To investigate the impact of antenna design on radar-based breast image quality.

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Background

Breast cancer is the most common cancer affecting women worldwide, and early detection and diagnosis is highlighted by the World Health Organization as a key priority.[1] Currently the only way to detect and diagnose breast cancer is with X-Ray mammography, which is incredibly costly and isn't suitable for younger women due to high radiation exposure.

In contrast, microwave-based breast imaging systems can be operated in local clinics and doctors' surgeries worldwide, improving access to potentially life-saving breast cancer screening for women of all ages world-wide.[2]

This project aims to model different microwave antenna arrays to find optimum configurations that can provide clinical grade images for doctors to quickly diagnose breast cancer.

Antenna Types

Many antenna designs exist, each with different characteristics and uses. Three distinct antenna designs were explored as part of this project:

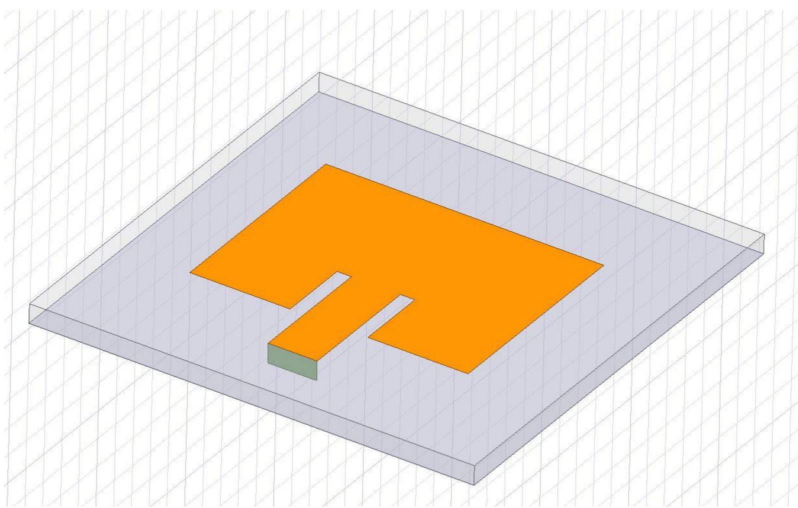

Fig. 1 - Microstrip Patch Antenna

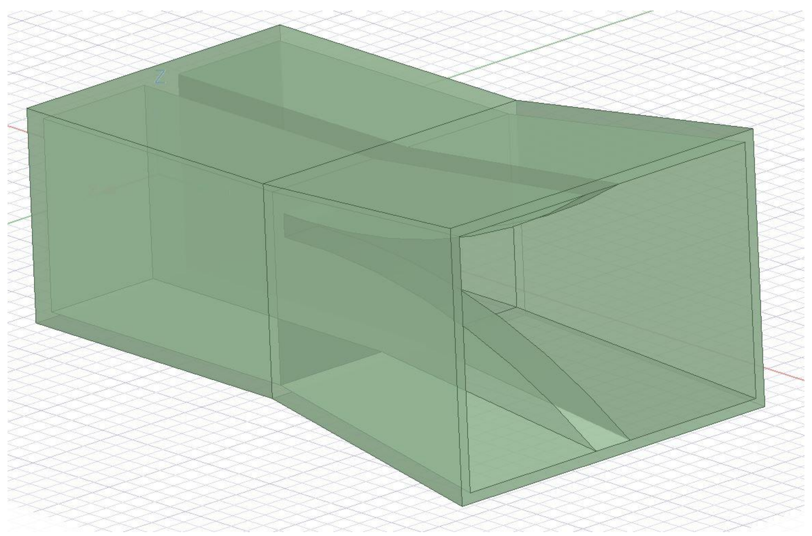

Fig. 2 - Horn Antenna

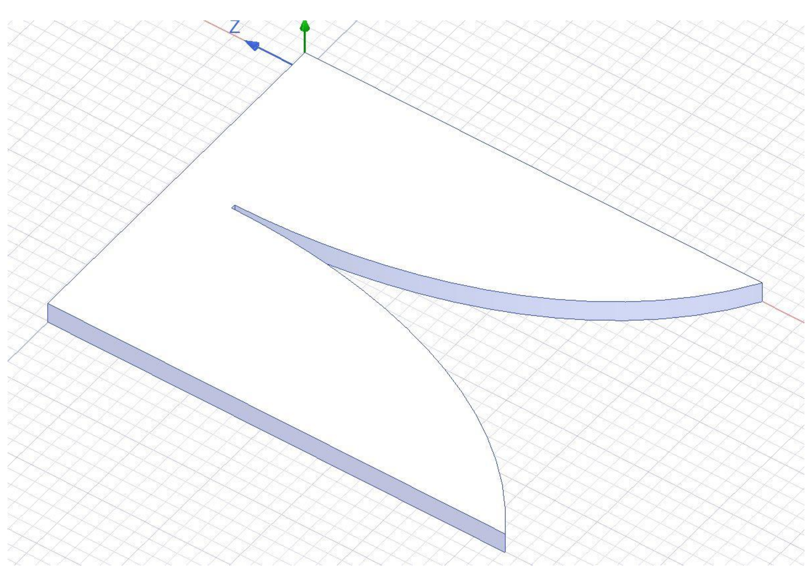

Fig. 3 - Vivaldi Antenna

Quantities such as frequency response, beamwidth and electromagnetic polarisation are import characteristics when choosing an antenna for breast imaging.

Ansys HFSS was used to determine these characteristics as well as model how they perform in a breast imaging scenario. Fig. 4.1 shows the total gain of the antenna as the electromagnetic wave propagates outwards.

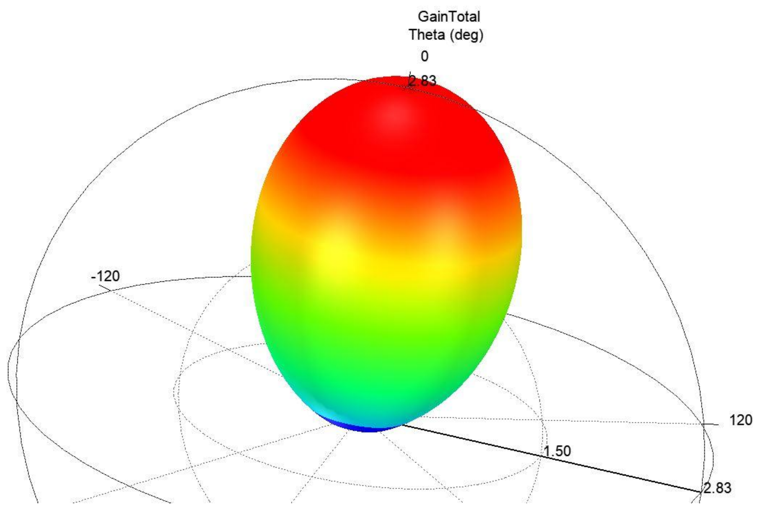

Fig. 4.1 - Patch Antenna Gain

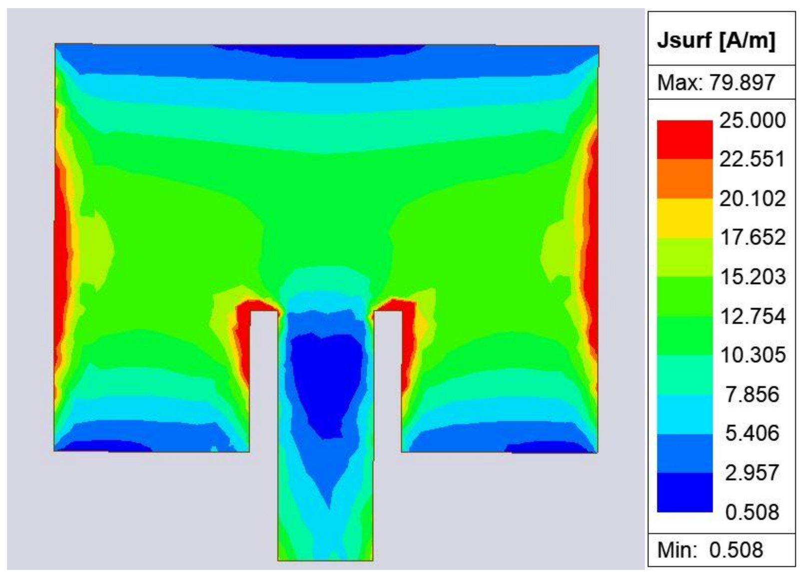

Fig. 4.2 - Antenna Current Distribution

Methodology

In addition to modelling different antenna parameters, a signal processing workflow was developed to test the antennas in an imaging scenario. Using the electromagnetic properties of breast tissue measured in a 2004 study by Poplack et al. a numerical breast model was constructed and a phantom tumour was placed inside.[3] The significant difference in magnetic properties between healthy and cancerous breast tissue is the foundation that radar-based breast imaging is built upon.

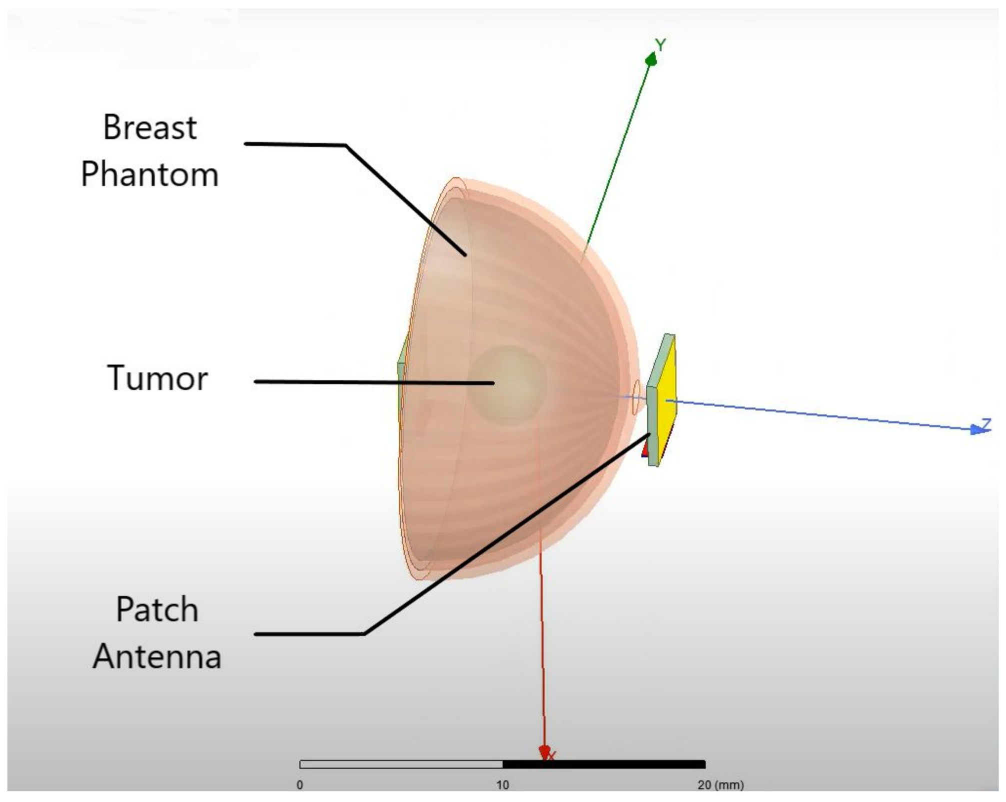

Fig.5 - Simulation Setup in Ansys HFSS

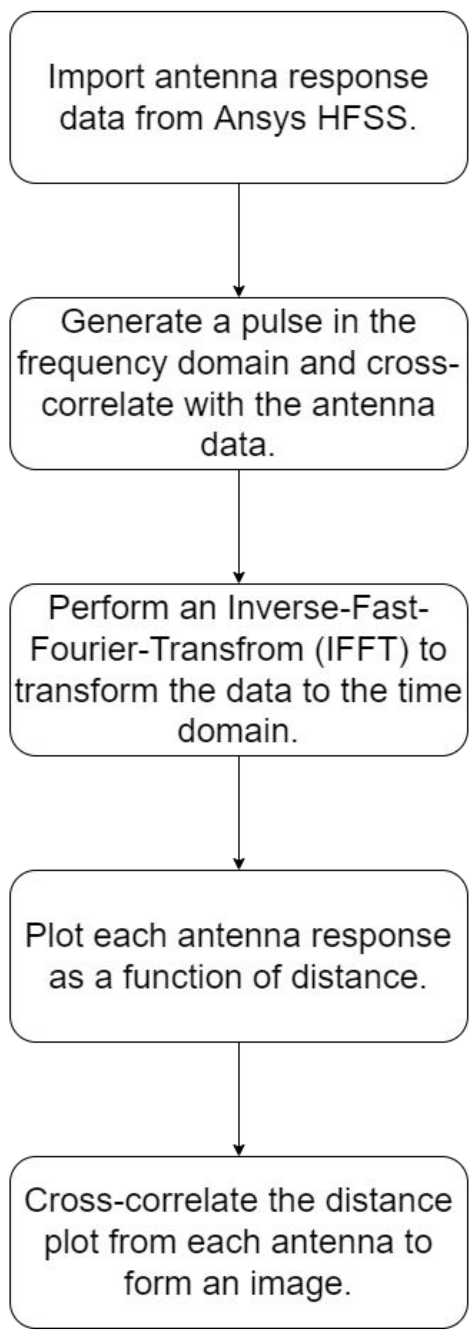

Fig. 6 - Antenna Imaging Workflow implemented in Python.

The raw Ansys HFSS data was exported to a python script that used various signal processing techniques seen in Fig. 6 to generate an image. A variety of open source libraries were used for data handling, processing and analysis including Pandas, Numpy, Scipy and Seaborn.

Despite using various boundary and initial conditions the data appeared to be heavily distorted once a second antenna was introduced to the system. While in theory any interaction between the two antennas should be accounted for during the calibration process, the interference from each antenna was strong enough to remove any positive indication that a tumour had been detected. This can be seen in Fig. 7: The two prominent rings should intersect at the point 'X' where the object is located. However they clearly just pass through where the other antenna is located.

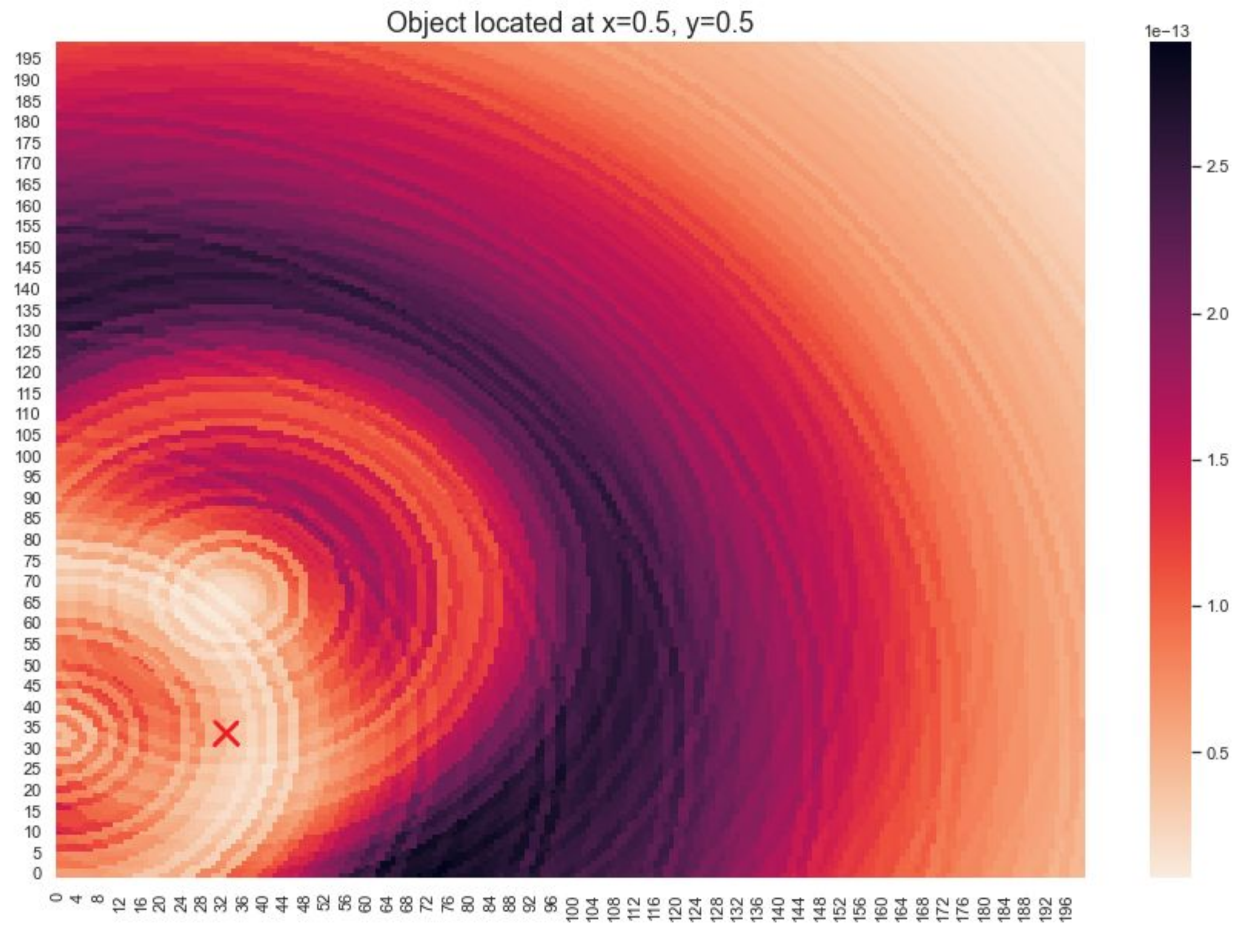

Fig. 7 - A phantom tumour of diameter 20 mm is located at position 'X'. The two distinct common centres indicate the patch antenna position.

Challenges & Solutions

The issue regarding antenna interference is likely due to the simulation setup parameters. Ansys HFSS and other electromagnetic simulation platforms use the finite element analysis (FEA) method to solve antenna simulations.

FEA works by transforming a continuous object into a mesh of small and discrete components which it can easily solve. The smaller these components are the more accurate the simulation results become. Increasing the number of mesh entities also increases the computational power required and hence the simulation time.

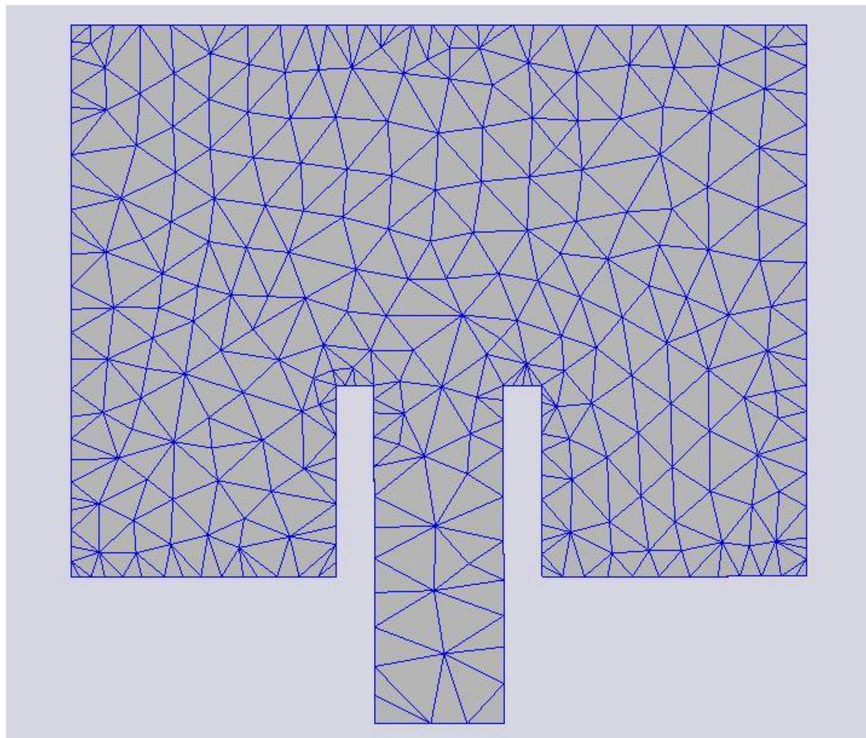

Fig. 8 - Patch Antenna Mesh Diagram

The Ansys HFSS student license used in this project only allows 70,000 nodes and a single processor core. This translated to a simulation time of approximately 2.5 hours per antenna.

Results & Next Steps

1. The microstrip patch antenna provides strong characteristics for breast imaging. The ability for it to be easily manufactured (compared to the horn and vivaldi types) and be formed into a hemispherical shape to suit a clinical implementation is also positive.
2. A large node count and GPU cluster is required to accurately simulate breast imaging with multiple antennas.
3. In the future, the signal processing pipeline could be implemented with an FPGA to provide real time imaging.

Acknowledgements & References

I would like to thank my supervisor Prof. Declan O'Loughlin and the School of Engineering for their help and support over the summer.

I would also like to extend my gratitude to the Laidlaw Foundation for funding this research project and to the Trinity Careers Service for giving me the opportunity to be a part of the 2022 Laidlaw Scholars Cohort.

[1] - DeSantis CE, Bray F, Ferlay J, Lortet-Tieulent J, Anderson BO, Jemal A. International Variation in Female Breast Cancer Incidence and Mortality Rates. Cancer Epidemiol Biomarkers Prev. 2015; 24(10): 1495-506.

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