# Acoustic Detection of Drones

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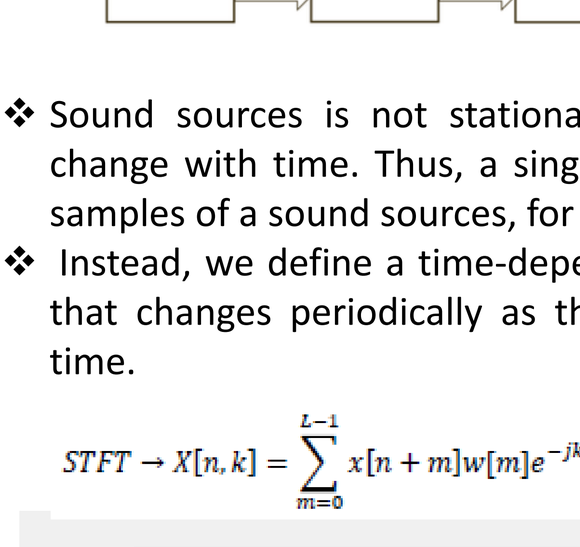
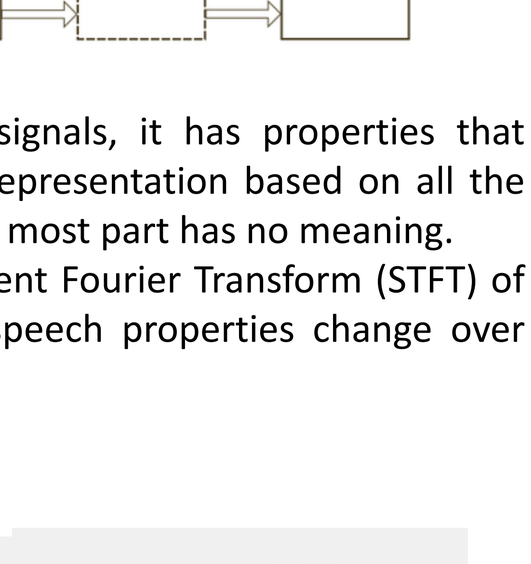
## Introduction

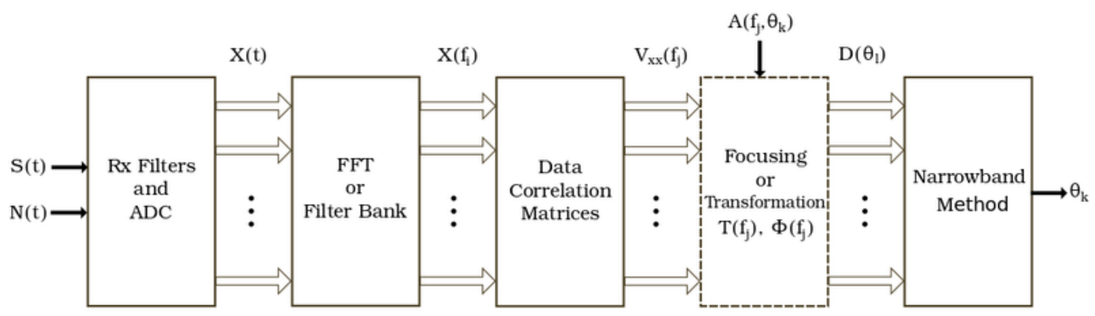
- Popularity of drones or unmanned aerial vehicles are increased. These vehicles are used in military and civilian. Accessibility of drones create privacy and security problem.
- To deal with these problems, drones can be detected using microphone array and signal processing techniques.

## Solution Methodology



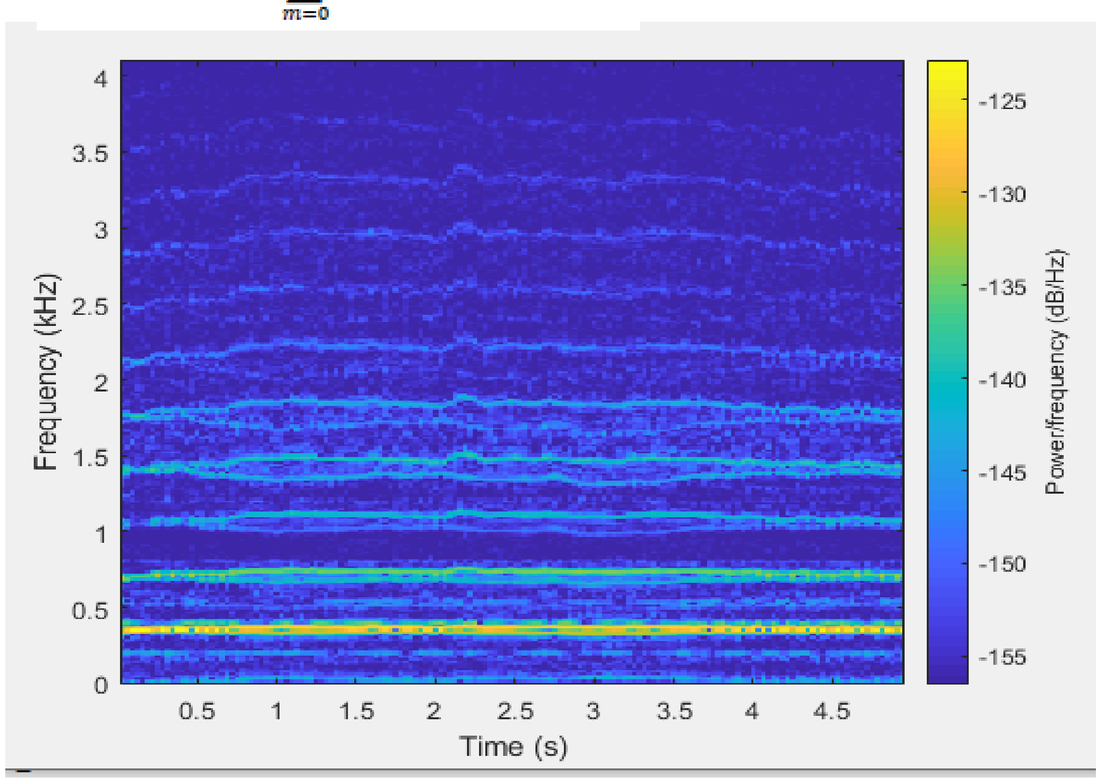




- Ambient sounds are collected through the microphone array.
- Uniform circular omnidirectional microphone array with 18 elements is defined. Radius is 1 meter. It is located on x-y plane.




- Sound sources is not stationary signals, it has properties that change with time. Thus, a single representation based on all the samples of a sound sources, for the most part has no meaning.
- Instead, we define a time-dependent Fourier Transform (STFT) of that changes periodically as the speech properties change over time.

$$STFT \rightarrow X[n,k] = \sum_{m=0}^{L-1} x[n+m]w[m]e^{-jk\frac{2\pi}{N}m}$$

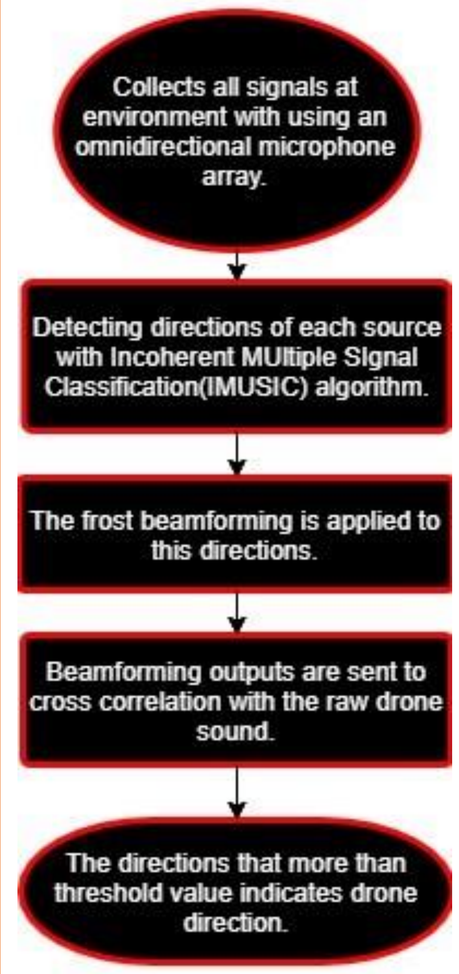



- After taking the STFT of the signals that coming from the microphone components, then after a compression process, narrowband MUltiple SIgnal Classification (MUSIC) model is applied.

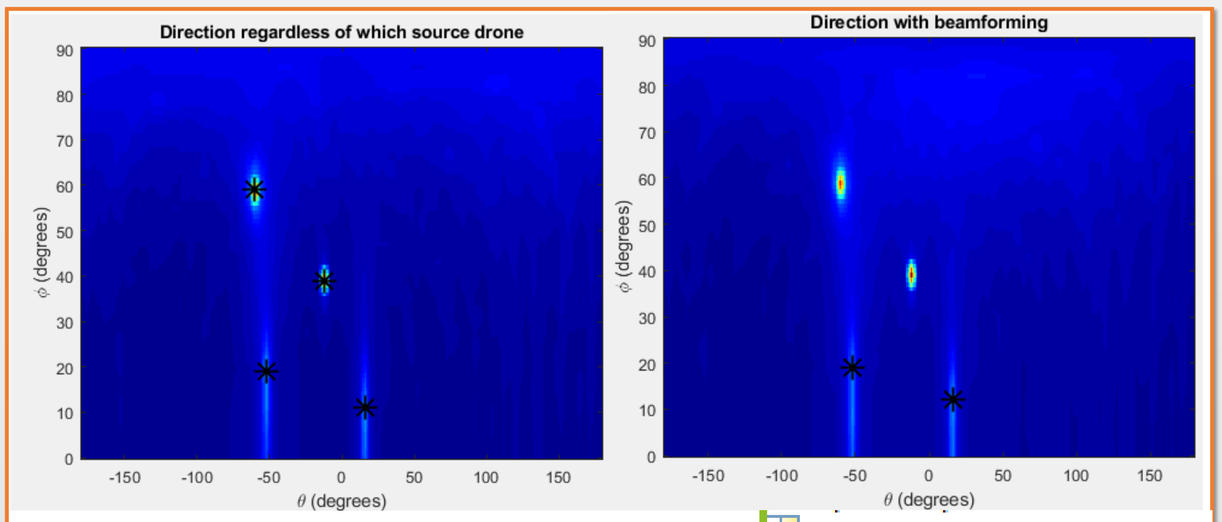
$$\mathbf{F}_1(\theta) = \frac{\mathbf{a}^H(f_j,\theta)\mathbf{a}(f_j,\theta)}{\frac{1}{L}\sum_{j=1}^{L}\frac{1}{M-D}\sum_{m=D+1}^{M}\mathbf{a}^H(f_j,\theta)\mathbf{E}_n(f_j)\mathbf{E}_n^H(f_j)\mathbf{a}(f_j,\theta)};$$

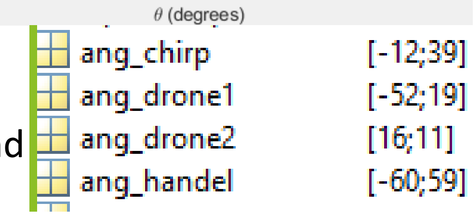
- Covariance matrix is generated by multiplying signal and its hermitian. Then, singular value decomposition is applied and signal is separated to subspaces and the lowest eigenvalue's subspaces is noise's subspaces.
- Beamforming is an array signal processing technique for enhancing signals from one or more directions while suppressing noise and interferences from other directions.

## Algorithm




## Results and Discussion




- The sounds have reached as in the picture on the right. Two drone sources and two interference are coming and there is additive Gaussian noise SNR is 10 dB.
- Direction of the two drones are found exactly the same direction.
- This whole project simulated on MATLAB and there is not implementation in real environment.
- In the future, computation complexity can be reduced by CSS algorithm instead of IMUSIC and robustness to different drone sound can be increased by indepent component analysis (ICA).

## References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