Multiple Signal Classification for Determining Direction of Arrival of Frequency Hopping Spread Spectrum Signals

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Disclaimer

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Personal Background

- MS in Electrical Engineering at the Air Force Institute Of Technology, March 2014.
- BS in EE at KFUPM in July 2011.
- M&S of DOA estimation.
- M&S of coded and un-coded communication systems.
- M&S of Radar range estimation.
- M&S of many multipath topology terrain estimation.
- Proof of concepts of EW components on UAV.
- I&S of many Jamming techniques on Rice FPGA board.
- M&S of SHM (Detection problem).
- Currently working on SDR Simulation on Raspberry Pi chip.
• Motivation.
• Assumptions.
• MUSIC Algorithm.
• Current Work.
• Developed Work.
• Results and Conclusion.
• Questions and Discussion.
Motivation

- Cognitive Radio.
- Direction of Arrival DOA.

Research Goal

- DOA of FHSS.
- Robust algorithm.
- Improving current implementation.
Research Motivation
FHSS Signals are common in military applications:

– Joint Tactical Information Distribution System JTIDS
Assumptions

- Different DOA.
- Sampling is greater than Signal Nyquist Frequency.
- Known number of primary users.
- Known hopping pattern.
- AWGN.
- Non-coherent detection / Slow hopping.

Modulations

- FHSS.
- PSK.
MUSIC Algorithm

Drivers

- High resolution.
- Resilience to noise.
- Robust / efficient.
- Eigenstructure method.
MUSIC Algorithm

Method \([2,4,6]\)

- Received matrix at time \(t\)
  \[ X = AS(t) + W(t) \]
  \[ R_{xx} = AR_{ss}A^H + R_{nn} \]
- Search for steering vector \(\mathbf{v}\) to noise subspace.
- \(\mathbf{v}\) convey \(\theta\)
Problem Scheme

User D with $\theta_0$ at $\{f_1, \ldots, f_5\}$

User 2 with $\theta_2$ at $\{f_1, \ldots, f_5\}$

User 1 with $\theta_1$ at $\{f_1, \ldots, f_5\}$

Array Sensor (M=6)

AWGN Channel No/2

MUSIC Algorithm
**Current Work**

- Research on wideband MUSIC DOA estimation
  - Incoherent Approach.
  - Coherent Approach.
  - The temporo-spatial Approach.
  - Frequency dependent modeling.
  - Rational Estimation.
Current vs. Developed

Need to know hopping sequence

Need to know number of users D

Start

Calculate the $M \times M$ Autocorrelation matrix $R_{xx}$ of the received data $X$ at each frequency bin $f$

Calculate eigenvalues and eigenvectors of $R_{xx}$ at each $f$

Construct a matrix consists of noise eigenvectors $U_n$ for at $f$

At each $f$, generate steering vectors $y$ for all angles between 0 and $\pi/2$ and then project on $U_n$.

Sum the projection coefficient over all frequency bins.

Square each coefficient, sum them and take the inverse. Peaks of $P$ represents DOA

End

Need to know $f$

Calculate the $M \times M$ Autocorrelation matrix $R_{xx}$ of the received data $X$

Calculate eigenvalues and eigenvectors of $R_{xx}$

Need to know number of users $D$

Construct a matrix consisting of noise eigenvectors $U_n$.

Generate steering vectors $y$ for all angles between 0 and $\pi/2$ and then project on $U_n$.

Calculate the projection of $y$ on $U_n$ for all steering vectors $y$.

Square the projection coefficients and take the inverse. Peaks of $P$ represent DOA at $f$

Repeat for all hopping channels

Take the mean of the DOAs

End
SNR

1km 1 degree 17m!

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Hs

- Single Frequency Algorithm
- FHSS Algorithm

Bias(θ) (degrees)

Number of hops $H_s$

Number of hops $H_s$
M

**Graphs:**

- **Beam power (dB):**
  - **M=10:**
    - Green line: Single Frequency Algorithm
    - Yellow line: FHSS Algorithm
    - Blue line: \( \theta_1 \)
    - Light blue line: \( \theta_2 \)
  - **M=15:**
    - Green line: Single Frequency Algorithm
    - Yellow line: FHSS Algorithm
    - Blue line: \( \theta_1 \)
    - Light blue line: \( \theta_2 \)
  - **M=20:**
    - Green line: Single Frequency Algorithm
    - Yellow line: FHSS Algorithm
    - Blue line: \( \theta_1 \)
    - Light blue line: \( \theta_2 \)
  - **M=25:**
    - Green line: Single Frequency Algorithm
    - Yellow line: FHSS Algorithm
    - Blue line: \( \theta_1 \)
    - Light blue line: \( \theta_2 \)
Conclusion

The research has advanced the research on DOA for FHSS:

- Noise levels.
- Accuracy of estimation (target recognition).
- Capitalization on the spectrum.
- Robust algorithm (Cost saving).
Q&A