THE CHALLENGES OF USING RADAR FOR PEDESTRIAN DETECTION

Keith Manston
Siemens Mobility, Traffic Solutions
Sopers Lane, Poole
Dorset, BH17 7ER
United Kingdom
Tel: +44 (0)1202 782248
Fax: +44 (0)1202 782602
Mobile: +44 (0)7808 822732
Email: keith.manston@siemens.com

Executive summary

Pedestrian detection forms the heart of the Puffin pedestrian control strategy, which is now mandated by the DfT for use on new sites. When fully functional, the detection enables Puffin pedestrian crossings to provide real benefits over the older Pelican pedestrian strategy.

Traditionally the design of the kerbside detectors, which are used to detected pedestrians waiting to cross the road, has posed the most difficult challenge to the reliable operation of Puffin crossings. Several different technologies including video detectors and pedestrian mats have been used in this area with varying degrees of success.

Radar detectors are frequently used for on-crossing applications, but delivering a radar solution for kerbside use, which performs reliably and at a reasonable cost, has proved difficult.

This paper briefly covers the ongoing development of the Siemens Heimdall above ground detectors, particularly focusing on the challenges that have been overcome to produce radar detectors suitable for both On-crossing and Kerbside applications.

SIEMENS

Introduction

The potential for using radar for all the pedestrian detection requirements of Puffin crossings has been a possibility for several years, but delivering a solution that performs reliably has proved illusive. The new versions of the Heimdall detector family from Siemens now seem to have the answer, but their development has been a significant challenge for the technical teams in the UK and Germany who were charged with their development.

Pedestrian detection forms the heart of the Puffin pedestrian control strategy which is now mandated by the DfT for use on new sites. When fully functional, the detection enables Puffin pedestrian crossings to provide real benefits over the older Pelican pedestrian strategy. These benefits are focused in two main areas:

- **Optimised pedestrian crossing times.** For Pelican crossings the pedestrian crossing time is fixed, usually as a duration long enough to ensure that, even when the crossing is heavily used, pedestrians are given adequate time to cross before conflicting vehicles are allowed 'right of way'.

  The impact of this is that when a crossing is lightly used the pedestrian green time is usually much longer than is really needed; resulting in significant wasted waiting time for vehicular traffic.

  Conversely, in Puffin implementations, the pedestrian green time is generally set to a minimal duration and is then extended by the use of ***on-crossing detectors***, but only for as long as there are pedestrians crossing. As soon as all pedestrians have reached the pavement, right of way is ceded to the vehicles, resulting in significantly reduced vehicle delays, particularly when the crossing is lightly loaded.

- **Minimisation of unnecessary vehicle stops.** Pedestrians do not always wait until they are given their own green light to cross the road. If the opportunity arises many will cross in traffic gaps, despite the fact they do not have a pedestrian green signal. In some instances Pedestrians will also 'change their minds' and decide not to cross, even though they may have already put in a pedestrian demand.

  In Pelican implementations this behaviour causes the crossing to move to pedestrian 'right of way', interrupting traffic flow, even though there may actually be nobody waiting to cross the road. This problem is solved at Puffin crossing by the use of ***kerbside detectors*** which sense the presence of pedestrians waiting to cross. Should all the pedestrians move away from the crossing before they are given right of way, the pedestrian demand is cancelled, preventing the crossing from unnecessarily stopping flowing traffic.

Since the introduction of Puffin crossings a variety of technical solutions have been used to provide the necessary detection functionality, including video, radar and occasionally pressure sensitive mats installed in the pavement. Each of these detection technologies have both advantages and disadvantages (summarised in table 1 below).

Above ground video solutions	Pedestrian mats (Kerbside)	Doppler radar (On crossing)

Advantages
• Flexible detection zones
 	
Disadvantages
• Performance in low light / at night difficult to achieve
  • Can be improved with IR illumination
• False detections due to shadows & changing light levels
• Use of PC set-up tools not ideal in some locations
• Requires regular lens cleaning to maintain performance
• Have a mixed performance and reliability reputation
	Advantages
	• Not affected by shadows or other environmental conditions
	
	Disadvantages
	• Generally poor wait area coverage
	  • Often requires special signage
	• Can be difficult / costly to install
	  • Requires civils works
	  • Not easy to retrofit to existing site
	• Long term reliability not proven
	  • Only limited installed base so far
		Advantages
		• Not affected by shadows or changing light levels
		  • Works equally well in daylight and at night
		• Relatively easy to install
		  • No special tools generally required
		
		Disadvantages
		Will only detect moving targets
		  • Not suitable for kerbside applications

Table 1

Typically the on-crossing detector functionality is delivered using mainly Doppler radar technology, which on the whole performs reasonably well and is relatively inexpensive. However, for kerbside applications, where video detection predominates, the performance of some existing solutions has not been so good This has led Siemens to review again the whole issue of pedestrian detection and in particular to question if other technologies could deliver better performance than that being achieved by the existing market offerings.

The requirements of Pedestrian detection

There are several regulatory specifications such as TR2506 (for on-crossing detectors) and TR2507 (for kerbside detectors), which define the performance requirements of pedestrian detection when use at Puffin crossings. Together with Technical Advice Notes issued by the DfT these set a framework within which new forms of pedestrian detection must operate.

But in addition to these documents, there are several other key requirements that Siemens have derived, based on extensive experience with existing solutions and also long observations of live crossings. Some of these are summarised in the adjacent box.

Key pedestrian detection requirements

• Should not be affected by shadows or other environmental considerations
  • Fog, rain, wind etc
• Must works equally well in daylight and at night
• Be easy to install
  • Ideally should not require special tools or the use of a PC
• Should not require frequent on-going maintenance
• Ideally cover the whole crossing or pedestrian wait area
  • Should not require special signage or pedestrian behaviour to be effective
• For kerbside applications, must be able to detect totally static objects including small children and pushchairs

Over many years Siemens Corporate Technology (CT), the research arm of Siemens AG, have built up an extensive expertise in sensor technologies resulting in a wide range of products being developed for both military and commercial applications. So, as far back as late 2003, CT undertook several studies to assess which technologies might offer solutions for a wide range of detection problems, including those of pedestrian detection at Puffin crossings.

Several options were identified, each offering benefits along with some drawbacks. (Table 3) After considerable research CT concluded that radar offered the best overall compromise and operation at 24GHz seeming to be an ideal choice for pedestrian applications (as well as other areas such as SCOOT and MOVA).

Technology	Advantages	Disadvantages
Passive Acoustic	• Passive so can be very low power • Accurate zones if multiple sensors used • Immune to changing light levels • Relatively low cost • No significant maintenance required	• Not good for detecting slow / static traffic • Very difficult to reliably detect pedestrians • Can be affected by environment (rain / snow etc)
Active Acoustic	• Immune to light levels • Relatively low cost • No significant maintenance required	• Difficult to achieve precise detection zone • Heavy rain / wind and snow can severally affect performance
24GHz Radar	• Immune to changing light levels • Relatively accurate zones possible • No significant maintenance required • Costs attractive compared to higher frequency (77GHz) radar solutions	• Active device so needs regulatory approval in all target markets
Passive Infrared	• Passive so can be very low power • Reasonably accurate zones possible • Relatively low cost • No significant maintenance required	• Can be affected by significant sudden temperature shifts • Fog and heavy snow can affect performance
Video	• Many accurate zones possible (if field of view permits) • Can provide visual overview of target area	• Can be badly affected by changing light levels and environmental conditions (Rain, snow etc). • Significant maintenance overhead

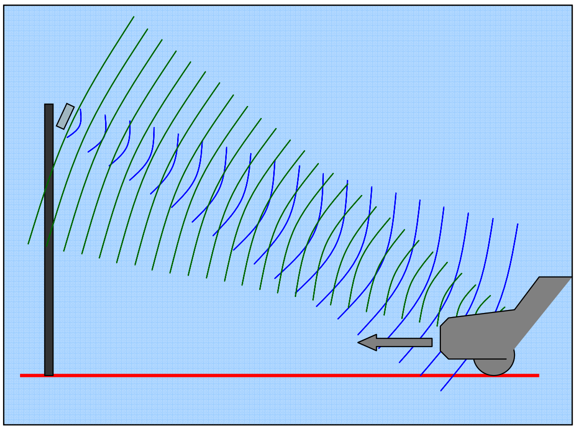
Table 3

Radar principals

Radar has been successfully used in traffic applications for many years, with most using Continuous Wave (CW) Doppler principals.

In this form of radar, microwave energy at a single defined frequency, is continuously beamed at the target zone.

Most existing radar solutions use CW Doppler principals

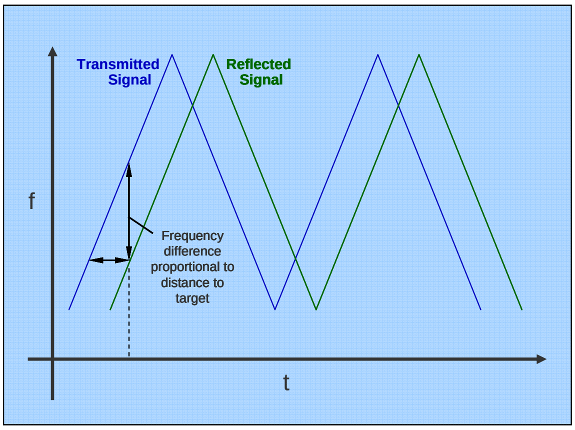


Any echoes returned from moving targets in the zone are frequency shifted in proportion to their speed (the Doppler effect). Based on the frequency shift both the direction of travel and speed can be easily determined and this type of radar forms the basis for most above ground VA detectors used today.

Doppler radars are relatively simple to produce and as well as VA applications are also used in most on-crossing detector solutions, where they generally perform reasonably well.

However if a target is static (i.e. not moving), there is no Doppler frequency shift in the returned echo, so the target is not registered. This is a serious limitation where the detection of static targets is needed, for example stop-line detectors and also kerbside detectors, which must reliably detect the presence of pedestrians, even when they are standing completely still.

FMCW techniques offer static target detection but are more complex than Doppler solutions



To overcome this limitation a more advanced type of radar, Frequency Modulated Continuous Wave (FMCW) can be used. In this form of radar the microwave energy transmitted is not a single frequency, but instead is modulated using a sweep frequency, so that it is constantly varying.

The time delay (and hence range) to any given target is very small and is extremely difficult to measure with accuracy when targets are only a few meters from the detector. However the target distance can be deduced by comparing the transmitted frequency and echo frequency at any given time, and this is much easier to do than trying to measure the actual time delay directly.

The range resolution and accuracy of the detector, which are particularly important for kerbside applications (and are discussed again later), can be improved by using higher frequencies, larger sweep frequencies and faster sweep rates. Critically, by using FMCW techniques completely static targets can be resolved as there is no reliance on the Doppler effect.

In principal FMCW radar seems to provide a good solution for kerbside pedestrian detection – so why has it taken so long to bring a working FMCW pedestrian kerbside to the market?

The challenges of using radar for pedestrian detection

After considerable research and development the first Heimdall detectors, based on 24GHz FMCW radar technology were released in 2009 and offered solutions mainly aimed at SCOOT and MOVA applications. These have now been widely deployed and perform well when compared to loop detectors, which are a useful benchmark.

However despite extensive development work it ultimately proved impossible to deliver reliable kerbside and on-crossing solutions using radar this frequency, with the kerbside being the most difficult application to solve. Two key problems were encountered.

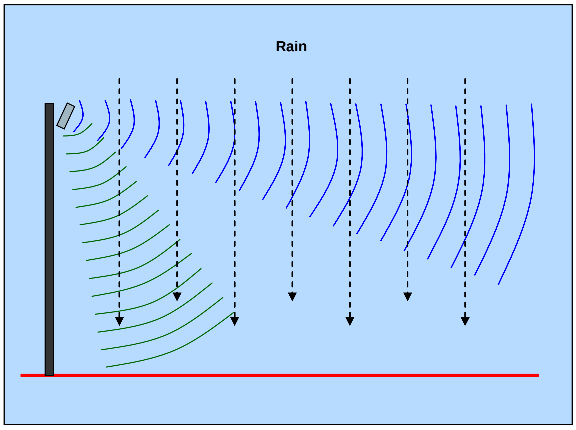
Susceptibility to rain: Rain offers two key challenges to radar detectors.

1) **Absorption**, where the radar energy is absorbed by the rain, which acts to reduce the effective range of any given radar solution.
2) **Backscatter**, where raindrops reflect the radar energy, so giving rise to false detection events.

Both of these phenomena are dependent on the radar frequency used and also to some extent on the size of the raindrops encountered.

Initially the choice of 24GHz radar was made, partly due to the belief that over the relatively short distances that are encountered in most traffic applications, radar at this frequency would offer a much better resolution than the more traditional 10GHz, but would also be largely unaffected by rain - and this is the case where the radar is generally looking through the rain, for example a simple Doppler radar used to detect approaching vehicles.

Rain has a greater effect on radars looking downwards



Because the rain is generally not moving towards or away from the radar detector there is no Doppler effect, so spurious detections due to rain rarely occur. This immunity is also helped by provisions in the HA specifications which require targets moving below a defined speed, usually 4 km/h or 8 km/h, to be ignored by the detector.

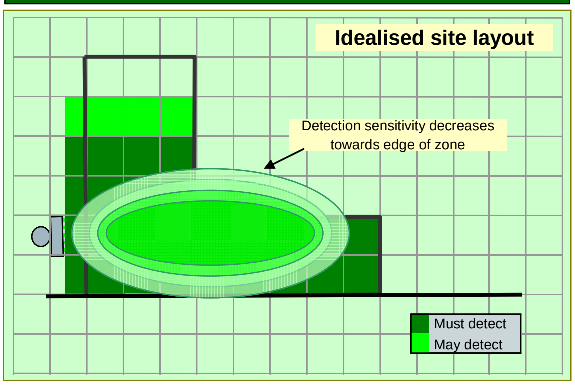
However, where the detector is looking downwards and it must also be able to detect static and slow moving targets such as pedestrians, the effect of falling rain travelling along the radar beam, is much more pronounced. This effect is exacerbated by the fact that pedestrian targets are much more difficult to detect than large metal vehicles, requiring the radar receiver to be much more sensitive and hence more likely to respond to the backscatter created by the falling rain.

Extensive trials and testing of the first Heimdall 24GHz kerbside and on-crossing detectors revealed that the effects of rain were sufficiently serious so as to suggest that these products would not be good enough to be release into the market.

Kerbside detection zone: The issues found with rain performance were compounded by the difficulty in achieving the detection zone shape and sizes needed for kerbside applications.

Typically simple radar detectors provide a detection zone which is roughly oval in shape. Whilst this is good for general vehicle detection it does not match well with the zone shapes needed for kerbside applications. In these it is necessary to detect pedestrians who are standing along the edge of the kerb (where an oval shape is acceptable) but also when they are approaching or standing on the approach section of the tactile pavement.

A simple radar detection zone



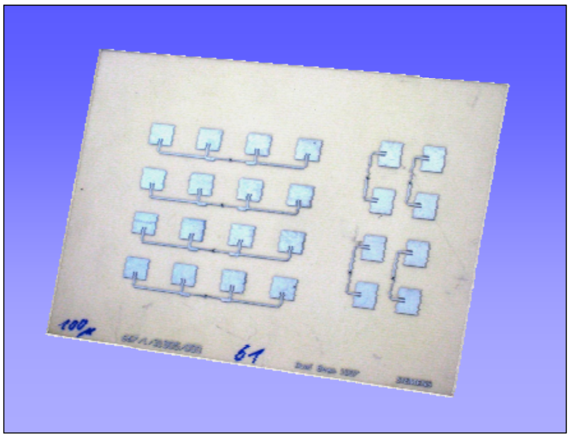
Furthermore it is critical that pedestrians can be detected when they are standing close to the push button, which is usually mounted on the same pole as the kerbside detector.

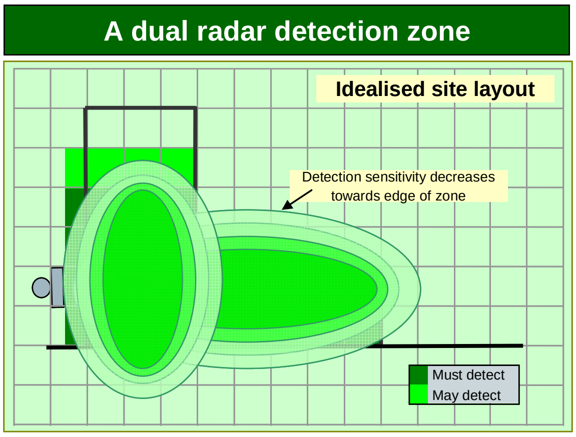
Once again, extensive testing demonstrated that a simple 24GHz radar would not be able to deliver sufficiently good performance to allow a kerbside detector of this type to be released into the market.

SIEMENS

Design changes for success

The key to resolving the performance issues found during initial trials has been two the result of two major innovations. The first is the use of an innovative ‘dual’ antenna, which allows two radar beams to be directed at the pedestrian waiting zone, one along the kerb edge and the second perpendicular to the road covering the approach tactile pavement area. This provides a zone shape that is much more suitable for kerbside applications.





The second major innovation has been a change of radar frequency to 13GHz. At this frequency the backscatter effects from rain are reduce significantly compared to 24GHz, allowing the radar to be more sensitive, (which also helps to increased zone size, allowing more of the waiting zone to be covered). The biggest benefit however is the significantly increased sweep bandwidth which is allowed at 13GHz, improving the resolution of the radar and allowing detection to be achieved much closer to the pole, particularly because returns from the nearside units mounted on the pole can be much more readily distinguished from pedestrians waiting near by.

One area of concern during the development program was the potential that the detection zone could, because of its shape, stray into the road, resulting in detection of vehicles as they passed the crossing. Initial trials did indeed find that this was the case but additional signal processing in the detector allowed such false detections to be reduced to an extent that they do not material affect the overall performance of the detector.

Conclusions

It has taken a sustained effort over several years to finally produce a radar detector that is suitable for Kerbside applications. The resulting Heimdall solution is simple to install and does not need complex set-up on street, specifically eliminating the need to use a PC or similar tools in an environment which is not always conducive to their use.

Because it uses radar techniques, it is also not affected by varying light levels and unlike some video based solutions shadows in particular do not affect its performance in any circumstances.

The predetermined detection zones may be a limitation in some cases – there is no ability to ‘draw’ complex zone shapes for example - but this is offset to some extent by a simple zone length switch which may be set to reduce to overall detection zone length where required.

One of the most significant advantages of using radar over other solutions based on video techniques is the relative absence of ongoing maintenance for the detector once it is installed. For video solution regular lens cleaning is needed if the performance of the detector is to be maintained. For Heimdall no such maintenance is necessary, helping to reduce the overall cost of ownership once installed.

The release of the Heimdall kerbside and on-crossing detectors now finally completes the Heimdall above ground detector range, range which also includes single and dual lane VA detectors as well as Stop line, SCOOT and MOVA versions.