Pseudo-Doppler Direction Finder

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Background and Project Goals

Determines direction toward signal source (RF, acoustic, etc.)

RDF applications: aerial navigation, tracking, locating pirate radio stations...
Pseudo-Doppler Direction Finding

Synthesize a rotating effective antenna by switching between elements in an array

Effective antenna moves toward/away from source $\rightarrow$ Doppler shift

Typically use a soft-switching profile to reduce phase discontinuities
Motivation

Originally idea: Radio Direction Finder (RDF) operating in FM band…

Same principle of operation holds for audio frequency

Analog solutions for most of the functionality

\( \frac{1}{4} \) wavelength = 8.5 cm for 1 kHz tone

\( c = 340 \text{ m/s} \)
High-Level Block Diagram

Pseudo-Doppler DF

- Microphone array and signal conditioning
- Electronically weighted audio mixer
- Control unit
- FM RX
- Bandpass filter
- Phase comparator
- Offset correction
- Display
Overview: Signal Acquisition Module

- Microphone array and signal conditioning
- Electronically weighted audio mixer
- Control unit

pseudo-Doppler signal (FM, 1kHz) → Electronically weighted audio mixer

Control unit → reference tone (SW, 100Hz)
Close-Up: Signal Acquisition Module

Signal Conditioning - Block Diagram

Considerations:
○ Why is AGC needed?
○ Why is BPF needed?
Close-Up: Signal Acquisition Module

Signal Conditioning - Implementation

- Mic input stage
- Band-pass filter with gain
- Compressor (with gain)

Complications with multipath?
Close-Up: Signal Acquisition Module

Control Unit - Block Diagram

Considerations:

○ Shape of bias waveform?
○ How to make quadrature?

Implementation: reference sinusoid → square wave → triangle (zero offset) → comparator → quadrature
Close-Up: Signal Acquisition Module

Voltage Controlled Audio Summer - Block Diagram

Microphone Signal Conditioner

Audio Mixer

Controllable Gain

Voltage Summer

FM pseudo-Doppler

Implementation: JFET operated in linear regime for voltage controlled gain
Phase Extraction

Control unit

VCO

Phase Comparator

Control Sq. Wave

Mixer

Integrator

Mixer

Integrator

to Display

DC

FM Demodulator

from Audio Mixer

FM

Schmitt Trigger

Sq. Wave
FM Demodulator

1st-order Phase locked loop

FM Input → Phase Detector → Output proportional to phase difference → Loop Filter → Demodulated signal → VCO → FM Input
Close-Up: FM Demodulator

Challenges:

- Tuning the low pass filter
- Jitter
Gilbert Cells and Mixing

Schematic
Phase comparison

Challenges:

- Asymmetry of components
Display

- Offset correction
- 16 Comp
- LED Display
- LED
- Oscilloscope XY
LED Display

Negative Terminals
- 0, Vref/15, 2Vref/15, ...
- 14Vref/15, Vref

Positive Terminals
- All connected at phase comparator output
Oscilloscope XY Display

<table>
<thead>
<tr>
<th>X:Y Ratio</th>
<th>0°</th>
<th>45°</th>
<th>90°</th>
<th>180°</th>
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Oscilloscope XY Display

555

Integrator

Phase Comparator Output
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<th>Week of</th>
<th>Tasks</th>
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<tbody>
<tr>
<td>April 11</td>
<td>Begin building individual modules</td>
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<td>April 18</td>
<td>Continue building individual modules. Begin integrating/debugging modules</td>
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<td>April 25</td>
<td>Continue integrating/debugging modules. Begin working on stretch goals</td>
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<tr>
<td>May 2</td>
<td>Continue working on stretch goals. Demonstration of complete system</td>
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Concluding Remarks

Expected outcome:

- Complete PD-DF system that can point toward speaker with good accuracy
- Extensions: lay out a PCB, redesign for RF, more elaborate interface

Next steps:

- Finish up individual modules (design, construction, test)
- Test interconnected modules
Questions?