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Experimental Investigation of Real Aperture Synthetically Organised Radar for Breast Cancer Detection

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Overview

- Breast cancer facts
- The microwave imaging technique used at Bristol.
- Practical measurements using stepped antennas
- Practical measurements using arrayed antennas (not in paper)
- Future work
- Conclusions
Breast Cancer Facts

- Breast cancer is one of the most common cancers in women
- A woman will be diagnosed with breast cancer every 3 minutes in US alone.

Breast Imaging Techniques
- **X-ray Mammography**
  - Relatively high false negative rate: 4%- 34%
  - High false positive rate : 70%
  - Poor contrast resolution
  - Ionising
  - Uncomfortable
- **Ultrasound Methods**
  - Small tumours have been detected
  - Poor spatial resolution
- **Contrast Enhanced MRI**
  - Too costly for mass screening purposes
Microwave Detection

- Clutter is a major problem.
- Especially skin reflection (also mutuals, tissue inhomogeneity, chest wall).
- A radar technique investigated in the field of Landmine Detection at Bristol gives good clutter rejection by combining all possible TX/RX pairs in an antenna array.
Microwave Imaging

- Real Aperture Synthetically Organised Radar
  - Number of paths is $N(N-1)/2$ (very large)

\[ V = \int_0^\tau \left( \sum_{i=1}^N c_i U_i (t - t_i) \right)^2 dt \]
16 Antenna Elements (-10 dB feed-antenna match from 4 to 9 GHz).
Yielding 120 paths
The antenna elements are excited in turn using a Gaussian-modulated two-cycle pulse at 6.5 GHz and all non-excited elements record the received signals.
Homogenous breast tissue
- Tumour $\varepsilon_r = 50 + j1.02$
- Skin $\varepsilon_r = 40 + j5.86$
Phase 1 Practical Set-Up

- Entire array simulated using mechanically driven pair of antennas.

![Graph showing Emulsion Dielectric Properties with frequency (GHz) on the x-axis and permittivity and attenuation (dB/cm) on the y-axis.](image)
Phase 1 Raw Time-Domain Data

[Graph showing signal strength over time with markers for skin reflections and tumour echo, and mutual coupling.]
Phase 1 Results

- Skin effect mitigated using the a similar path technique.

- 6mm tumour (position $x = 46\text{mm}$, $y = 69\text{mm}$, $z = -45\text{mm}$).
Phase 2 Practical Setup

- Fully-populated array replaces mechanically-scanned antennas
- Scan time of 2 minutes
Phase 2 Practical Setup – phantom tank and array
Phase 2 Practical Setup – microwave switches
Phase 2 Practical Setup – switch drivers
Phase 2 Practical Setup
Phase 2 Experimental Results

- 4 mm tumour
- 120 Paths for focusing
- Full background subtraction to reduce skin clutter
Phase 2 Experimental Results

- 6 mm tumour
- 20mm from skin
- Offset method used to reduce skin clutter
Phase 2 Experimental Results

- 6 mm Tumour
- 15mm from Skin
- Similar paths used to reduce skin clutter

- Similar path measurements not sufficiently similar.
Conclusions

- Breast cancer detection using microwaves would be a very attractive, freely repeatable, and low-cost alternative, or adjunct, to Mammography.
- Detailed, realistic, FDTD models have been invaluable in designing antenna elements and validating the focussing and clutter-rejection techniques.
- Skin clutter rejection techniques arise from the identification of similar paths with the array.
- Improved experimental accuracy is now a priority (e.g. more repeatable switch performance).
- A curved array and phantom is under construction.