

ML-Assisted Chirp Detection via Beamforming for Radar-Communication Coexistence

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SPECTRUM

BACKGROUND

U.S. National Spectrum Strategy:

- 3.1-3.45 GHz being considered for shared use with incumbent airborne radar systems.
- Requires more agile spectrum management than for CBRS shared spectrum (3.55 – 3.7 GHz).

PROBLEM STATEMENT

Detect the presence of an incumbent radar signal at the BTS **without explicit channel estimation or spectrum sensing**.

If detected, **downlink transmissions are suspended**.

Hypothesis Testing Problem

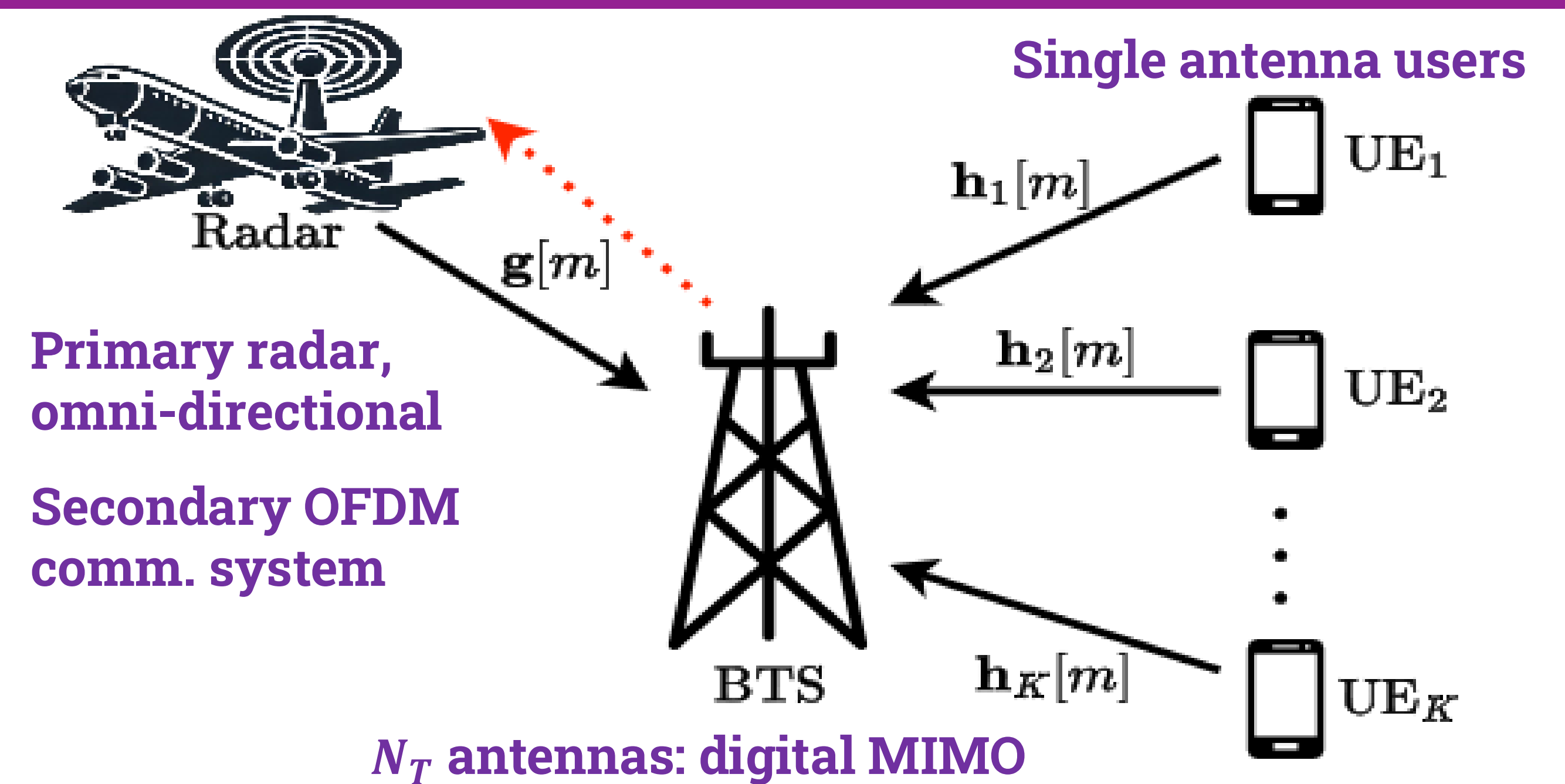
$$\mathcal{H}_0: \mathbf{Y}[m] = \sum_{k=1}^K \mathbf{h}_k[m] \mathbf{x}_k^H[m] + \mathbf{N}[m]$$

Labels: Received signal matrix, subchannel m , user, noise

$$\mathcal{H}_1: \mathbf{Y}[m] = \sum_{k=1}^K \mathbf{h}_k[m] \mathbf{x}_k^H[m] + \mathbf{g}[m] \mathbf{s}^H[m] + \mathbf{N}[m]$$

Labels: uplink pilots, radar chirp

NON-COOPERATIVE SPECTRUM SHARING



- The radar emits a low-duty cycle chirp waveform; overlaps in frequency with comm. system.
- The BTS does not know the chirp duration, duty cycle, and has no a priori channel state information.
- BTS downlink transmissions may interfere with the radar; UE uplink transmissions (low-power) do not.
- Incumbent activity is intermittent and infrequent so that secondary user has an incentive to share.

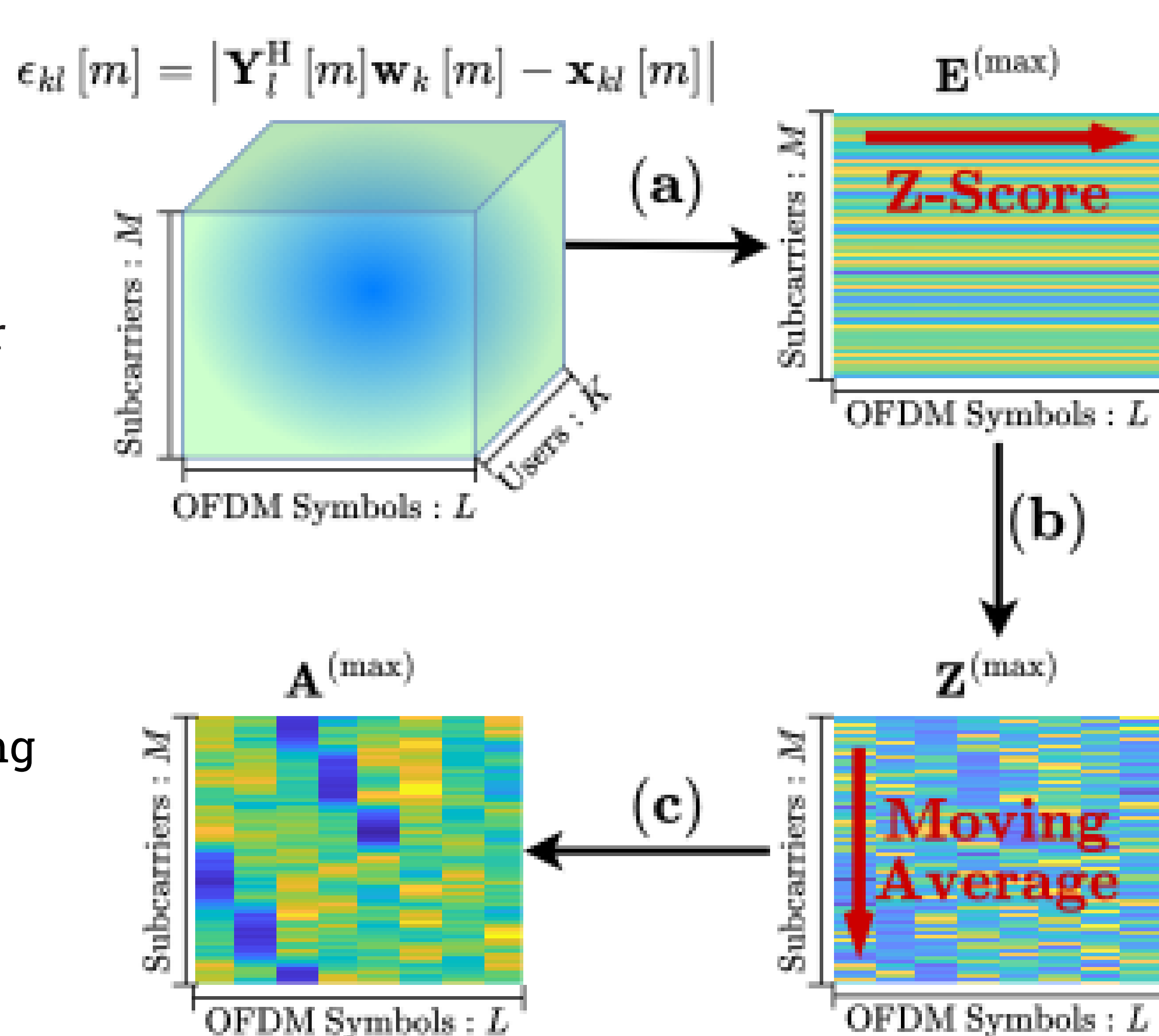
ML-ASSISTED CHIRP DETECTION ALGORITHM

Method: Look for **anomalies in residual errors** during uplink adaptive estimation of downlink beamformer.

Protocol: If radar activity is detected, communication system **immediately vacates the band**.

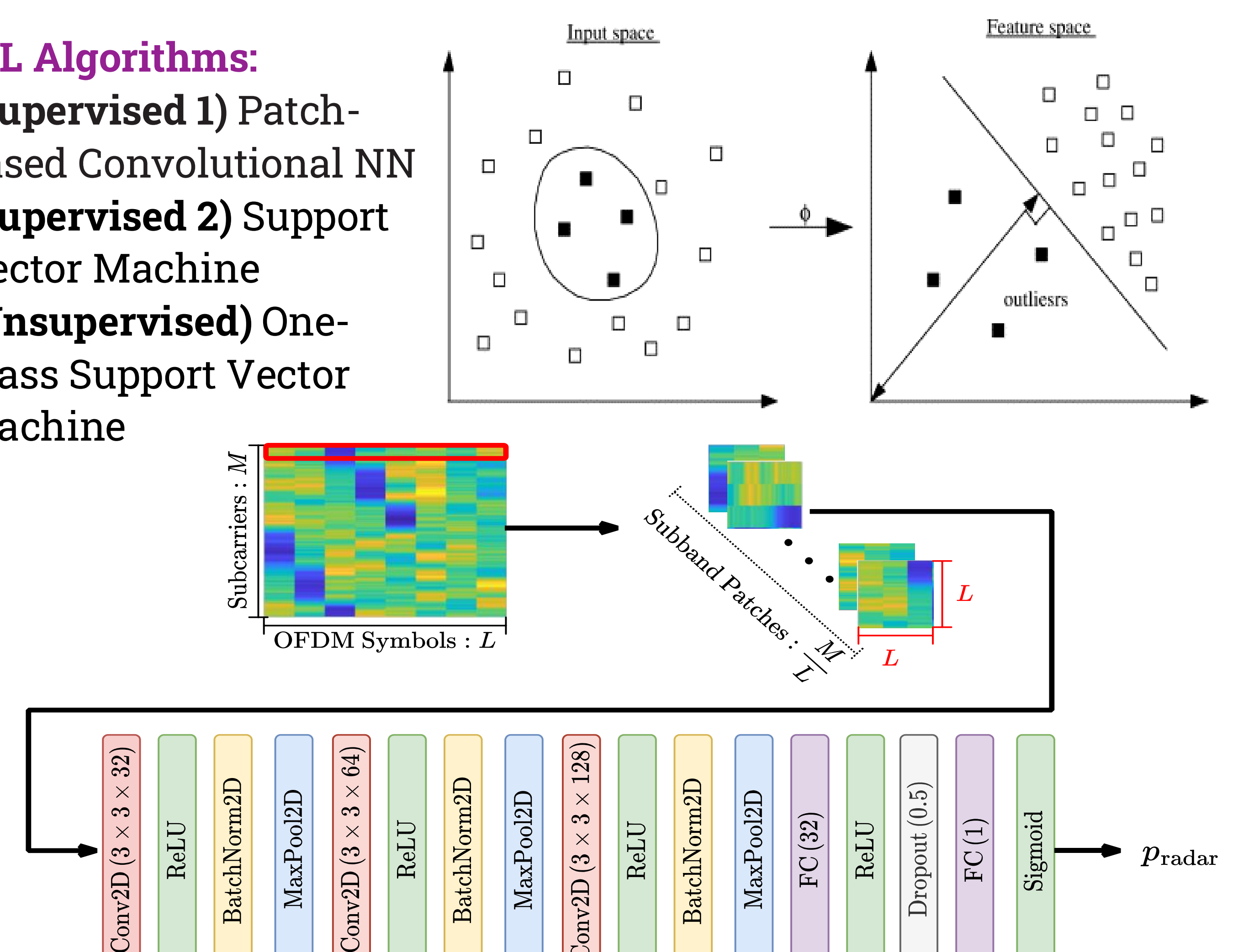
Preprocessing Steps:

- Project 3D error cube to 2D by taking maximum error across users.
- Compute Z-scores across pilots to extract temporal patterns.
- Apply moving average filter to enhance patterns across frequencies.

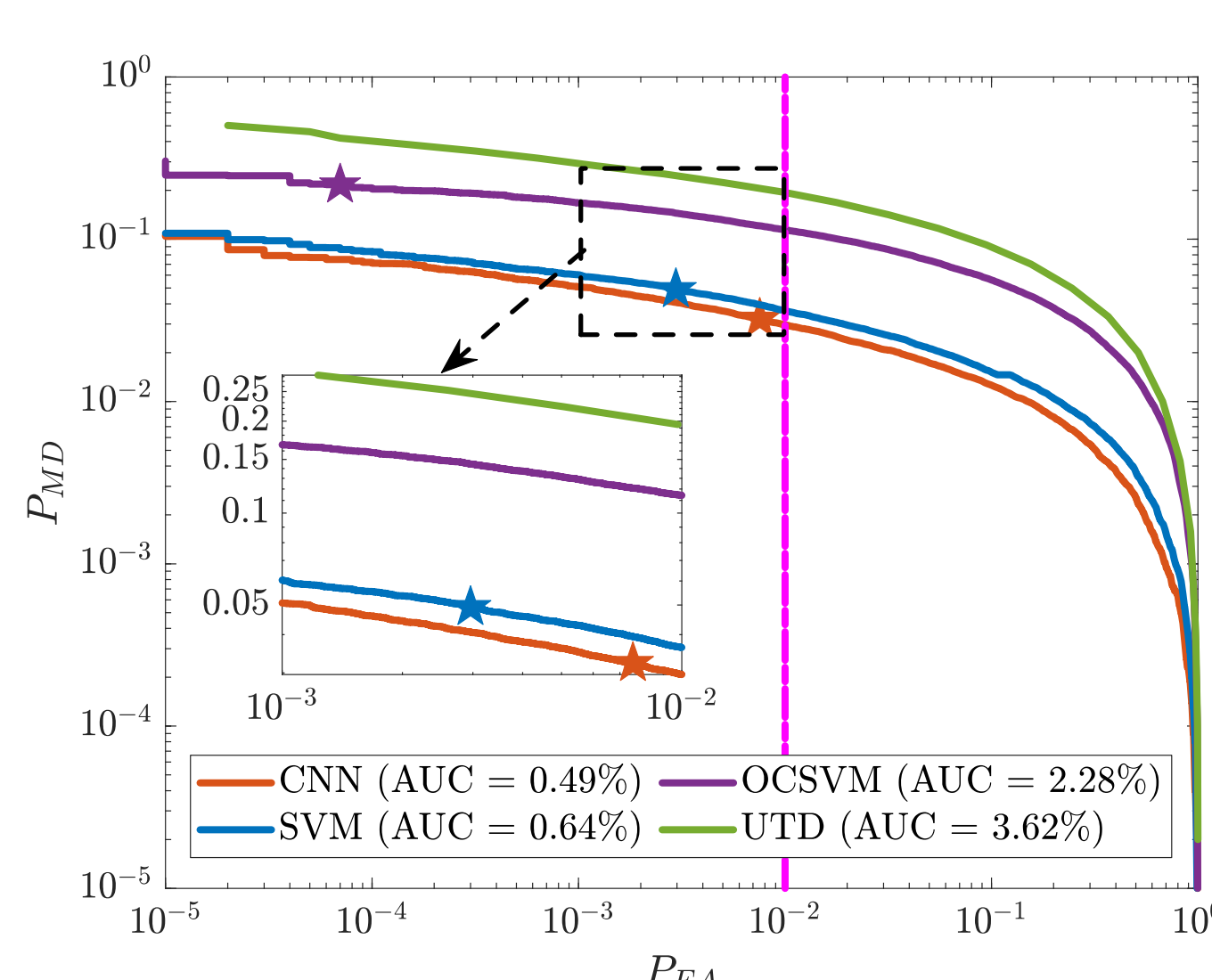


ML Algorithms:

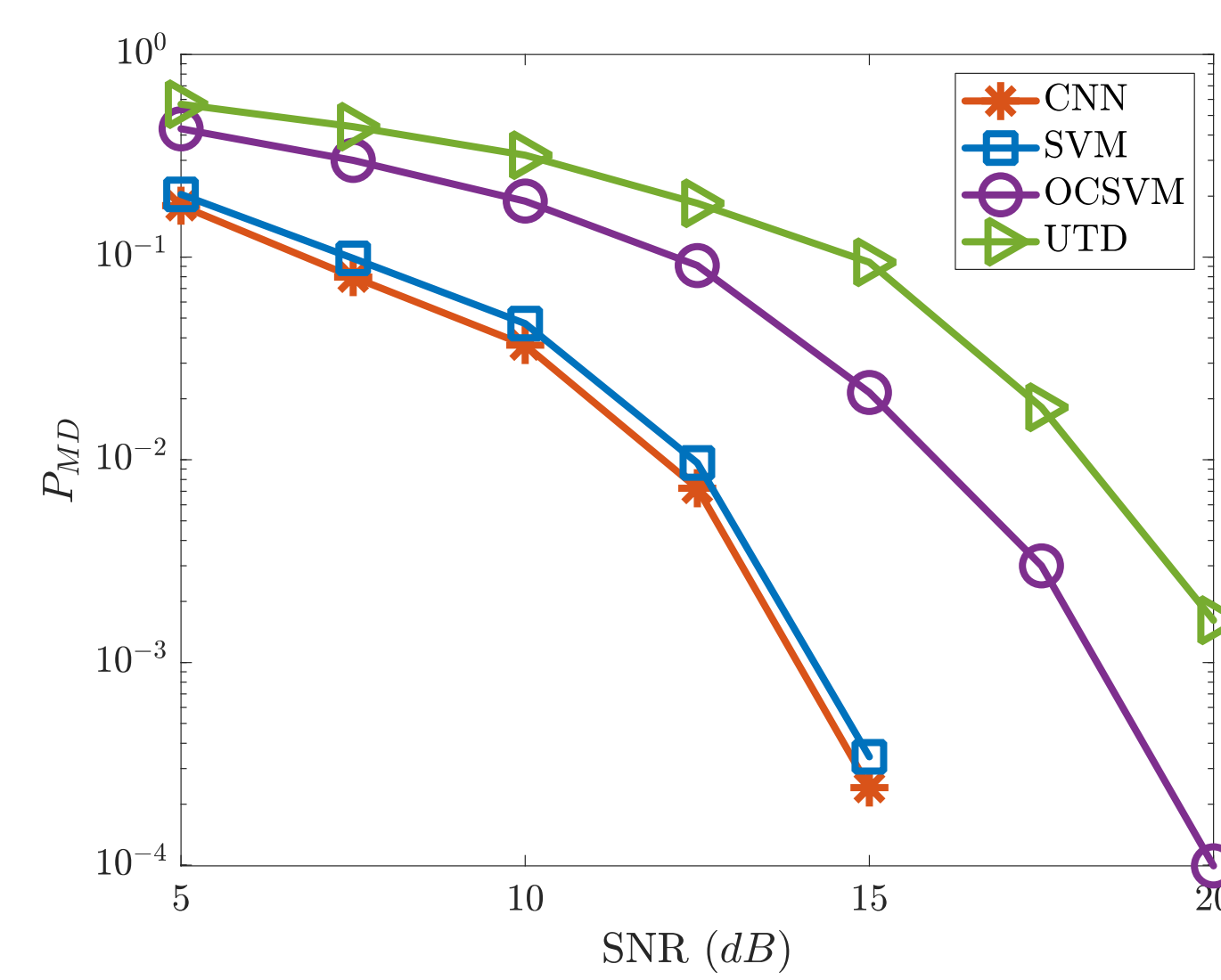
- (Supervised 1) Patch-based Convolutional NN
- (Supervised 2) Support Vector Machine
- (Unsupervised) One-Class Support Vector Machine



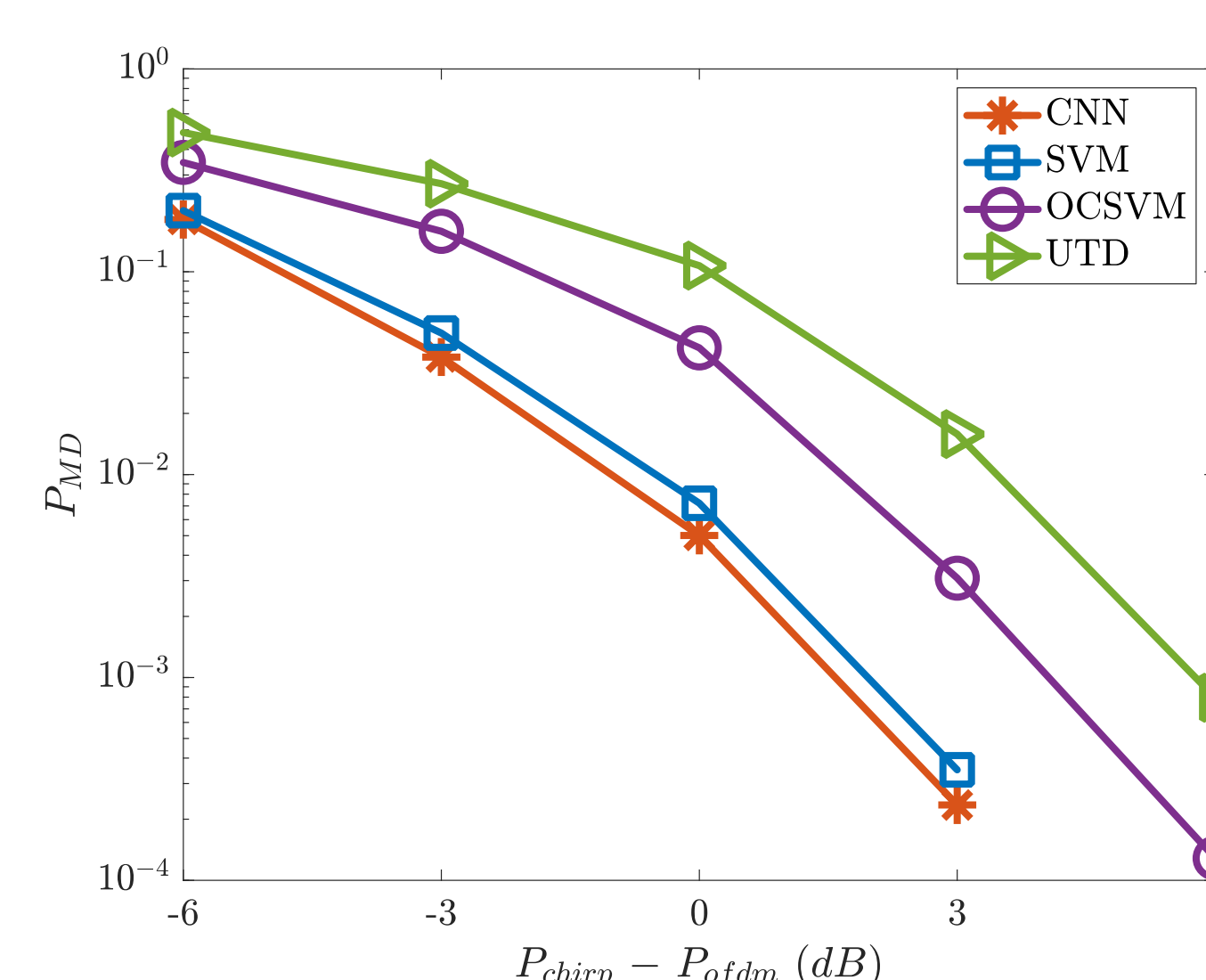
SIMULATION RESULTS



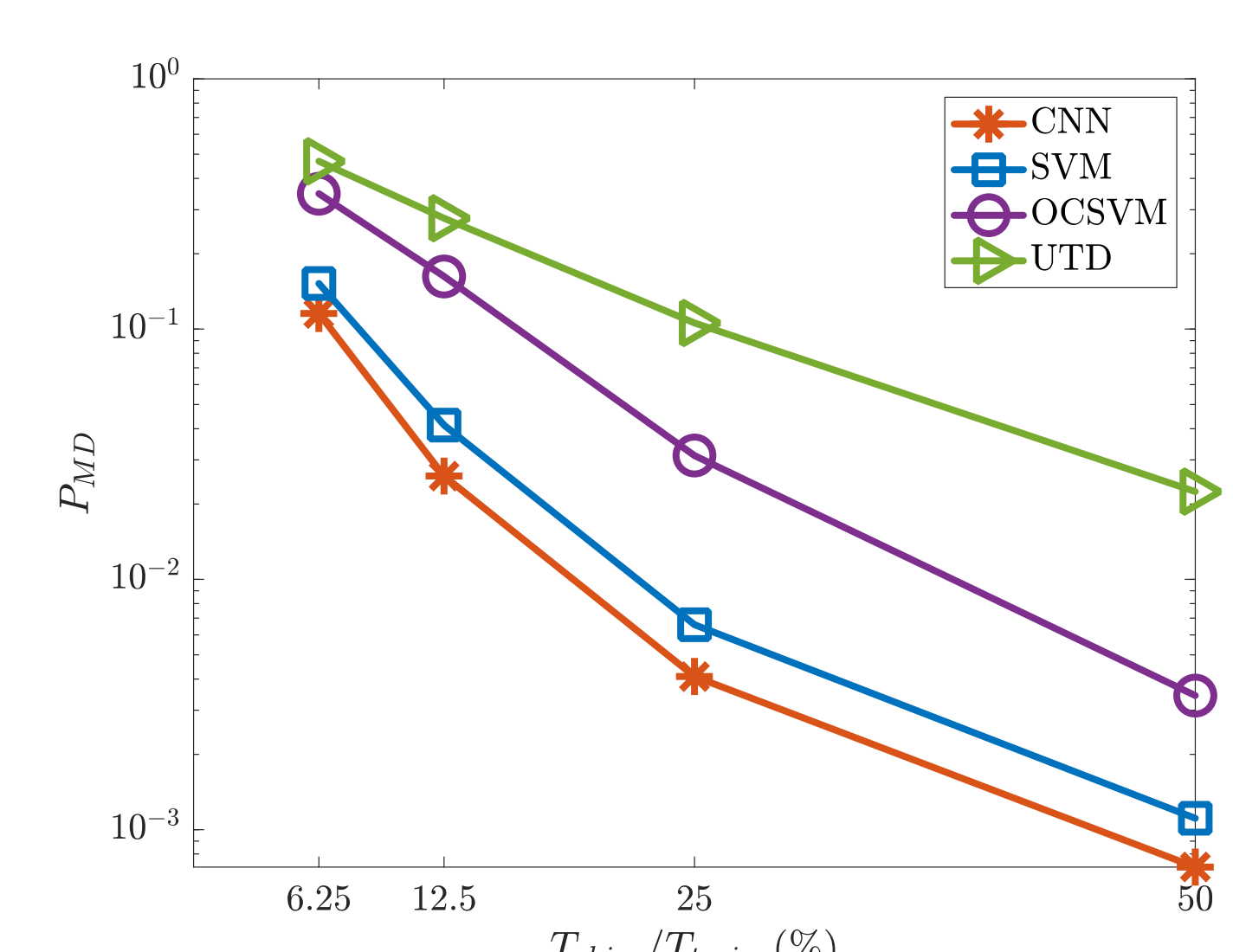
At 1% False Alarm Rate: CNN reduces missed detection probability to 3% (vs. 19.5% for baseline)



At 15 dB SNR: CNN achieves 0.02% missed detection (vs. 9.4% for baseline)



Higher chirp power → Better detection (for all methods)



Longer chirp duration → More consistent patterns → Better detection