Phase Interferometry Direction Finding

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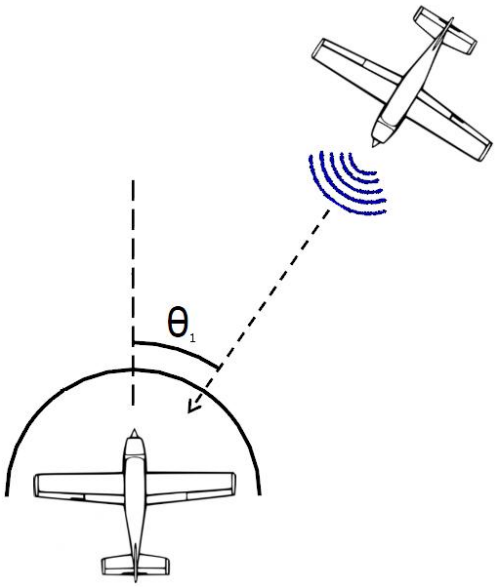
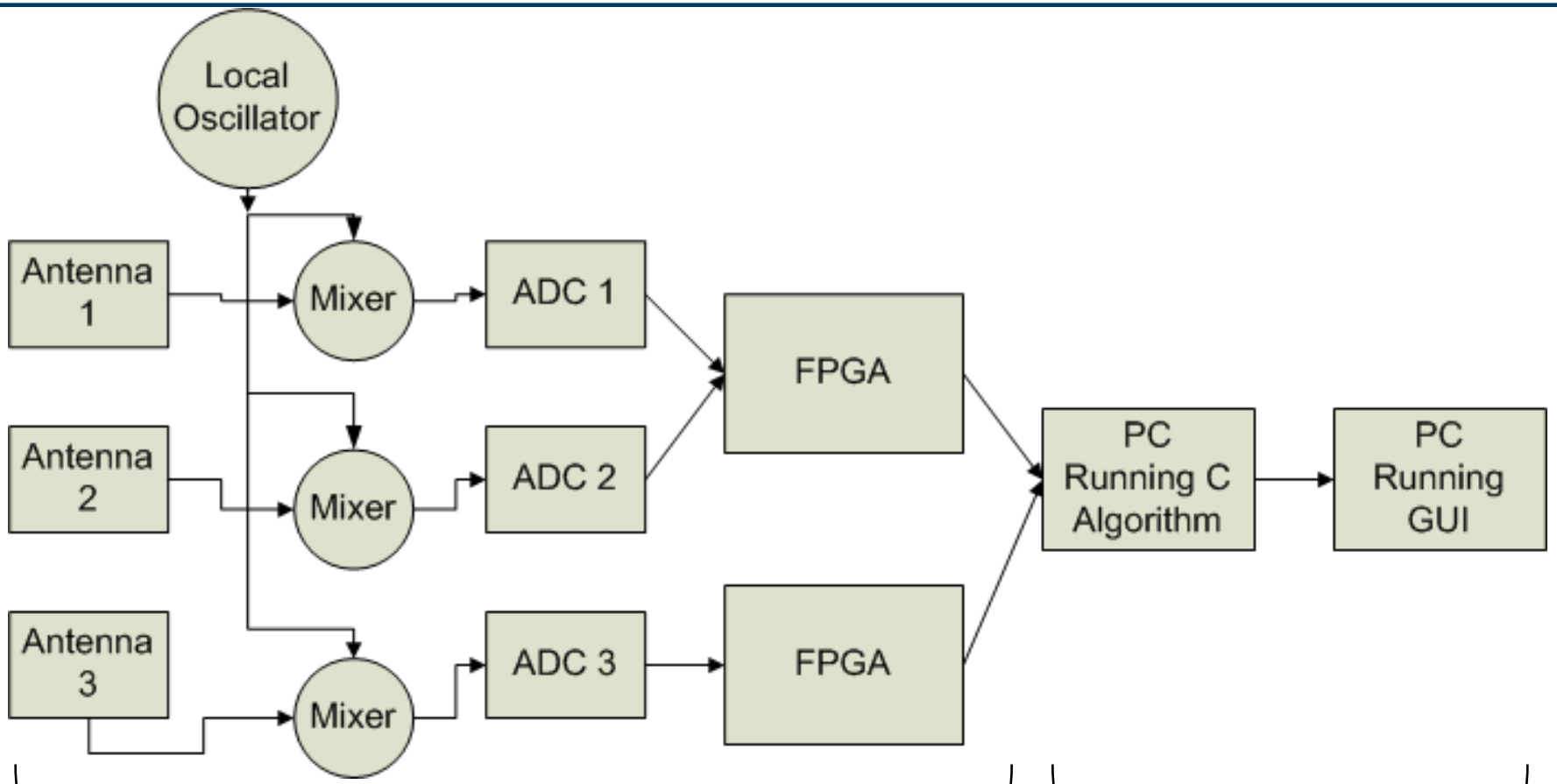
Overview

- **Project Goal**
  - **Create a passive Direction Finding system for an airborne platform capable of determining the Angle of Arrival (AoA) in the azimuth plane.**
  - **Display results in a real-time graphical interface**

Specifications
±2.5° accuracy
40 dB dynamic range
90° field of view
1 Hz update rate
100 MHz bandwidth IF signal
X Band Frequency (8-12 GHz)
Secondary Objectives
Track 3 beacons
180° field of view



Planned System

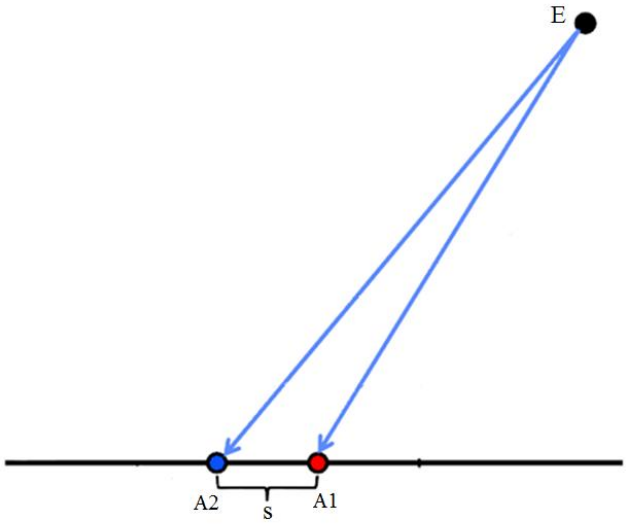


Contents

Passive Direction Finding

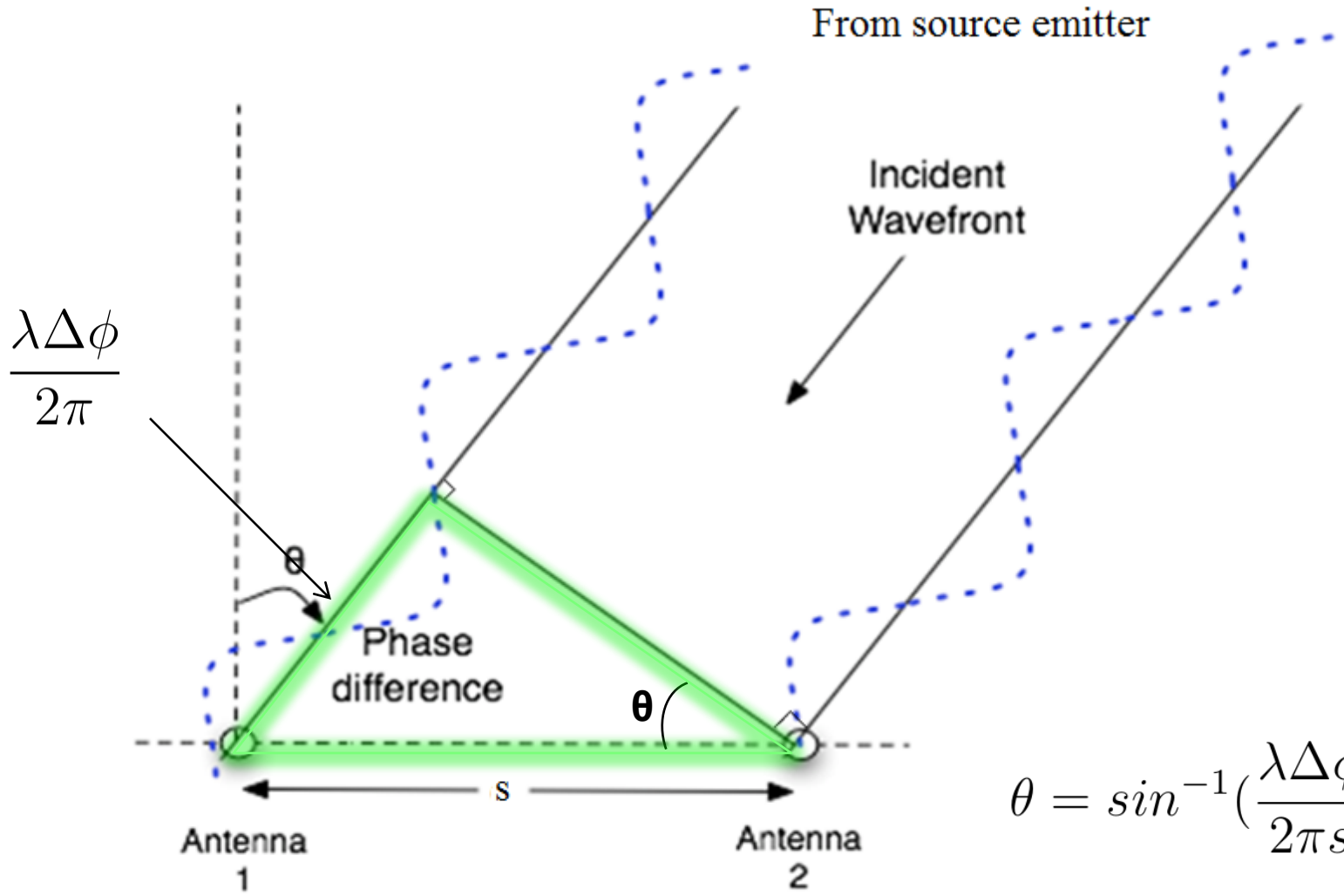
Method	Complexity	Size	Accuracy
Time Difference of Arrival	Medium	✖	✓
Amplitude Comparison	Low	✓	✖
Phase Interferometry	High	✓	✓

Scope of this project

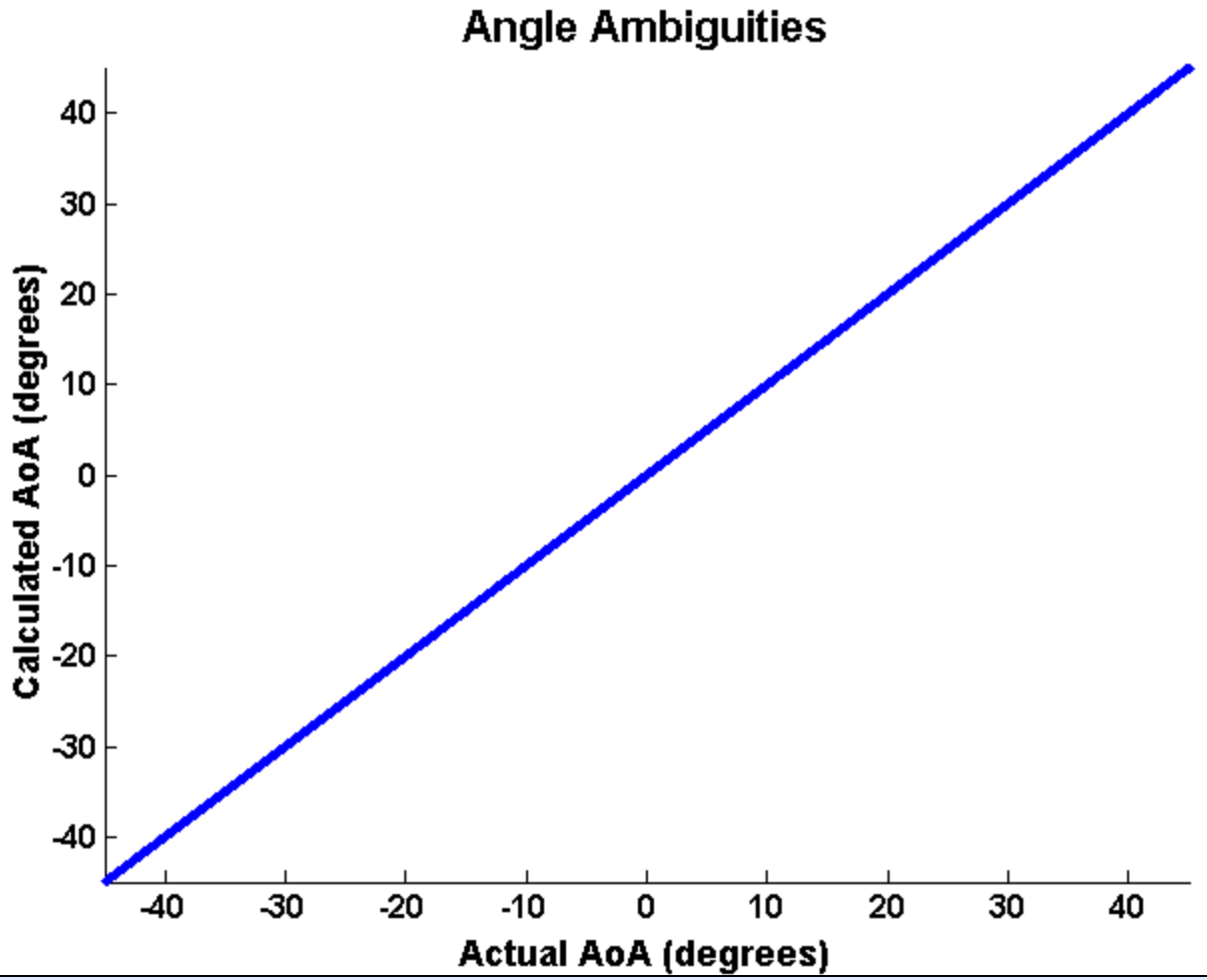


Interferometer Geometry
(Massa, O'Connor, Silva, 2011)

Phase Interferometry

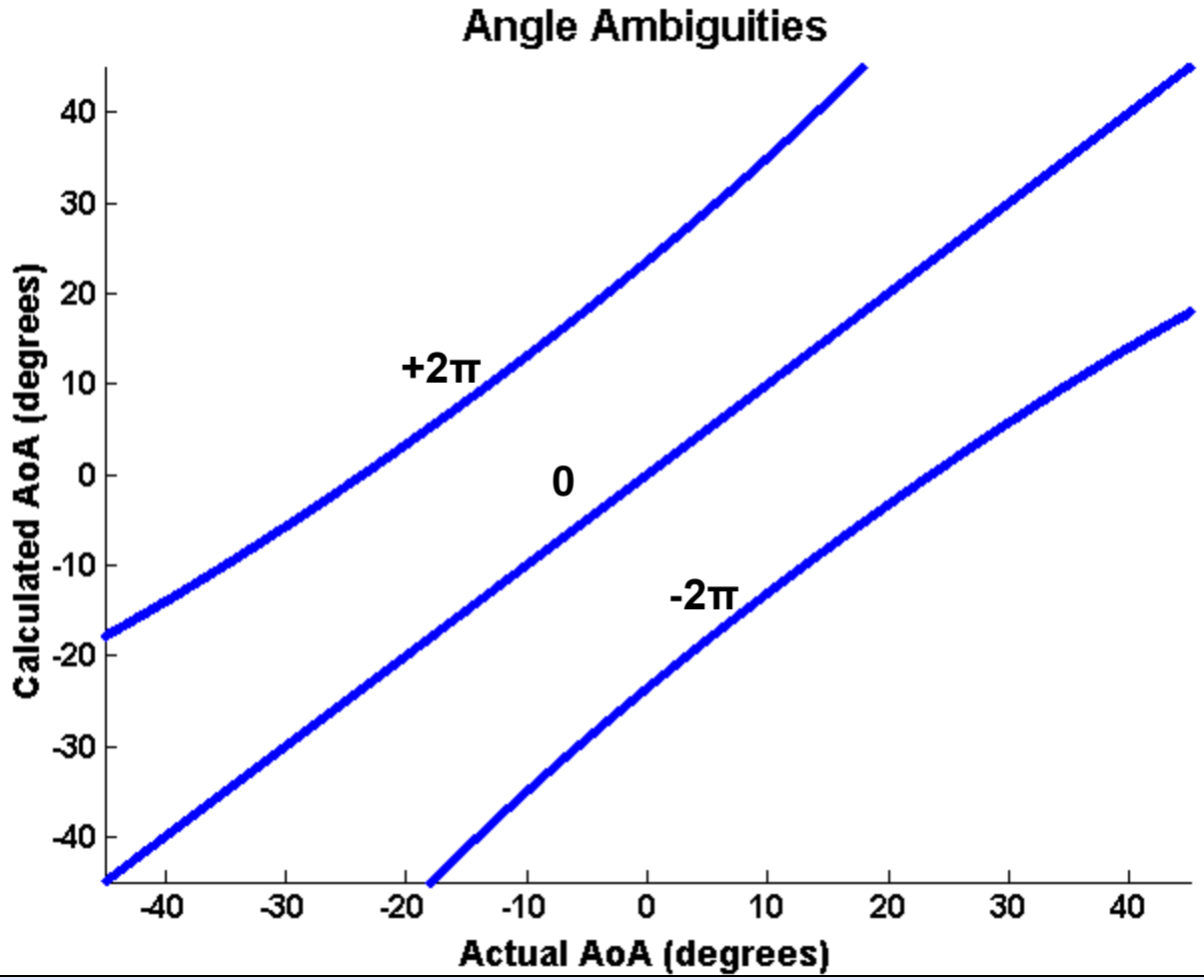


Phase Ambiguities



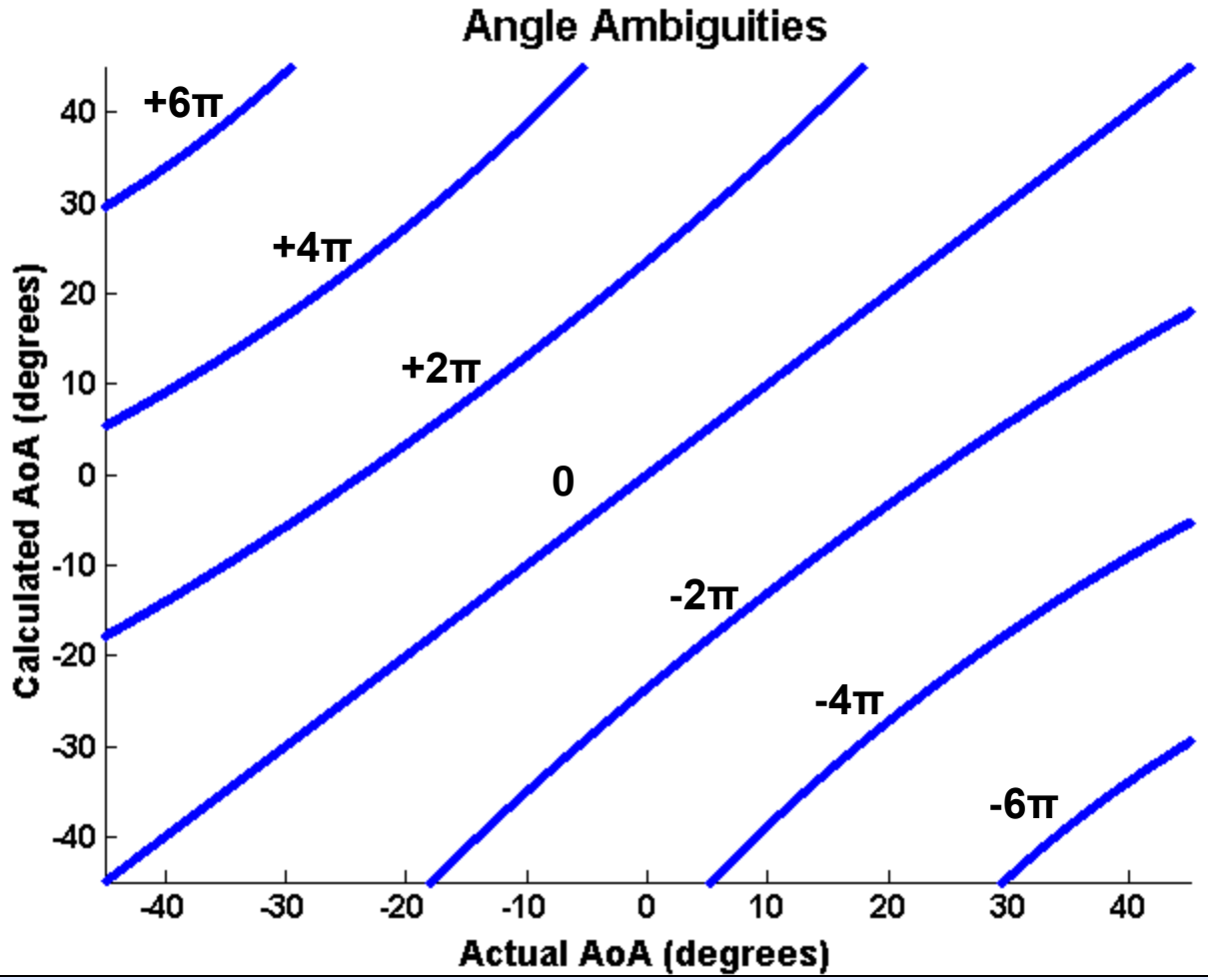
Phase eclipsing causes ambiguous results due to antenna spacing and wavelength

Phase Ambiguities



Phase eclipsing causes ambiguous results due to antenna spacing and wavelength

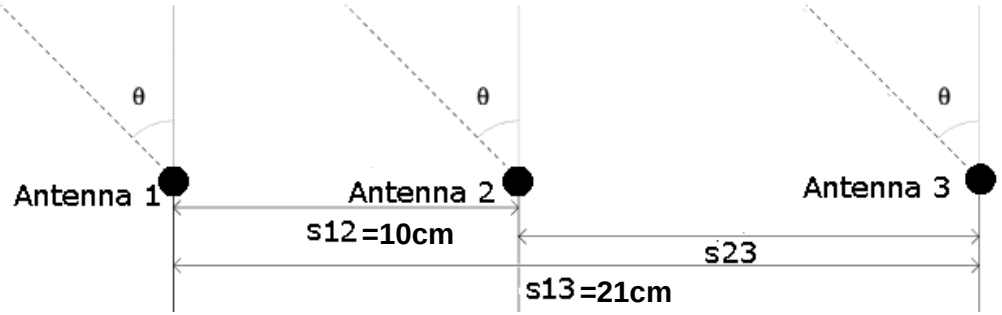
Phase Ambiguities



Phase eclipsing causes ambiguous results due to antenna spacing and wavelength

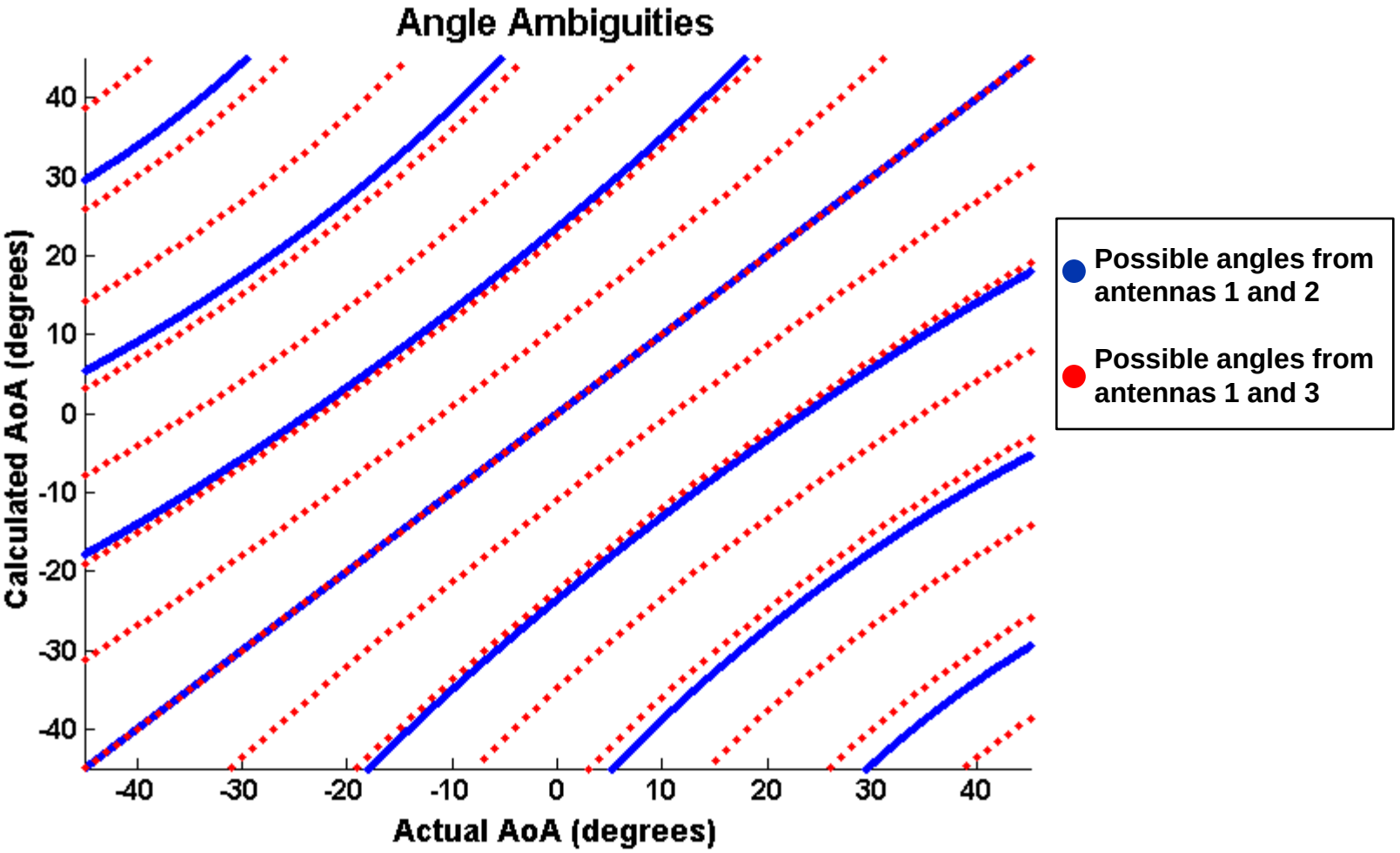
Resolving Ambiguities

- Utilize multiple antennas for disambiguation
  - Compute Phase difference from Antenna 1 to 2
  - Compute Phase difference from Antenna 1 to 3
  - Compare possible angle solutions for common angle value



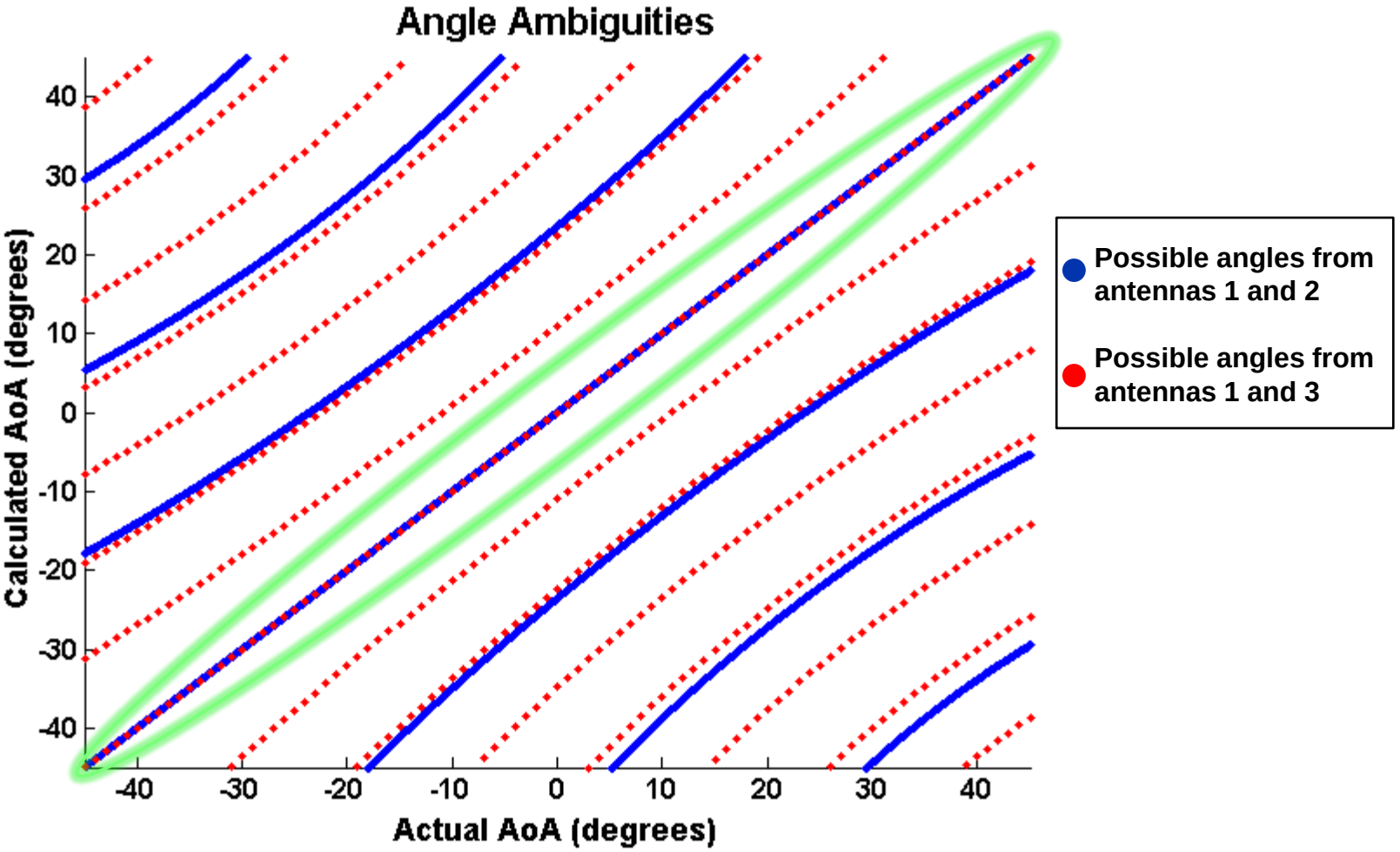
Antenna Spacing selected based on RF input requirement to minimize ambiguities

Resolving Ambiguities



Adding a third antenna provides unambiguous result

Resolving Ambiguities

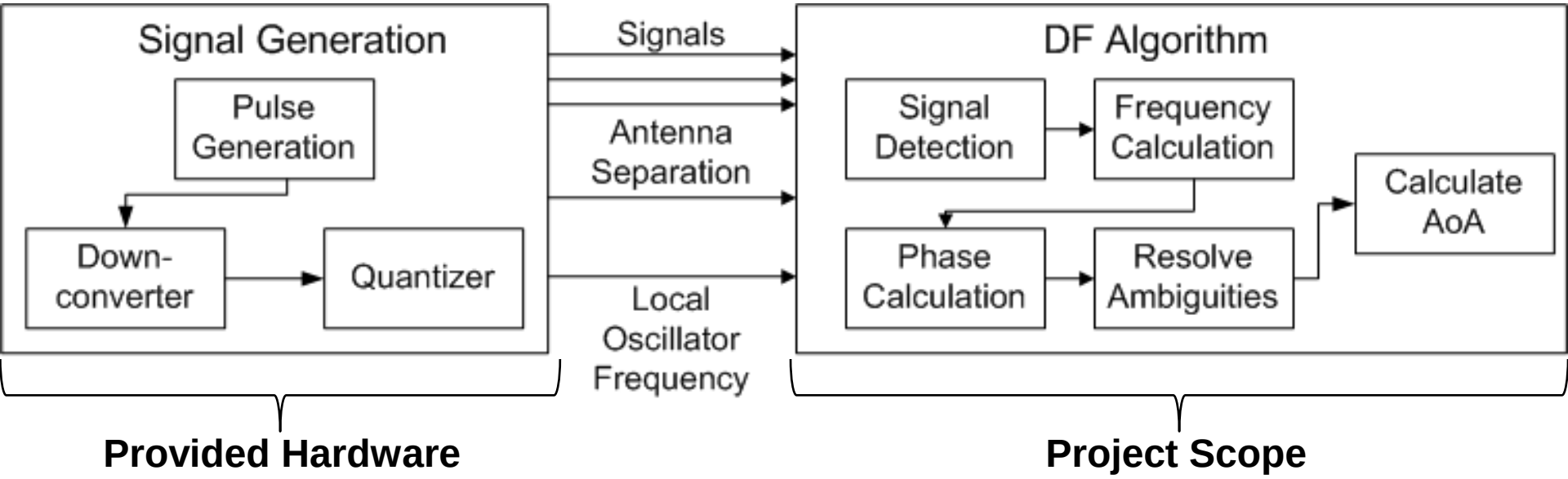


Adding a third antenna provides unambiguous result

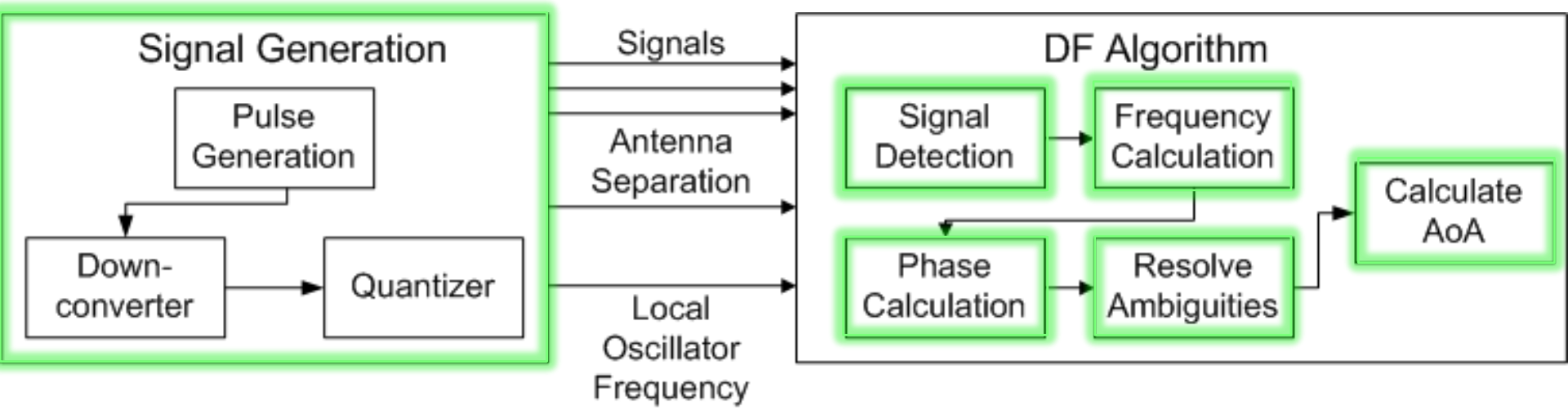
Contents

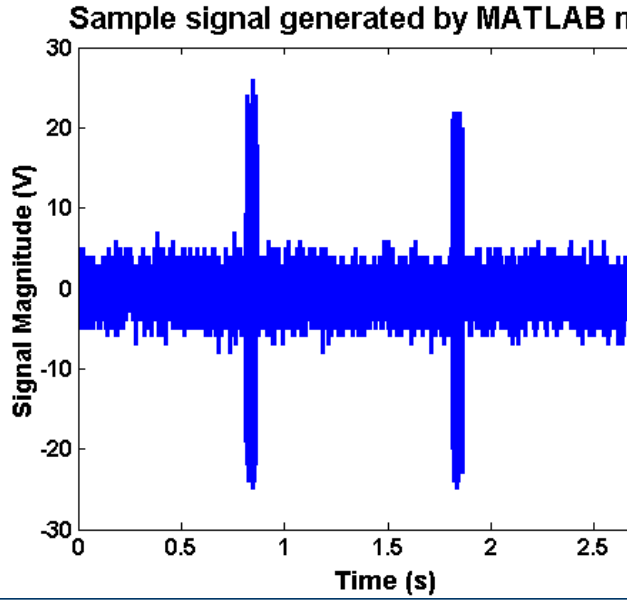
MATLAB Model

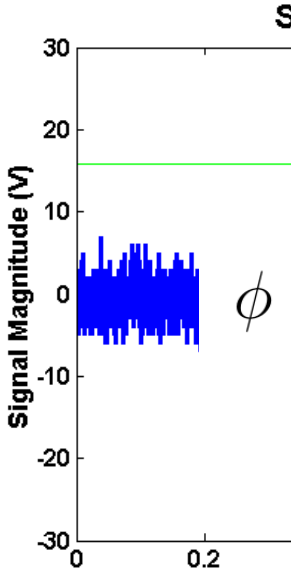
- **Used to develop and test the direction finding algorithm**
- **Simulates every step of the physical system**
  - **Pulsed wave generation, frequency down-converting, sampling waves**
  - **All processing steps in the final system tested in model first**

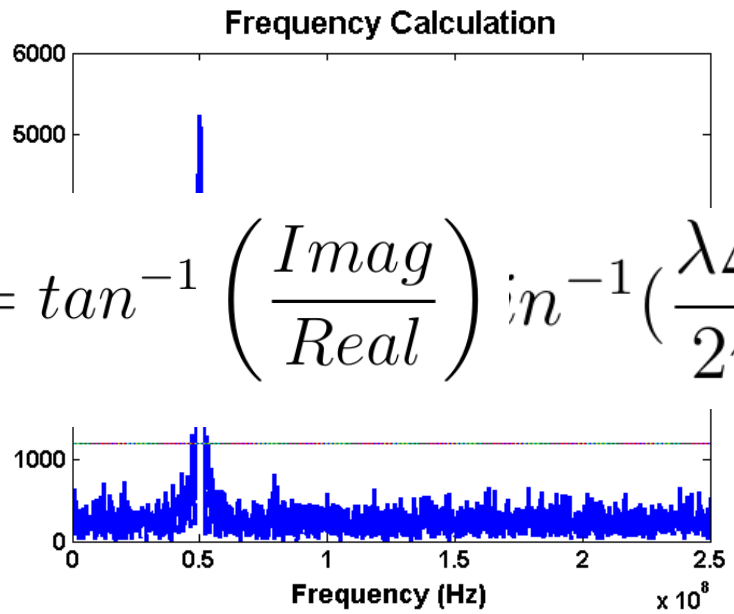


MATLAB Model







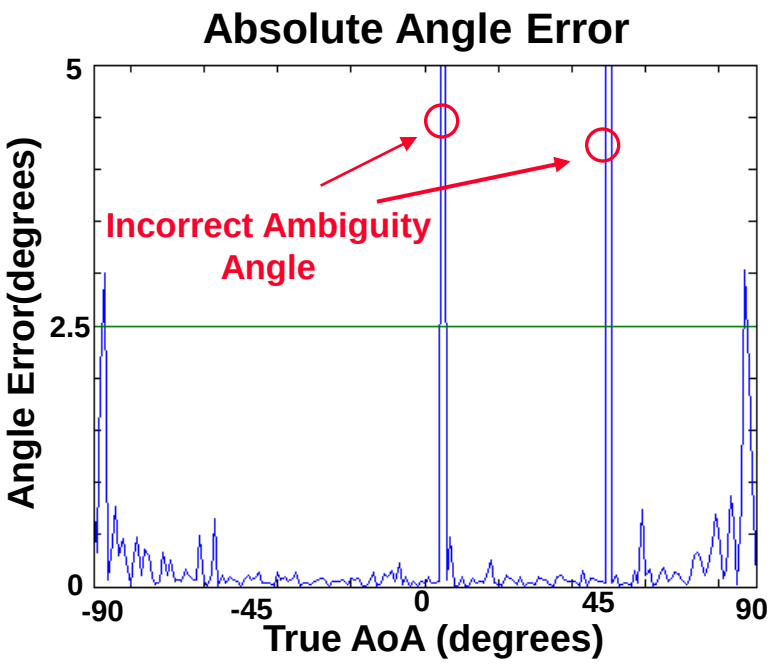


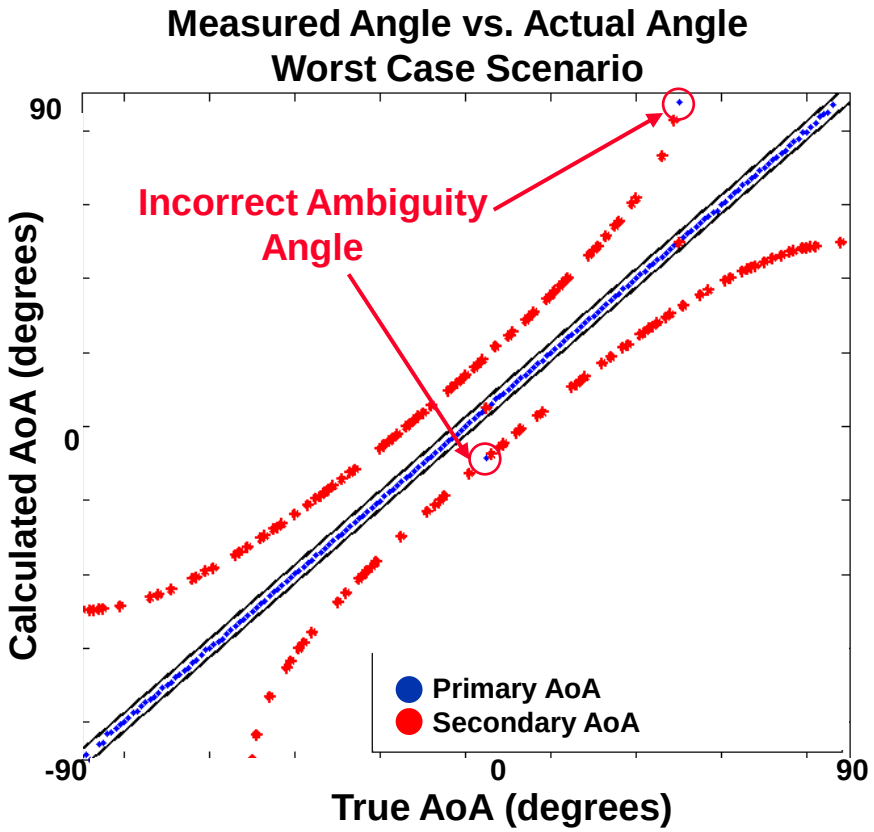
$$\phi = tan^{-1}\left(\frac{Imag}{Real}\right) :n^{-1}(\frac{\lambda\Delta\phi}{2\pi s})$$

MATLAB Results

Algorithm Performance	
Mean Error	0.097°
Mean Certainty	0.87
Ambiguity Error	1.08%

P = -40dBfs F = 12GHz D = 1km

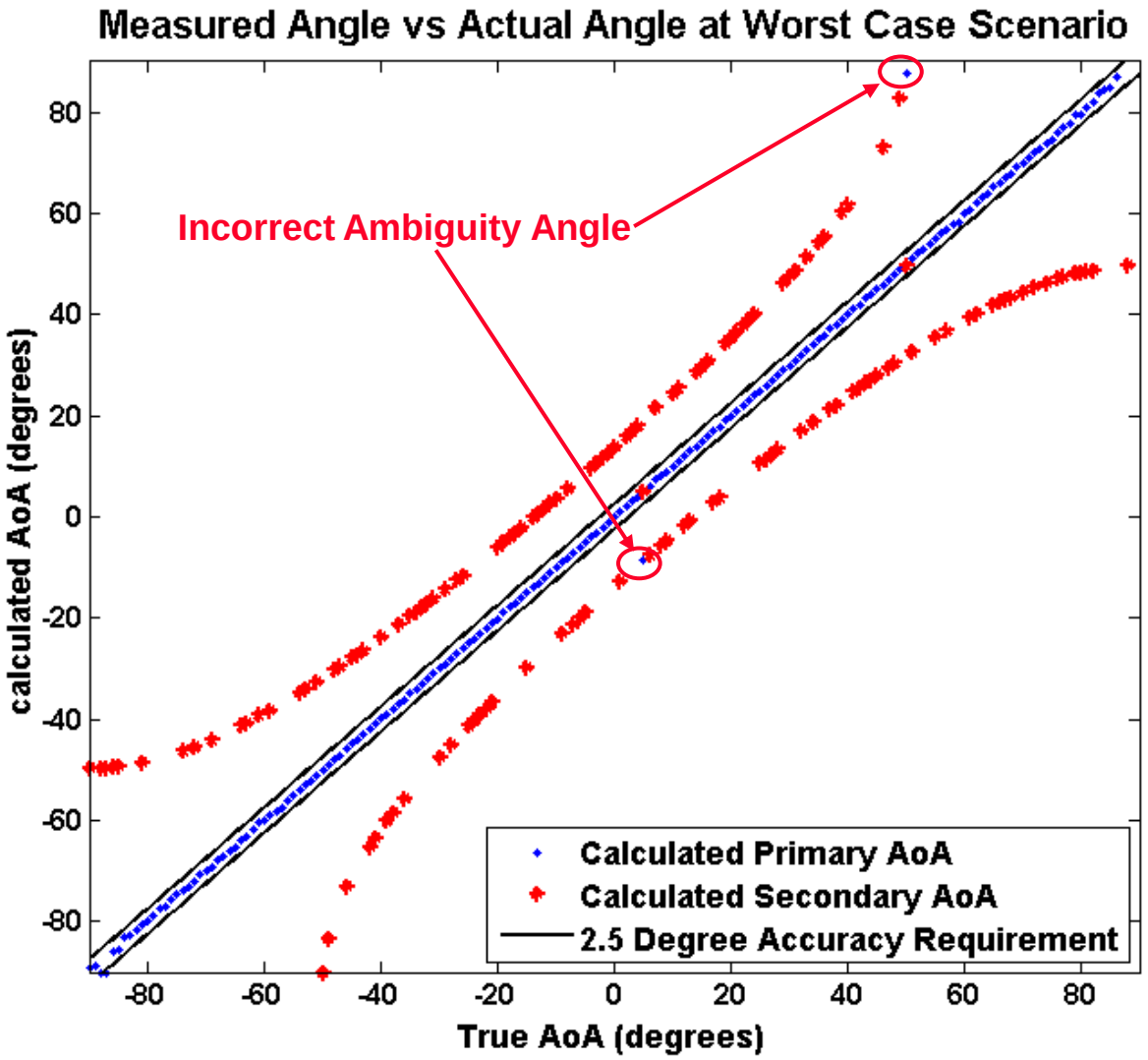




Rare ambiguity errors can cause erroneous calculations

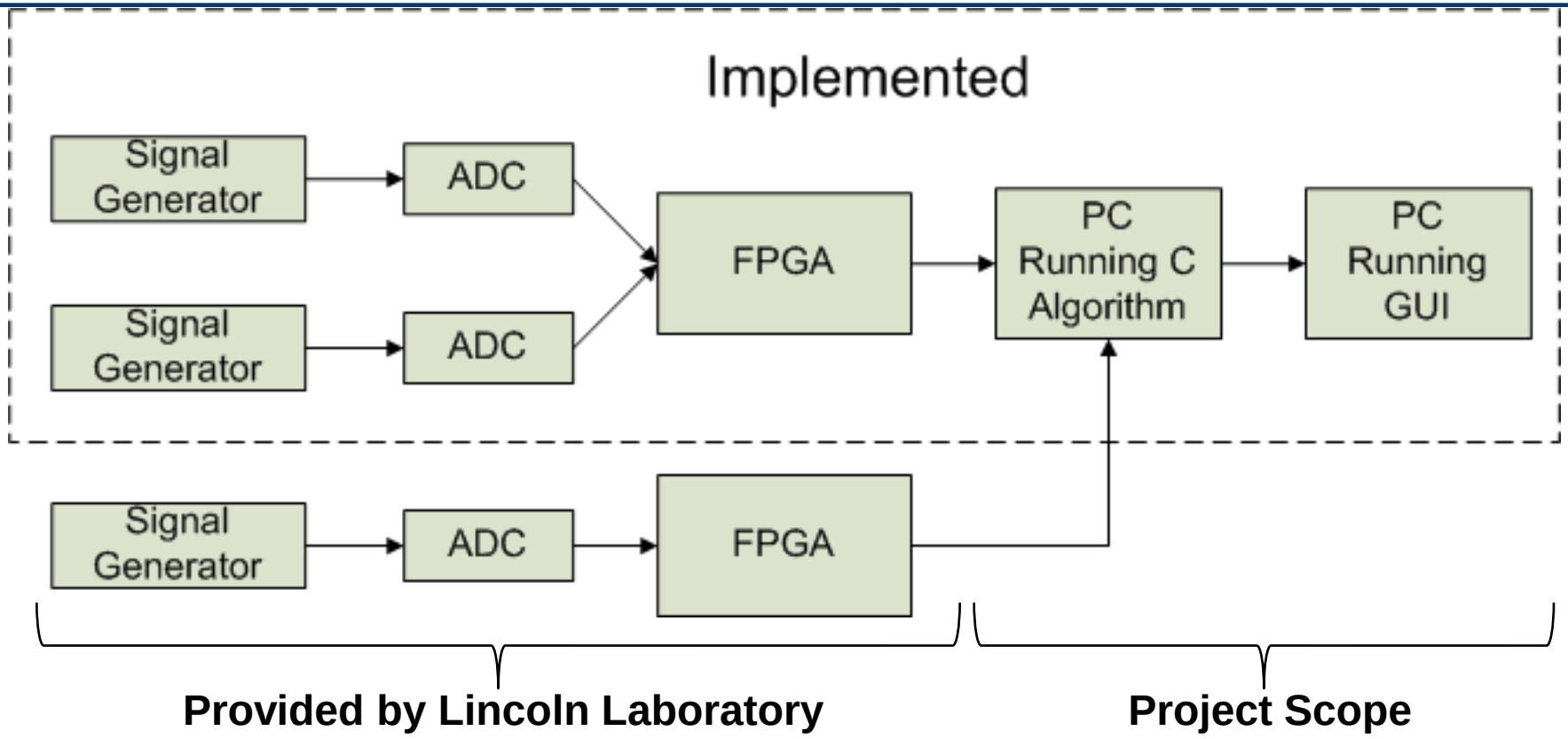
MATLAB Results

Algorithm Performance	
Mean Error	0.097°
Mean Certainty	0.87
Ambiguity Error	1.08%



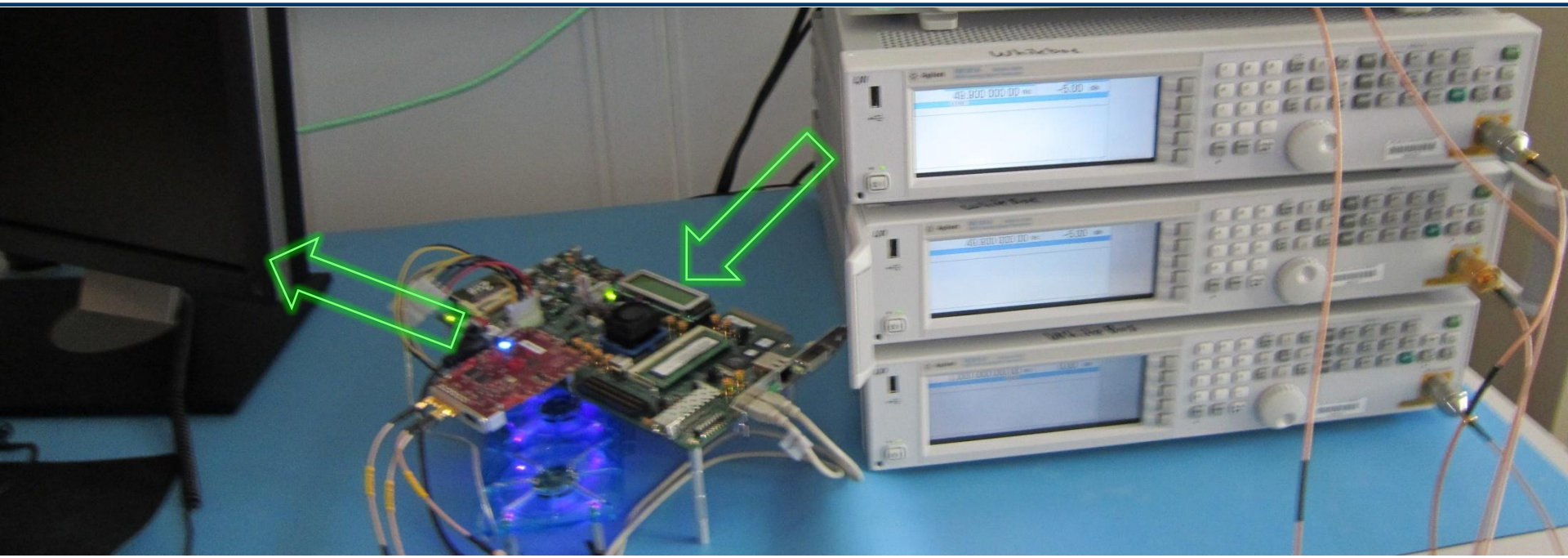
Contents

Prototype System



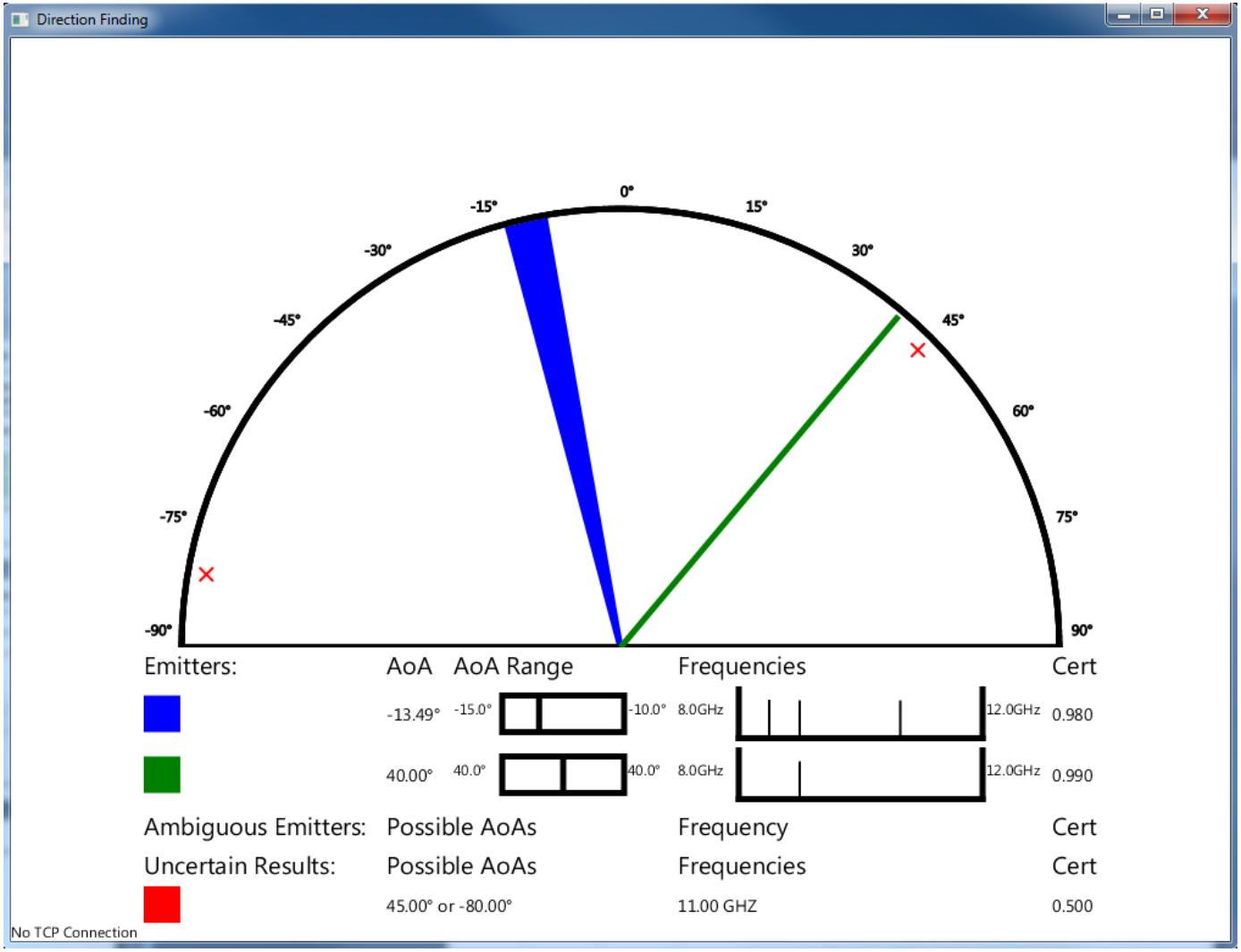
Third input channel not implemented due to hardware issues
Three antenna mode tested with MATLAB inputs

Prototype Results



- Strong agreement between verified model and C algorithm
- Processing time within specification
  - Data transfer accounts for 99.7% of latency
- GUI demonstrated with simulated and captured data

Real-Time Display GUI



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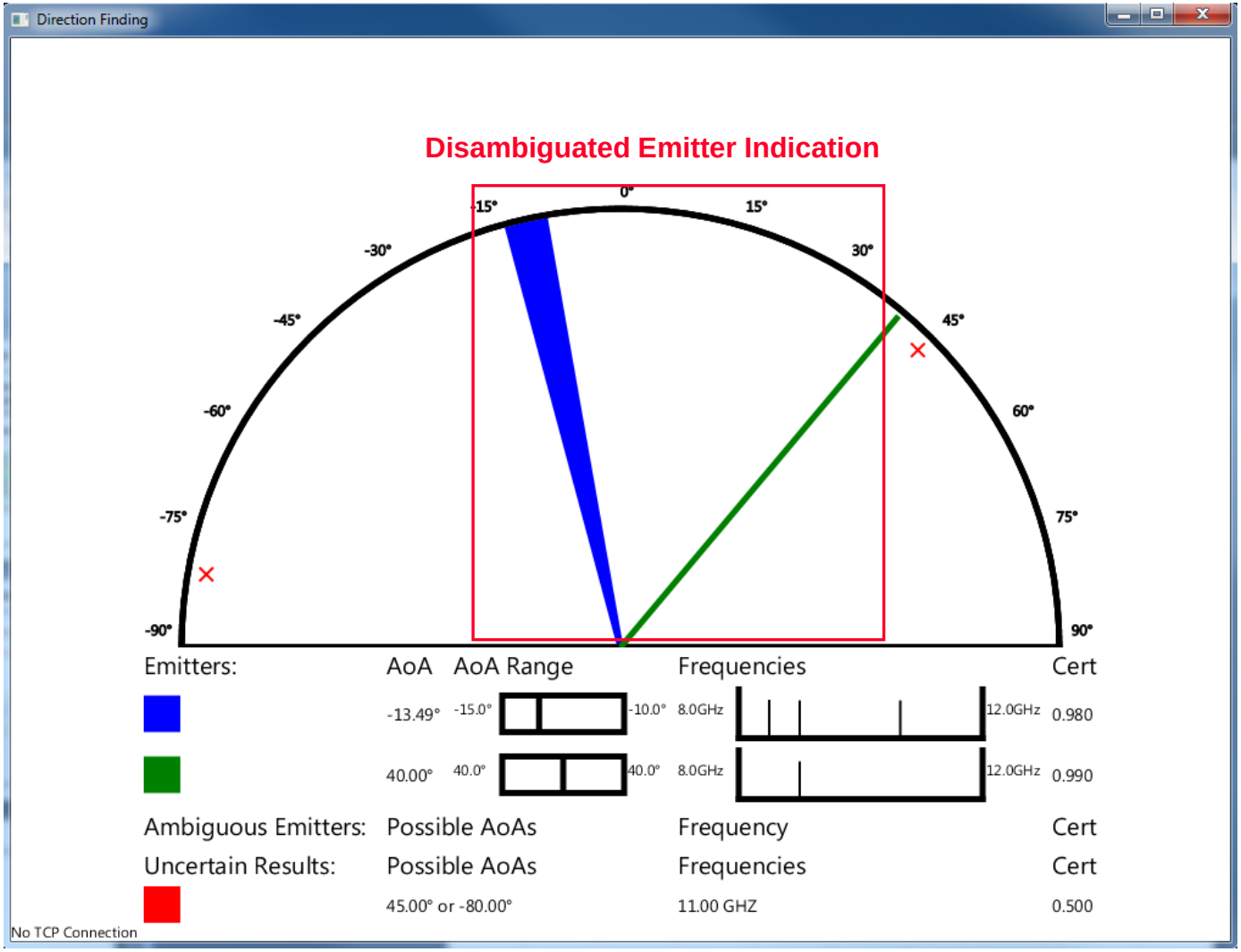

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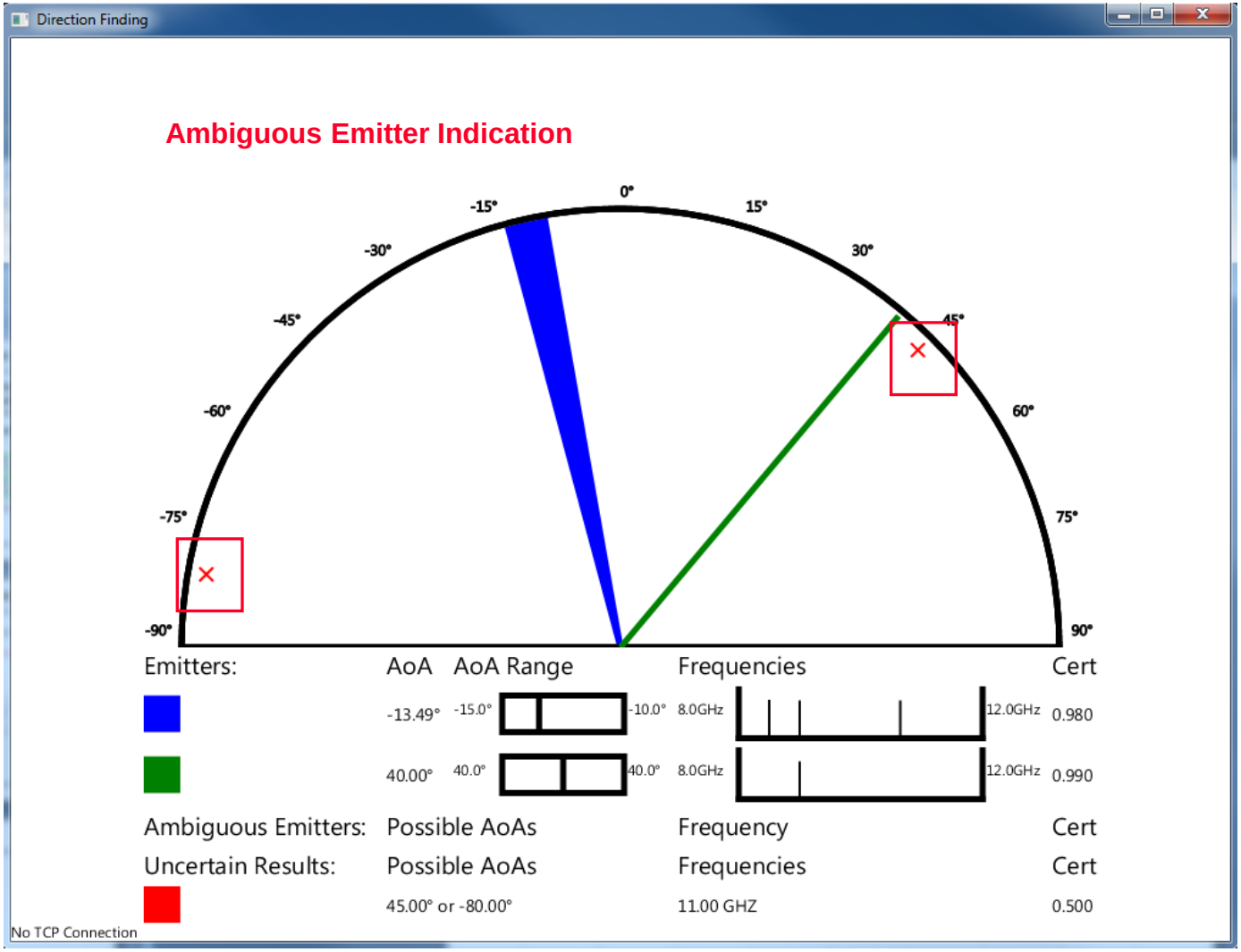
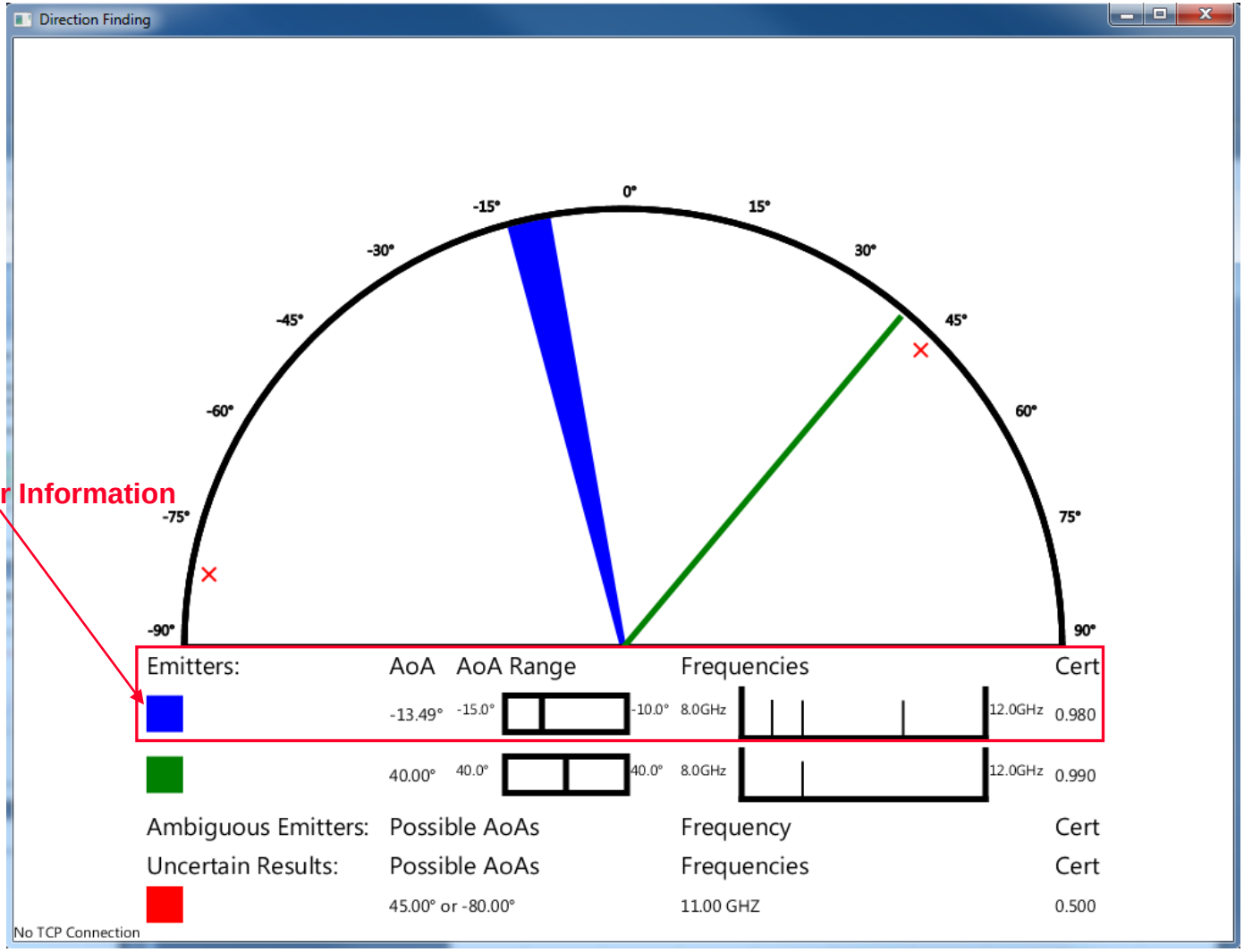
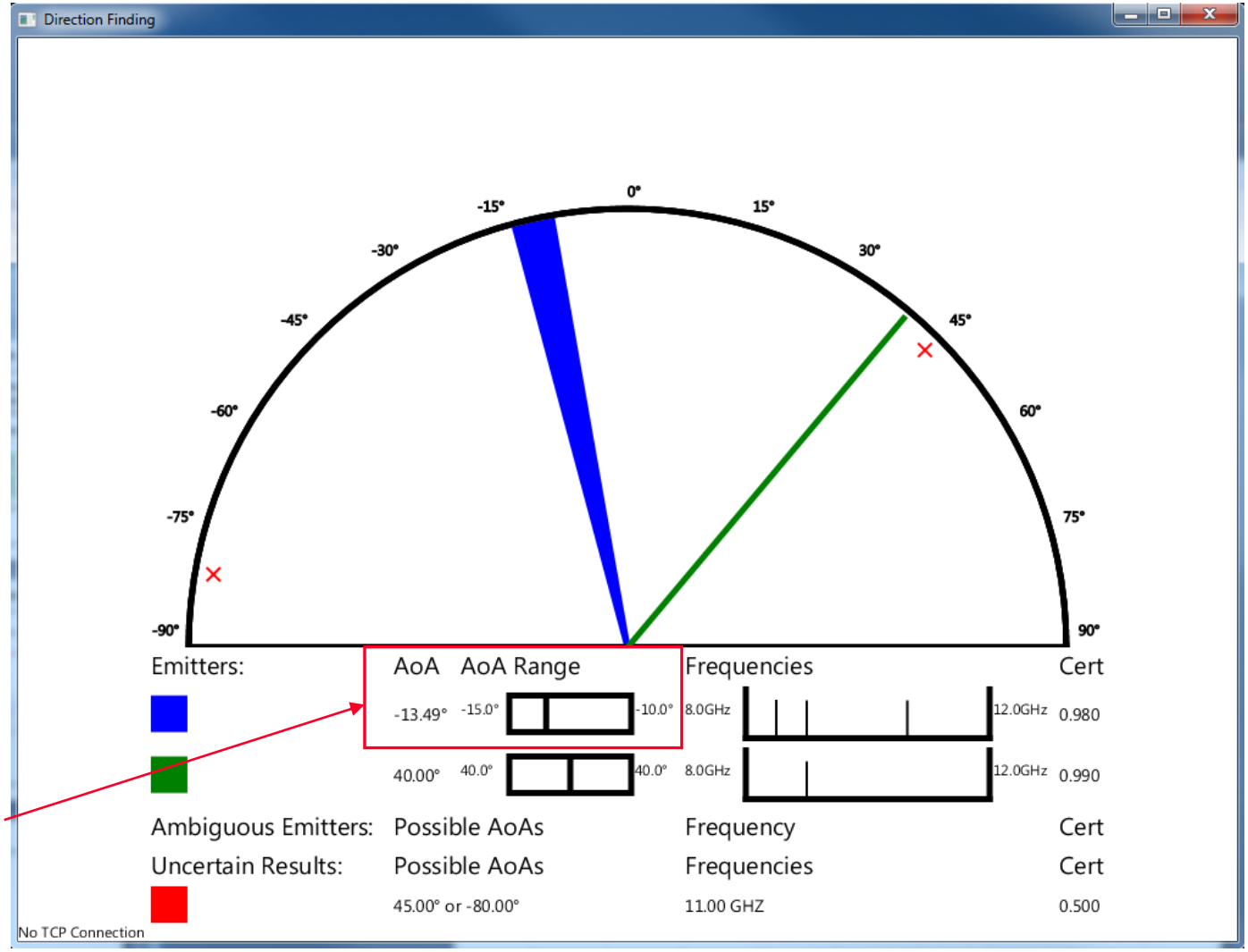


Real-Time Display GUI



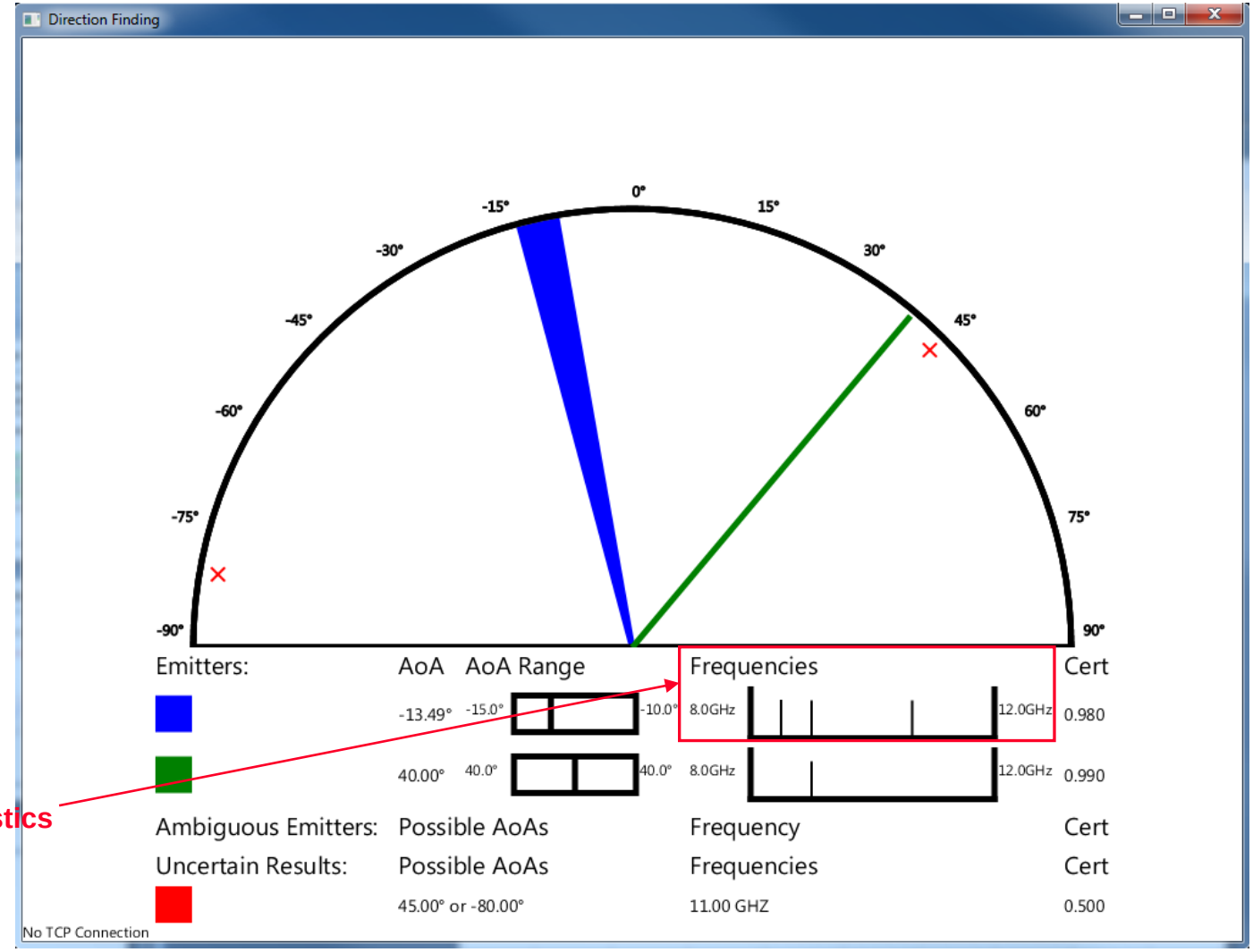
Detailed Emitter Information

Real-Time Display GUI



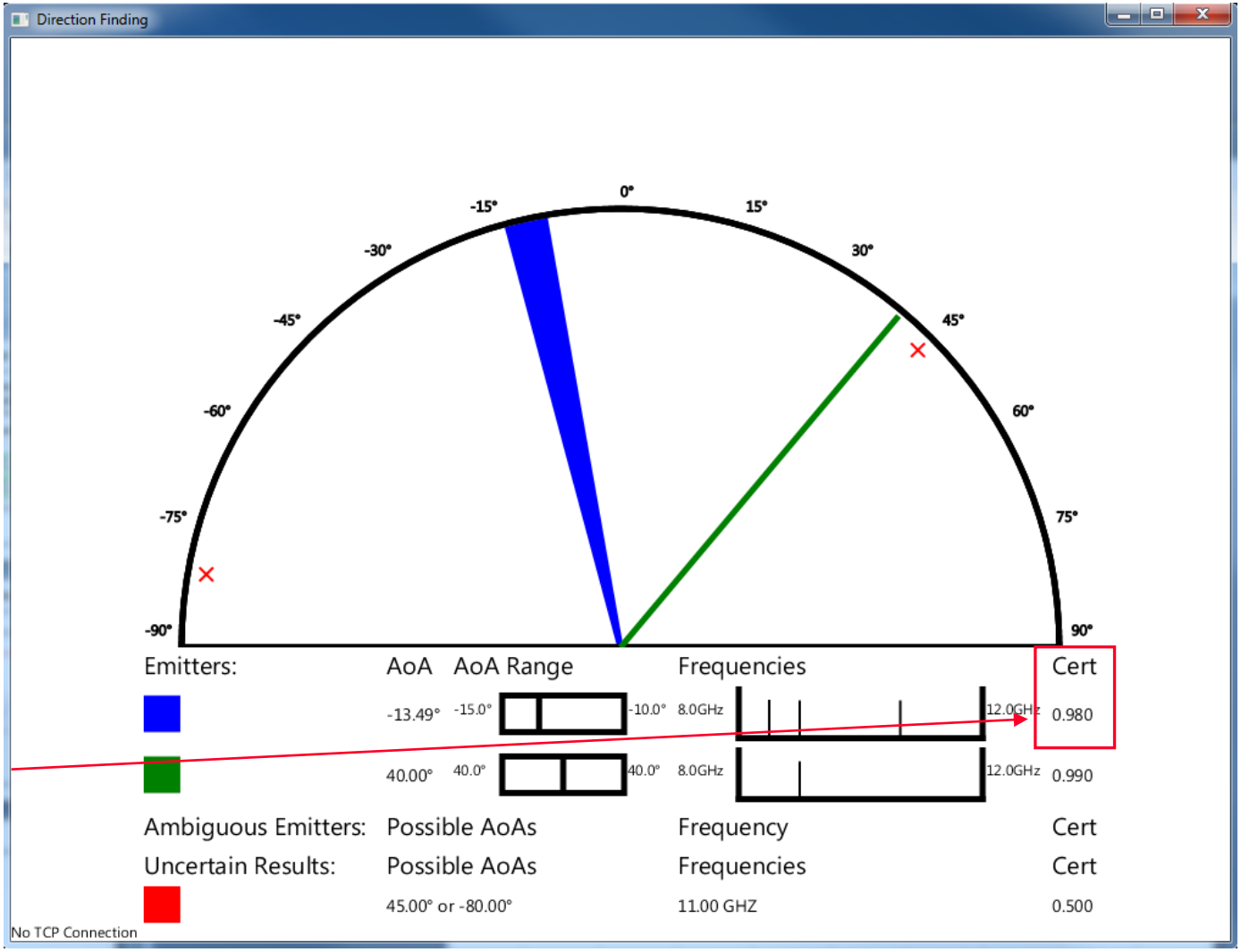
Angle Statistics

Real-Time Display GUI



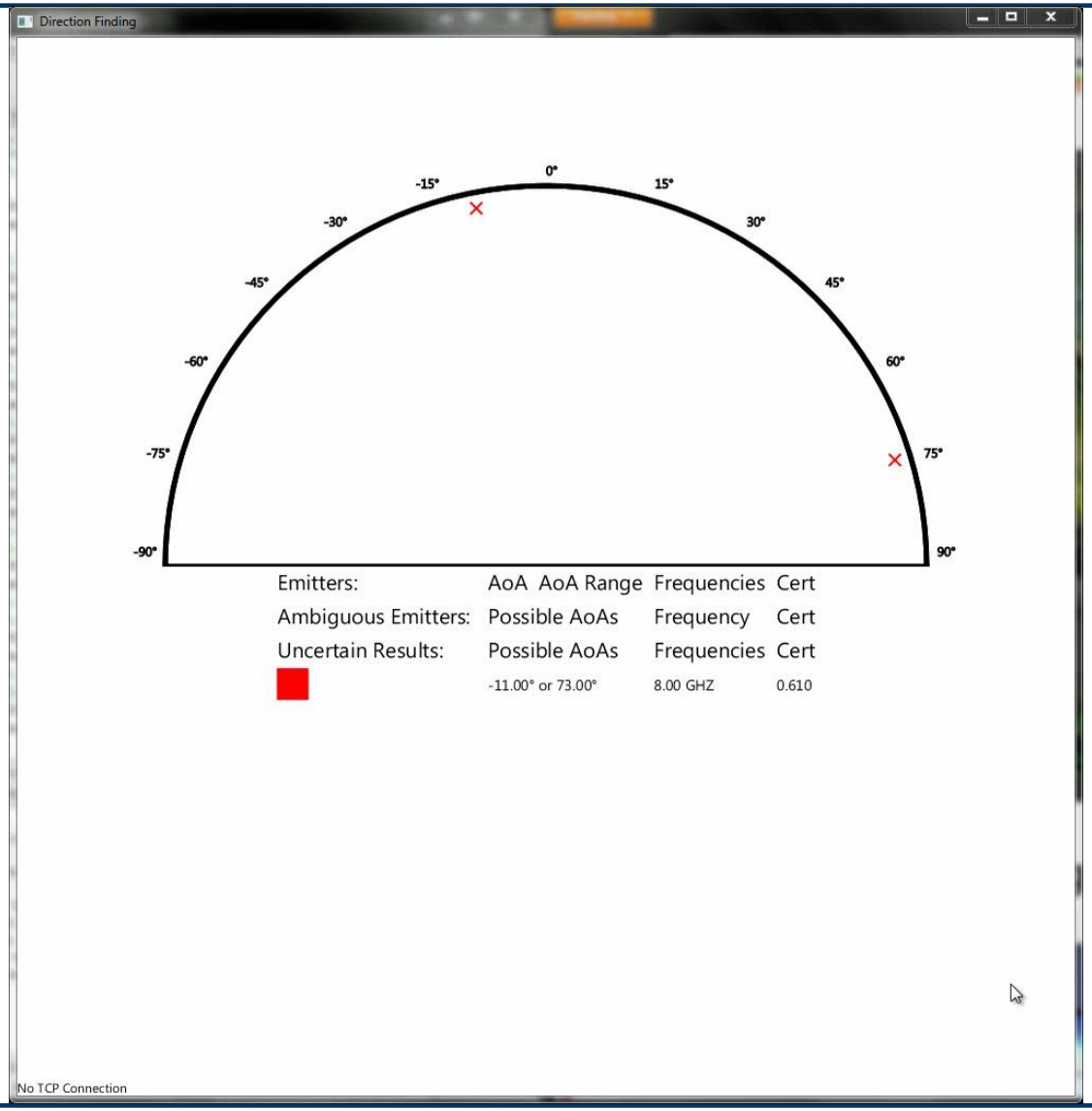
Frequency Statistics

Real-Time Display GUI



Angle Certainty

Real-Time Display Demo



Contents

Future Work

- **Performance**
  - **Combine phase interferometry and amplitude comparison for two antenna solution**
  - **Move real-time processing to FPGA**
  - **Enhance tracking algorithm to reduce probability of false ambiguity selection**
- **Testing**
  - **Test three channel operation with live data**
  - **Verify operation with antennas connected**

Conclusion

- **Successfully met all primary requirements with simulated signals**
- **Extended field of view to ±85°**
- **Capable of identifying multiple emitters per batch**
- **Three channel operation verified with simulated data**
- **Two channel operation verified with live signal generator data**

Acknowledgements

Emily Anesta

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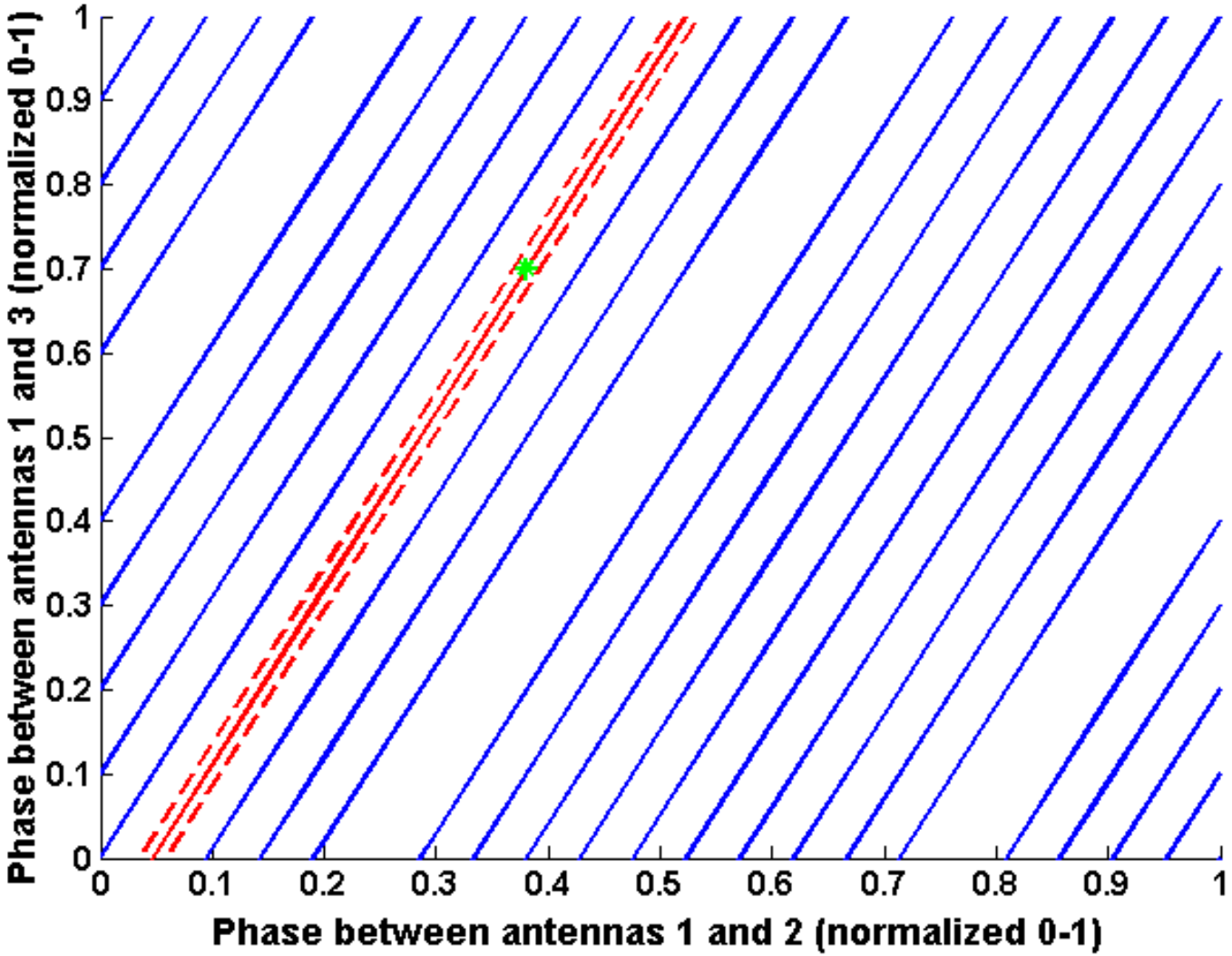
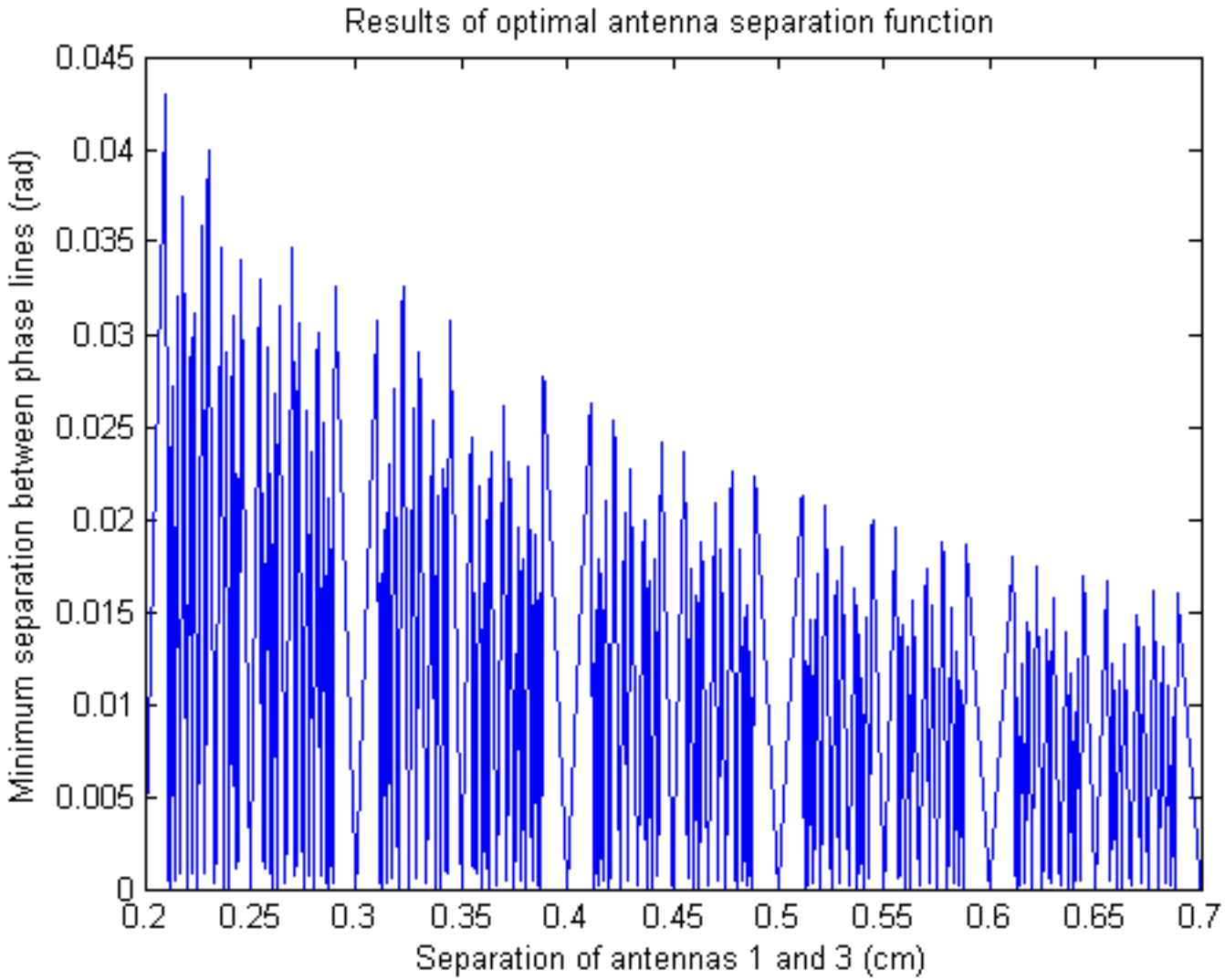
Resolving Phase



Finding Optimal Antenna Separation



GUI Sample for Two Channel Inputs