Pressure injury sensing using ultra-wide band array antenna and machine learning

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Research introduction

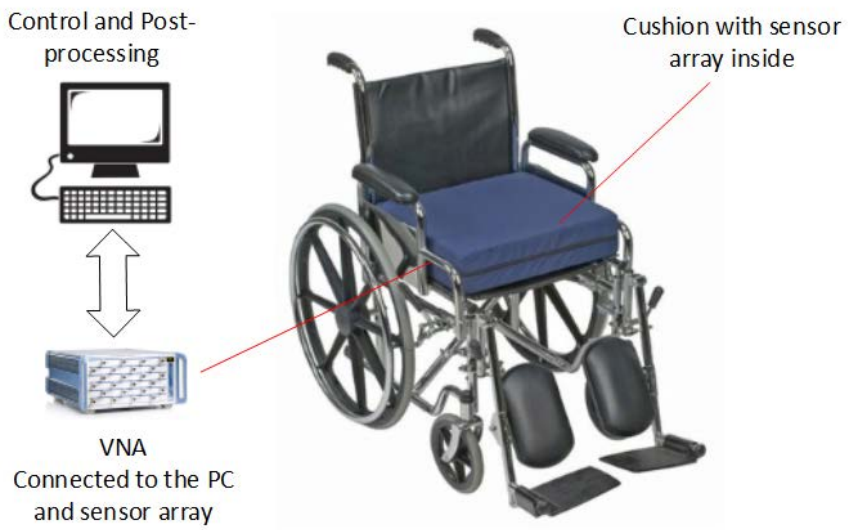
- Medical Devices and Vulnerable Skin Network

QMUL WP: Early detection of pressure injury with wireless sensor networks

The overall aim of this project is to develop a low-cost microwave sensing device, which is flexible and can be integrated into mattresses and cushions for real-time and unobstructive detection/monitoring of pressure injury in people at risk.

Objectives:

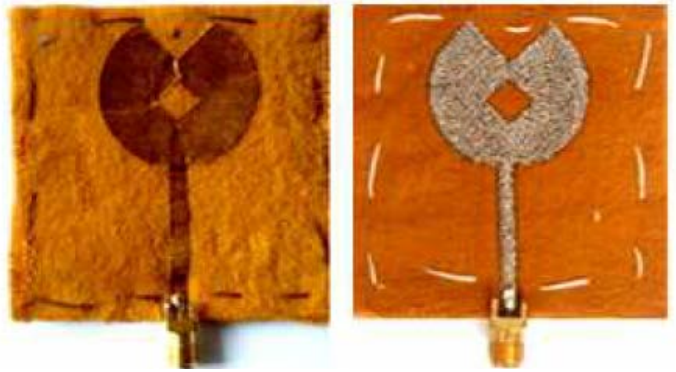
- RF sensor array for data acquisition
- Control software for signal generation and reception
- Data processing algorithms for pressure injury detection/monitoring



RF sensor array design

Antenna array design objectives:

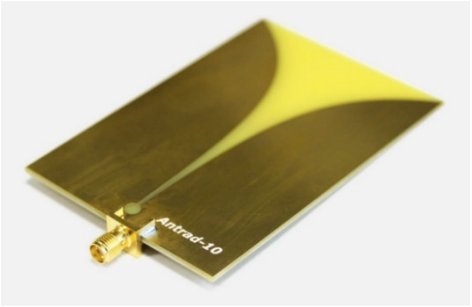
- Low cost
- Rich information
- Flexible
- Reliable



UWB textile wearable antenna

Objectives translated:

- Relative low frequency (microwave)
- Wideband operation(more frequency points)
- Can be easily integrated into mattress
- High gain (directional)



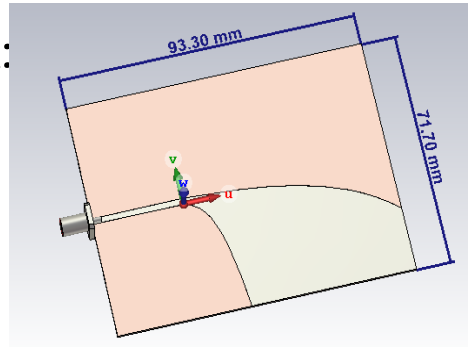
UWB Vivaldi antenna

Textile antennas perfectly fit the first three requirements but are susceptible to antenna bending. For the initial design, conventional Vivaldi antenna is adopted.

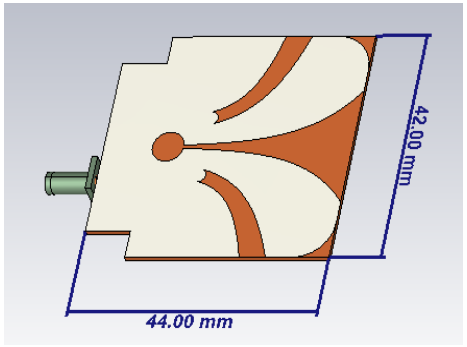
RF sensor array design

Vivaldi antenna design:

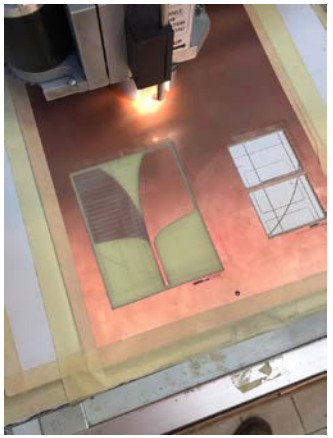
- Freq: 3 - 8.5 GHz
- S11: < -10 dB
- Gain: > 5 dBi



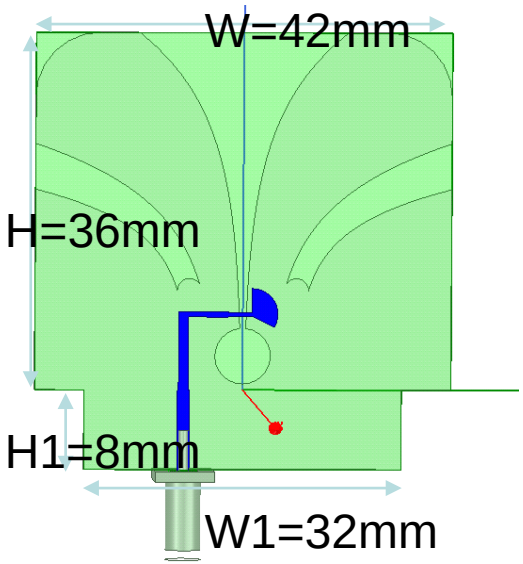
Initial bulky design



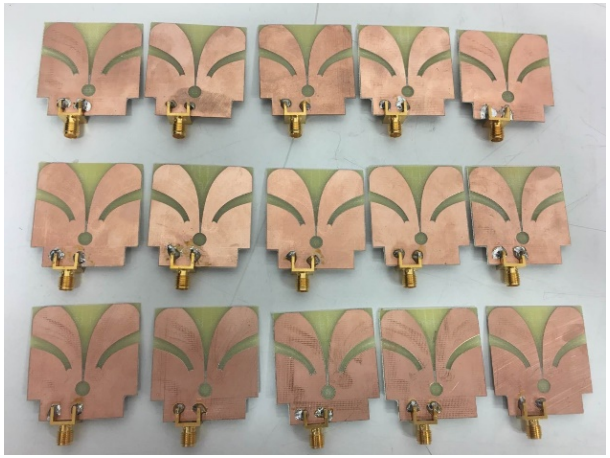
Compact design



Fabrication process



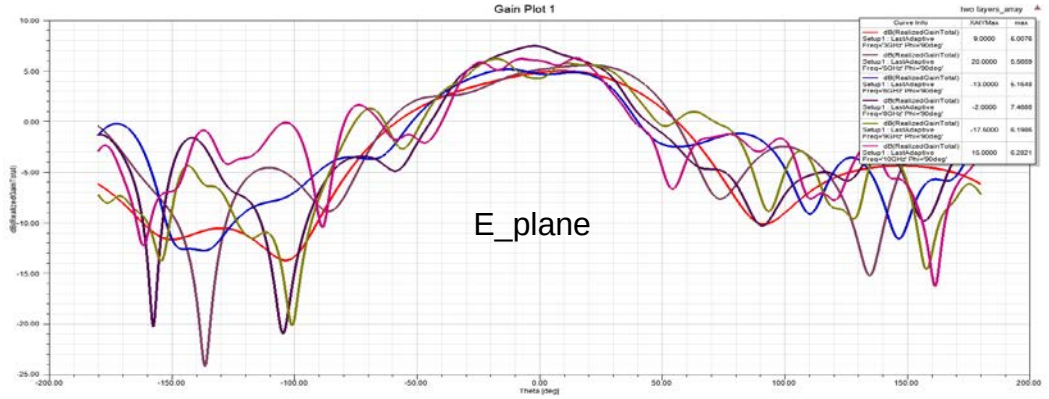
Antenna dimension



Fabricated elements

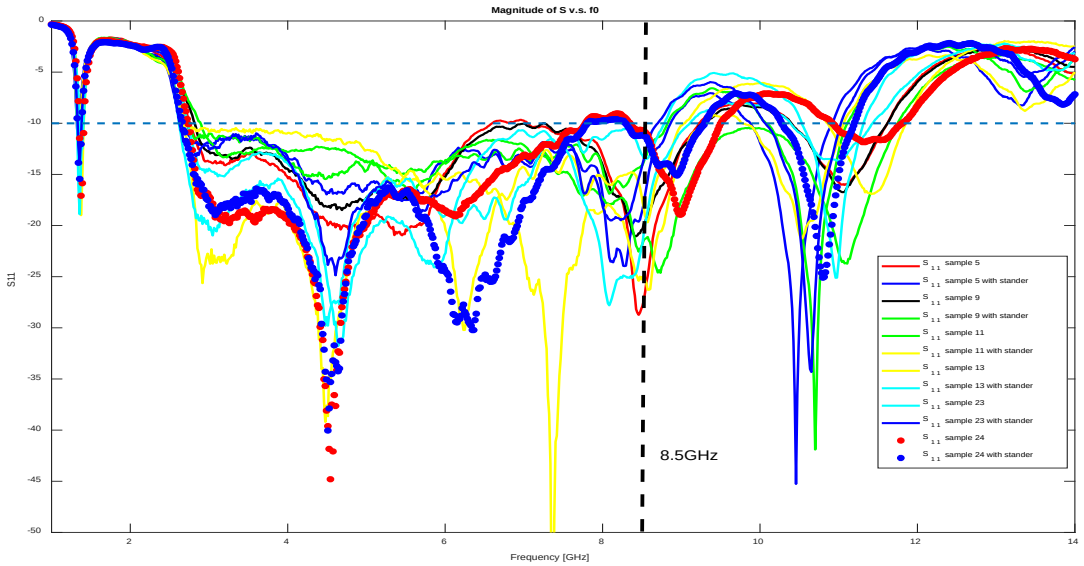
Final array

RF sensor array design

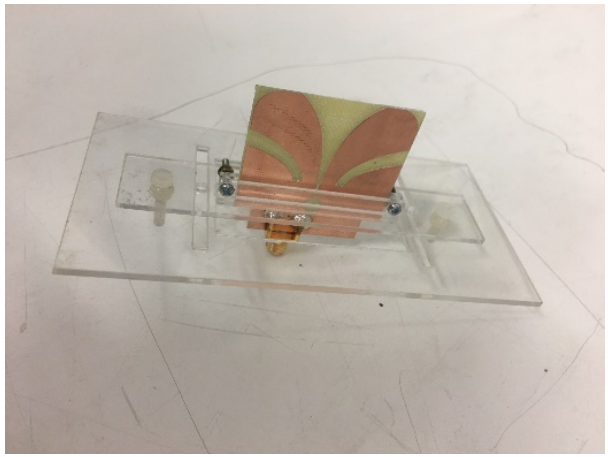


Simulated gain patterns at different frequencies

Frequency (GHz)	Gain_H (dBi)	Gain_E (dBi)
3	5.3	5
5	5.3	5.56
8	8	7.46
9	6.28	6.2
10	6.77	6.28



Measured S11 results of the element with the stand



Antenna with the stand

Control software

Automated signal generation and reception

- S-parameter reading from 24 ports
- Data acquisition in real-time

R&S ZNBT8 24-port vector network analyser (VNA)

System requirement:

- Windows
- Matlab
- NI VISA library

Data acquisition in two steps:

1. Generate traces according to port number

Signal transmitted from port 1 and received at port 5 is represented as S51

2. Read data from all traces; store data and timestamp
3. Repeat step 2 until finish

Example:

Generate a trace ('trc1') to show the S21.

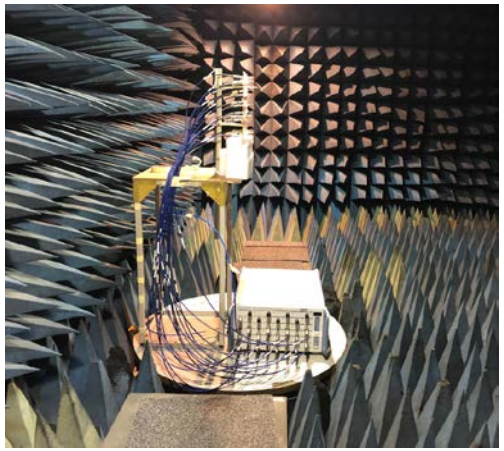
CALC1:PAR:SDEF "Trc1", "S21";
:DISP:WIND:TRAC1:FEED "Trc1"

Final code:

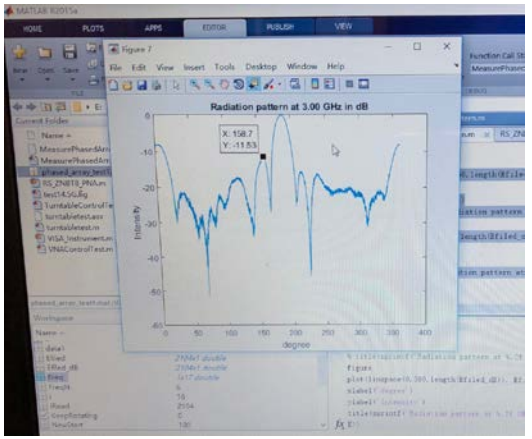
MeasureSParameter.m → Function for measurement

RS_ZNBT8_PNA.m → Class for Control of VNA

VISA_Instrument.m → Class for basic communication with VNA



Array measurement at chamber



Measured radiation pattern

Postprocessing algorithm

Research objective:
Early detection/monitoring of pressure injury.

Two possible approaches:

- **Microwave imaging**

Using imaging techniques like MRI to image the human body and identify the pressure injury.

Challenges: Requires very high resolution to spot pressure injury; Imaging quality highly dependent on the electromagnetic contrast of the injury tissue.

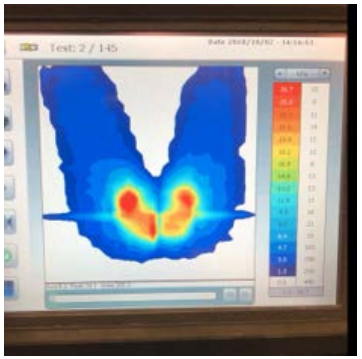
- **RF pressure sensing**

Pressure injury <- pressure monitoring <- pressure map + RF signal +machine learning.

Challenges: requires a large amount of data for training.

MMW scanner

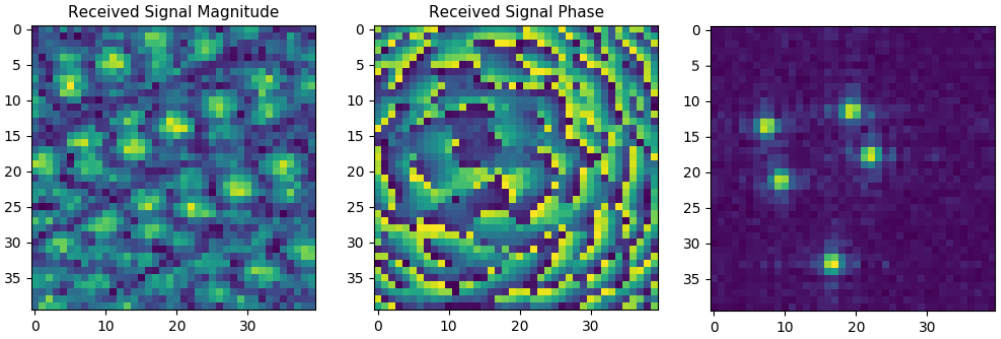
MMW imaging



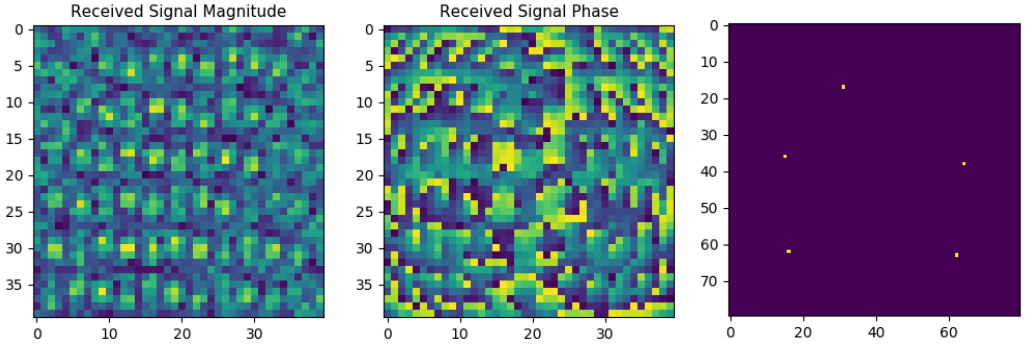
Pressure sensing

Microwave imaging approach

Improve resolution with compressive sensing

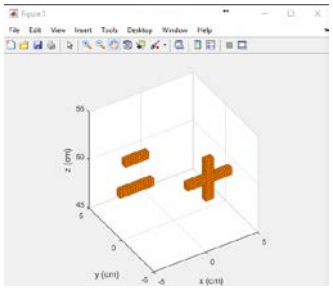


Conventional imaging algorithm for reconstruction of 5 point targets

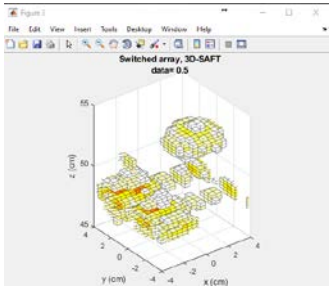


Compressive sensing algorithm for reconstruction of 5 point targets

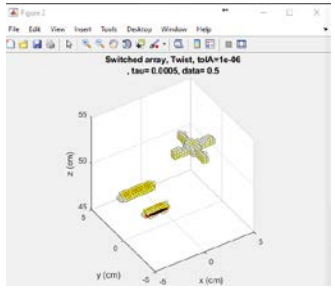
3D imaging example



Ground truth



Conventional

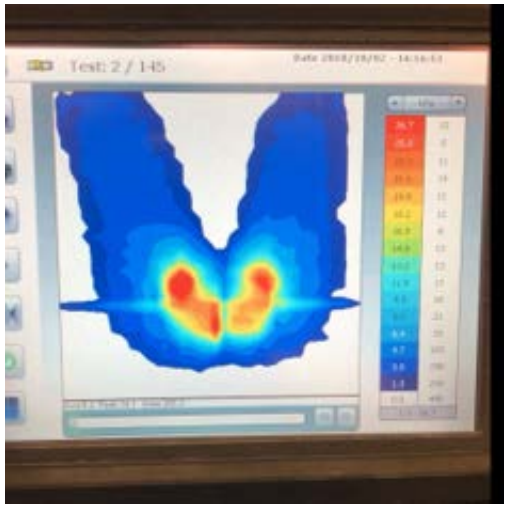


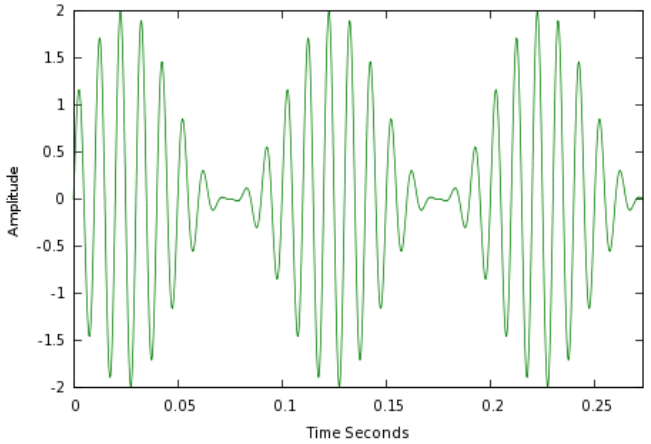
Compressive sensing

RF pressure sensing approach

Machine learning

- Pressure map signal
- RF signal





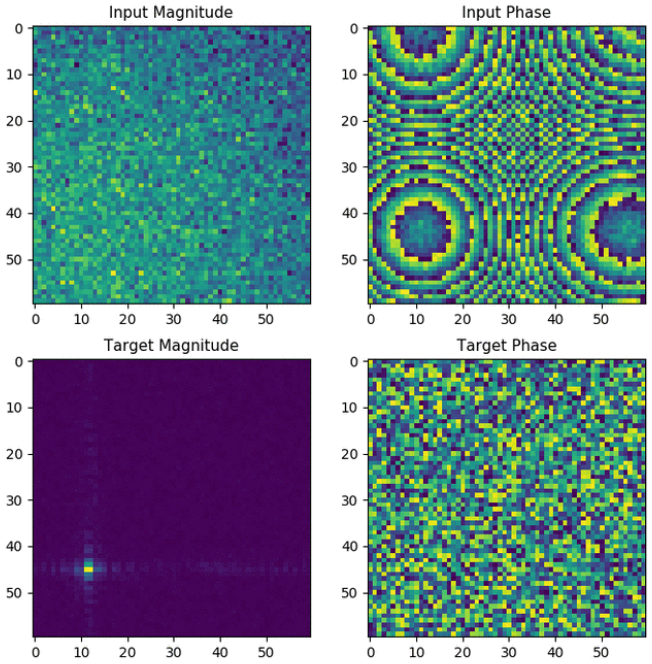
Microwave imaging + machine learning example

Machine learning

RF signal

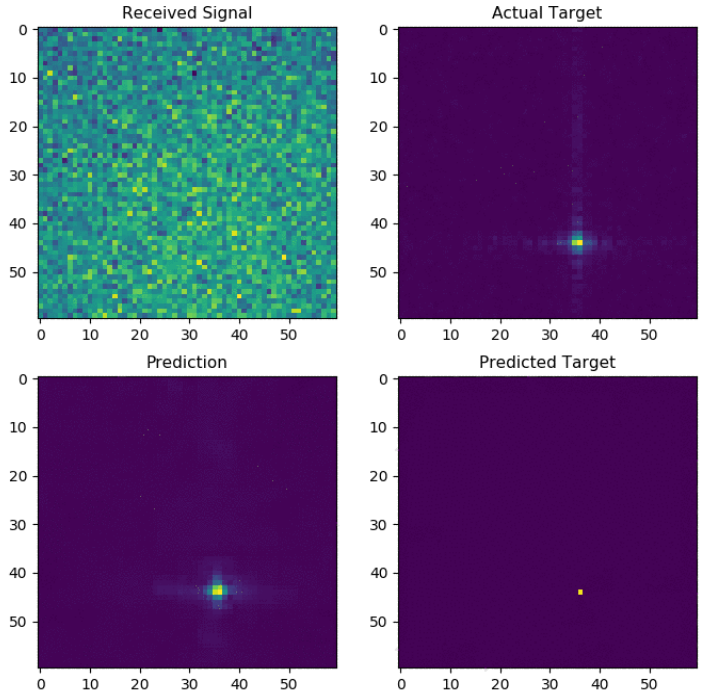
Image Reconstruction

Training



10k sets of RF signal and reconstruction

Prediction



ML reconstruction

Thanks