The challenges of pedestrian detection using radar

- Pedestrian detection requirements
- Current technology
- Challenges for new solutions
- Potential alternative technologies
- Radar - background
- Radar for pedestrian detection
  - Early results
  - Technology challenges
  - Technology solutions
  - Current results
- Final summary
- Questions
Pedestrian detection requirements

Requirements for pedestrian detectors

Formal specifications

HA Specifications
- TR2506 - On crossing
- TR2507 - Kerbside

DfT publications
- TA 1/02
  (Installation of Puffin crossings)
Pedestrian detection requirements

Requirements for pedestrian detectors

Formal specifications

Practical performance requirements

Reliable detection
- Not affected by environmental conditions
- Static objects as well as people

Compatible with control equipment
- LV and ELV systems
Pedestrian detection requirements

Requirements for pedestrian detectors

- Formal specifications
- Practical performance requirements
- Generic requirements

Easy to install
- Ideally no special tools
- Simple installation concept
- No use of PCs on street

Easy to maintain
- Fit and forget
- No regular maintenance

Pedestrian detection that works well can significantly improve crossing efficiency
<table>
<thead>
<tr>
<th>Current technology solutions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Above ground video solutions</strong></td>
<td><strong>Pedestrian mats (Kerbside)</strong></td>
</tr>
<tr>
<td><strong>Advantages</strong></td>
<td><strong>Advantages</strong></td>
</tr>
<tr>
<td>• Flexible detection zones</td>
<td>• Not affected by shadows or other environmental conditions</td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td>• Performance in low light / at night difficult to achieve</td>
<td>• Generally poor wait area coverage</td>
</tr>
<tr>
<td>• Can be improved with IR illumination</td>
<td>• Often requires special signage</td>
</tr>
<tr>
<td>• False detections due to shadows &amp; changing light levels</td>
<td>• Can be difficult / costly to install</td>
</tr>
<tr>
<td>• Use of PC set-up tools not ideal in some locations</td>
<td>• Requires civils works</td>
</tr>
<tr>
<td>• Requires regular lens cleaning to maintain performance</td>
<td>• Not easy to retrofit to existing site</td>
</tr>
<tr>
<td>• Have a mixed performance and reliability reputation</td>
<td>• Long term reliability not proven</td>
</tr>
</tbody>
</table>

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Challenges for new solutions

Key requirements

Reliable detection
- Not affected by shadows or other environmental considerations
  - Fog, rain, wind etc
- Works equally well in daylight and at night
- Easy to install
  - Ideally should not require special tools or the use of a PC
- Should not require frequent on-going maintenance
- Will cover the whole crossing or pedestrian wait area
  - Should not require special signage or pedestrian behaviour to be effective
- For kerbside applications, is able to detect totally static objects including small children and pushchairs
### Possible above ground technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive Acoustic</td>
<td>• Passive so can be very low power</td>
<td>• Not good for detecting slow / static traffic</td>
</tr>
<tr>
<td></td>
<td>• Accurate zones if multiple sensors used</td>
<td>• Can be affected by environment (rain / snow etc)</td>
</tr>
<tr>
<td></td>
<td>• Immune to changing light levels</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Relatively low cost</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• No significant maintenance required</td>
<td></td>
</tr>
<tr>
<td>Active Acoustic</td>
<td>• Immune to light levels</td>
<td>• Difficult to achieve precise detection zone</td>
</tr>
<tr>
<td></td>
<td>• Relatively low cost</td>
<td>• Heavy rain / wind and snow can severely affect performance</td>
</tr>
<tr>
<td></td>
<td>• No significant maintenance required</td>
<td></td>
</tr>
<tr>
<td>24GHz Radar</td>
<td>• Immune to changing light levels</td>
<td>• Active device so needs regulatory approval in all target markets</td>
</tr>
<tr>
<td></td>
<td>• Relatively accurate zones possible</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• No significant maintenance required</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Costs attractive compared to higher frequency radar solutions</td>
<td></td>
</tr>
<tr>
<td>Passive Infrared</td>
<td>• Passive so can be very low power</td>
<td>• Can be affected by significant sudden temperature shifts</td>
</tr>
<tr>
<td></td>
<td>• Reasonably accurate zones possible</td>
<td>• Fog and heavy snow can affect performance</td>
</tr>
<tr>
<td></td>
<td>• Relatively low cost</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• No significant maintenance required</td>
<td></td>
</tr>
<tr>
<td>Video</td>
<td>• Many accurate zones possible (if field of view permits)</td>
<td>• Can be badly affected by changing light levels and environmental conditions (Rain, snow etc).</td>
</tr>
<tr>
<td></td>
<td>• Can provide visual overview of target area</td>
<td>• Significant maintenance overhead</td>
</tr>
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</table>

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Radar - background

Radar has been successfully used in traffic applications for many years.

Most existing radar solutions use CW Doppler principals.

Operational principals:
- Single frequency microwave energy is continuously beamed at target zone.
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Operational principals
- Single frequency microwave energy is continuously beamed at target zone
- The return echo from a moving target is frequency shifted in proportion to its speed
  - The direction of travel can be determined by the frequency shift
  - Static targets produce no frequency shift so are not detected
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- The return echo from a moving target is frequency shifted in proportion to its speed
  - The direction of travel can be determined by the frequency shift
  - Static targets produce no frequency shift so are not detected
- Doppler radar solutions are relatively simple
  - Ideal for VA detection
  - Also work well for pedestrian on-crossing solutions
- Heimdall on-crossing detectors use Doppler radar principals.
Detection of static targets using radar is more challenging

FMCW techniques offer a viable solution

Operational principals
- Microwave energy is modulated using a sweep frequency
Detection of static targets using radar is more challenging

**FMCW techniques offer a viable solution**

![Graph showing transmitted and reflected signals with frequency difference proportional to distance to target]

**Operational principals**

- Microwave energy is modulated using a sweep frequency
- The time delay (and hence range) to any given target is proportional to its frequency at any given time
  - Range resolution and accuracy can be improved by using larger sweep frequencies and faster sweep rates
Radar - background

Detection of static targets using radar is more challenging

FMCW techniques offer a viable solution

Operational principals
- Microwave energy is modulated using a sweep frequency
- The time delay (and hence range) to any given target is proportional to its frequency at any given time
  - Range resolution and accuracy can be improved by using larger sweep frequencies and faster sweep rates
- Completely static targets can be resolved
  - Moving targets can also be resolved by combining FMCW and Doppler techniques
- In principal FMCW radar seems to provide a good solution for kerbside pedestrian detection
Detection of static targets using radar is more challenging

<table>
<thead>
<tr>
<th>FMCW techniques offer a viable solution</th>
<th>Operational principals</th>
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<tbody>
<tr>
<td>Frequency difference proportional to distance to target</td>
<td>• Radar energy is modulated using a sweep frequency</td>
</tr>
<tr>
<td>Transmitted Signal</td>
<td>• The time delay (and hence range) to any given target is proportional to its movement at any given time</td>
</tr>
<tr>
<td>Reflected Signal</td>
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So, why has it taken so long to produce a viable, radar based kerbside detector?
Heimdall - early results

Choice of 24GHz offers several benefits
- Useable frequency band in many countries
- Reasonable cost position
  - Much cheaper than 77GHz solutions
- Higher frequency than most existing radars used in traffic applications
  - Believed to offer better target resolution than lower frequencies

Early Heimdall development based on 24GHz technology

Successful in delivering a range of detection solutions
- SCOOT / MOVA
- Stop-line
- VA detection

Did not deliver sufficiently good performance to be used in on-crossing and kerbside applications
Kerbside application is the most challenging
Initial performance concerns

Susceptibility to rain
- Rain has no significant impact on range as targets are always relatively close
- Significant ‘backscatter’ encountered at 24GHz
- Major issue for pedestrian detection, when detectors are generally looking down
  - Acts to reduce detector sensitivity
**Initial performance concerns**

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**Zone size and shape**
- Achieved zone size quite small
  - Difficult trade-off between zone size and susceptibility to rain
- Required kerbside zone requirements not easy to deliver with simple radar
- Very difficult to achieve good performance ‘close to the pole’
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Pole vibration
• Pole vibration easily detected as movement by Doppler radars
Initial performance concerns - actual performance

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Design changes for success

Key to success has been a change in approach for the pedestrian versions of Heimdall

Change in frequency to 13GHz
- Effect of ‘back scatter’ from rain is much reduced
  - Enables bigger zones to be achieved
- Offers higher bandwidth allocation than either 24GHz or 10GHz
  - Improved target resolution
  - Allows better discrimination of ‘pole’ and people

Use of innovative dual antenna design
- Provides much better zone shape for kerbside applications
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Use of innovative dual antenna design
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Some concern over detection of vehicles travelling close to the kerb

Idealised site layout
### Heimdall pedestrian detection now delivers good performance

- Zone sizes adequate for most applications
  - Zone length adjustable with simple DIL switch setting
- Not affected by light levels, shadows etc
- Can reliably detect completely static targets
- False vehicle detection rate very low due to special vehicle rejection algorithm
- Installation and set-up very simple
  - Does not need PC or special software tools to be used ‘on-street’
  - Does require correct sighting to avoid signal head hoods etc
    - Can see through hoods to some extent
    - Only limited ability to adjust zones
Actual kerbside performance

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Test site 1 (Side A)

Test site 1 (Side B)
Heimdall range

Heimdall now offers a complete range of vehicle and pedestrian detection solutions

**Vehicle types**
- Standard vehicle
- Single lane vehicle
- Stop line
- Selectable vehicle speed
- SCOOT / MOVA

**Pedestrian types**
- On-crossing
- Kerbside

All types use radar principals and offer reliable detection performance under all lighting conditions
Heimdall range

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Questions?
The Challenges of pedestrian detection using radar