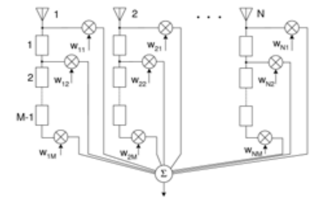
GPS Antennas, Antenna Electronics and Receivers

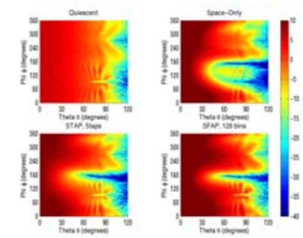
Antenna Characterization

- State of the Art Antenna Measurement Facility.
- CEM tools to predict the antenna performance on an infinite ground plane and/or small platforms.
- Hybrid EM tools to predict the performance of GPS antennae on any platform of interest. (Aircraft, Ship, Spacecraft, etc.)
- Gain, phase, group delay measurements and prediction.

Antenna Electronics

- Advancing various AJ systems
  - Signal Processing Techniques (transversal filters, frequency domain filtering, etc.)
  - Spatial Processing Techniques
  - Joint Techniques (STAP, F-STAP or SFAP)

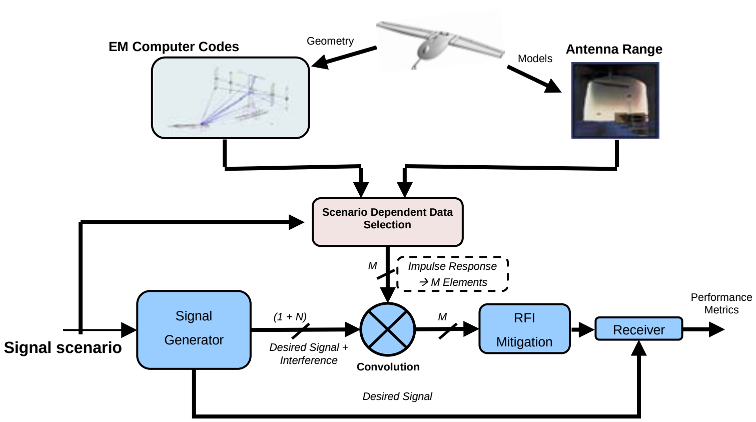




Single Wideband Jammer @ ϕ=170^{0}
Additional nulls indicate adaptive array is reacting to both jammer and multipath sources.

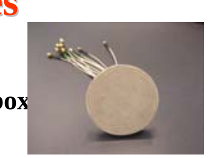
- Complete Performance Metrics
  - Jammer suppression
  - Satellite availability
  - Percentage coverage
  - Pseudo-range error
  - Carrier phase error

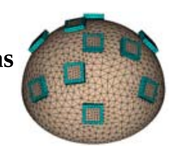
End-to-End System Simulation



Current Research Activities

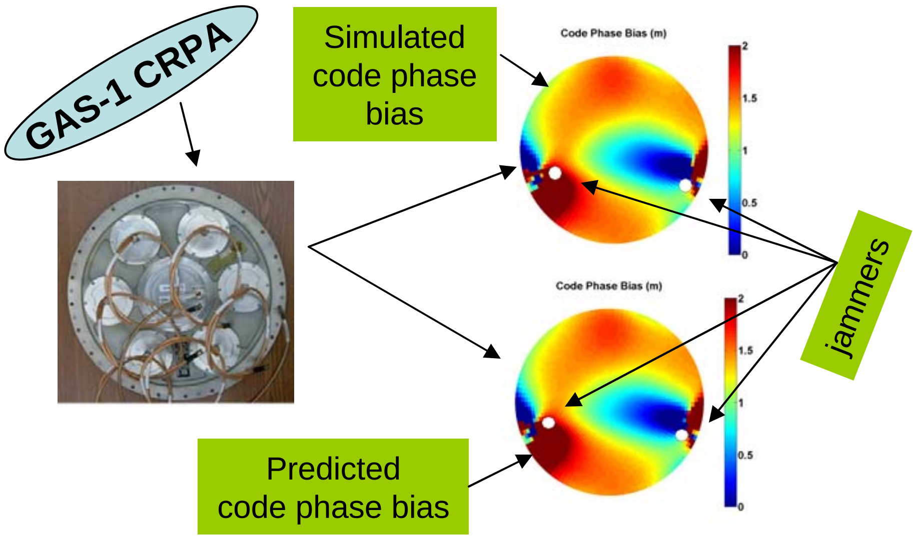
- ONR Grant
  - Reduced size CRPA for L band coverage
  - Techniques to improve the performance of AE box
- AFOSR Grant
  - Prediction of antenna and AE induced biases
- GPS Wing and AFRL/SNRN
  - GPS systems on rotorcrafts
  - Mutual coupling effects
  - CRPAs for FRPA size foot print
- NAVAIR Pax River
  - Non-planar GPS antenna arrays and small antennas with new materials
- Consortium of Ohio Universities on Navigation and Time keeping (COUNT)





Phase Center Characterization of GPS Antennas

THE OHIO STATE UNIVERSITY
ElectroScience LABORATORY



OBJECTIVES

- Find new methods to characterize phase center of GPS AJ antennas.
- Develop techniques to predict, compensate/correct for phase center variations in the presence of jammers.
- Carry out sensitivity analysis.

APPROACHES/TECHNICAL CHALLENGES

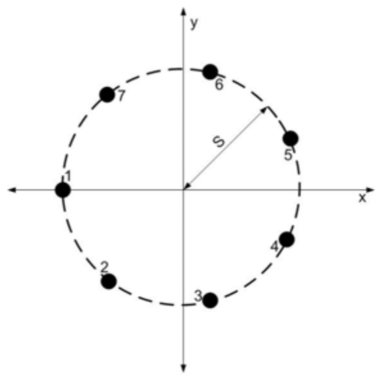
- Use antenna transfer function to characterize, predict, and correct antenna induced biases for multi-element AJ antennas in the presence of jammers.
- One needs to know the in situ response (gain and phase of individual elements) of the antenna array which can vary between antenna units and will contain measurement errors.

ACCOMPLISHMENT/RESULTS

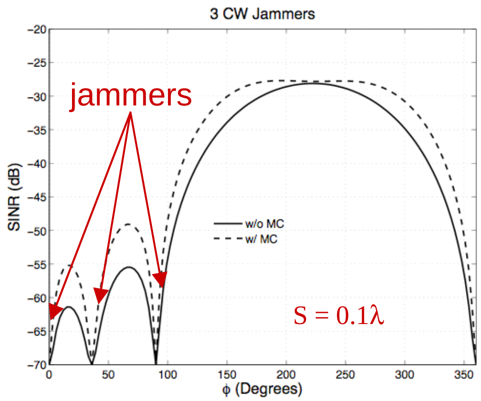
- Developed a new approach to predict the antenna induced biases in GPS receivers.
- Predicted biases have excellent agreement with the simulated results.
- Developed methods to correct antenna induced biases in GPS receivers.

Long-Term Payoff: Increase the accuracy and integrity of PVT solution obtained using GPS in hostile environment

Mutual Coupling in GPS AJ Antennas



Antenna Array of 7-dipoles



Output SINR in the presence of three CW Jammers

Method/Approach

- Consider circular antenna arrays of seven elements.
  - Use different element types (dipoles, micro-strip patches, etc.)
  - Vary inter-element spacing (circle radius)
- Study the AJ performance of the antenna arrays under various jamming scenarios
  - CW jammers
  - Partial band jammers
  - Wideband jammers
- Establish some general trends, and physical reasons for these trends.
- Develop techniques to improve the AJ performance of antenna arrays under strong inter-element coupling.

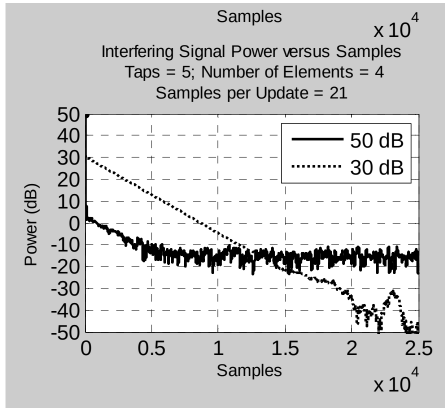
Background

- Military GPS receivers have to operate in unfriendly RF environment.
- State-of-the-art GPS receivers use anti-jam (AJ) antennas for electronics protection.
- There is a push to install AJ antennas on small platforms (UAVs, small aircraft, missiles, bombs, etc.)
- For these small platforms, the antenna size is reduced significantly leading to large coupling between the antenna elements.
- What are the effects of antenna inter-element coupling on the nulling performance of AJ antennas?
- What needs to be done to counter the effects of inter-element coupling?

Preliminary Results

- AJ performance of an antenna array, as expected, degrades with decrease of inter-element spacing.
- Most of this degradation is due to decrease in antenna aperture size, and not due to mutual coupling.
  - Reduced antenna aperture implies loss of resolution , so that jammer and desired signals with small angular separation can not be distinguished.
- For CW and narrow band jammers, mutual coupling does not lead to any further degradation in AJ performance.
- For wideband jammers, mutual coupling can lead to further performance degradation. One can, however, recover loss in performance using STAP based antenna electronics.

AJ ASIC for Hand-Held GPS Receivers



Transient response for two CW Jammers

Method/Approach*

- Study LMS-based and RLS-based nulling implementations algorithms for AJ processing
  - Computational efficiency
  - Stability and convergence speed
  - Consistent with low power ASIC implementation.
- Select one or two potential algorithm for ASIC implementation.
- Establish performance of the selected algorithm under the signal scenarios of interest.
- Study quantization error effects
- Work with RBS Technologies to develop/improve ASIC.

Background*

- State-of-the-art military GPS receivers use adaptive antennas (CRPA) to operate in hostile RF environment.
- In adaptive antennas, individual antenna element weights are calculated on-the-fly to suppress interfering signals while maintaining coverage in the upper hemisphere.
- Current GPS adaptive antennas are designed for on-platform application, and are not suited for hand-held GPS receivers.
- Efficient AJ processing ASIC is needed for hand-held GPS receivers.

Preliminary Results

- LMS-based implementations, are computationally efficient. However, convergence speed depends on incident signal strength. For strong signals, implementation can become unstable.
- One can avoid the instability using normalized LMS (NLMS).
- One can further improve performance using a smoothing approach.
- For wideband signals and for signals with unequal strength, NLMS also converges slowly.
- RLS-based algorithms converge fast but, but are not as computationally efficient.

*This project is an Air Force SBIR (FA8650-07-M-1156) with RBS Technologies.

GPS AJ Antennas on RotorCrafts

THE OHIO STATE UNIVERSITY
ElectroScience LABORATORY

Background

- Performance of GPS receivers mounted on rotorcrafts is affected by the blade movement.
  - true for fix reception pattern antennas (FRPA) as well as controlled reception pattern antennas (CRPA).
- To study the performance degradation analytically or using wave front simulators, one needs to develop approaches to measure/calculate the time domain response of the individual antenna elements mounted on a rotorcraft.
  - Approach should be good for all blade rotation speeds, and should cover the frequency bands of interest.
- Efficient methods to convolve the antenna element time domain response with the incident signals are also needed.

Method/Approach

- Measure/analyze the response of an antenna mounted on a rotorcraft for different orientations (positions) of the blades such that one rotation period is covered
  - Angular step size for the blade positions will depend on the frequency of operation as well as the dimensions of the blade.
  - The rotation period will depend on the number of blades. For four blades, the one rotation period is 90 degrees.
- For given blade rotation speed, map the blade position data to the time domain response of the antenna.
  - It is assumed that the blade shape does not vary with the blade rotation speed.
- Since the time domain response is periodic, it can be represented by a Fourier series.
- Use the Fourier coefficients along with frequency of various harmonics to convolve the incident signal with the antenna response.

Preliminary Results

- The approach has been verified for CW incident signals.
- Using computer simulations, we have demonstrated the performance degradation in GPS AJ antennas.
- The approach is being extended to finite bandwidth incident signals with arbitrary power spectral density.
- Developing experiments to verify the analytical results.

Range Evaluation and Stray Signal Analysis

Quiet Zone Field Probing

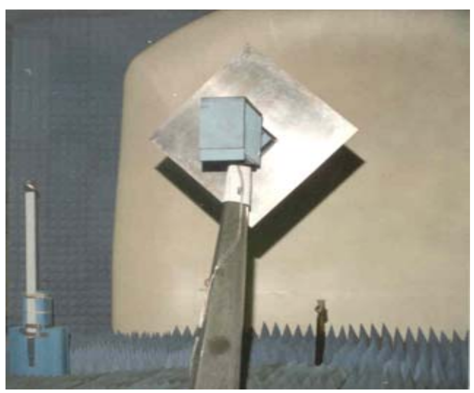
- Direct measurement of quiet zone field quality
  - Taper
  - Ripple
  - Phase uniformity
  - Cross-polarization
- Probe data can be processed to localize stray signal sources

Stray Signal Analysis

- Near field focusing
- DOA estimation techniques
  - MUSIC algorithm
  - Beam forming
  - Parameter estimation techniques
- Time of Arrival (TOA) Estimation Techniques
  - Conventional Fourier transform
  - Superresolution techniques
  - Sinograms
  - Probe data calibration
- Time and Direction of Arrival (TADOA) Estimation
- Time domain near field focusing

Diagonal Flat Plate Test

- Well suited for RCS ranges
- Large dynamic range
- Direct detection of stray signal sources
- Radar imaging tools can be employed for further processing of data.



Examples of Stray Signal Analysis