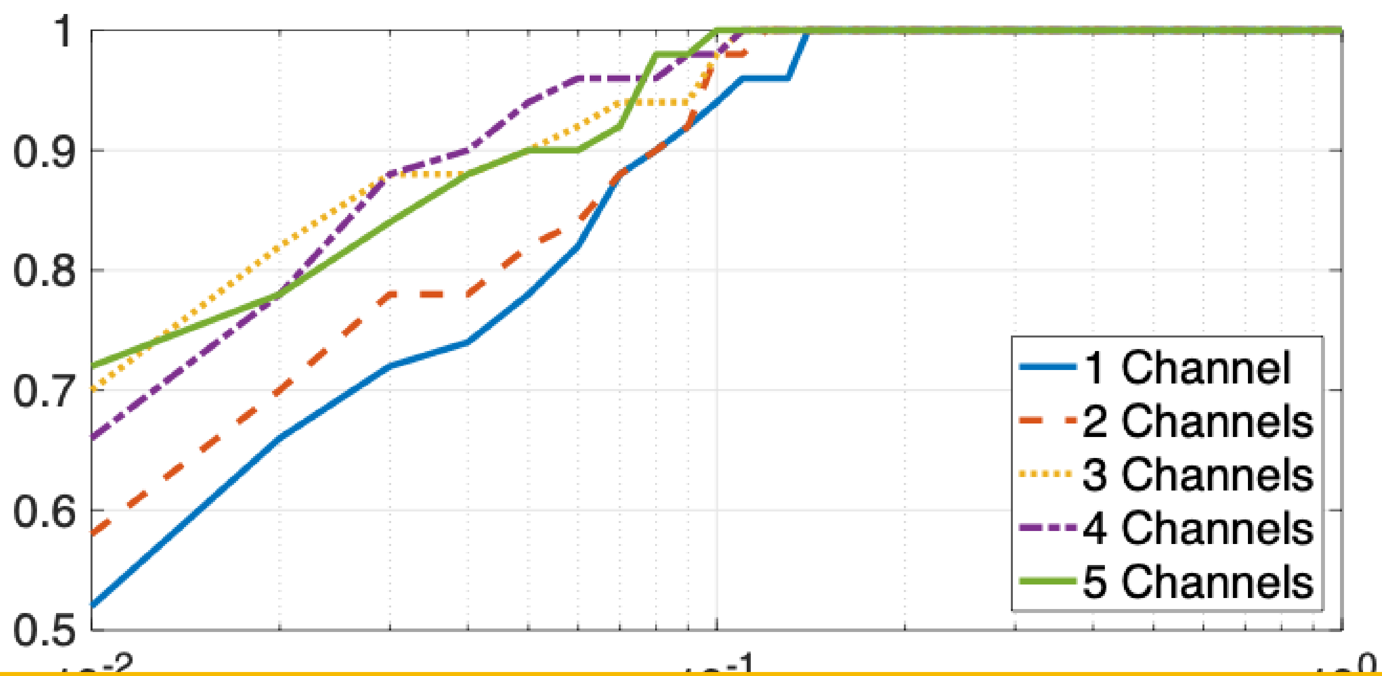
SNR = 15dB

Canon has a lowest BER with low SNR and more collided tags

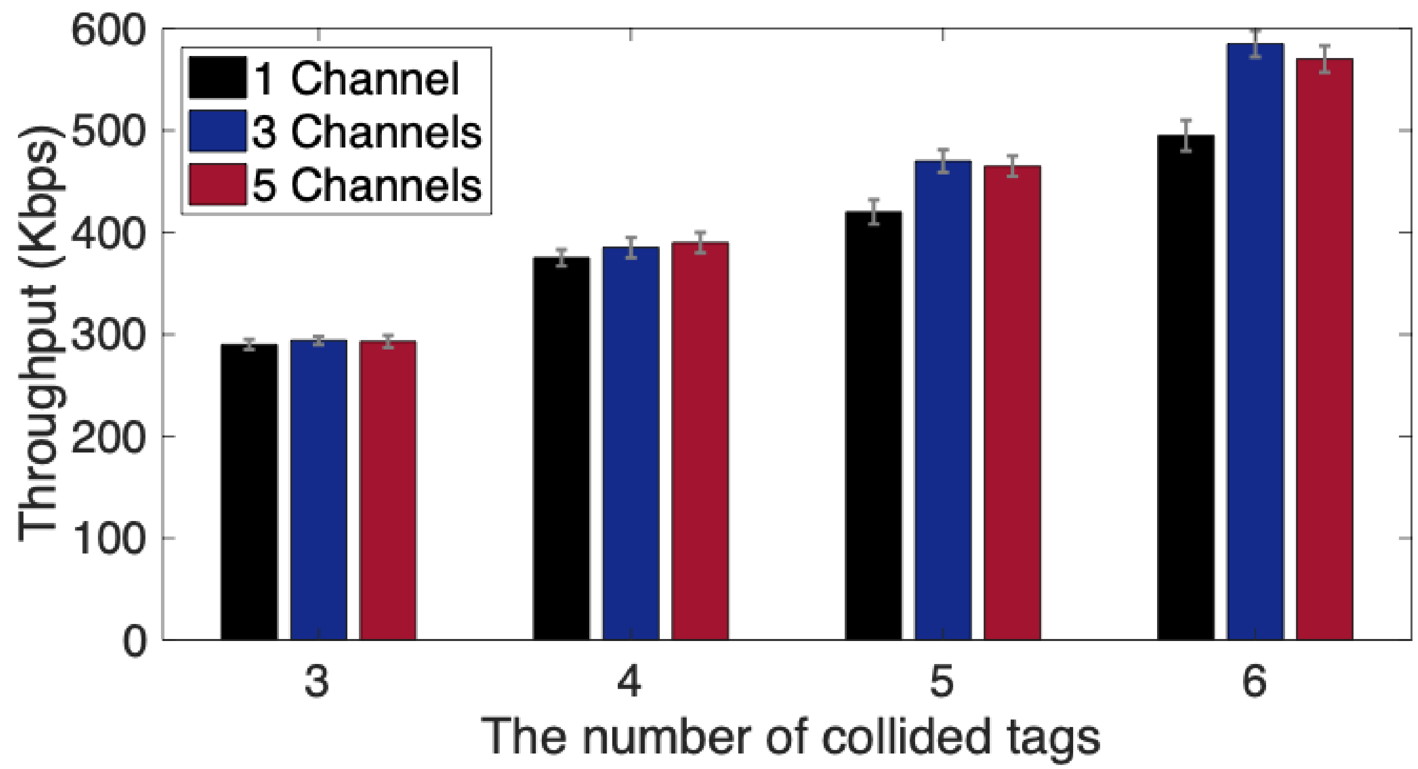


SNR = 11dB

Evaluation

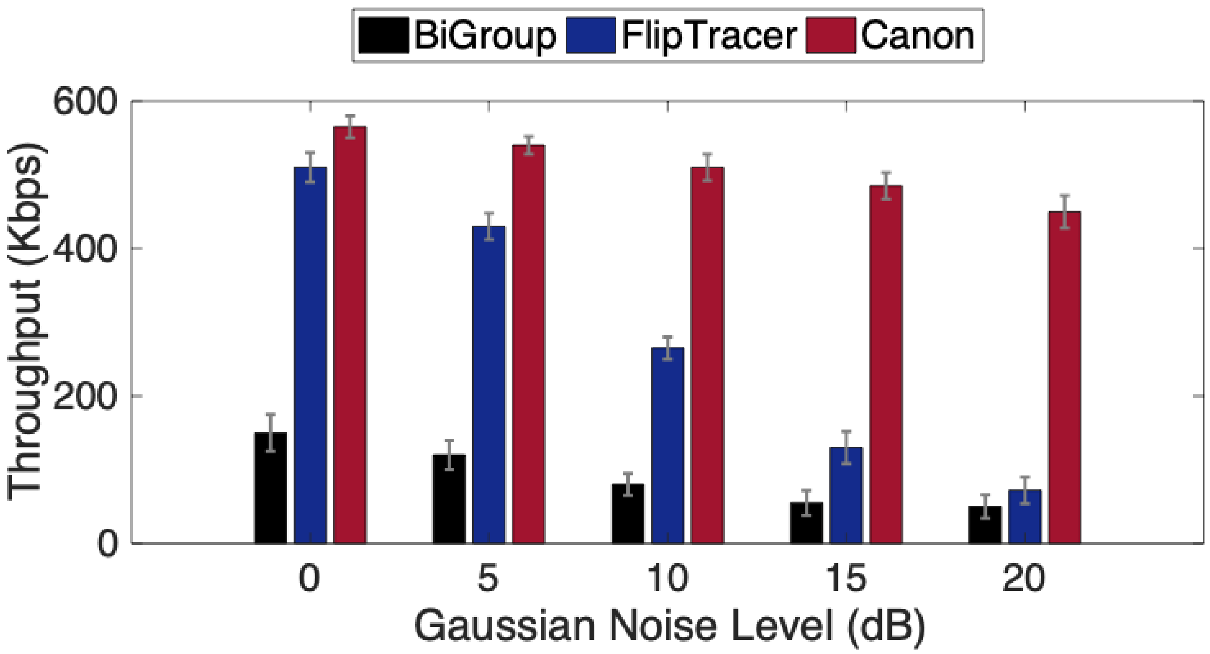


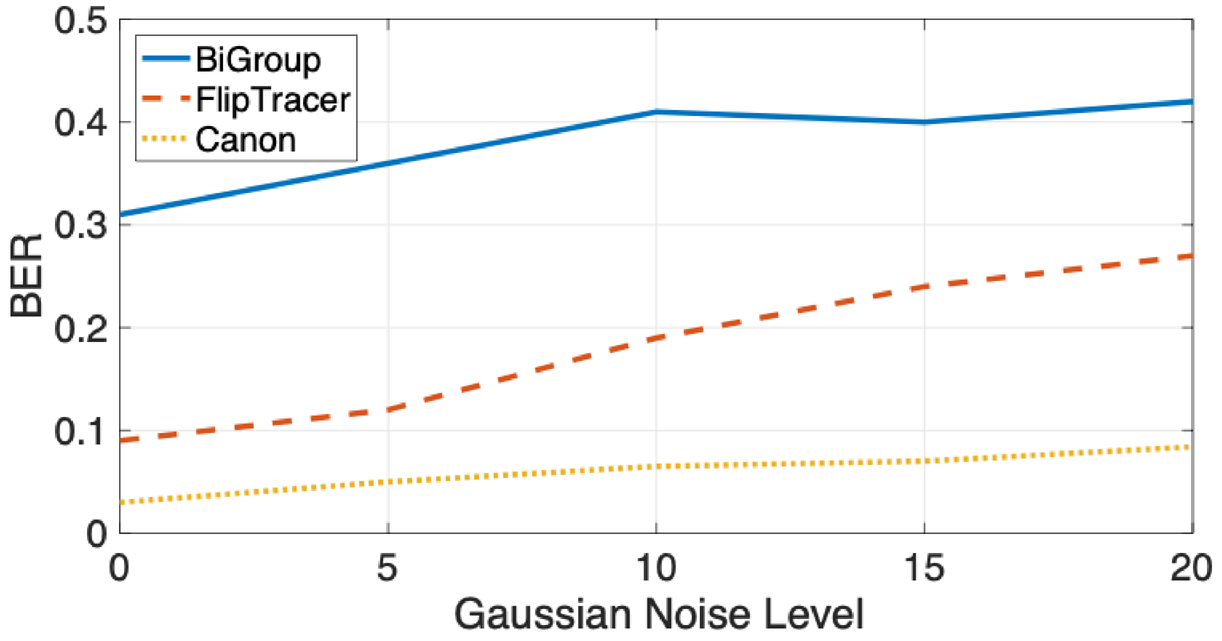
3 Channels will be enough for less than 6 tags



Evaluation

Performance under different environment noises





Canon can achieve highest performance and lowest BER under noisy environment

Conclusion

- We find the IQ clusters could be indistinguishable in practical scenarios.
- We design a reliable parallel decoding system that exploits the information from multiple channels.

Thank you !

Q&A