Direction Finding on Spread Spectrum Signals (DFSSS)

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Sponsor:
CG-761 – Mr. Ed Thiedeman
Introduction

• Emergency Position Indicating Radio Beacon (EPIRB)

• EPIRB has aided the CG in saving 39,000 lives
Needs and Objectives

- Problem: Coast Guard assets will not be able to DF on EPIRBS emitting the new Direct Sequence Spread Spectrum (DSSS) signal

- Goal: Create a continuous and user friendly system to home in on the new generation EPIRB signal
Requirements

- Make a continuous system
- Make a user friendly system
- Optimize efficiency of the system
  - Antenna construction
  - Cost of hardware
System Overview

OctoClock

Host Computer

Ethernet Switch

PPS in

REF in

Ethernet Cables

URSP RX

URSP RX

URSP TX

USRP RX

USRP RX

USRP TX
System Overview

Antenna array: half-wave monopoles

USRPs and Clock equipment rack

New tower for increased processing
System Overview (rack view)

To the antennas topside

- Calibration
- OctoClock
- USRP RX bank
- BNC Relays
- New Com Tower
GNU Radio Companion (GRC)
GNU Radio Companion (GRC)
GNU Radio Companion (GRC)
GNU Radio Companion (GRC)
Incoming Calibration Signal
GNU Radio Companion (GRC)
**Multiple Signal Classification (MUSIC) Algorithm**

- \( R = ASA^H + Q \)
  
  Eigen Decomposition of incoming data

- \( J(\theta) = (\sum_{m=M+1}^{N} |\bar{a}^H(\theta) \cdot \bar{u}_m|)^{-1} \)
  
  Peak estimator function
GRC Transmitter

- Need to emulate new Direct Sequence Spread Spectrum Signal
- Consists of pseudo random binary data to spread signal around a center frequency
GRC Transmitter

- EPIRB specs: GMSK: 1bit/symbol, 38,400 chips/sec
- Center Frequency: 406.05MHz, null to null 76.8kHz.
Testing Procedure

- Test signal centered at 435MHz, $\lambda = 0.6892m$
- Far field pattern assumed at 6.892m
- Test at 15 yards = 13.716 or approximately 2 times the far field
- Calibrate and then data collect
Testing Procedure

Transmitter

Receiver
Initial Problems Encountered

- Trouble understanding how to test the system
- Error due to multipath

Narrow Band, angle 6 degrees
Wide Band, angle 0 degrees
Narrow Band Data

<table>
<thead>
<tr>
<th>Angle of Incoming Signal</th>
<th>Angle 0°</th>
<th>Angle 30°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1 (blue)</td>
<td>2.5</td>
<td>Test 1</td>
</tr>
<tr>
<td>Test 2 (red)</td>
<td>2.3</td>
<td>34</td>
</tr>
<tr>
<td>Test 3 (green)</td>
<td>5.1</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>3.3</td>
<td></td>
</tr>
</tbody>
</table>
Wide Band Data

<table>
<thead>
<tr>
<th>Angle 0°</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1 (blue)</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>Test 2 (red)</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>Test 3 (green)</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>3.6</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Angle 30°</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1 (blue)</td>
<td>35.9</td>
<td></td>
</tr>
<tr>
<td>Test 2 (red)</td>
<td>31.8</td>
<td></td>
</tr>
<tr>
<td>Test 3 (green)</td>
<td>31.1</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>32.9</td>
<td></td>
</tr>
</tbody>
</table>
Wide Band Data

![Graph of Angle of Incoming Signal vs. \( \theta \) (degrees)](image)

<table>
<thead>
<tr>
<th>Angle 45°</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Test 1 (blue)</td>
<td>52.8</td>
</tr>
<tr>
<td>Test 2 (red)</td>
<td>50.1</td>
</tr>
<tr>
<td>Test 3 (green)</td>
<td>49.1</td>
</tr>
<tr>
<td>Average</td>
<td>50.6</td>
</tr>
</tbody>
</table>
Continuous System

- Road to completion
  - MUSIC Block
  - User Datagram Protocol (UDP)
  - MySQL

- Achieved through MatLab© and LibreOffice Base
Continuous System
Wide Band Data

<table>
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<th>Angle 0°</th>
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<th>Angle 30°</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>3.6</td>
<td>Average</td>
<td>32.9</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>1.85</td>
<td>Std. Dev.</td>
<td>2.59</td>
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</tbody>
</table>
Wide Band Data

Angle $45^\circ$

<p>| | |</p>
<table>
<thead>
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<tbody>
<tr>
<td>Average</td>
<td>50.6</td>
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<td>Std. Dev.</td>
<td>1.91</td>
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Future Work

- Expand to multidimensional array
- Explore optimization
- Create EPIRB message
Acknowledgements

- Dr. Paul Crilly
- Dr. Richard Hartnett
- Dr. Ali Reza
- CDR Armstrong
- Class of 2017 EEs
Questions?