Detection and Identification of Remotely Piloted Aircraft Systems Using Weather Radar

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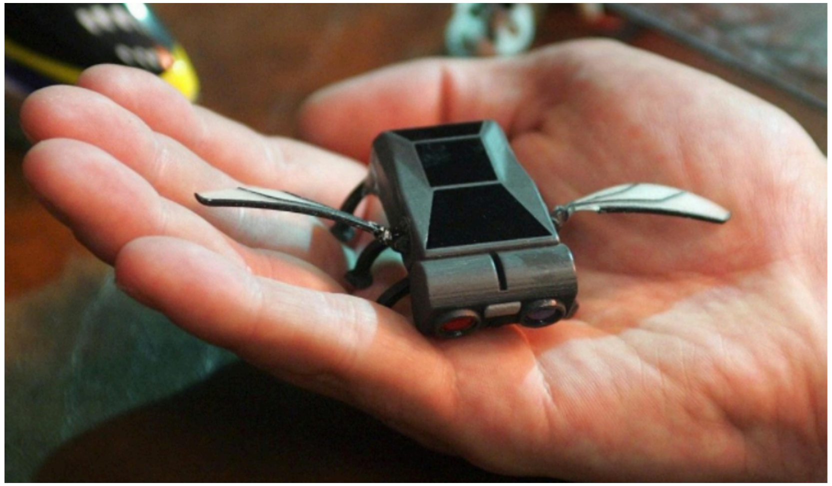
Motivation – UAV misuse

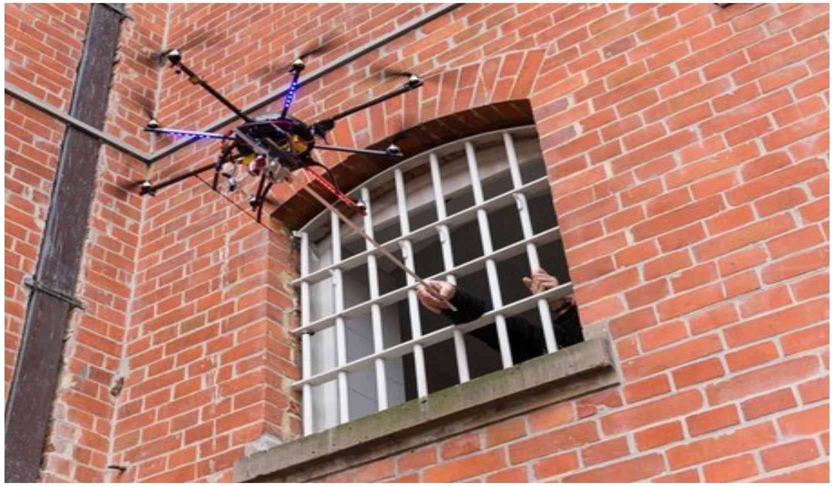
- rogue drones in airport vicinity

- terrorist drone threat

- espionage and data hacking

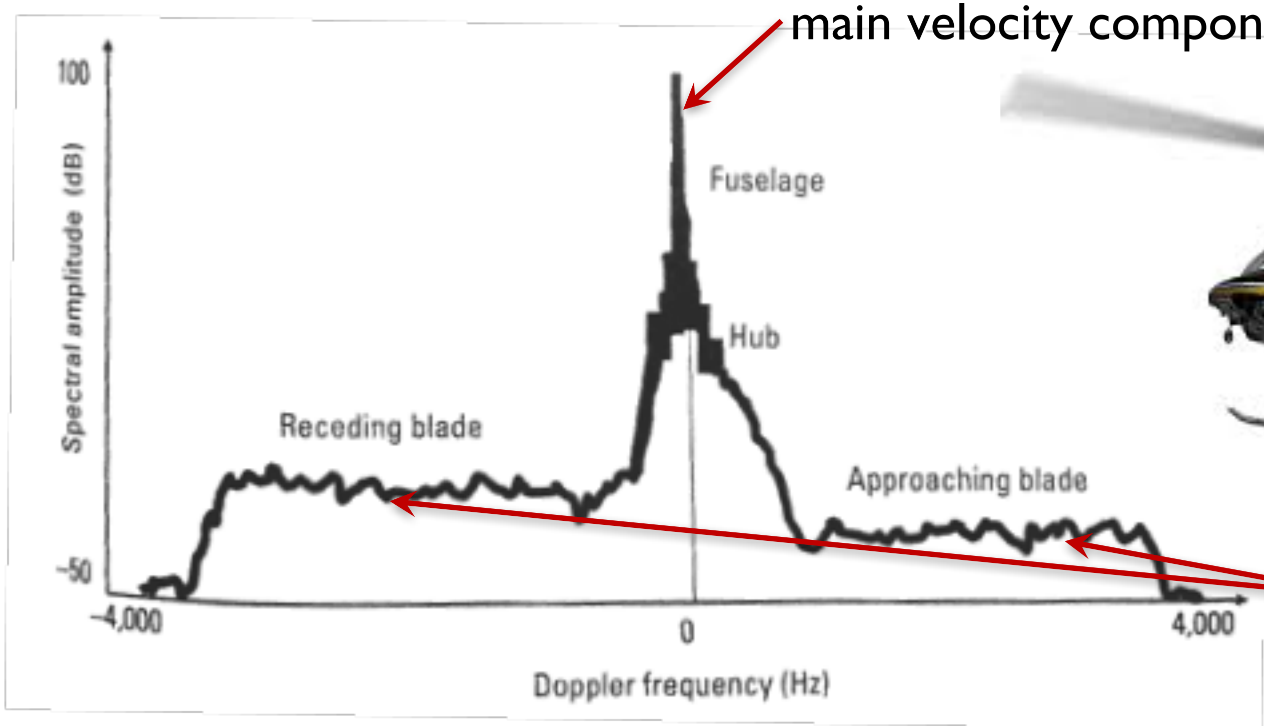


- fly contraband into prisons



Laws can be enforced only if the threat is detected!

Approach – micro-Doppler analysis



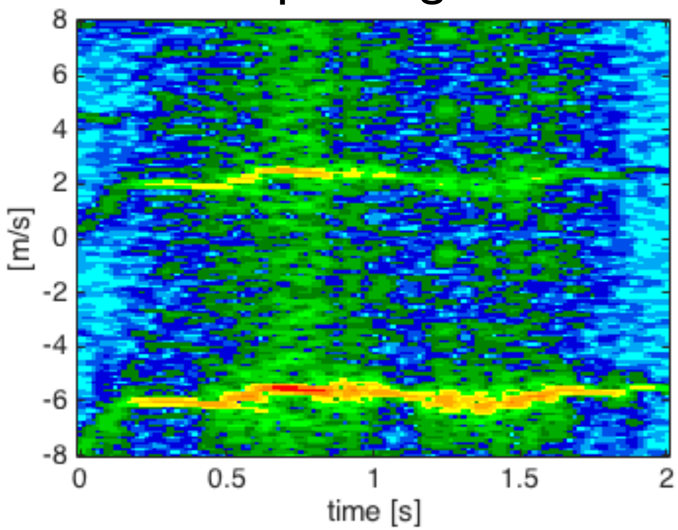
Mechanical vibrations or rotations of structures on a target may introduce frequency modulation on the radar return known as the micro-Doppler (m-D) phenomenon.

V. Chen, *The Micro-Doppler Effect in Radar*, Norwood MA: Artech House, 2011.

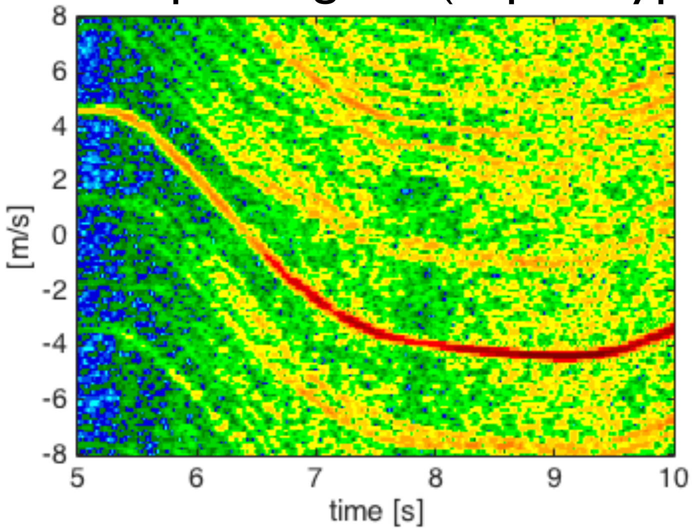
Relevant features for drone detection - theory

- Spectrum width
  - several meters per second for birds
  - much wider for drones
  - high sampling rates are necessary to avoid micro-Doppler signature aliasing
- Spectrogram symmetry
  - symmetric for drones
  - asymmetric for birds
- Spectrogram periodicity
  - determined by rotor rotation rate or wing beat
  - higher for drones
  - high sampling rates are necessary

Bird spectrogram



Drone spectrogram (copter-type)



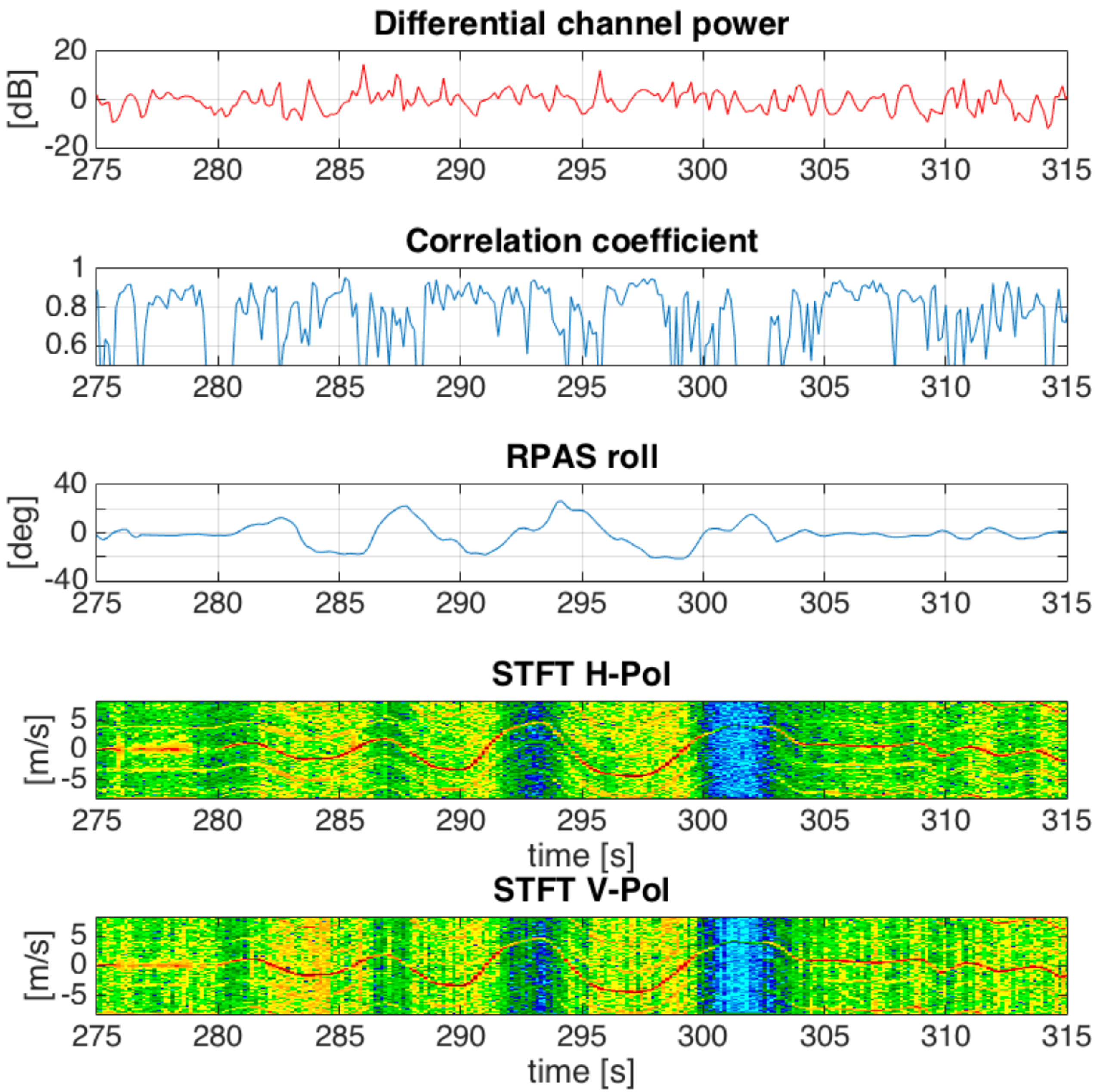
R. I. A. Harmanny et al, *Radar Micro-Doppler Feature Extraction Using the Spectrogram and the Cepstrogram* , in Proceedings of the 11th European Radar Conference, 2014

Experiment setup

- beam azimuthal resolution at the drone location ~ 8 meters
- range gate resolution – 24 meters
- drone to radar distance ~ 400 meters

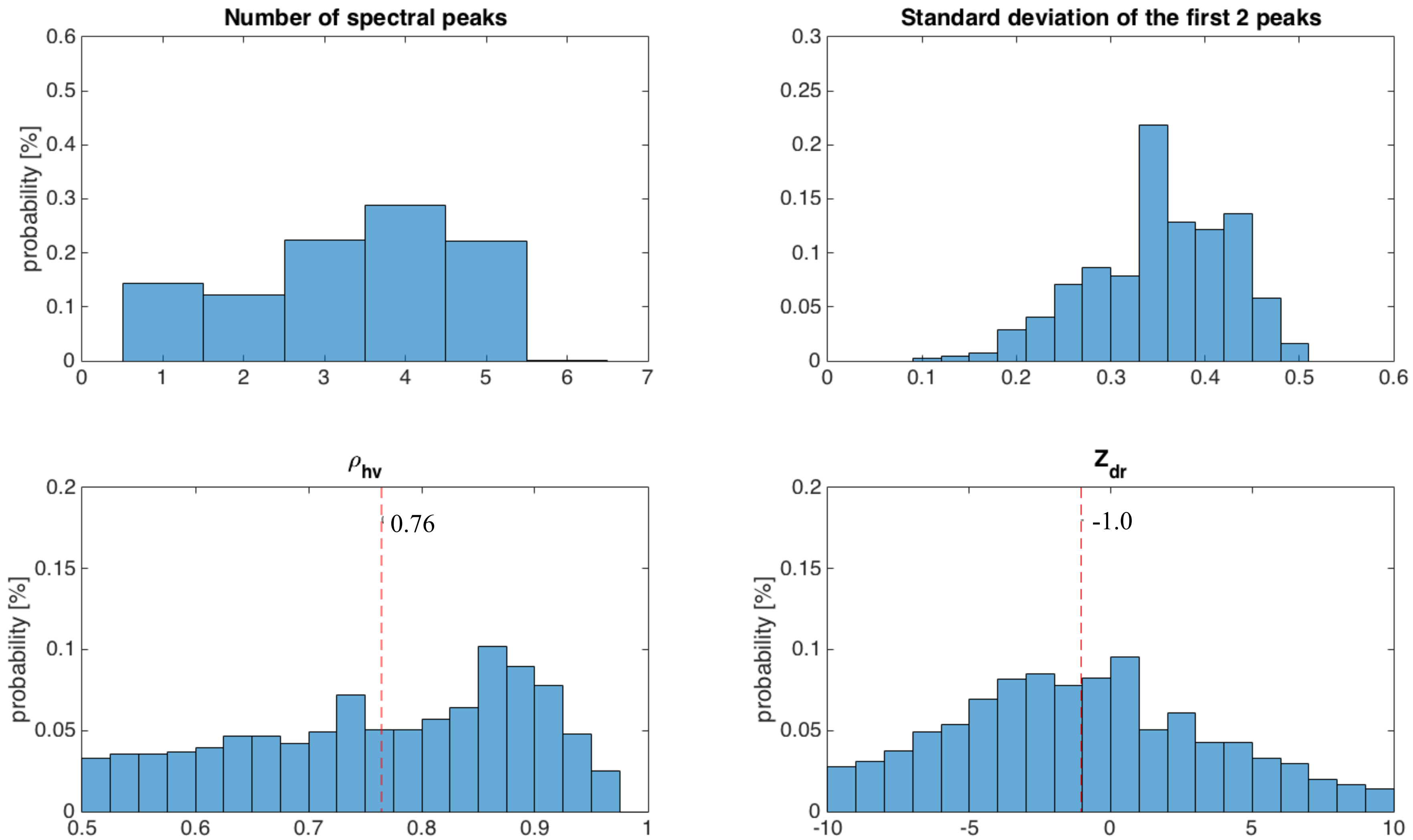
- drone (hexacopter) hovered or flew in circles within a single radar range gate
- high-power, dual-polarized radar with a fixed antenna (10 degree elevation tilt) and PRF = 1kHz

Drone observations



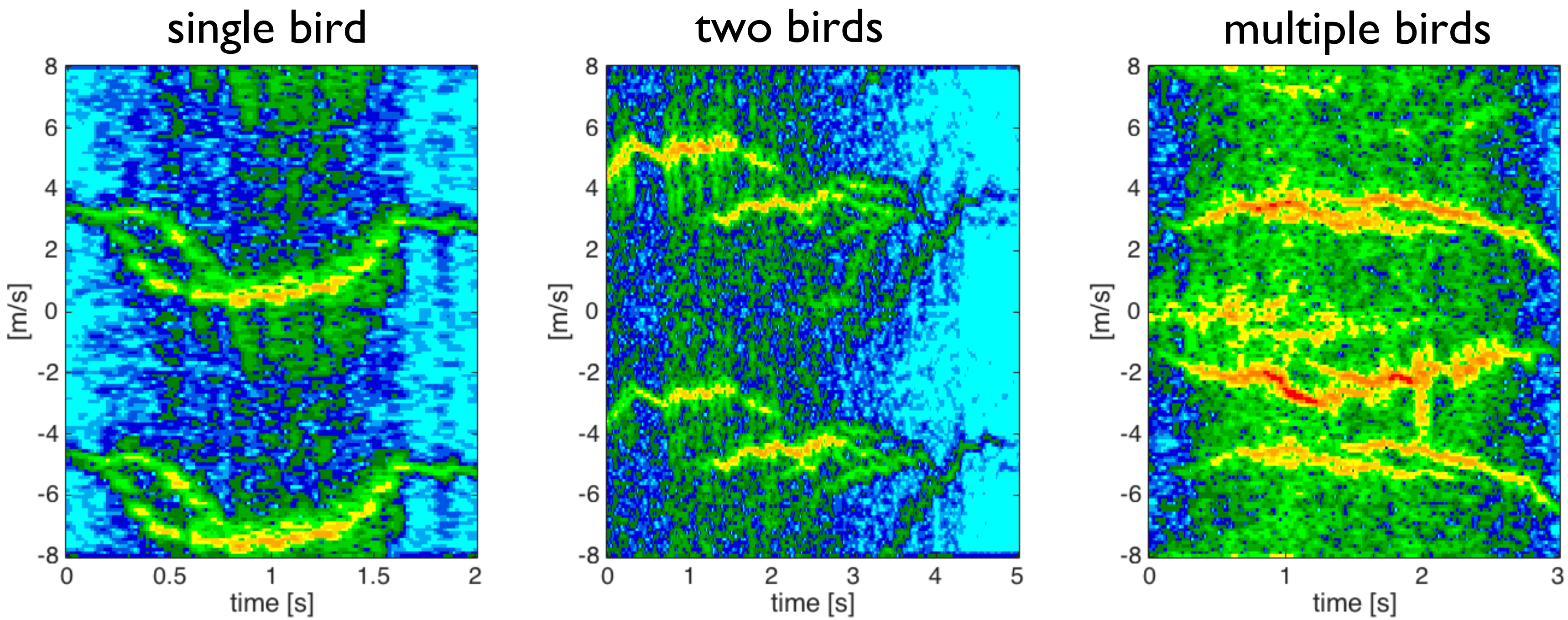
- high standard deviation in differential channel power
- correlation coefficient larger than 0.8 when drone is within a beam
- no significant difference in spectrograms for H- and V-polarizations
- multiple peaks in spectrogram due to low sampling frequency and multiple rotors

Drone statistics



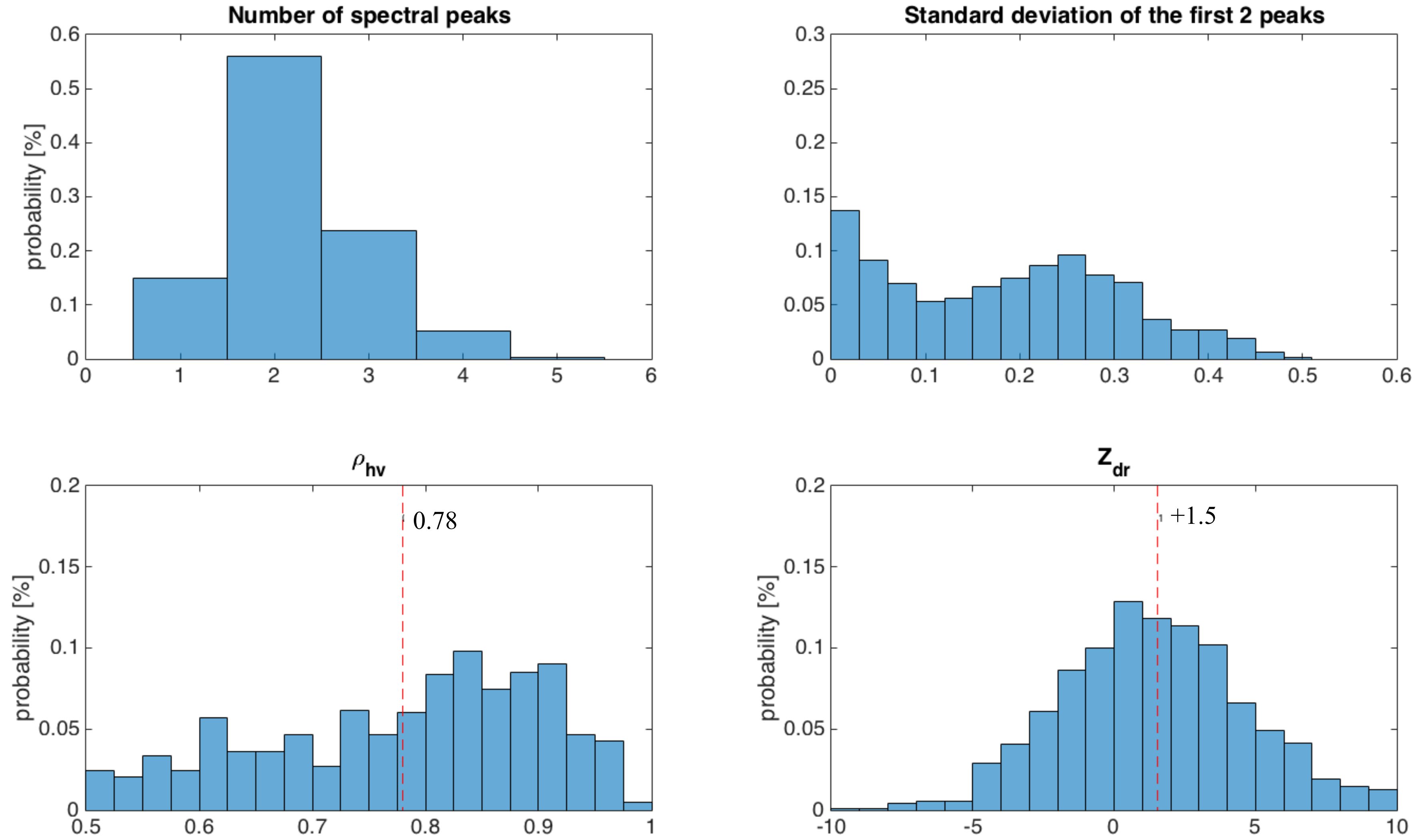
- statistics represent 80 seconds of a hovering drone dataset
- on average 3+ peaks in spectrum are detected
- main peak significantly stronger when compared with secondary spectrum peaks

Bird observations



- even number of peaks in spectrogram
- comparable power in peaks
- spectrum width of multiple birds can be comparable to drone

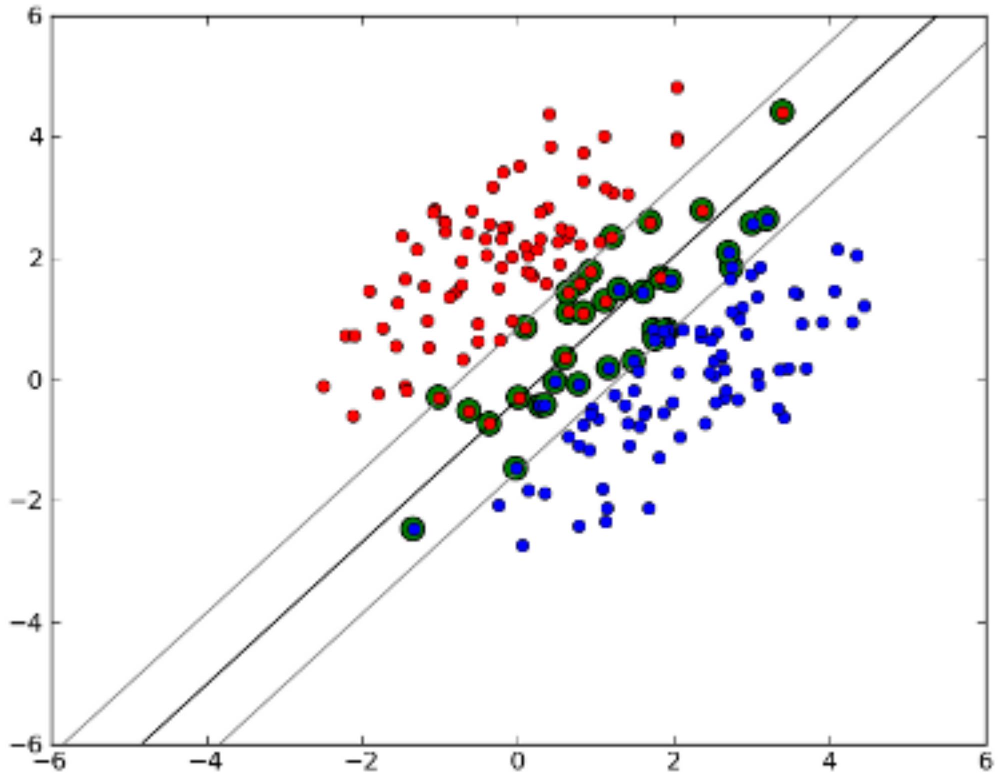
Birds statistics



- statistics represent 12 different bird(s) observation (~50 seconds)
- on average 2 comparable peaks in spectrum are detected
- positive Zdr with narrower distribution when compared to drone

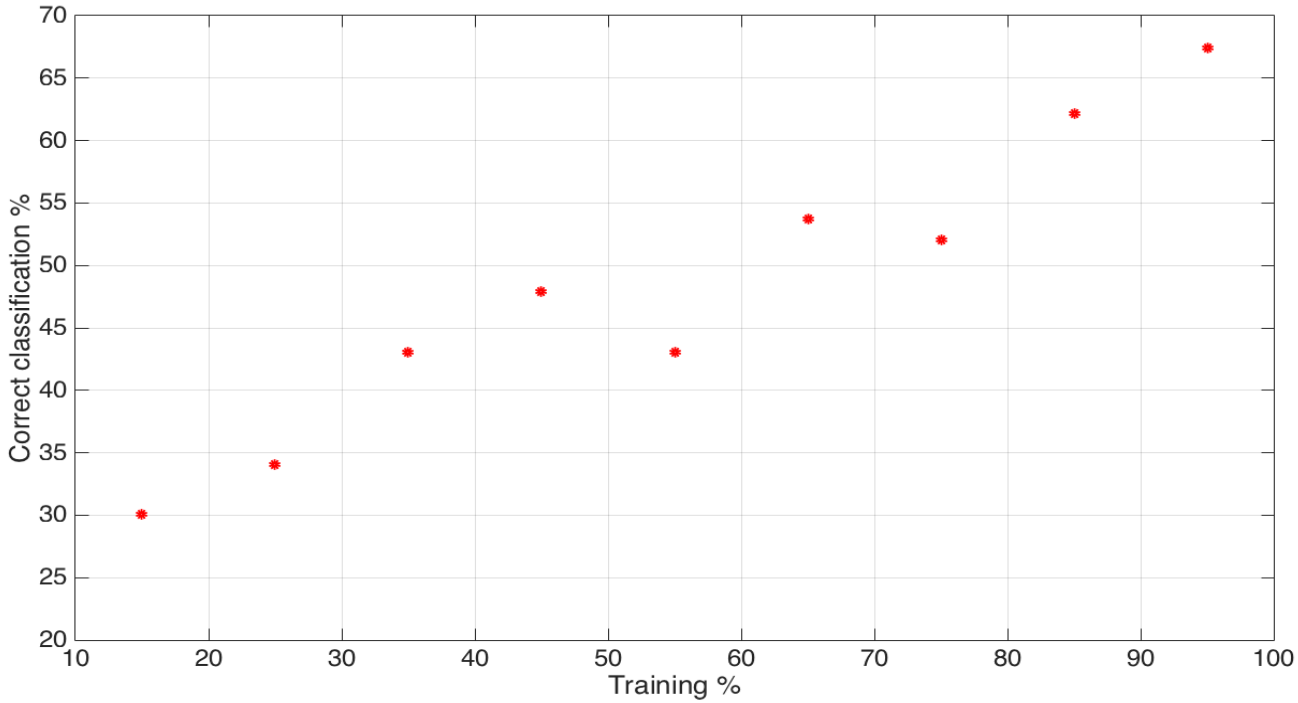
Support vector machine classifier (drone vs. bird)

- commonly used for a binary classification
- attempts to find a hyperplane that divides the two classes with the largest margin in a high-dimensional feature space
- uses a subset of training points in the decision function (called support vectors) and is memory efficient



Classifier performance

- up to 80 seconds of hovering drone observations and 50 seconds of bird observations used to train the SVM classifier using the means and standard deviations of the 4 features – number of spectral peaks, standard deviation of first two peaks, correlation coefficient, and differential phase
- 80 seconds dataset representing maneuvering drone was used for classifier evaluation
- visible trend in correct classification as the size of the training set is increased

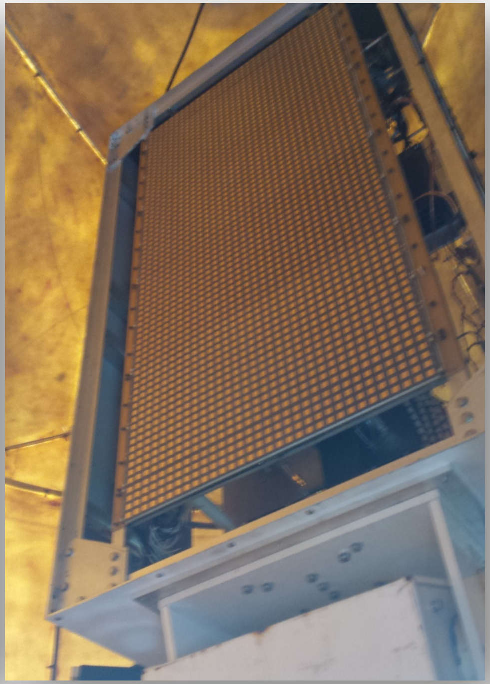


Conclusions

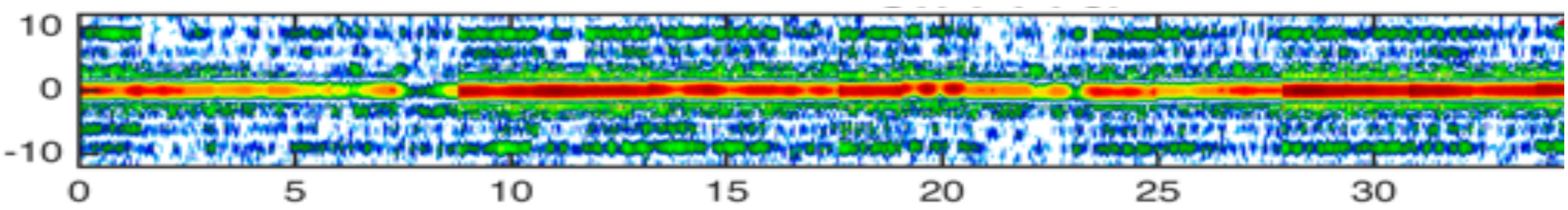
- weather radar can detect and identify a remotely piloted aircraft system, but high sampling rates are recommended to avoid micro-Doppler signature aliasing
- Micro-Doppler signature is the most distinctive feature to distinguish drones from birds
- machine learning can be used to distinguish birds from drones, but more data (of drones and birds) is needed to improve classifier performance
- additional features and machine learning algorithms need to be evaluated

Future work

- UMass received an NSF grant to demonstrate the drone detection and tracking capabilities of its weather radars
- experiments scheduled for Fall'17 using a phase-spin weather radar
- this radar scans electronically in the elevation plane and move mechanically in the azimuth
- capable of scanning the entire sky (volume scans)



drone signature detected at 1180m using a solid-state low-power radar



Thank You!

Questions?