# Optimising an acoustic emission sensor network on a panel of complex geometry using a Local Interaction Simulation Approach

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## 1. Introduction

Historical trends show that the number of commercial aircraft will double in the next fifteen years [1]. With the increasing complexity of aircraft structures and materials there is an essential need to continually monitor the structure for damage. This task is difficult to achieve using traditional non-destructive testing (NDT) methods alone. It is therefore proposed that a structural health monitoring (SHM) system should be implemented for the continual monitoring of the structure [2]. It is forecast that the implementation of such a system will result in increased safety, cost and time savings in maintenance as well as mass savings of up to 15% in the aerostructure [3].
There has been a reluctance within the aerospace industry to adopt acoustic emission (AE) techniques based on previous experiences [4]. One of the main issues associated with the failure of AE techniques to detect damage can be attributed to poor considerations for sensor placement [4]. Although there have been many studies conducted with the aim of optimising sensor placement for SHM applications there are few published works with the specific aim of optimising an AE sensor network. This is most likely because AE is passive technique which makes an experimental investigation difficult.

## 2. Procedure

The aim of this research was to develop a methodology for the sensor placement of acoustic emission sensors. To reduce the complexity of the problem an isotropic material was considered for investigation with a view that the proposed methodology could be subsequently adapted for more complex materials and structures.
A 3mm thick 6062-T6 aluminium plate of dimensions 1250mm x 320mm was used for the testing of this methodology. A representative model was created in the local interaction simulation approach (LISA) environment using a commercially available version of the software. The use of LISA has many advantages over that of other numerical modelling approaches. The main benefit however is its convergence performance through the use of NVIDIA CUDA graphical processor architecture first developed by Packo *et al.* [5].
An area of investigation was assigned of dimensions 400mm x 280mm at the centre of the plate. A grid of candidate sensor locations were placed within the area of investigation on a grid spacing of 20mm totalling 615 sensors. In addition, a 10mm grid of AE source locations was positioned covering the area of investigation which totalled 2349 locations as shown in
Figure 8. To test the methodology a 200kHz 5-cycle Hann-windowed sine wave excitation was used to represent a candidate AE source. A separate model was run for each source location which was measured at all of the sensor locations.

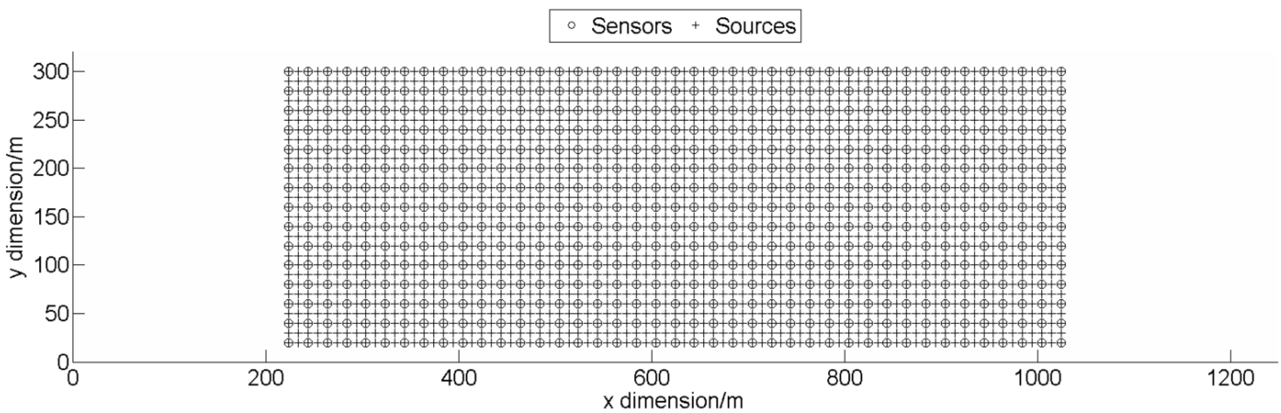


**Figure 1. The location of the sources and sensors within the area of investigation**

The measured waves of all of the sources for each candidate sensor location were collated and the peak intensity of the first wave packet calculated using thresholding techniques. A series of holes were then added within the area of investigation to add a level of additional complexity in similar approach to that adopted by Baxter [6] for trialling AE techniques.

## 3. Discussion and results

Three, four and five-sensor networks were considered with the objective of maximising the coverage achievable by these network sizes. A fitness function to assess the fitness of different sensor networks was constructed using statistical techniques and interrogated using a genetic algorithm to find the optimal solution. An example of a derived solution for a three-sensor network is shown in
Figure 9

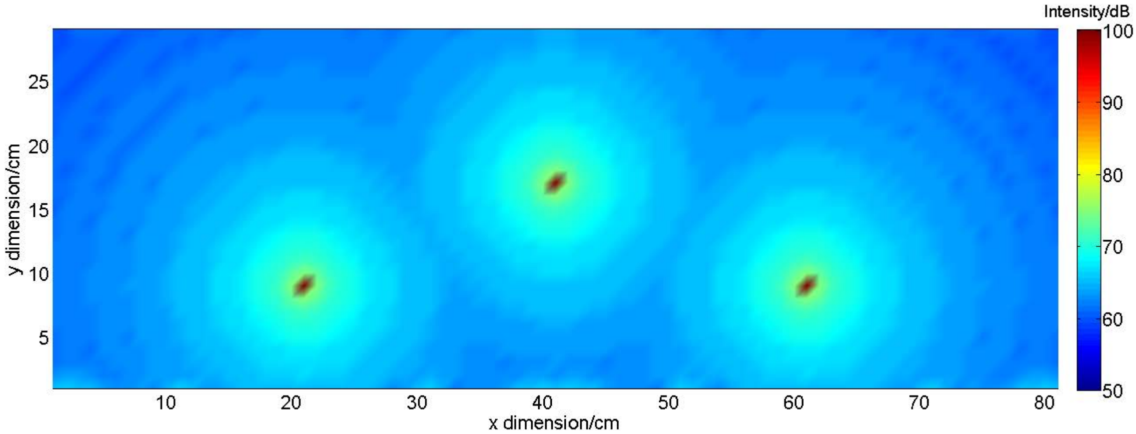


**Figure 2. Intensity plot for a three-sensor network**

The benefits of the LISA techniques have been fully exploited within this study as a multi-source, multi-sensor approach has been able to be modelled in a relatively short period of time with an acceptable level of accuracy. This has enabled this methodology for AE sensor networks to be developed and explored. It should be noted however that the input used to represent the AE source is not truly representative of that of an AE source. In reality, the frequency content of an AE signal may be much higher and as such, the peak of intensity of the wave diminishes at a much greater rate due to the attenuation phenomena exhibited by Lamb waves. To improve this, a more representative source should be created for mapping the structure such as that of an H-N source [7].
An additional benefit of this methodology is that the multi-sources used for the optimisation of the sensor locations can be used for damage location using the delta-t location technique [6]. Although this has not been presented for the plate in question, the technique is showing some promise.

## 4. Conclusions

This study has presented a multi-source, multi-sensor methodology for the placement of AE sensors using the LISA technique. The rapid convergence and global search characteristics of genetic algorithms have been fully exploited to interrogate a wide search space in order to derive optimal sensor placement solutions. The added complexity of adding holes to the plate strengthens the methodology and demonstrates that it can be expanded to be used for the placement of sensors on less conventional structures.

## References


1. Airbus, *Global Market Forecast - Futures Journeys 2013 - 2032*. 2013: Blagnac Cedex, France.
2. Speckmann, H. and R. Henrich. *STRUCTURAL HEALTH MONITORING (SHM) - OVERVIEW ON AIRBUS ACTIVITIES*. in *16th WCNDT 2004 - World Conference on NDT*. 2004. Montreal, Canada.
3. Speckmann, H. and H. Roesner, *Structural Health Monitoring: A Contribution to the Intelligent Aircraft Structure*, in *ECNDT 2006*. 2006: Berlin.
4. Carlyle, J.M., *In-flight acoustic emission research.* 1981.
5. Paćko, P., et al., *Lamb wave propagation modelling and simulation using parallel processing architecture and graphical cards.* Smart Materials and Structures, 2012. **21**(7): p. 075001.
6. Hsu, N.N. and F.R. Breckenridge, *CHARACTERIZATION AND CALIBRATION OF ACOUSTIC EMISSION SENSORS.* Materials Evaluation, 1981. **39**(1): p. 60-68.
7. Baxter, M.G., *Damage Assessment by Acoustic Emission (AE) During Landing Gear Fatigue Testing*, in *Institute of Materials and Manufacture*. 2007, Cardiff University: Cardiff University.