Through-the-wall Imaging Radar

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Introduction

Objective: to investigate the feasibility of implementing a synthetic aperture radar (SAR) to image objects behind a wall, using a pair of horn antennas and a vector network analyser (VNA).

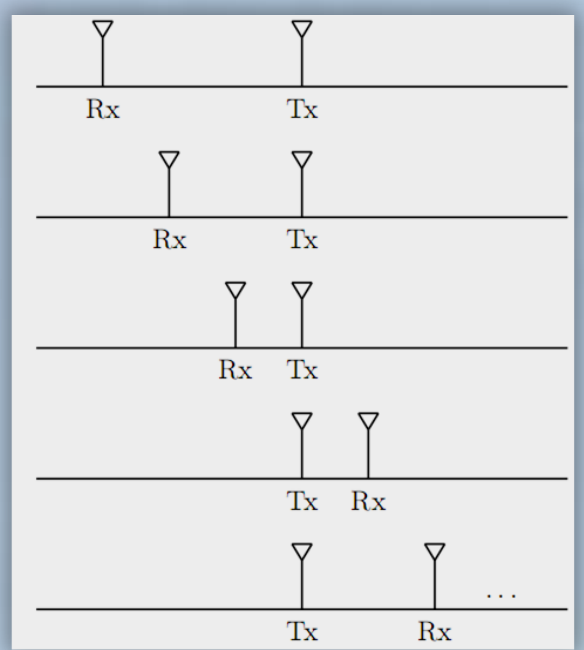
Motivation

- Application: Military or Search & Rescue operations
- Academic: Research interest in through-the-wall imaging

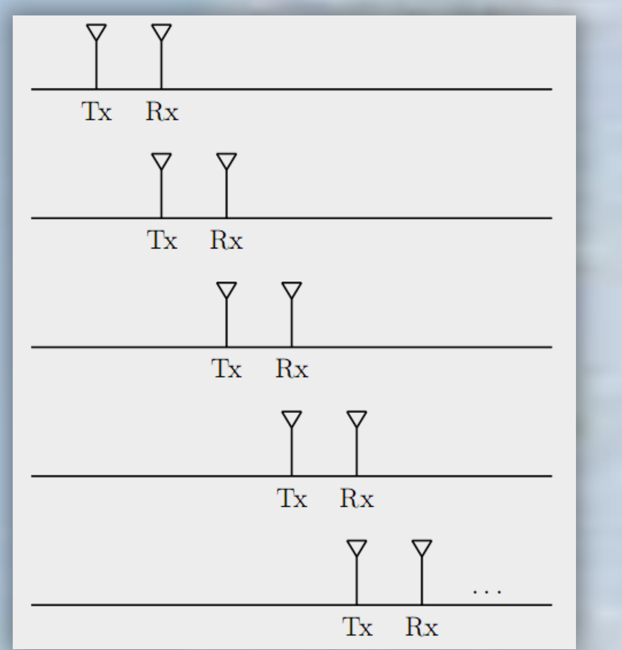
Theory – Radar Design

Synthetic Aperture

Cross range resolution is determined by wavelength, aperture size and range: $\Delta CR \approx R\lambda/D$. Good resolution requires larger aperture D which can be synthesized by moving horn antennas. Two SA configurations: bistatic and pseudo-monostatic are used.



Bistatic



Pseudo-monostatic

Pulse Compression Technique

A dual port VNA generates the stepped frequency transmitted signal and uses the second port as a receiver enabling the response of the environment in frequency domain to be measured. The use of stepped frequencies allows larger bandwidth, hence better range resolution.

Results

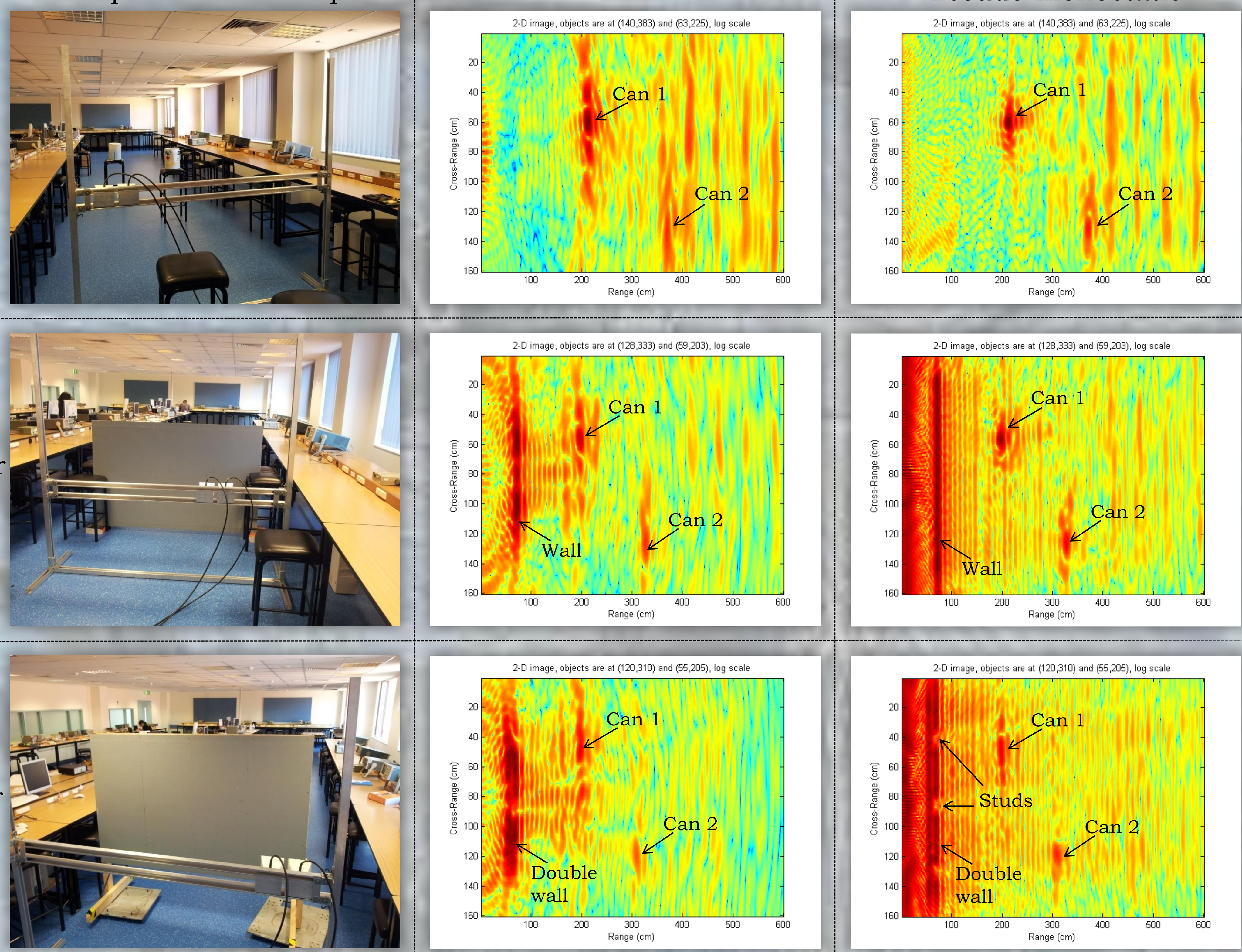
Sample results for constructed wall

Experimental set-up | Bistatic | Pseudo-monostatic

No wall

One plaster board

Two plaster boards



Remarks

- Regression analysis was used to calibrate out unknown cable and system delays
- Objects are resolved at correct locations
- Resolutions
  - ➢ Down range resolution of 10cm for both configurations
  - ➢ Cross range resolution of 10cm for pseudo-monostatic and 15cm for bistatic
- Wall is partly resolved in bistatic configuration
- Confusing near field pattern close to the SAR

References

1. Baranoski, E.J., "Through-wall imaging: Historical perspective and future directions," *Journal of the Franklin Institute*, vol. 345, no. 6, pp. 556-569, 2008.

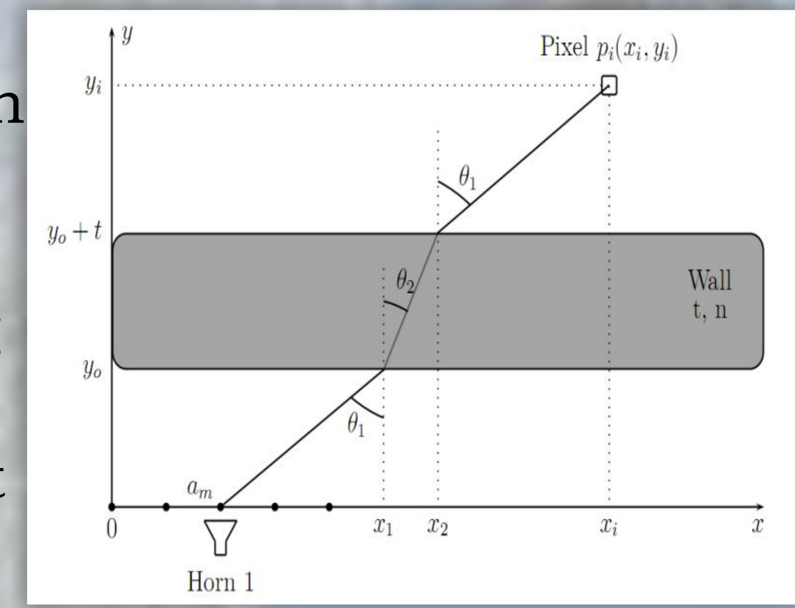
2. Braga, A.J. and Gentile, C., "An Ultra-Wideband Radar System for Through-the-Wall Imaging Using a Mobile Robot," *Communications, 2009. ICC '09. IEEE International Conference on*, vol., no., pp.1-6, 14-18 June 2009.

3. Ahmad, F., Amin, M.G., Kassam, S.A., "Synthetic aperture beamformer for imaging through a dielectric wall," *Aerospace and Electronic Systems, IEEE Transactions on*, vol.41, no.1, pp. 271- 283, Jan. 2005.

Theory – Image Processing

Focusing delay geometry

Electromagnetic distance between horn antennas via a pixel is calculated using Fermat's principle of least time:

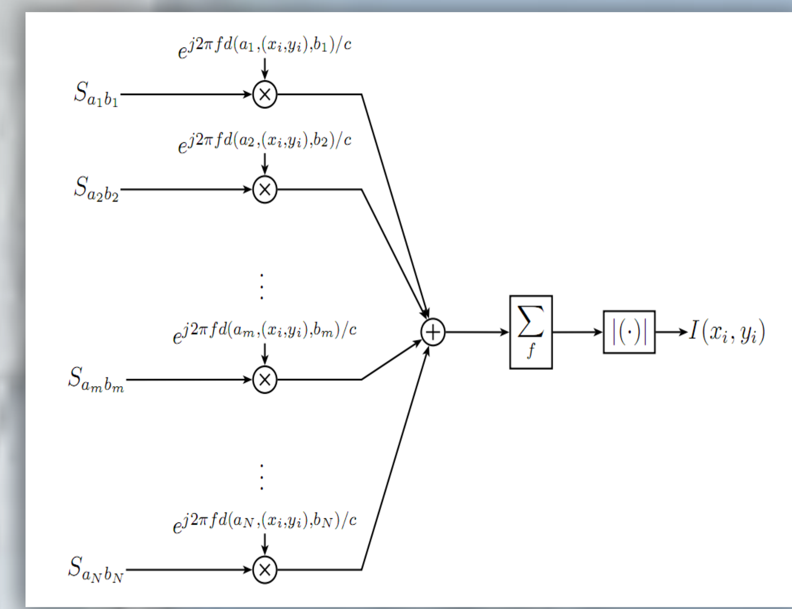


$$d(a_m,(x_i,y_i)) = \sqrt{(\hat{x}_1 - a_m)^2 + y_o^2} + n\sqrt{(\hat{x}_2 - \hat{x}_1)^2 + t^2} + \sqrt{(x_i - \hat{x}_2)^2 + (y - y_o - t)^2}$$

where $\hat{x}_1$ and $\hat{x}_2$ are chosen to minimise d

Focusing implementation

For all antenna positions, the frequency response is left-shifted by the focusing delay and they are then added.



Constructive interference occurs if there is an object at the pixel.

Project Outcomes

2-D image of the region of interest behind a wall has been successfully generated. The pseudo-monostatic configuration results in better cross range resolution compared to bistatic case. Experiments were conducted for various wall materials (pin-up board, constructed wall, office wall) and the results prove the feasibility of imaging through the wall.

Future Works

- Automatic data acquisition and signal processing by dedicated hardware.
- 3-D imaging of complex environment.