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BEIJING INSTITUTE OF TECHNOLOGY

Orthcatter: High-throughput In-band OFDM Backscatter with Over-the-Air Code Division

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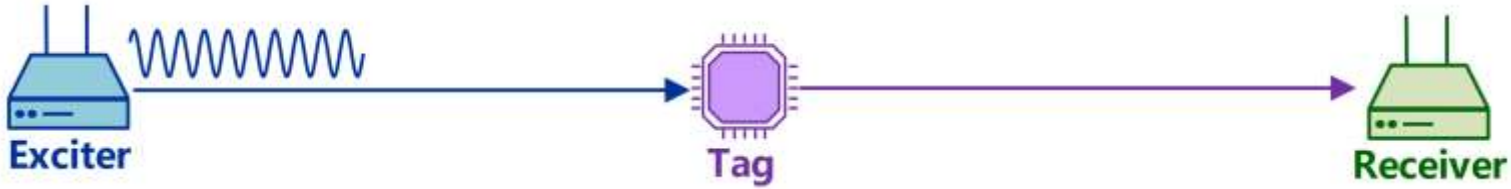
OFDM backscatter communication

☐ Ambient backscatter:

- Utilize the existing exciters for passive communication
- Play an important role in future wireless applications



OFDM backscatter communication

Side-band backscatter system

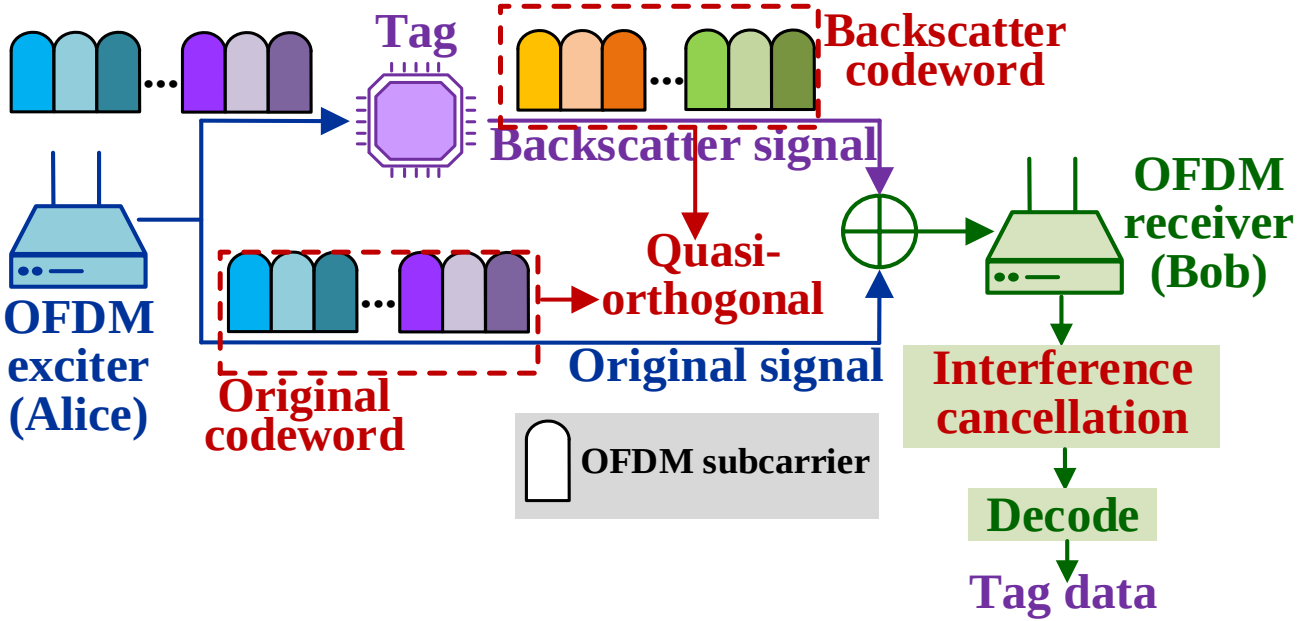
Technology	High throughput	Little spectrum occupation	Single receiver
Lscatter	✓	✗	✗
SyncScatter	✓	✗	✗
HitchHike	✓	✗	✗
STScatter	✓	✗	✓
RapidRider	✓	✗	✗
TScatter	✓	✗	✗

In-band backscatter system

Technology	High throughput	Little spectrum occupation	Single receiver
WiFi Backscatter	✗	✓	✓
WiTAG	✗	✓	✓
Study in [22][23]	✗	✓	✓
Orthcatter	✓	✓	✓

Due to the trade-off between less spectrum occupation and higher throughput, no existing work except Orthcatter satisfies the design requirement.

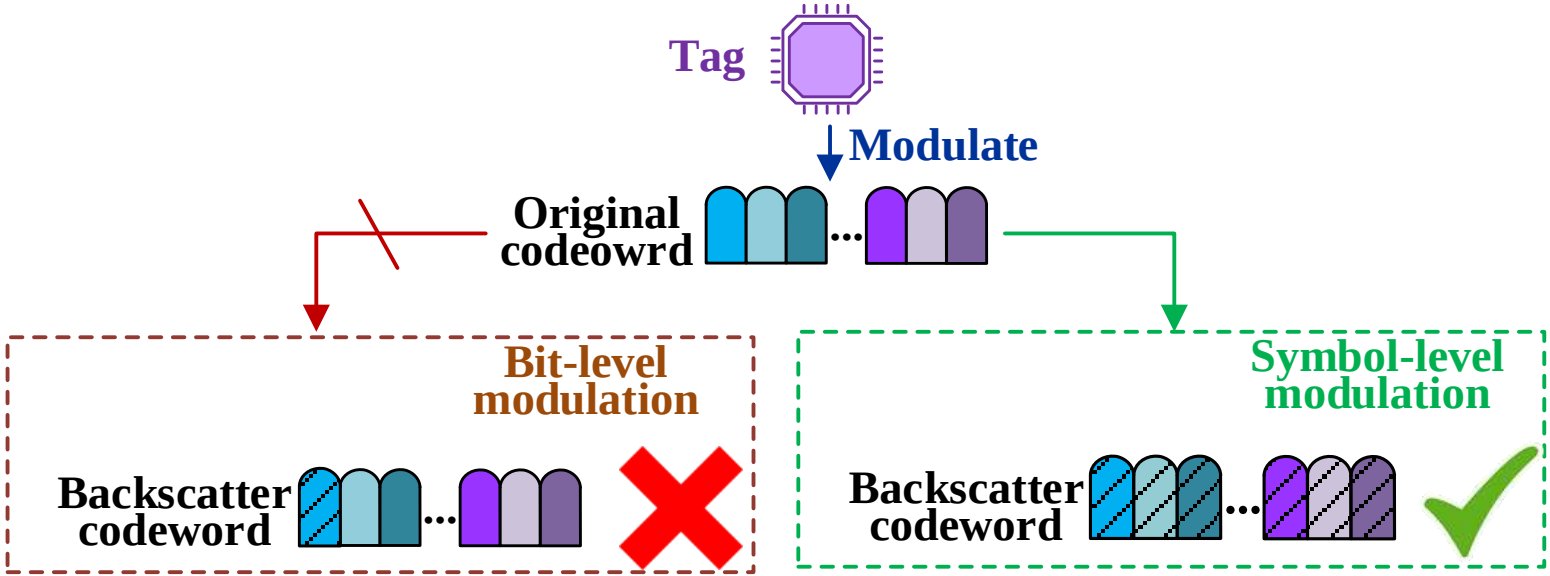
Overview



- Tag makes the original and backscatter codewords quasi-orthogonal, enabling the interference cancellation.
- Bob extracts the backscatter signal from the suppression signal, decoding tag data under much smaller interference.

Design challenge

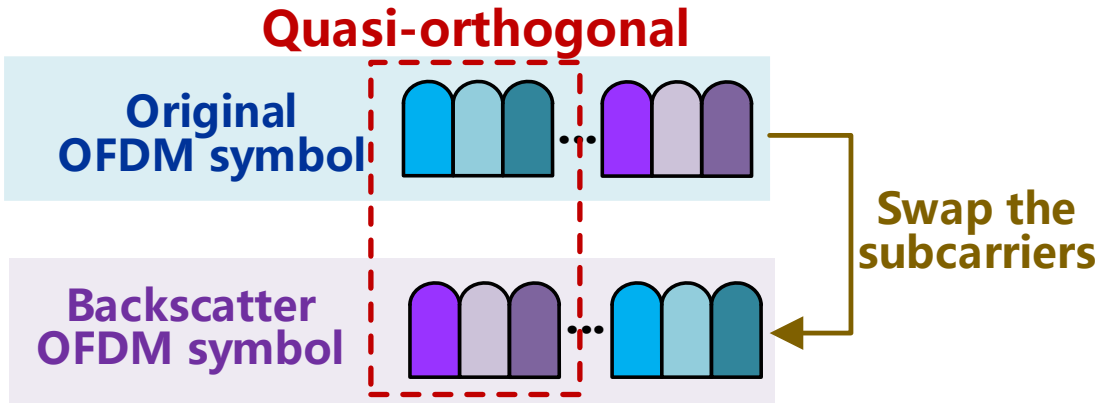
- **C1: How to design the quasi-orthogonal codewords utilized for backscattering?**



Tag cannot modify each bit of the excitation data to create the quasi-orthogonal backscatter codewords

Design challenge

➢ **C2: How to passively generate the backscatter codewords?**



- Tag need to swap the subcarriers to make the halves of the original and backscatter symbol quasi-orthogonal.
- Tag must embed its data at half-symbol level.

Design challenge

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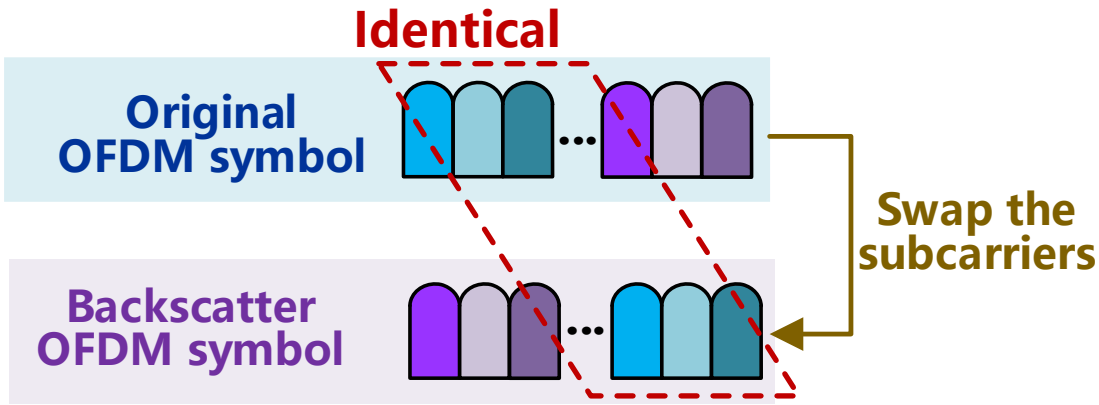

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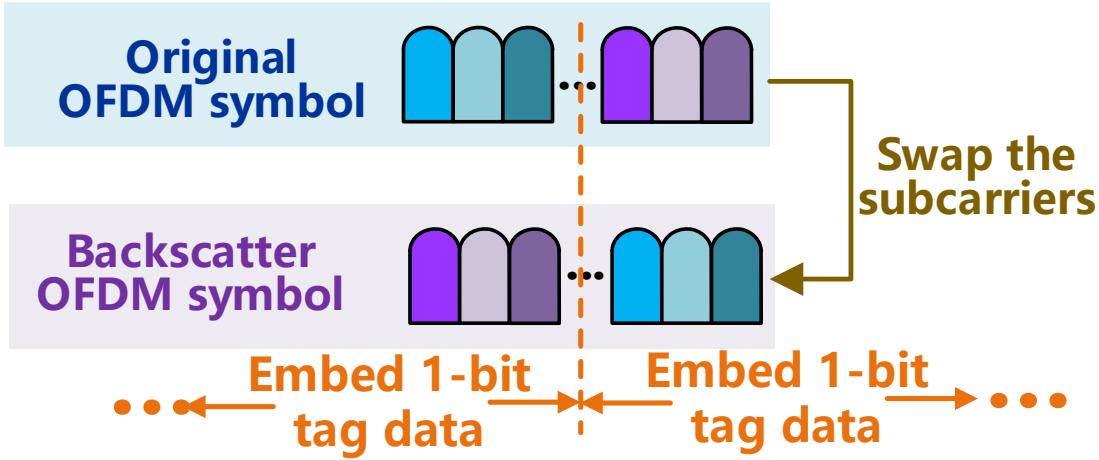

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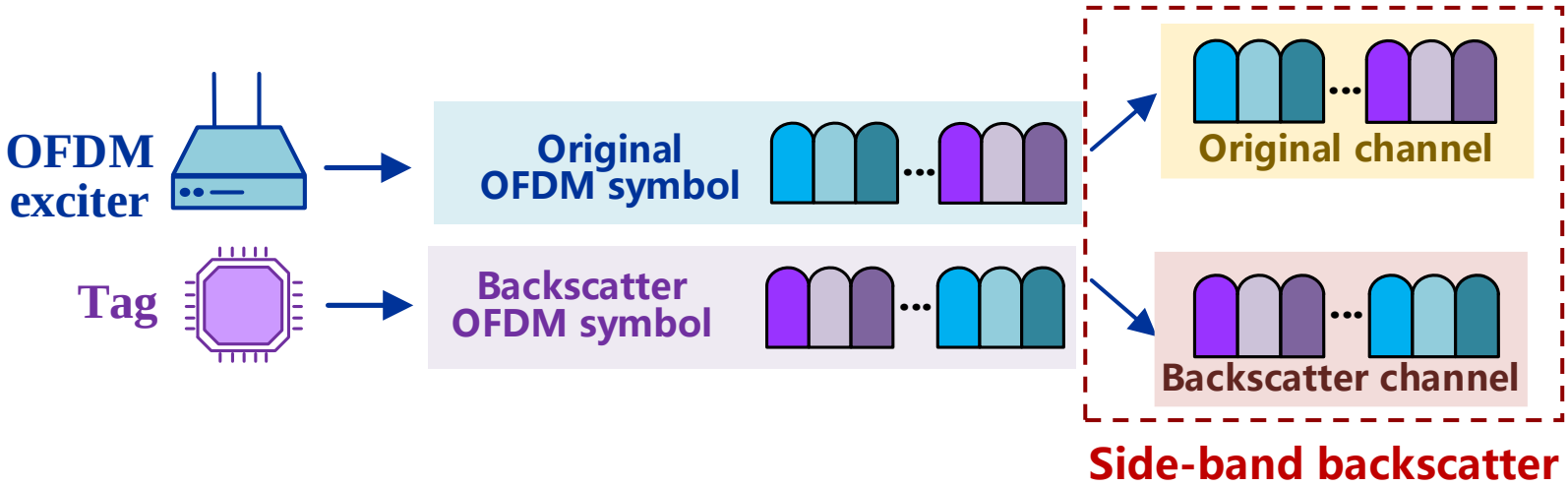
Design challenge

➢ **C3: How to cope with the interference from the original signal?**



Unlike the side-band backscatter works, the backscatter signals in Orthcatter falls in the original channel, and thereby significantly interfered with by the original signal.

Design challenge

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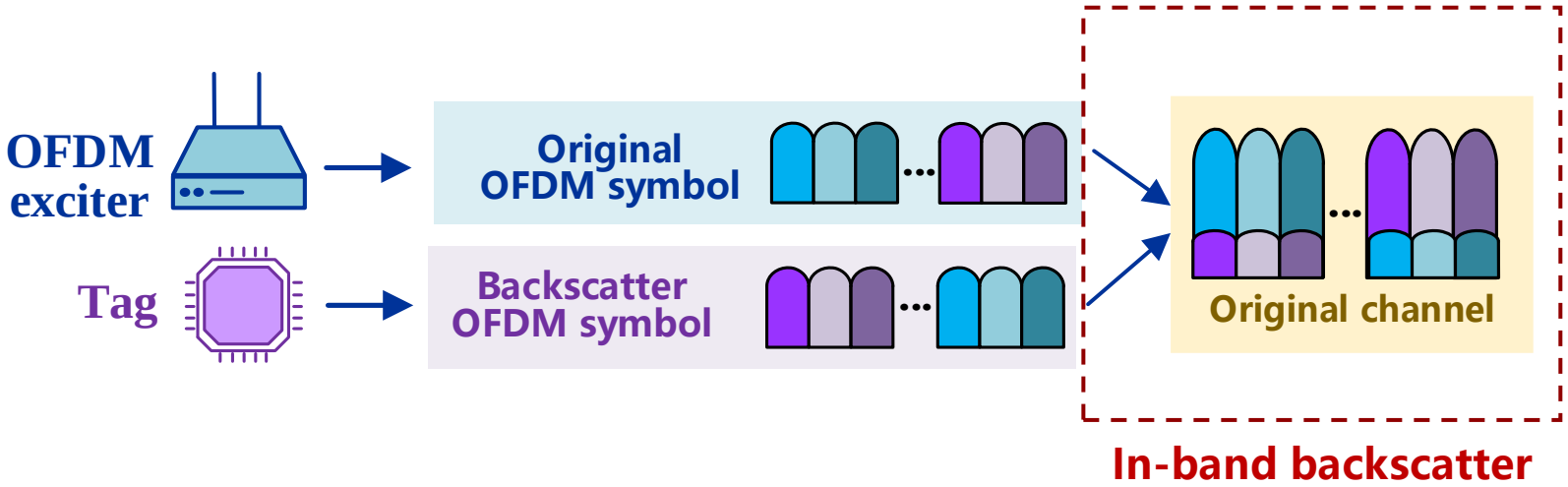

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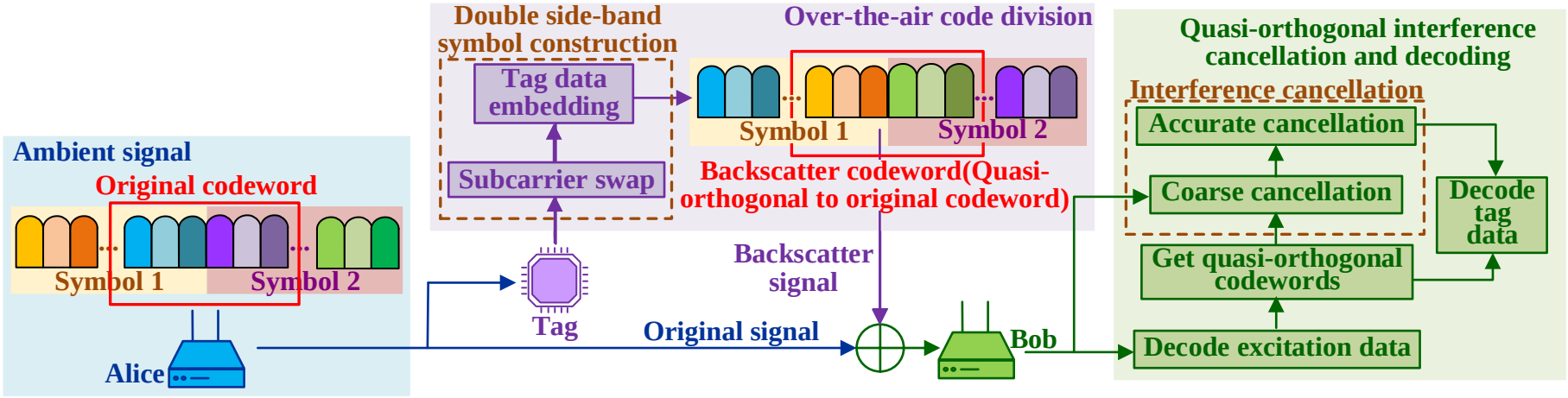
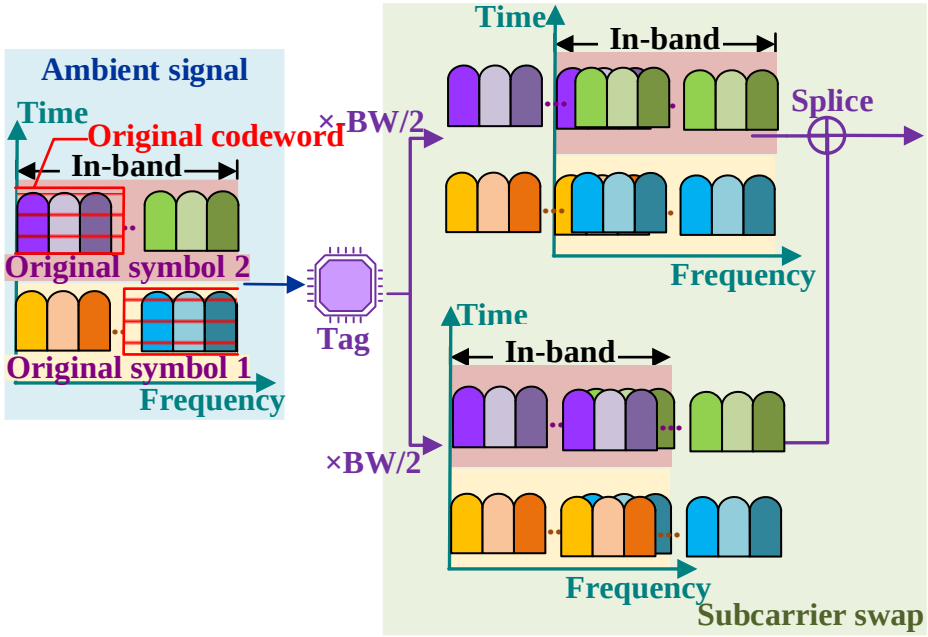
Design Overview

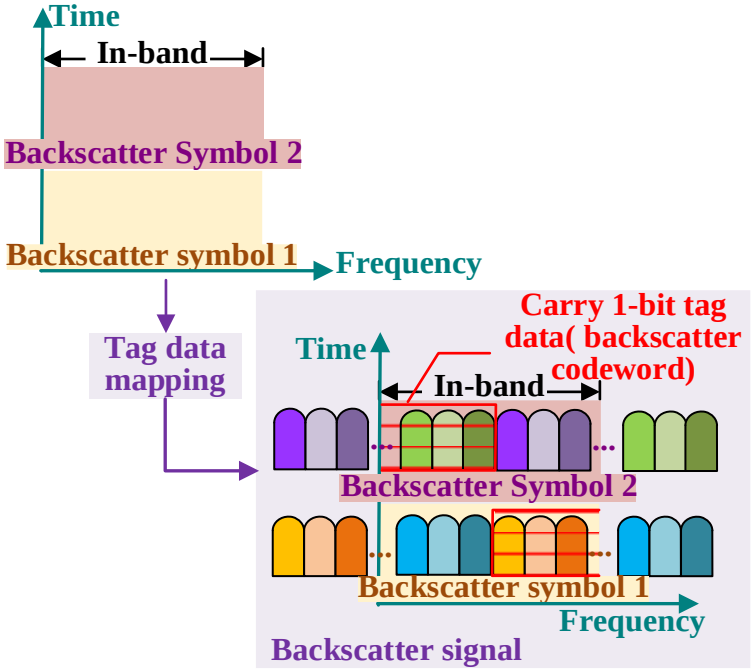


➢ Technical contributions

- Over-the-air code division
- Double side-band symbol construction
- Quasi-orthogonal interference cancellation and decoding

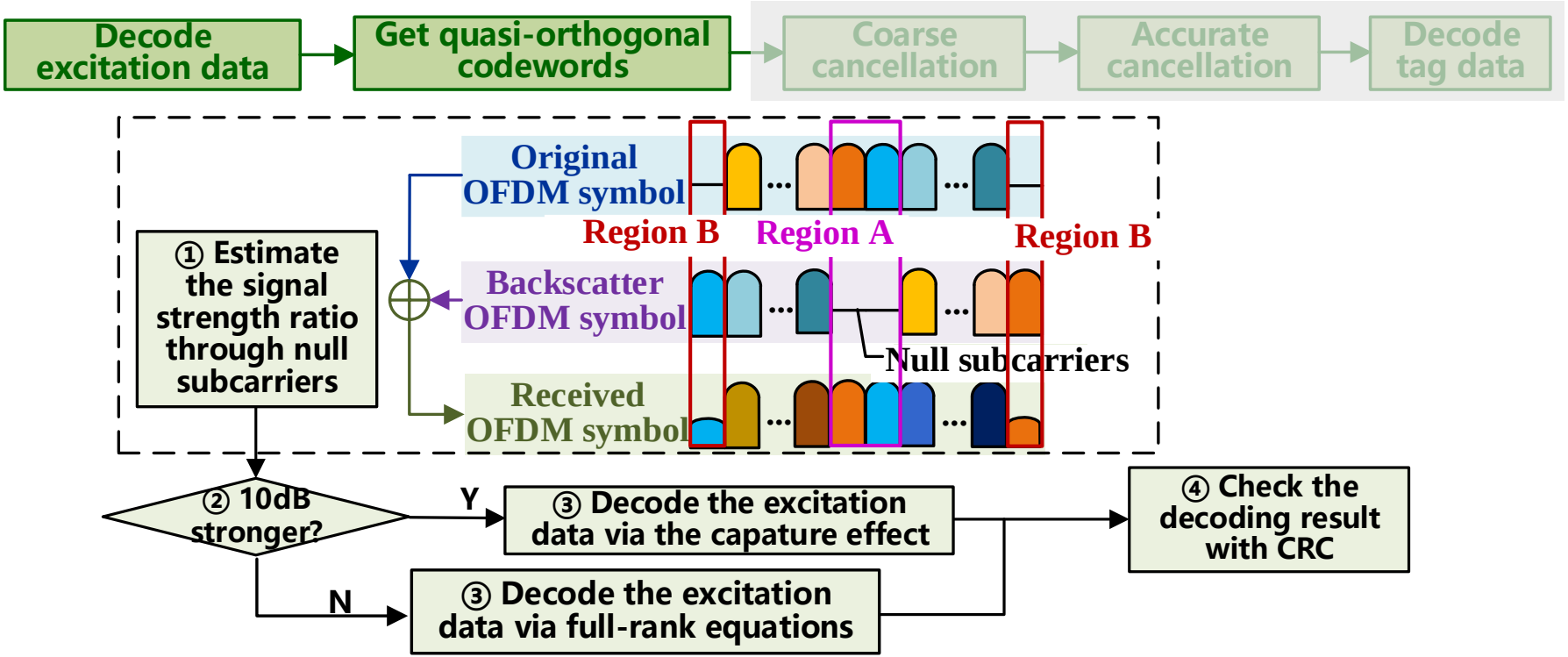
Modulation





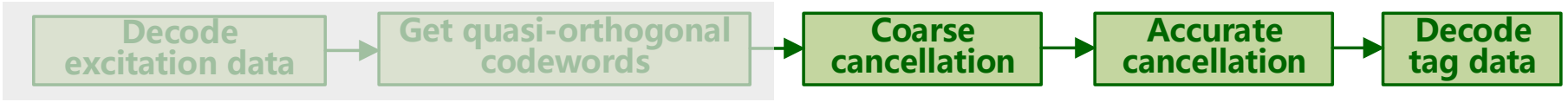
- Reverse the order of the first and second half of each OFDM symbol.
- Piece the second half of the first symbol, and the first half of the second symbol, to form the backscatter codeword.

Demodulation



Get quasi-orthogonal codewords under either big or small excitation signal

Demodulation



① **Coarse cancellation:** Reconstruct the received original signal with the quasi-orthogonal codewords

Decrease the convergence time

② **Accurate cancellation:** Reconstruct the original signal based on the adaptive filtering algorithm

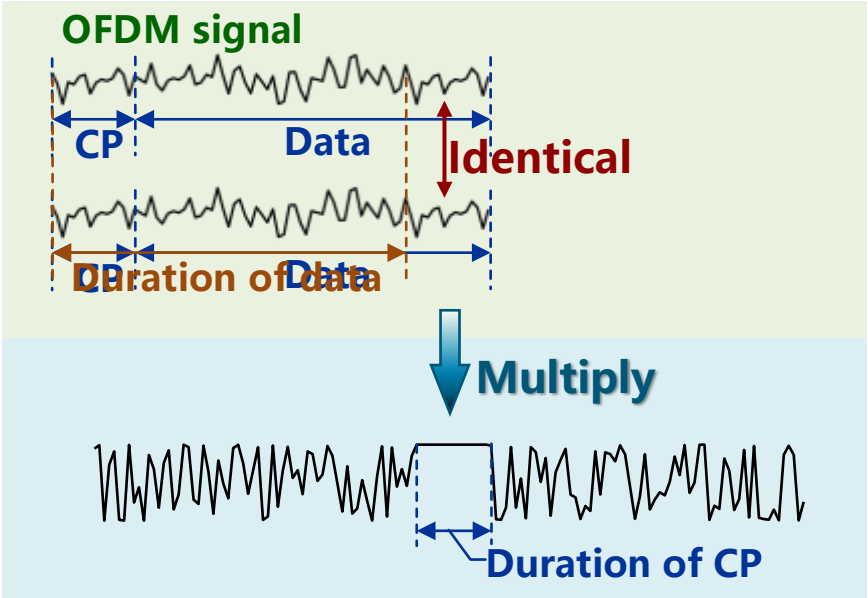
Decrease the remaining original signal due to frequency selective fading

③ **Decoding:** Decode the tag data with the interference cancellation result and backscatter codewords

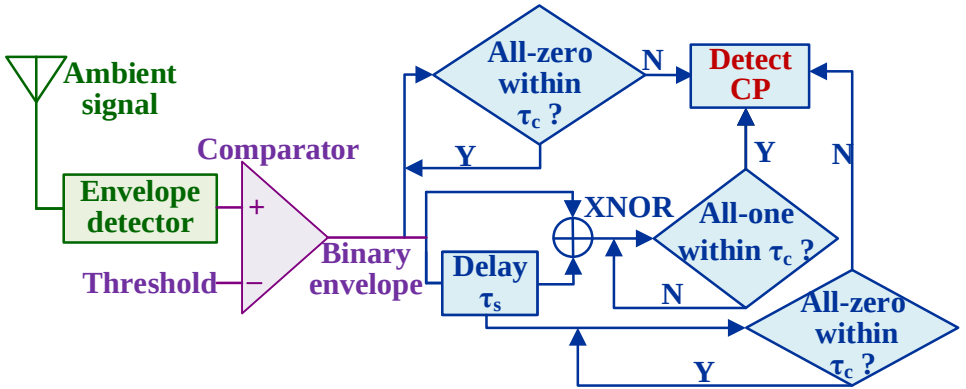
Get quasi-orthogonal codewords under either big or small excitation signal

Implementation

➢ **Challenge:** How to improve the synchronization distance?



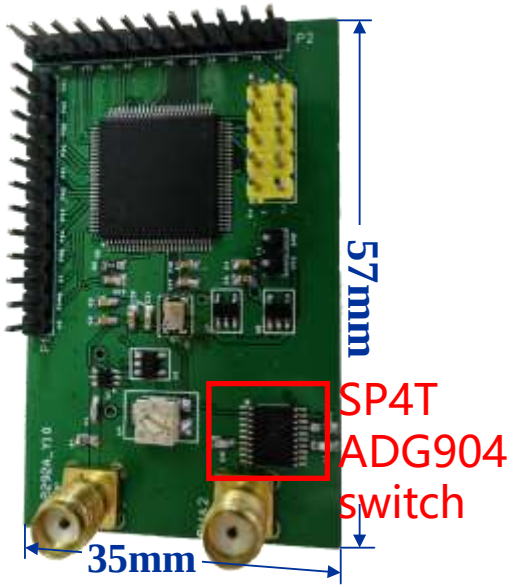
➢ **Proposed scheme**

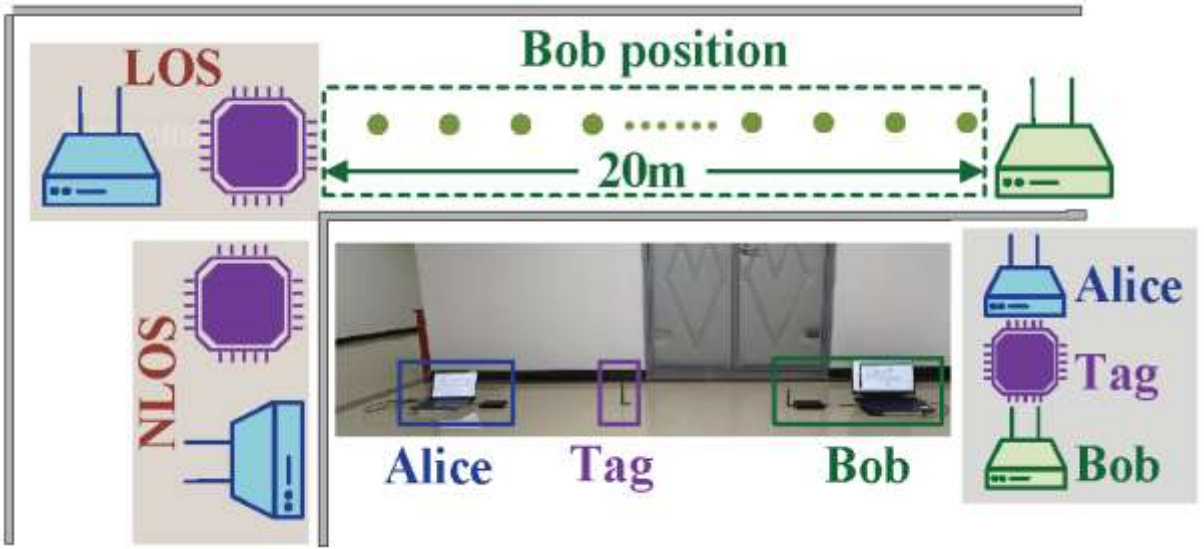


- Enable accurate synchronization within a longer distance.
- Consume similar power as traditional approach.

Implementation

➢ Hardware design and experiment setup

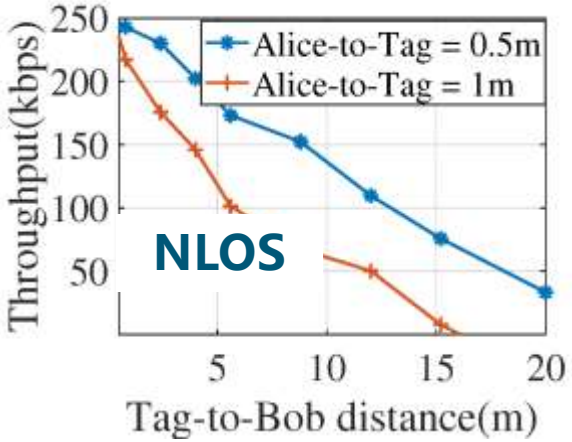


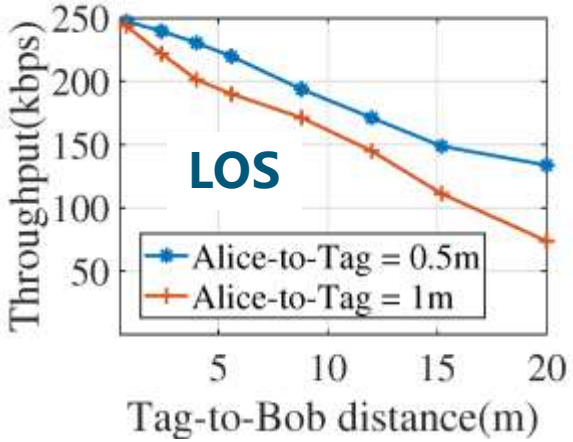


- Implement tag following an open-source platform (HitchHike Sensys'16)
- Choose two typical commercial OFDM signals as exciters: 802.11g WiFi and LTE.

Evaluation

➢ Performance under different setting





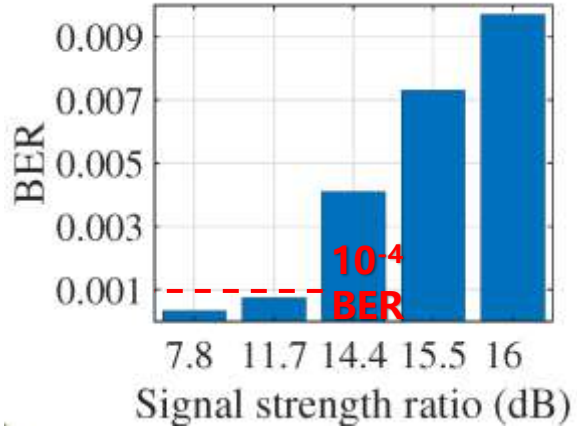
System	RapidRider	Study in [22]	Study in [23]	Orthcatter
Throughput	237kbps	40kbps	54kbps	**248kbps**

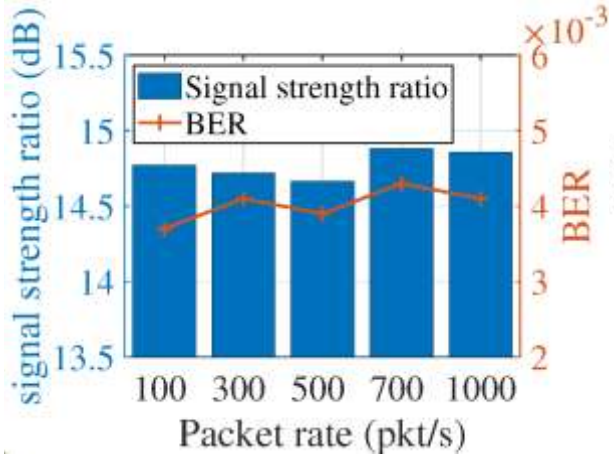
Side-band system

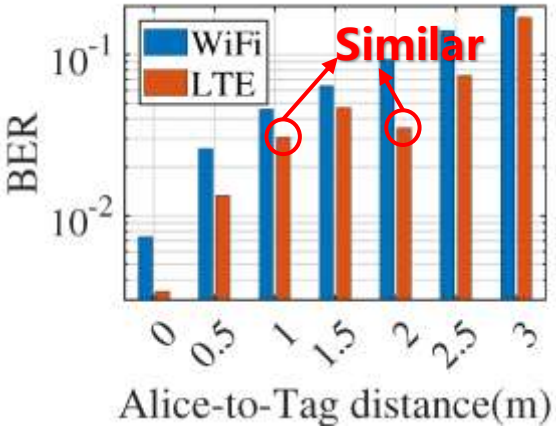
In-band system

Evaluation

➢ Performance under different exciters







- Minimal BER is 3.4×10-4, over 300× better than other in-band works.
- Changing the excitation packet rate hardly impacts the BER.
- When the Alice-to-tag distance is within 2m under LTE exciter, the synchronization error hardly impacts the decoding result.

Conclusion

- Orthcatter is the first in-band OFDM backscatter work that embeds tag data at single-symbol rate.
- We propose a sliding window matching scheme that enables accurate synchronization at longer distance.
- Orthcatter is generic and workable under different OFDM excitation including WiFi and LTE.
- We evaluate Orthcatter under different settings and exciters.

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Thank you!

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