Millimeter & Microwave Screening of People, Bags and Footwear

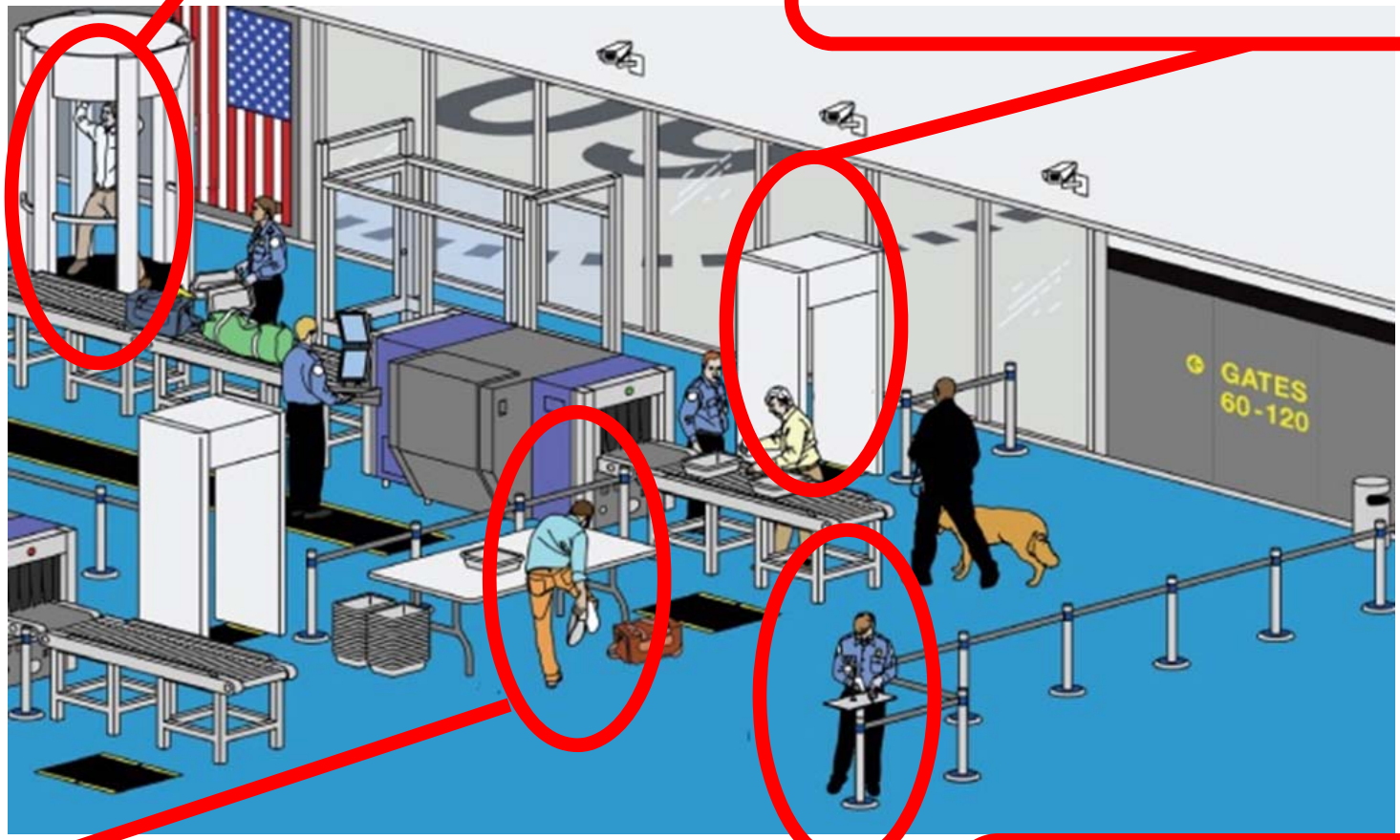
Radio Physics Solutions Inc.

Centre for Sensing & Imaging
Manchester Metropolitan University
http://www.soe.mmu.ac.uk/csi/

Why Bother, Who Cares ?

Non-contact 'pat-down' with handheld millimeter-wave radar

'Conventional' body scanning with cost effective passive millimeter-wave imaging systems



Rapid screening of footwear for concealments without necessitating removal of shoes

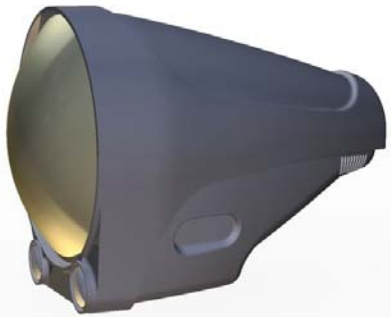
Illustration by Mark Nerys, obtained from http://www.wired.com/2013/06/fa_planehijackings/

Stand-off (25 meter) concealed threat detection with millimeter-wave radar

Radio Physics Solutions Inc.

Radio Physics Solutions is an SME which is based in Salem NH and London UK.

The company develops innovative millimeter-wave technologies for security screening, communications and navigation applications.



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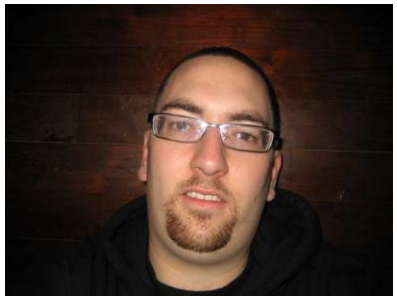

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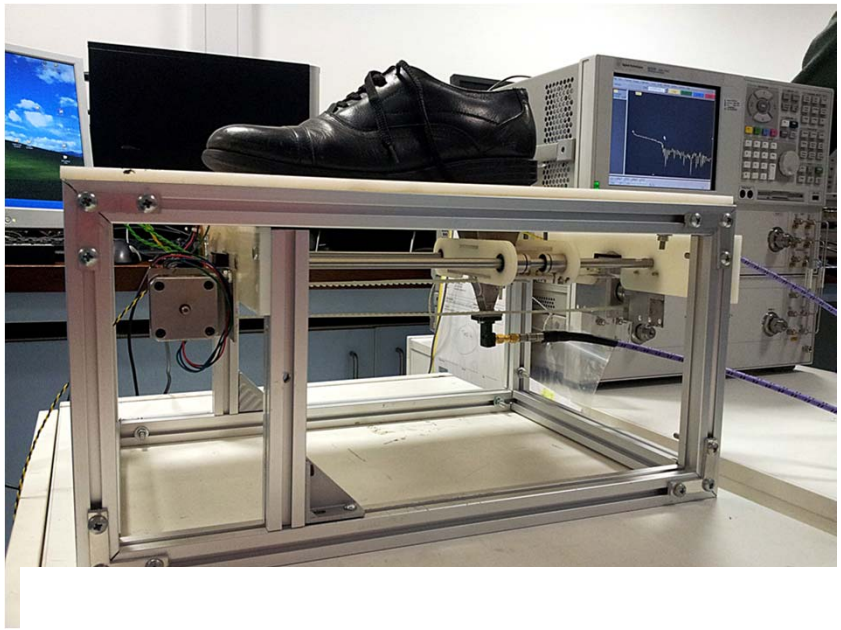
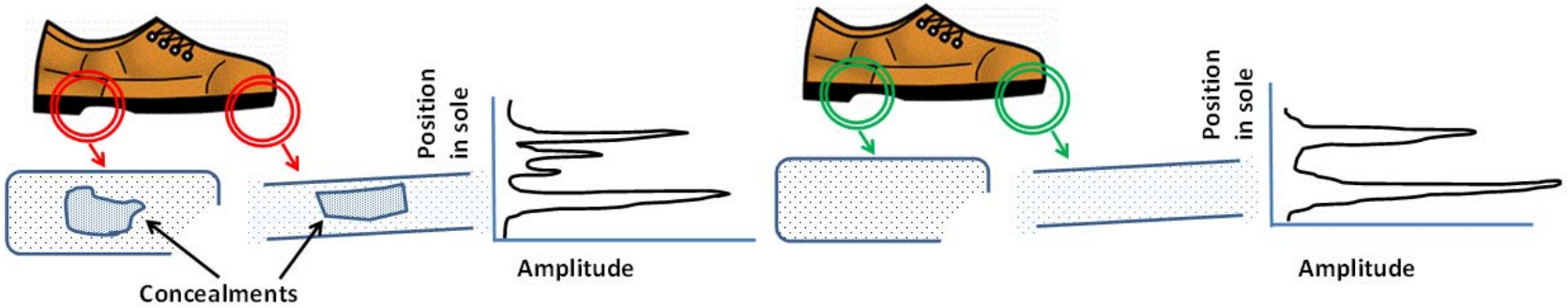
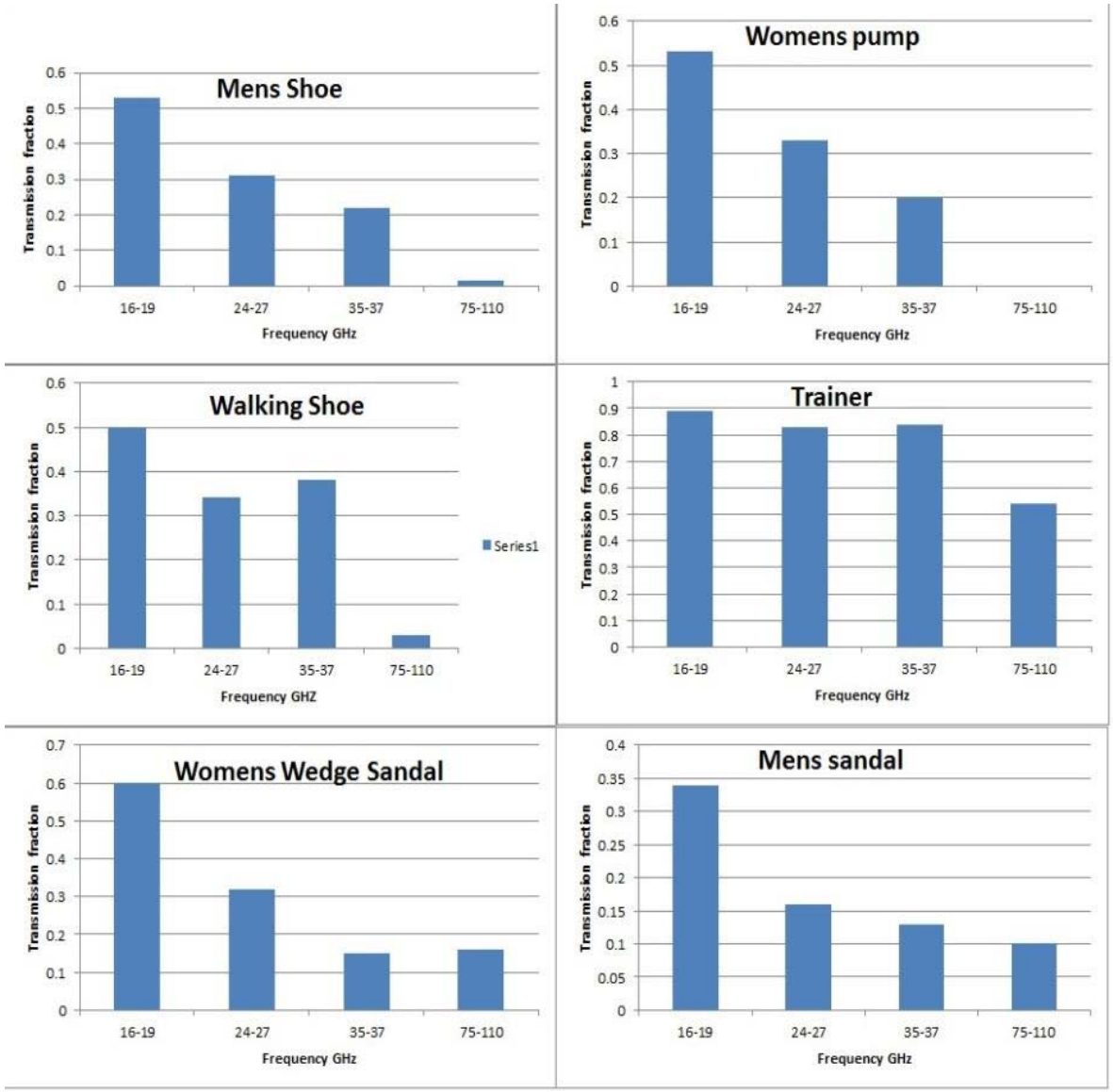
Microwave Radar for Screening Footwear



- UWB Stepped Frequency Radar is implemented to determine the presence or absence of concealments within the sole of the shoe.
- The scan be carried out without necessitating the removal of the shoe
- Small (< 1cm^3)metallic and non-metallic concealments are detectable with this approach
- Detection relies on reflection of transmitted microwaves at interfaces where the complex permittivity of the propagating medium changes



Why Microwaves ?



Some data from rough and ready trials designed to estimate the transmittance of typical shoes at different frequency bands.

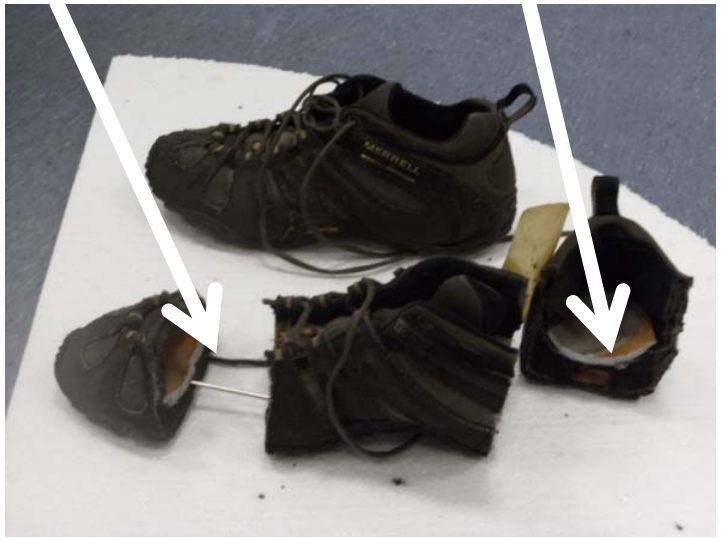
- The principal loss is by absorption, reflection losses are typically smaller
- Microwave gives suitable penetration into the sole and spatial resolution to enable system to operate reliably over most shoe types
- Higher frequency bands often suffer too great attenuation to be useful

Example Concealments

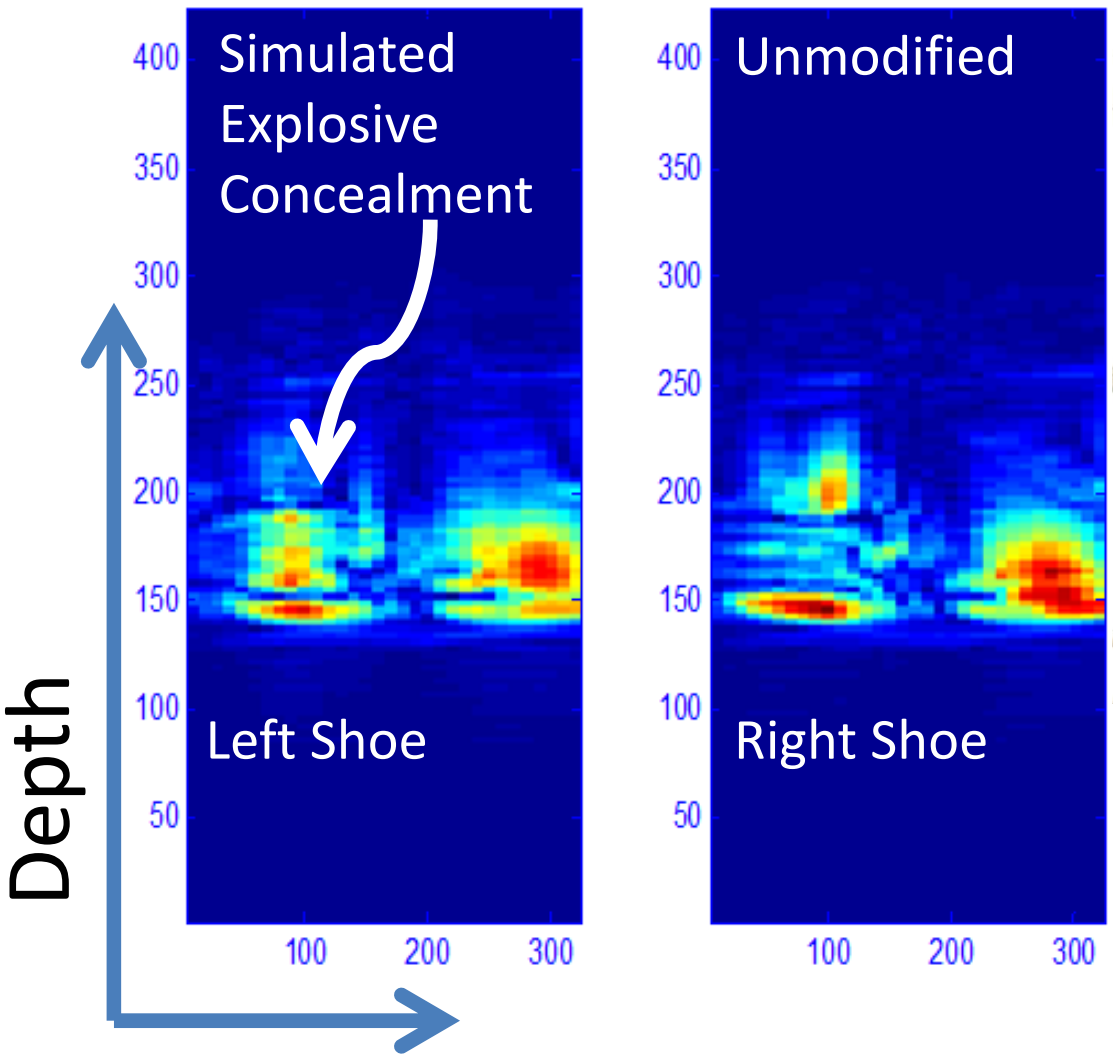
Shoes were modified with concealments made in the sole Explosive simulant was used to mimic ‘shoe bombs’. Metallic and non-metallic concealments can be detected easily with the system.

Concealed metal detonator

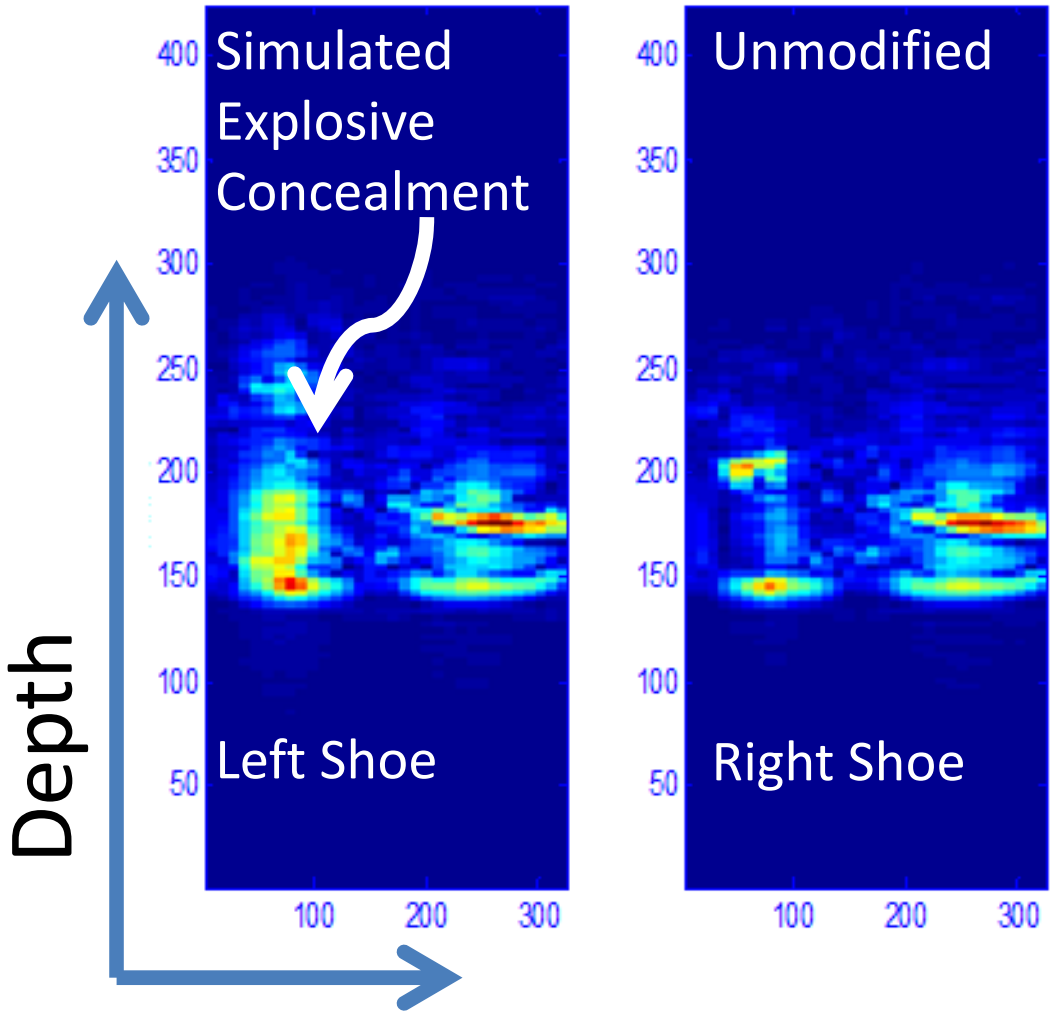
Concealed explosive charge



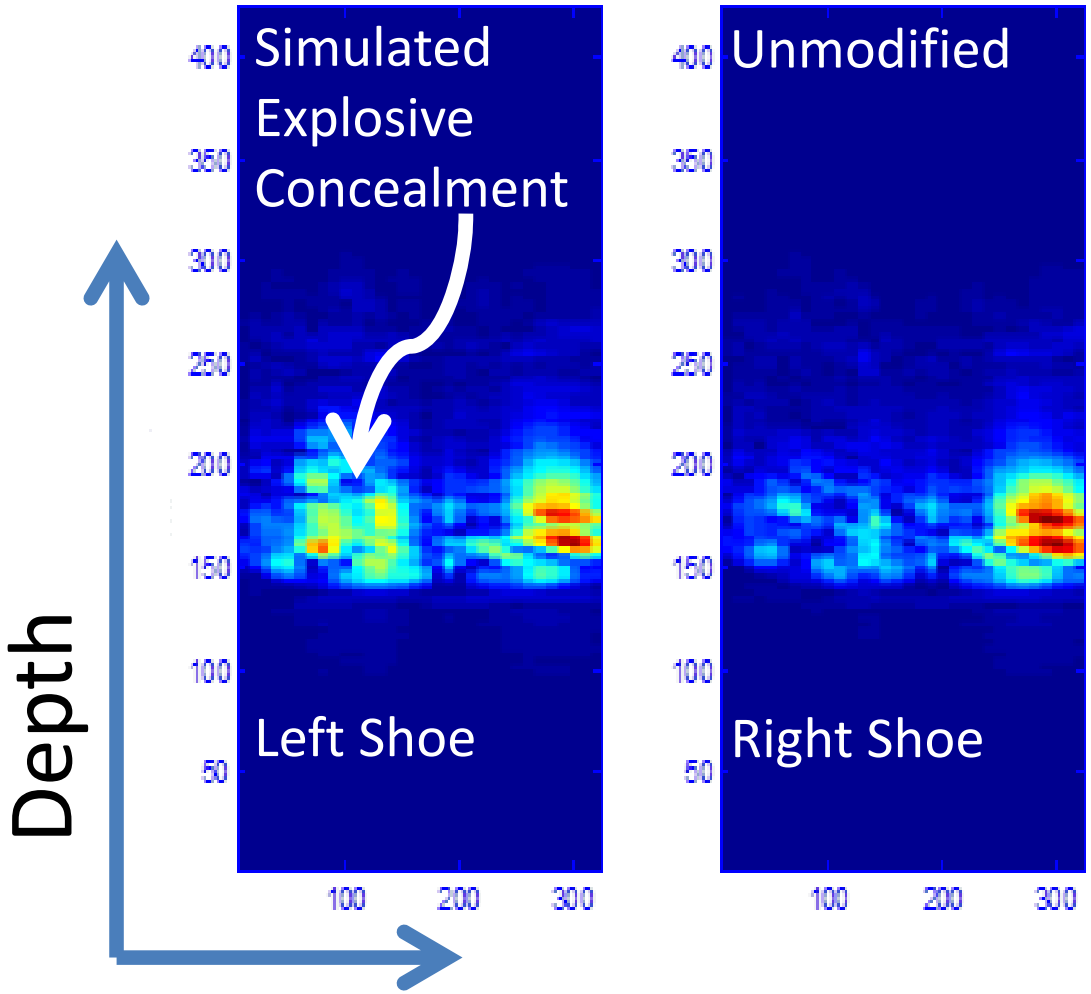
Example Scans: Men's Shoes



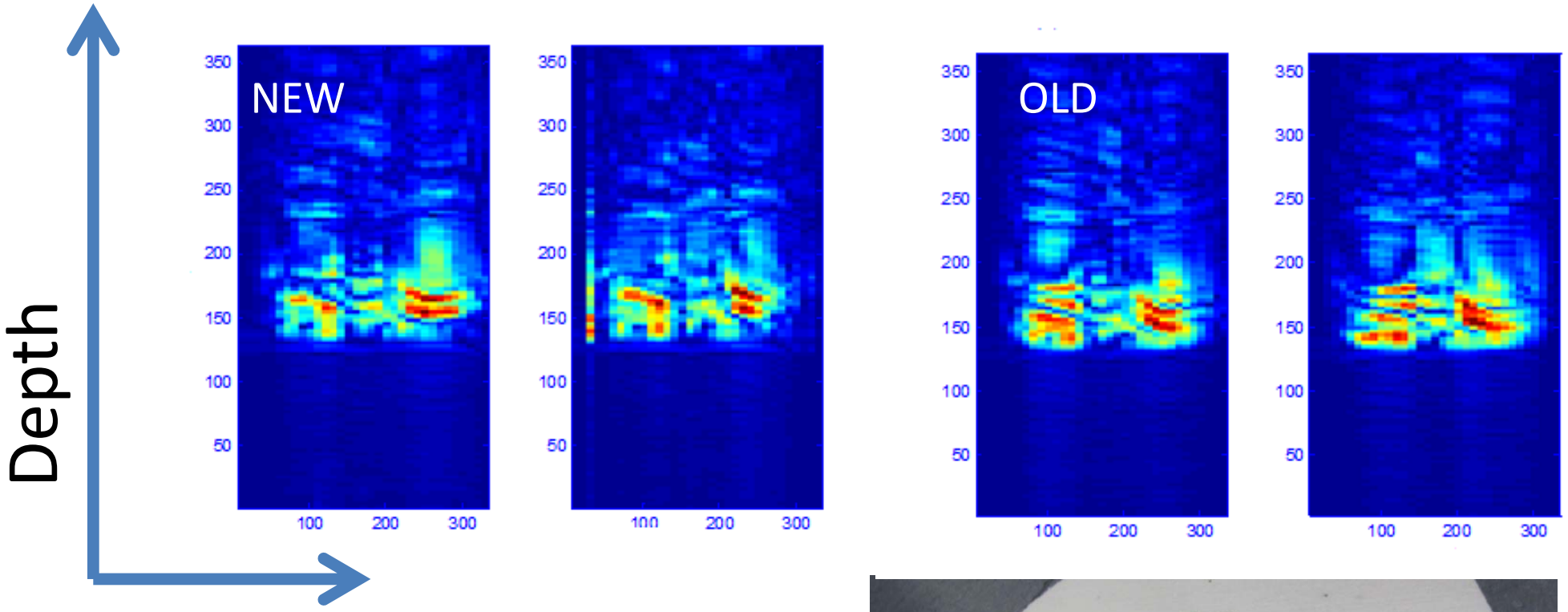
Example Scans: Women's Shoes



Example Scans: Sneakers



Sensitivity

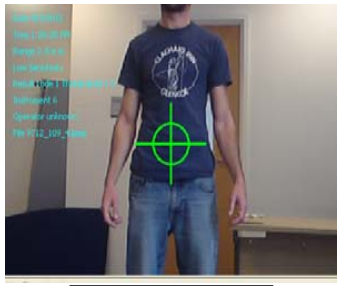


MiRTLE & MiRLIN Radar for Concealed Threat Detection

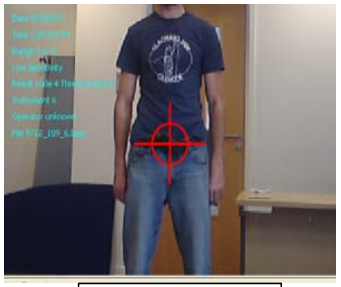
MiRLIN

MiRTLE

Handheld (MiRLIN) system in use



CLEAR



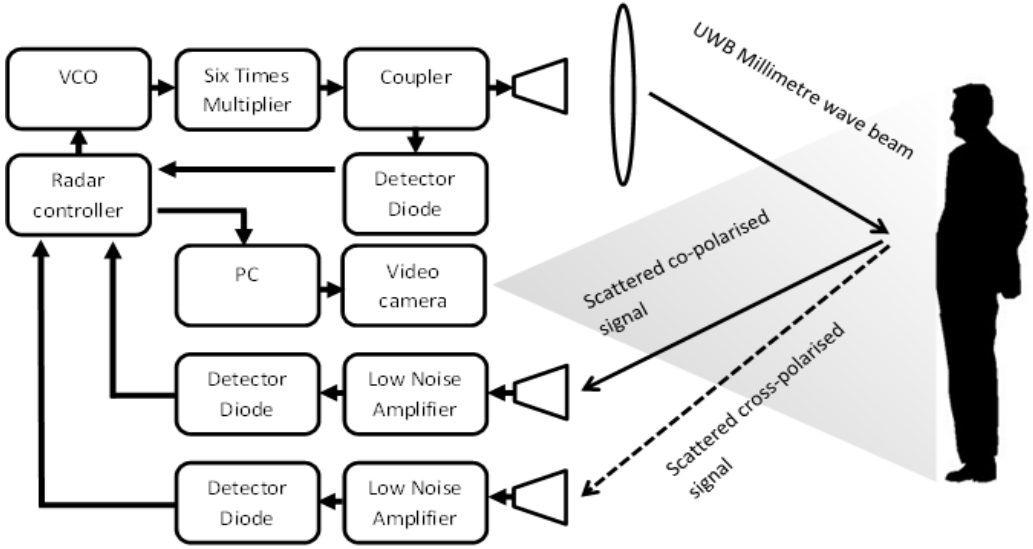
THREAT

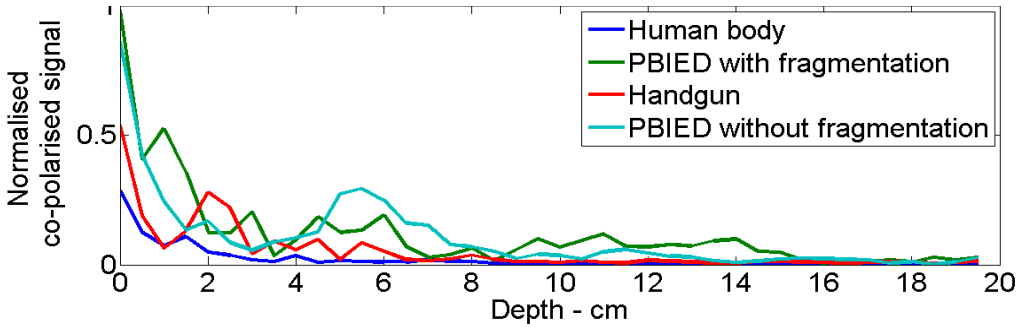
- Implements simple ‘direct detection’ radar for UWB sweep
- Beam width < 1 degree
- Targets classified by polarimetric ‘depth spectrum’
- Data is classified using Neural Network to render autonomous Threat/No threat indication
- Two systems: handheld for screening up to 10 meters; tripod mounted for screening at up to 25 meters

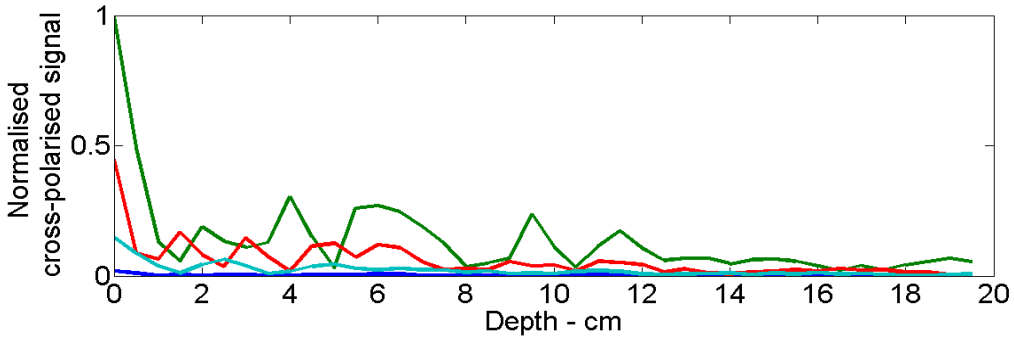
Trials/Assessments

H1 2013	H2 2013	H1 2014	H2 2014	H2 2014
3 trials successfully completed with the UK Home Office	4 trials successfully completed with Scotland Yard	Technology assessment successfully completed with US Army (ART/TSOA Mission) uniquemissioncell.org/	Invited to second technology assessment to US Army in Quantico VA (ART/TSOA Mission)	MiRTLE / MiRLIN product launch

System Outline







The system has three MMW channels:

- One narrow frequency sweep to range to target
- Two orthogonal UWB channels to produce depth spectrum data
- Depth spectrum data contains information on separation of partially reflecting surfaces, information on range order of surfaces is lost due to direct detection operation

$$S(t) \propto \sum_{m=1}^{M} \Im^{-1}\left\{\sqrt{\sigma_m(\nu)}\right\} \otimes \delta\left(t - \frac{2z_m}{c}\right)$$

$$S(t) \propto \sum_{m=1}^{M}\sum_{n=1}^{M} \Im^{-1}\left\{\sqrt{\sigma_m(\nu)\sigma_n^*(\nu)}\right\} \otimes \delta\left(t - \frac{2|z_m - z_n|}{c}\right)$$

Data Processing Steps

1. Data Acquisition

- Ultra Wide Band sweep 75-108 GHz, 256 points in 1ms
- Orthogonal receivers Co- and Cross-polarised

2. Data Processing

- DIFT → 'Depth Spectrum'
- Select lowest 40 data points (corresponding to optical depths of 6-240 mm)
- Scale signal for range (mix of inverse square and R^{-4})

3. Neural Network

Input data – Hidden layer – output

10 elements 10 nodes

Gives a "threat value" between 0 - 1

- Trained on measurements of person with and without threat items

4. Threshold Filtering

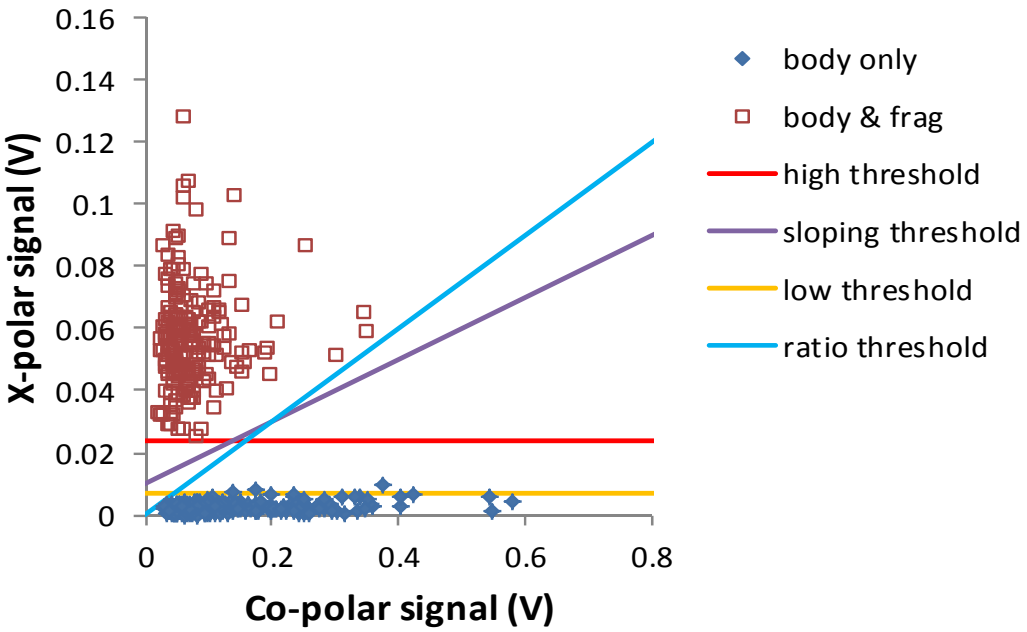
- NN output > "pre-defined confidence level"
  → Threat Indication "1"

5. Persistence Filtering

- Successive indications …01101111001…..
- Within moving time window, if number of indications > threshold
- → Threat Alarm

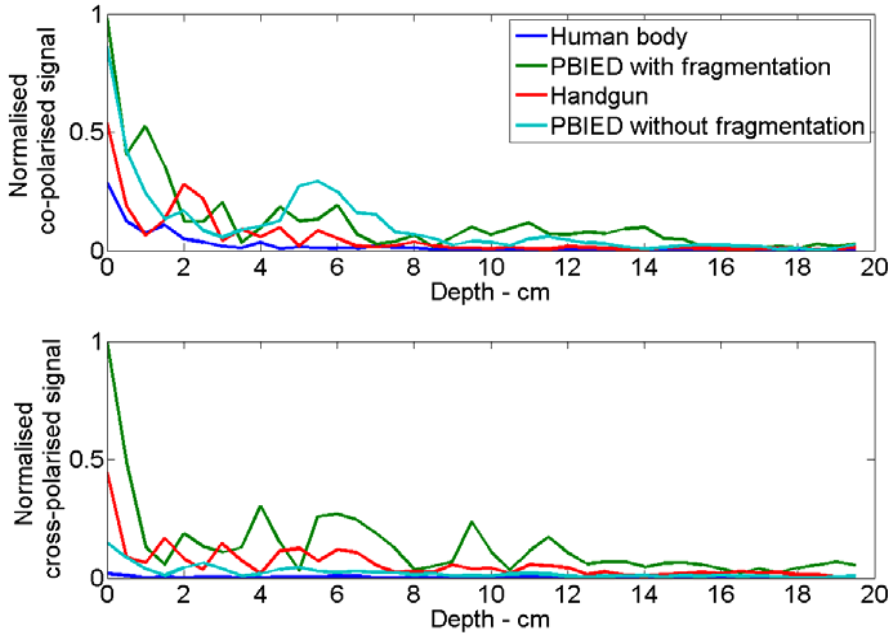
Operation

Video of prototype MiRTLE operation taken with a 100% plastic, 3D printed handgun as the threat object.



Data showing polarising effect of simulated PBIED with fragmentation placed on body.

- This data is the averaged return over the entire depth spectrum and shows clustering.
- Different thresholds can be used to determine whether PBIED is likely to be present based on this crude return



A better method is to measure the relative amount reflected back from the target in different frequency bands and then perform an DIFT on these data to obtain a 'depth spectrum'

- Depth spectrum data reveals information on the axial extent of the target

Millimeter-wave Imaging

- Using active millimetre-wave imaging it is possible to see what is being concealed in carried bags.
- This example is taken from an active imager, in which incoherent illumination is used to avoid specular reflection.
- The system collects images in real time at 8 frames per second.
- Here, there is a concealed ‘pressure cooker bomb’ concealed in a rucksack.
- Migration toward aperture synthesis with a real time correlator.