[C1/C6] Autocalibration and Flexible Array Signal Processing

Theme: Detection, Localisation & Tracking Theme

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Project Objectives

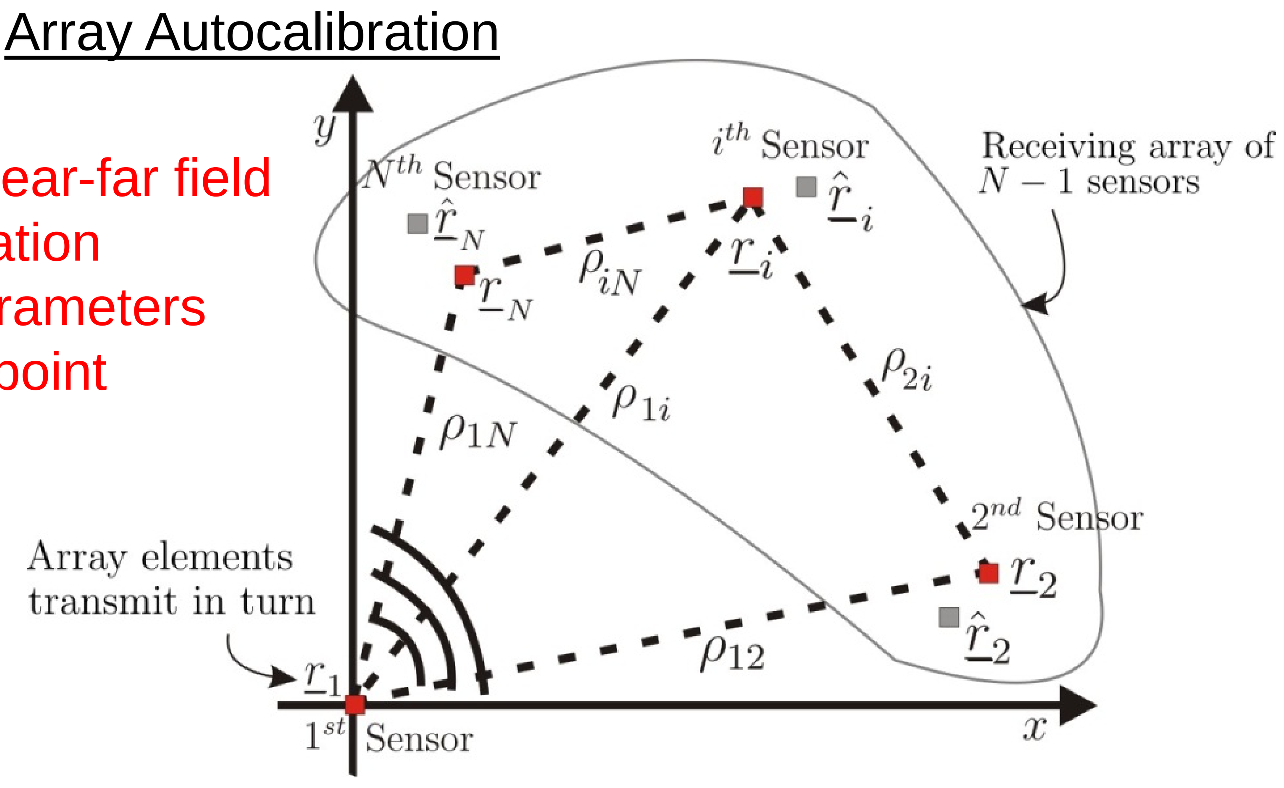
- Analyse uncertainties and their effect in an array system
- Develop pilot, self and hybrid calibration algorithms to perform smart, online and automatic calibration of the array
- Investigate flexible array systems
- Develop flexible array signal processing techniques for detection, localisation and tracking in wideband or narrowband environments

Array Calibration

- **Problem**: Array systems contain different types of uncertainties such as electrical (i.e. gain, phase, coupling effects) and geometrical which affect the performance of an array system
- **Aim**: Develop algorithms to estimate the array uncertainties
- **Approaches employed in this project**:
  1. Express planar array as a Virtual Uniform Linear Array
  2. Pilot calibration – single or multiple frequencies
  3. Self calibration using Biogeography Based Optimisation
  4. Autocalibration allowing array elements to operate as transceivers

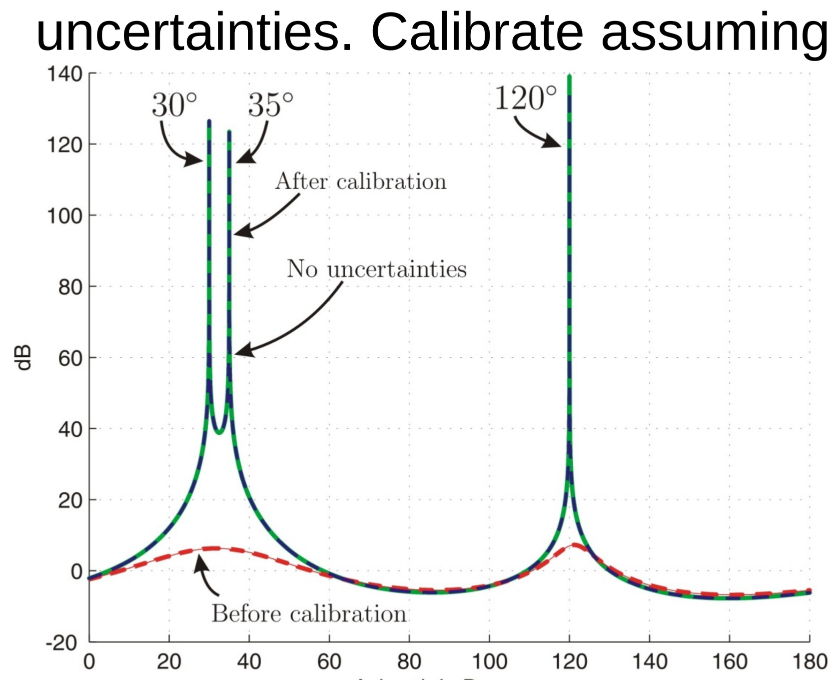
Array Autocalibration

Key aspects:
- Transmitters in arrays near-far field
- Spherical wave propagation
- Range and direction parameters
- Rotate array reference point

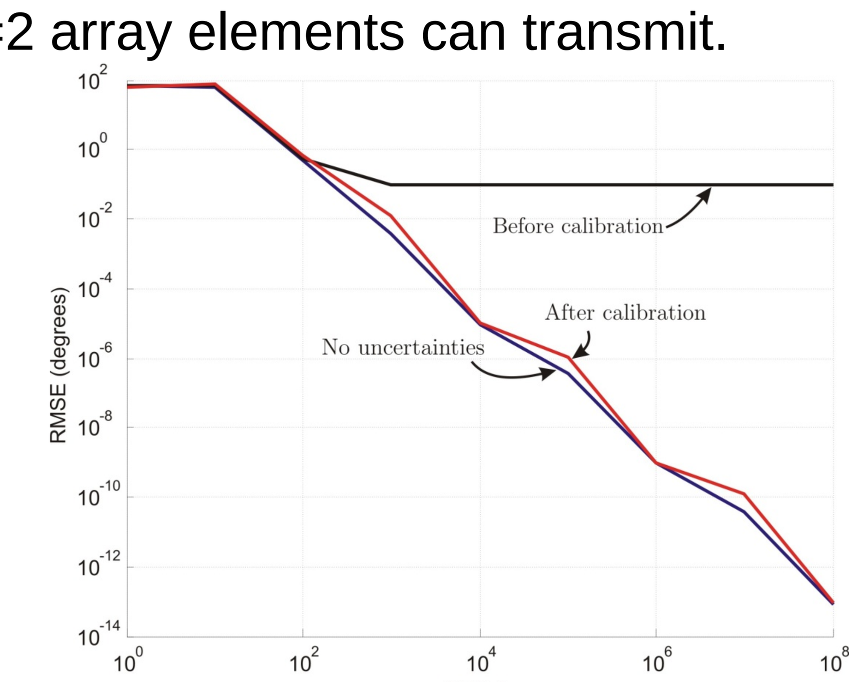


Autocalibration Example – MUSIC algorithm performance

- N=6 Sensor Uniform Circular Array with gain, phase and 2D geometrical uncertainties. Calibrate assuming M=2 array elements can transmit.



MUSIC spectrum for 3 sources at 30˚, 35 ˚ and 120 ˚ azimuth under L=100 snapshots and SNR=30dB



RMSE for 1 source at 30˚ azimuth using MUSIC over 200 realizations

Publications

[1] Y.I. Kamil, A. Manikas and M. Willerton, "*Source Localization using Large Aperture Sparse Arrays*," IEEE Trans. Signal Processing, November 2012.

[2] M. Willerton, Y.I. Kamil and A. Manikas, "*Auto-Calibration of Sparse Arrays of Sensors*," IEEE Trans. Antennas and Propagation (under review).

[3] M. Willerton, K. Stavropoulos and A. Manikas, "*Pilot Based Array Calibration in the Presence of Sensor Uncertainties*," Trans. Antennas and Propagation (under review).

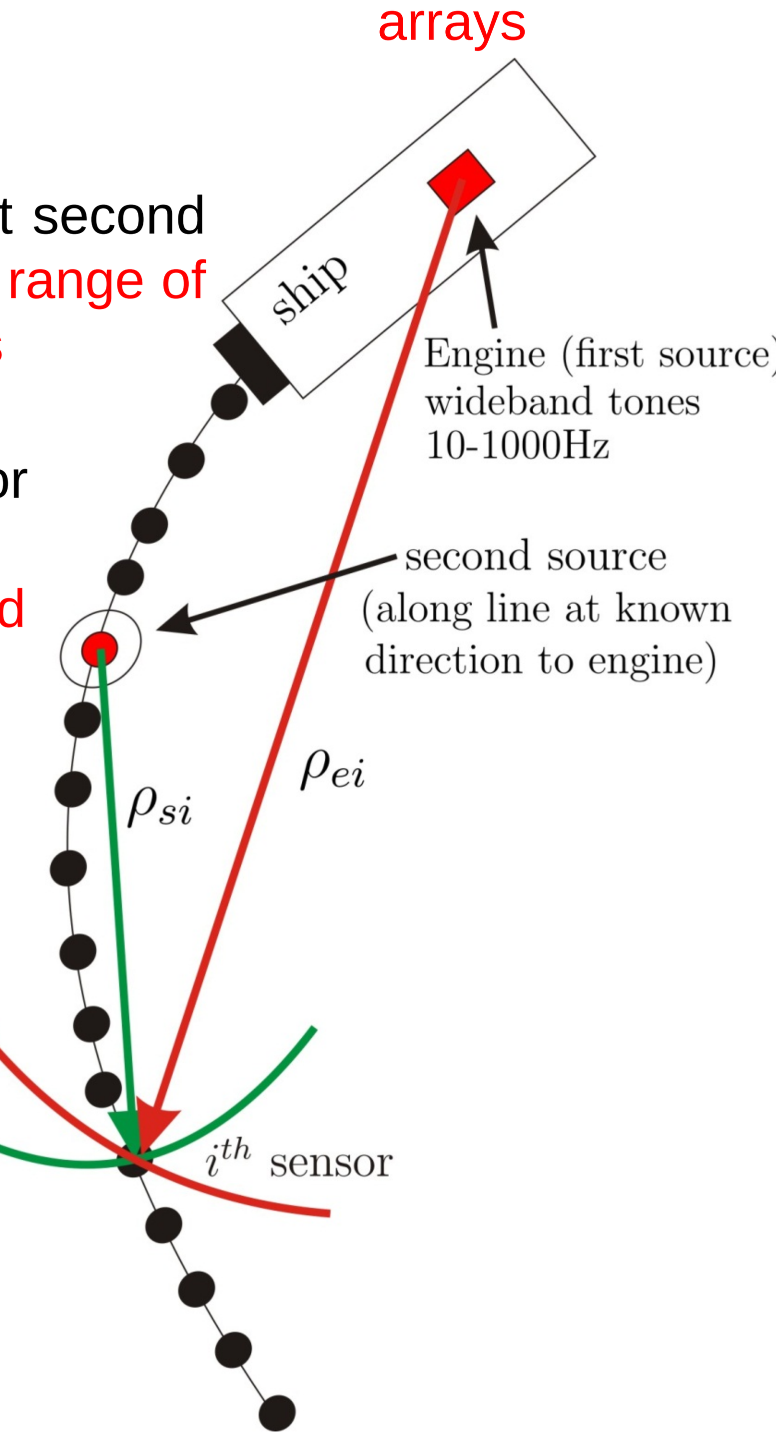
[4] M. Willerton and A. Manikas, "*Array Shape Calibration using a Single Multi-Carrier Pilot,*" Signal Sensor Processing for Defence (SSPD 2011), September 2011, London, UK.

[5] M. Willerton and A. Manikas, "*Virtual Linear Array Modelling of a Planar Array*," 2nd IMA Conference on Mathematics in Defence, October 2011, Swindon, UK.

Flexible Array Signal Processing

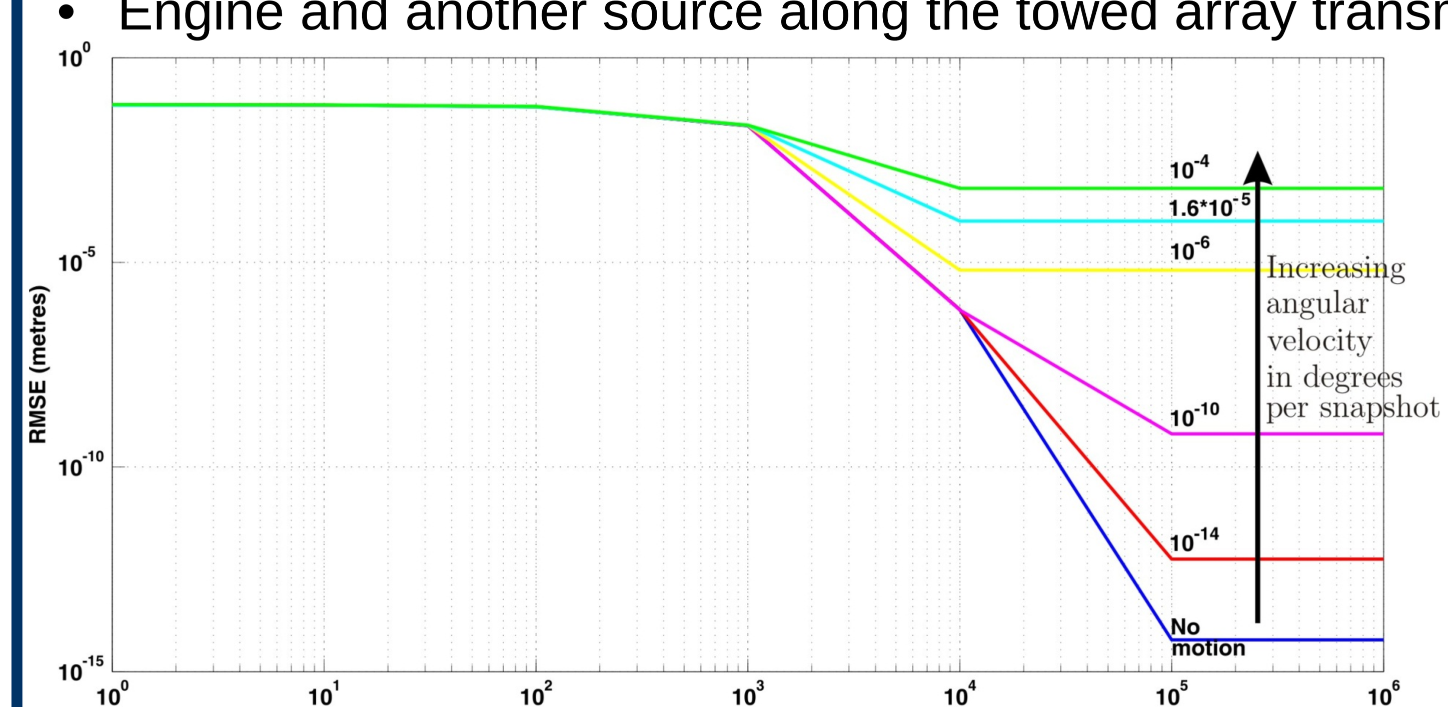
- **Problem**: Array shape may be a time varying function
- **Aim**: Develop algorithms to track array shape over time
- **Approaches employed in this project**:
  1. Eigenvector based methods
     - Slow varying geometries
     - Partition data in to time frames
     - Using the engine as a source, construct second order statistics of array data to estimate range of the engine to each of the array elements
     - In R^2 space either:
       1. Use another transmitter (pilot or transmitter on the towed array)
       2. Assume sensor spacing remains fixed
  2. State space based methods
     - Array geometry may now change on a snapshot by snapshot basis
     - Devised state space model to "filter out" array uncertainties by solving a H^∞ optimisation problem. The array can then be seen as static
     - The state space model may also be used to estimate the true direction of a pilot source if it contains errors (before a pilot calibration or eigenvector based flexible array approach is applied)

Applications include towed arrays



Eigenvector Example – Array elements towed in an arc at different speeds

- Gain, phase and location uncertainties with array moving in a circular arc
- RMSE of sensor locations after the proposed approach degrades as the array moves faster
- Engine and another source along the towed array transmit



- N=64 Sensors
- 0.5m intersensor spacing
- M=2 Transmitters (inc. engine)
- 100 Iterations
- Varying SNRxL

Conclusions

- Developed a pilot based global array calibration algorithm which estimates gain, phase and sensor location uncertainties using sources at known locations operating at single or multiple frequencies
- Devised a novel array autocalibration algorithm which allows the array to calibrate itself assuming array elements can operate as transceivers
- Successfully devised methods to track the shape of a towed array using eigenvector methods and state space approaches. Future scope is to investigate how to opportunistically exploit the flexible array.

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MINISTRY OF DEFENCE

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