Chirp Detection via Adaptive Beamforming for Radar-Communication Coexistence

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BACKGROUND

In the United States, the spectrum management landscape is balancing national security with the economic imperative of efficient spectrum utilization. The National Spectrum Strategy involves potentially repurposing the 3.1-3.45 GHz band, currently used by the DoD for shared federal and commercial use, necessitating robust radar-communication coexistence strategies. The CBRS band, spanning 3.55-3.7 GHz, exemplifies this coexistence with a three-tiered access system that allocates spectrum across incumbent naval radars, satellite services, and secondary commercial users, though its adaptability is limited, suggesting the need for more agile management approaches.

SYSTEM MODEL

We consider an incumbent radar system which coexists with an OFDM communication system that do not coordinate spectrum access or share system or signal parameters. We aim to detect the presence of the radar, that employs low-duty cycle chirp waveform, at the BS without explicit channel estimation or spectrum sensing.

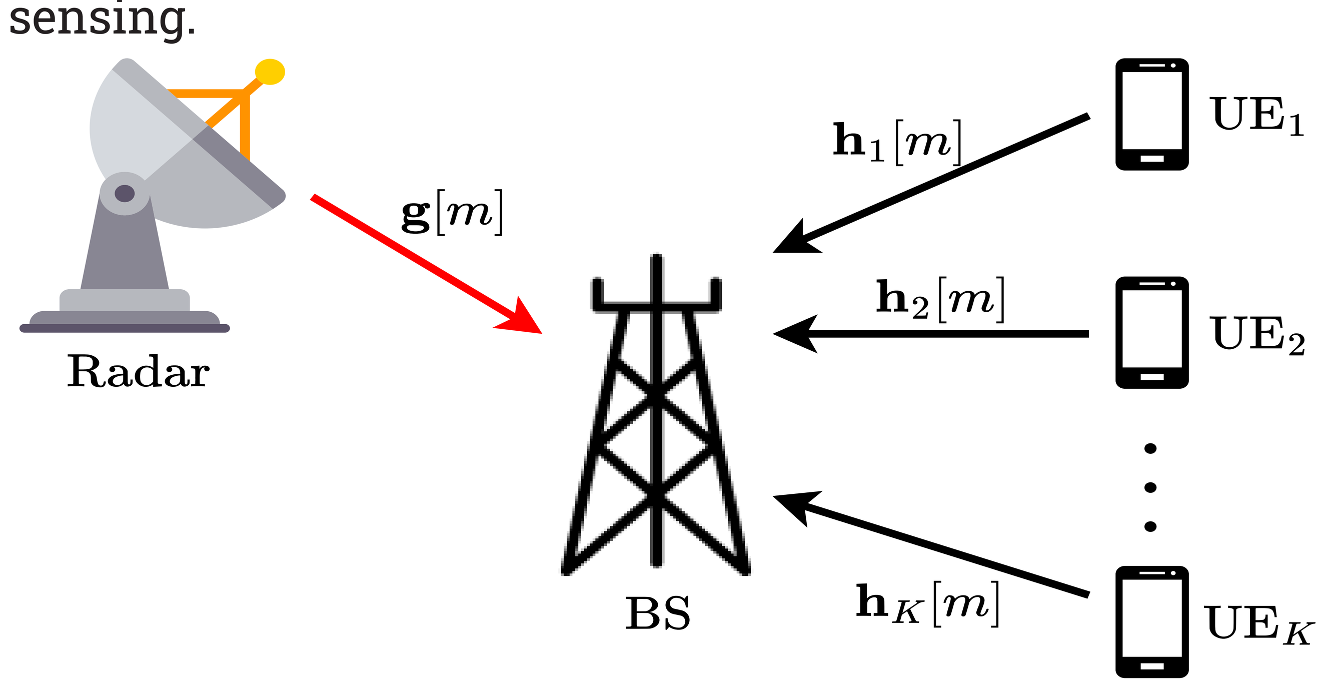

Fig: Non-cooperative radar-communication coexistence scenario

Hypothesis Testing Problem

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

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

Downlink Beamformer Optimization

$$\min_{\{\mathbf{w}_k[m]\}_{k=1}^{K}} \sum_{k=1}^{K} \left\|\mathbf{w}_k^{\mathrm{H}}[m]\mathbf{Y}[m] - \mathbf{x}_k^{\mathrm{H}}[m]\right\|_2^2$$

$$\text{s.t.} \sum_{k=1}^{K} \|\mathbf{w}_k[m]\|_2^2 \leq P_T$$

CHIRP DETECTION ALGORITHM

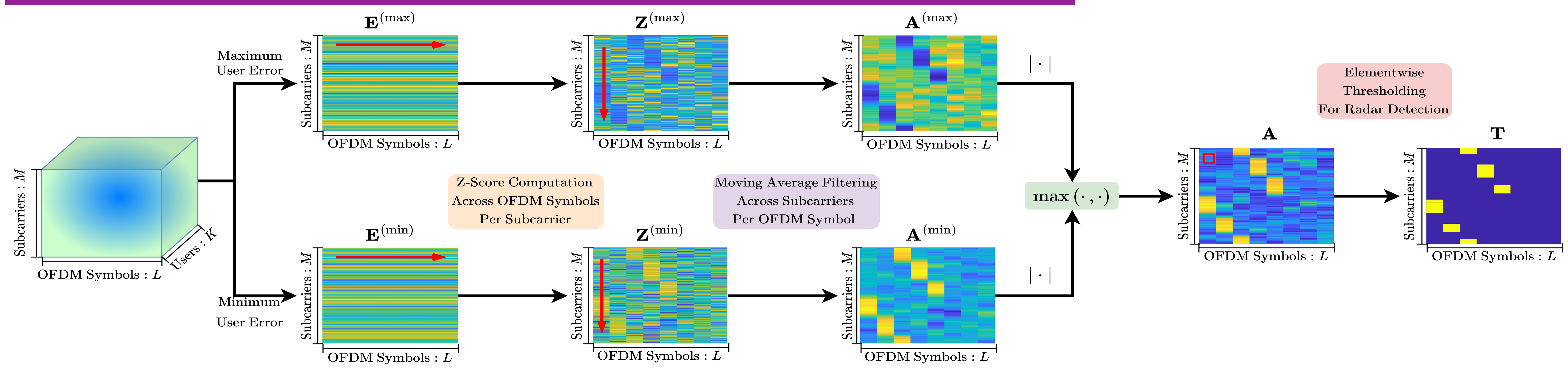

Fig: Steps in chirp detection algorithm starting with computation of beamforming errors across users, pilots, and subcarriers $\epsilon_{kl}[m] = \left(\mathbf{Y}_l^{\mathrm{H}}[m]\mathbf{w}_k[m] - \mathbf{x}_{kl}[m]\right)^2$ (left) to the threshold outputs across pilots and subcarriers (right).

HYBRID TTD ARRAY

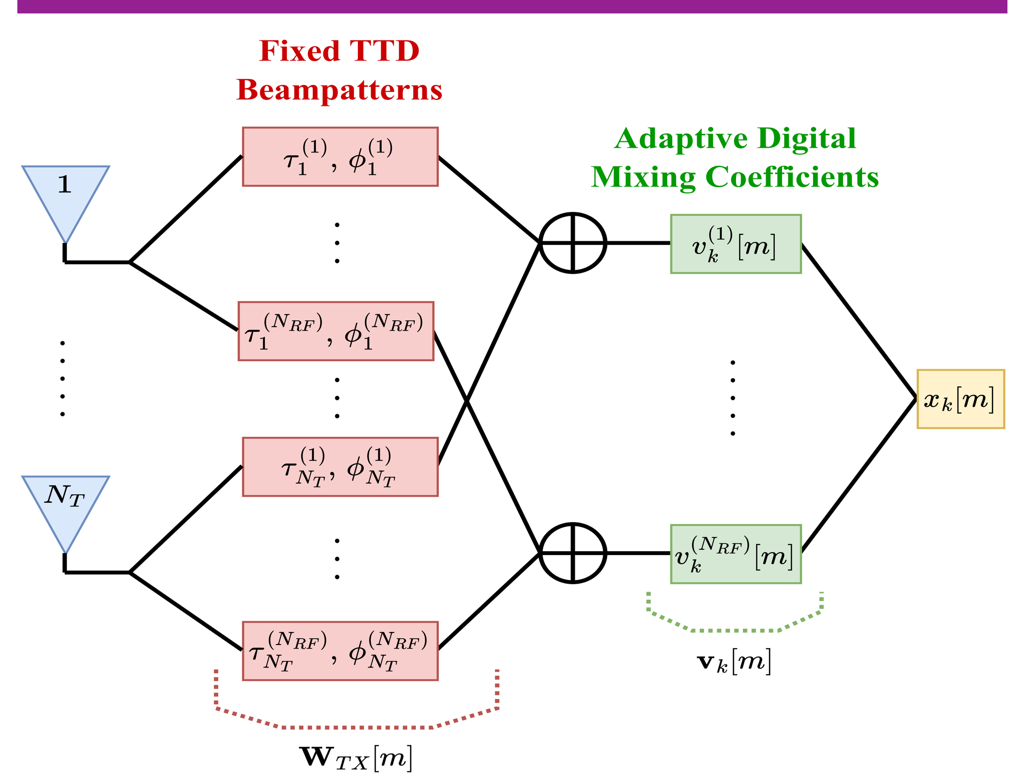

Fig: Hybrid True-Time-Delay array for reduced rank beamforming

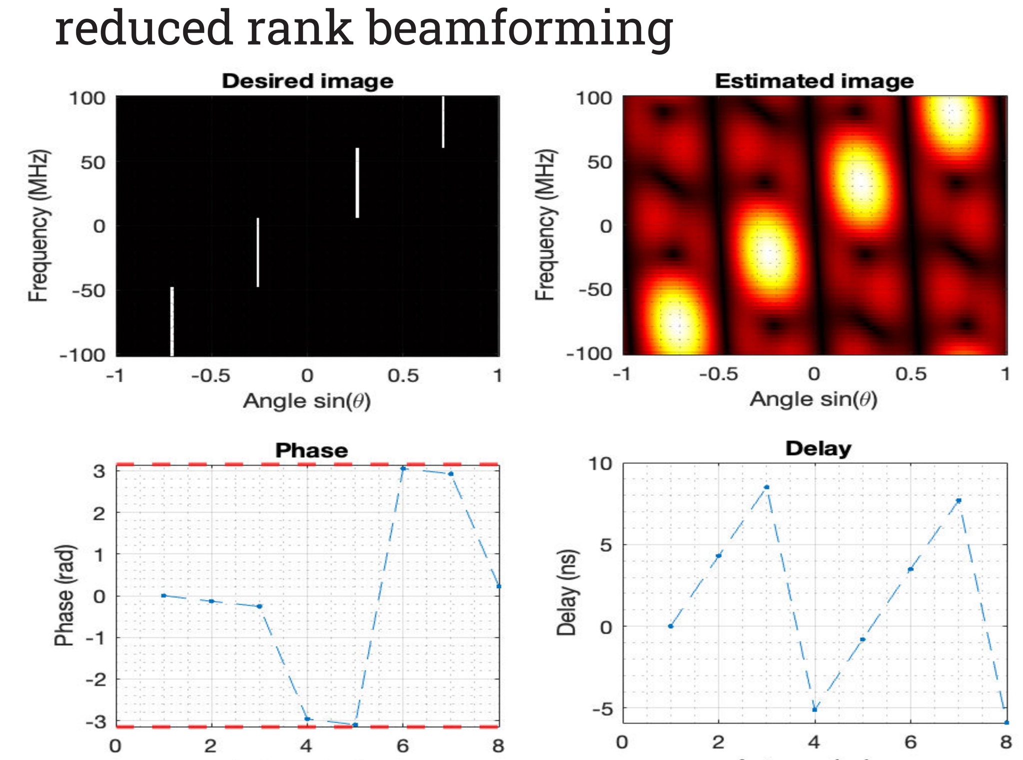

Fig: Staircase analog TTD beampatterns per RF-chain

SIMULATION RESULTS

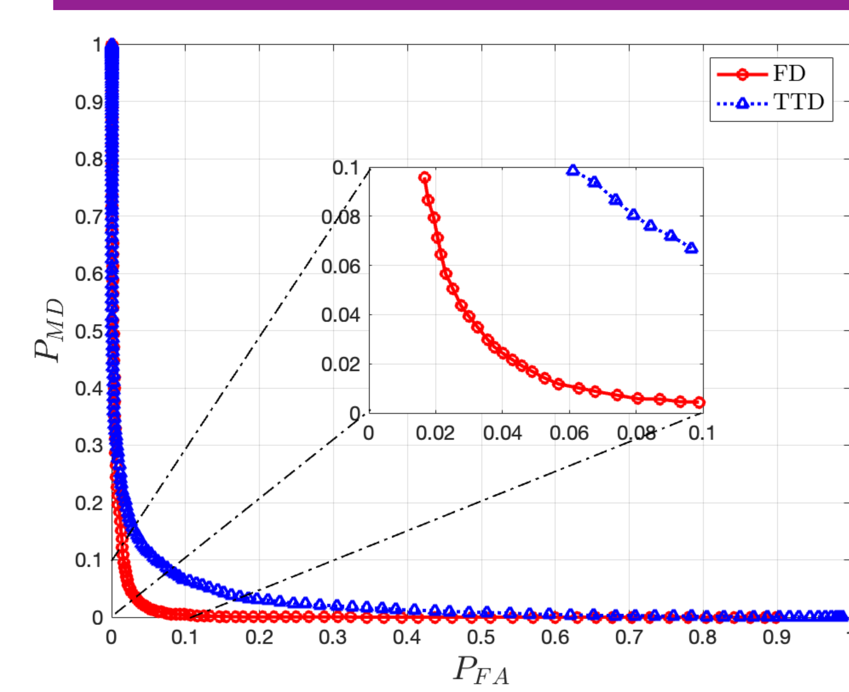

Fig: Inverse ROC curves at 15 dB SNR and $P_{chirp}/P_{ofdm} = 6\ dB$ when chirp spans two OFDM symbols

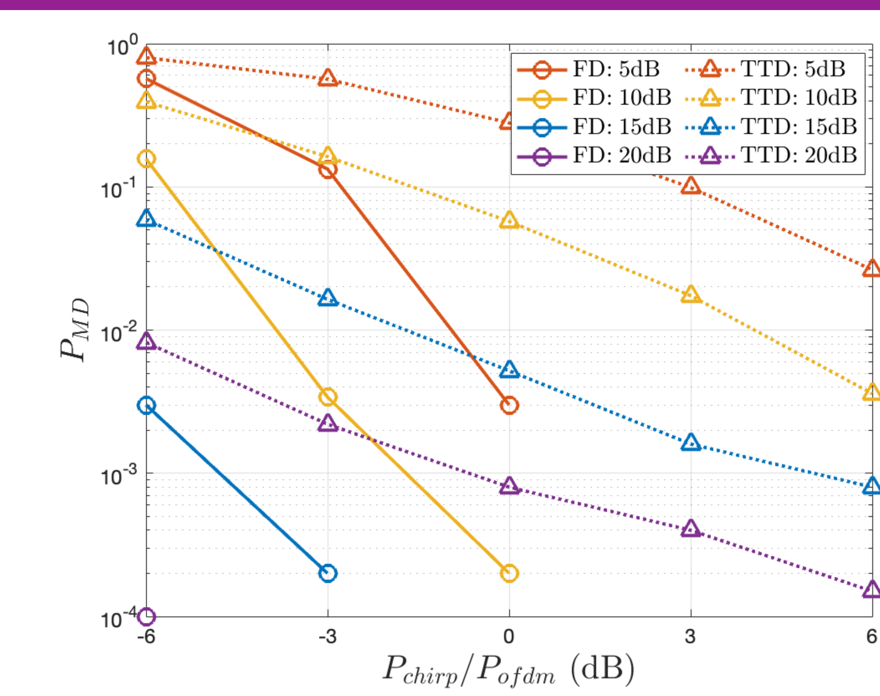

Fig: P_{MD} versus for chirp-power for varying SNRs when chirp spans two OFDM symbols

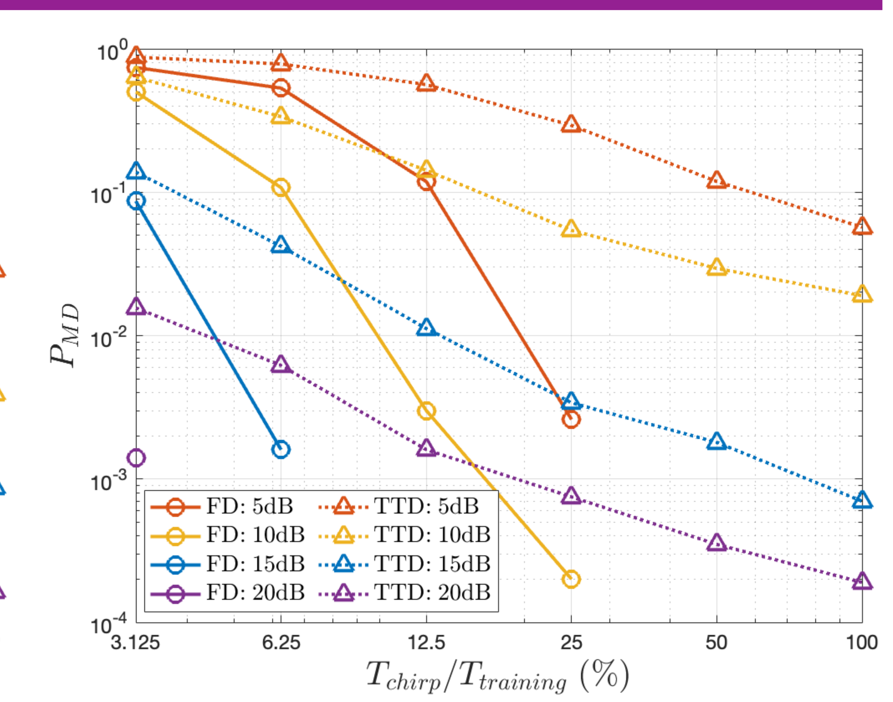

Fig: P_{MD} versus for chirp-duration for varying SNRs when $P_{chirp} = P_{ofdm}$

CONCLUSIONS AND FUTURE WORK

Motivated by the scenario in which the incumbent does not directly coordinate with the communication system, the detection method does not rely on channel state information or chirp parameters such as bandwidth and duty cycle. Rather the method exploits discrepancies in errors observed after beamformer optimization across frequency and time. Simulation results have illustrated the performance with respect to SNR, chirp power, and chirp duration.

Here we have not considered performance tradeoffs between the communication system and radar. In particular, adaptive beamforming via uplink training when the radar is present can mitigate downlink interference to the radar.

ACKNOWLEDGEMENTS

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