

## ABOVE GROUND SCOOT AND MOVA DETECTION IN PRACTICE

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### Executive summary

SCOOT and MOVA are now very well established as the strategies of choice for adaptive traffic control in networked and stand alone applications. Both strategies rely on a high level of accurate traffic data and traditionally this data is gathered by detector loops buried in the road surface. However, being in the road surface, detector loops are vulnerable to damage and their repair inevitably results in significant costs and disruption to traffic.

The obvious solution is to move the detection out of the road surface altogether and use above ground detection, but until relatively recently the performance of such detectors has not really been shown to be good enough for SCOOT and MOVA applications.

This paper briefly covers the development of the Siemens Heimdall above ground detectors for SCOOT and MOVA and goes on to review the performance of the detectors, both in a controlled test environment and the successful implementation in practical installations.

## Introduction

SCOOT and MOVA are now very well established as the strategies of choice for adaptive traffic control in networked and stand alone applications on the UK's roads. Both are also finding favour in markets outside of the UK, where their capability to deliver a high level of performance is increasingly being recognised.

Both strategies rely on a high level of accurate data about the flow of traffic within the road network, or for MOVA, on the approaches to intersections under MOVA control. Traditionally this data is gathered by detector loops buried in the road surface, which when correctly installed and functioning have been shown over many years to provide an accurate representation of traffic flows. Loops have other advantages; they are all but invisible once installed, so there are no 'streetscape' issues, it is very difficult to steal a loop so they are much less prone to vandalism or theft and they are almost completely immune to poor weather conditions.

However, being in the road surface, detector loops are vulnerable to damage. This can be caused by simple movement of the road surface as it ages, failure of joints between the road loop and its feed from the detector card and from the many different bodies responsible for services under the road, which from time to time have to excavate the road surface to access them. Once damaged there is little chance of being able to repair a loop so it has to be replaced, which given its location in the road surface inevitably results in significant costs and disruption to traffic. Because of the likely traffic disruption it is often difficult in practice to effect loop repairs in a timely manner and in some cities it has been suggested that up to 25% of SCOOT loops may be out of action at any given time.

The obvious solution is to move the detection out of the road surface altogether and use above ground detection, but until relatively recently the performance of such detectors has not really been shown to be good enough for SCOOT and MOVA applications.

## Possible above ground technologies

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. It seemed likely that this expertise could be used to address the problem of SCOOT and MOVA detection and as far back as late 2003 CT undertook several studies to assess which technologies might be suitably used for SCOOT and MOVA. Several options were identified, each offering benefits along with some drawbacks. After considerable research CT concluded that radar offered the best overall compromise and operation at 77GHz seeming to be an ideal choice. This frequency offered:

- Excellent target resolution, so it would be possible to define detection zones very precisely, which was considered important if SCOOT and MOVA loops were to be emulated accurately.
- Good immunity to adverse weather conditions, particularly over the short ranges needed for SCOOT and MOVA application.
- Small antenna size, meaning that the overall size and visual impact of the detector could be minimised.
- Widespread acceptance of the frequency band, meaning that the detector could be used worldwide, with minimum limitations.

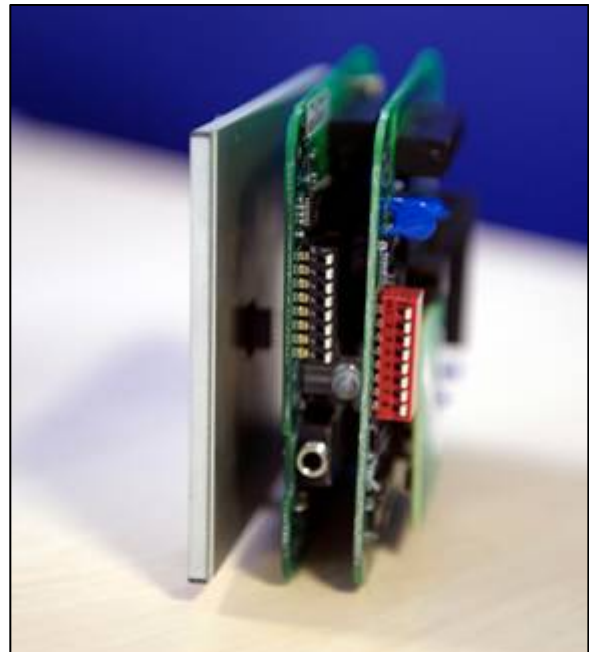
Unfortunately, after more detailed evaluation it became clear that solid state 77GHz technology was still in its infancy and although it offered a very good technical solution, the product costs were found to be very high. However, radar operating at 24GHz seemed to offer similar benefits at a much lower cost, so the development of what was to become the Siemens Heimdall detector was initiated.

## Development challenges

Any development of detection technology for the traffic market has to recognise that product cost is a very significant driver when choosing technology solutions. If these are too high product adoption in the market will tend to be limited, even if the performance achieved is good. Similarly, installation and maintenance cost considerations are also important, as a good product that is difficult to set up and costly to maintain will also be less attractive in the market than one that is simple to install, with little or no on-going maintenance requirement. These criteria provided significant challenges for the Siemens development teams, but ones which they have successfully met.

For example the radar antenna assembly uses an advanced planar design which, to minimise costs, is double sided, with the antenna on one side and the Radio Frequency (RF) circuits on the other. However, due to the specialist substrate material required to perform at the high frequency used for the detector (24GHz), the antenna Printed Circuit Board (PCB) would have been too flexible for practical use. In addition the attachment of 'screening can' to provide RF shielding of critical sections of the antenna assembly also proved difficult and expensive.

To solve these problems the aluminium backing plate, which was originally planned to be just a mounting plate to support the PCB, was re-designed to also house the RF circuitry. (See picture) The backing plate and chamber now takes on the role of both physical support and RF shielding. The backing plate is also used to accurately mount the RF PCB at very precise distances from the Heimdall housing front face. This helps to ensure that the RF performance is consistent throughout the manufacturing process and helps to reduce testing costs.



A second key challenge was to ensure that the performance of the detector was sufficiently good and as far as possible, could offer a 'loop equivalent' for SCOOT and MOVA applications. For SCOOT in particular it is necessary to achieve accurate count performance and occupancy of individual vehicles, to generate LPU values within the SCOOT algorithm. As explained in the following section this was not easily achieved but through extensive testing and design evolution the Heimdall detector now uses a Texas Instrument DSP to provide a range of complex tracking algorithms that enable the detector to be a "point and walk-away" installation, all without compromising the accurate generation of SCOOT LPU values.

## Experiences in practice

Proving of new detection technology is often time consuming, requiring several stages of validation before sufficient confidence is gained to enable the product to be released onto the market. In the case of Heimdall, extensive testing was undertaken at the Siemens Poole test site (see picture), prior to deployment in live installations.

The general method of assessment was based on a 'ground truth' approach, where data from a reference loop is used to provide the 'control' against which the performance of the above ground detector is validated.

For the purposes of performance testing the above ground detector under test is then installed above or close to the reference detector, in order to ensure equal or similar traffic conditions occur on both detectors simultaneously.

Initially only count and occupancy measures were assessed, which demonstrated that apparently the detector performed well. However, the SCOOT algorithm also uses a figure of merit called the Link Profile Unit (LPU) in order to model the junction.



The modelling is used to predict the optimum modifications to the junction timing variables. The LPU is a weighted amalgamation of 'detector flow' and 'detector occupancy'. Ensuring a close correlation between the LPU values, generated by a reference loop and the detector under test will ensure that the link and by implication the SCOOT system performance, would be largely unaffected if the loop were to be replaced by the detector under test.

Unfortunately initial Heimdall assessments demonstrated that although both count and occupancy measures individually seemed to be good, the overall LPU comparison was relatively poor, particularly under partially congested conditions – just when the data needs to be as valid as possible so that SCOOT can work most effectively. After considerable investigation, where both the performance of the radar and the signal processing of the radar data were scrutinised again, modifications to both were undertaken and the detector retested. These tests resulted in much improved LPU performance, whilst maintaining both count and occupancy accuracy.

Figure 1 shows a simple comparison of 'detector flow' between the Heimdall SCOOT detector and the reference test loop, with data being collected in 5 minute sample periods.

On initial inspection the correlation between the two is very close but a more detailed evaluation of the differences (figure 2) does show some apparent significant differences at certain times.

It is clear that the large variations between the reference loop and Heimdall occur generally during the night when there are few vehicles passing the test site. Consequently a single false positive or missed vehicle would result in a significant apparent error rate during these night time periods, with the smallest variations during daylight hours.

The analysis of the performance data for the reference loop has also identified that it tends to miss some fast moving motor cycles. The Heimdall detector however detects all objects above ground height and therefore is more accurate than the loop in these cases, but the effect is to show a slight 'over count' in some instances.

The reference loop also generates some false positives as it detects vehicles driving close to the loop but in the opposite direction, on the opposite carriageway. The test Heimdall detector has an adjustable mounting bracket, allowing modification of the mounting angle, so that the detection zone width can be adjusted to suit the individual road topology and is effective at avoiding counting these vehicles, but giving a slight 'undercount' in some circumstances.

The LPU data collected for the Heimdall detector against those generated by a loop does show good correlation (figure 3). However there is also a consistent variation during the peak hours. This is explained by the fact that the Heimdall detector virtual loop length is ~1.8m whereas the physical loop has a detect zone of ~2.0m in length. This is an approximate reduction in detection zone of around about 10% and the average variation in LPU values is similarly between -5% and -10%. In a live installation it is expected that this would be accounted for during the normal validation of the link so is not considered a significant issue.

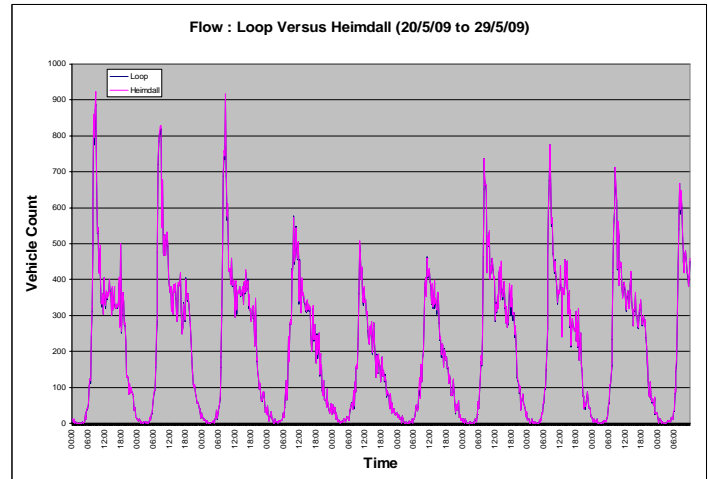


Figure 1

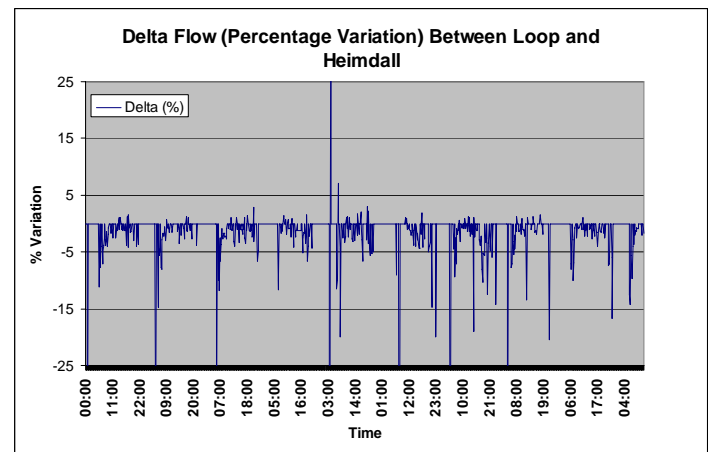


Figure 2

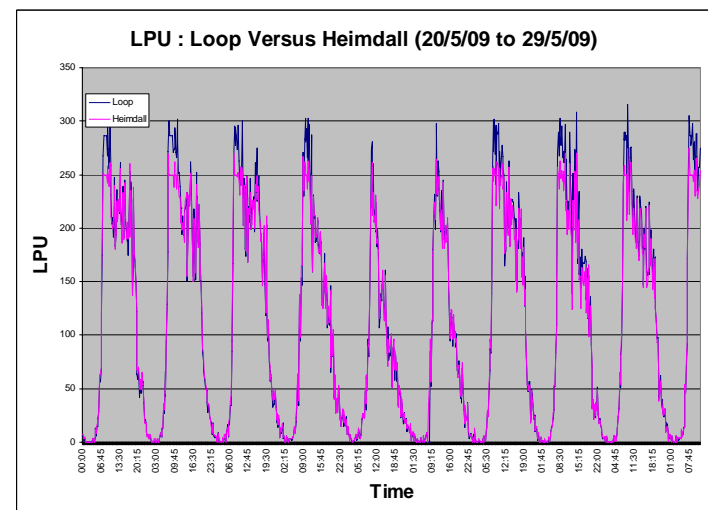


Figure 3

Overall, the trial on the test site has demonstrated that the Heimdall detector has good performance as far as count, occupancy and LPU measures are concerned. The trial periods spanned daytime and night time operation as well as periods of bad weather, including heavy rain and wind without any significant change in the detectors performance which provided enough confidence to undertake live on-street trials.

## Live trial results.

To further validate the performance of the detectors seven further trial site installations have been undertaken in:

- Poole – Fleetsbridge Roundabout (SCOOT – count site) – 1 detector.
- Southampton – Bittern Triangle (SCOOT) – 1 detector.
- Bournemouth – Cemetery Junction (SCOOT – count site) – 1 detector.
- Cardiff - Leckwith Giratory (SCOOT) – 1 detector.
- Winchester. (Battery Hill / Romsey Road) (SCOOT) – 1 detector.
- Wimborne - Willett Arms (MOVA) – 2 detectors.

A number of different set-up arrangements have been tested, some with and some without reference loops, but being used as 'real' detectors in live installations. A full set of detailed results on all the trials is available from Siemens (Document 667/AY/31900/000 - Technical Report on the Performance of Heimdall SCOOT/MOVA Above Ground Detector).

This paper will just concentrate on two of these to illustrate performance in different settings.

## SCOOT site (Winchester – Battery Hill / Romsey Road)

A single detector has been installed in Winchester, along side a reference loop sometimes used by TRL, with the data being gathered from the Hampshire UTC system.

Initial results from the detector were not as good as those obtained from the Poole test site (Figure 4). Further investigation highlighted that the detector was not correctly aligned to comparison loop and once this was corrected the correlation between loop and detector count proved to be extremely good. (figure 5).

In addition the data has been assessed by TRL to gain an independent view of its implications for acceptable SCOOT performance.

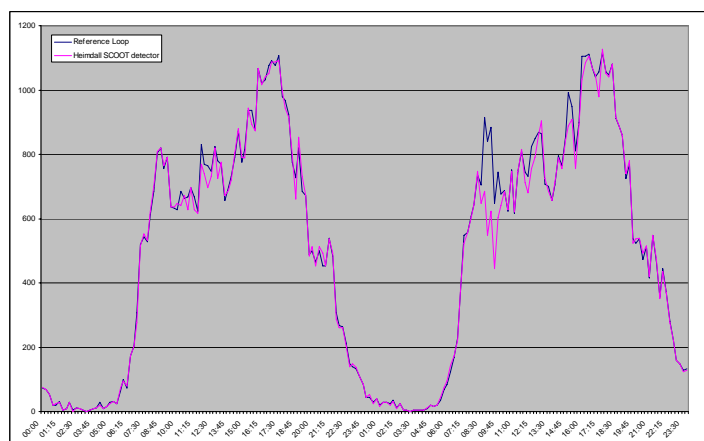


Figure 4

*“There is an indication that the Heimdall misses some vehicles, about 1% compared with the loop. There are also instances where the Heimdall detects a vehicle, but the loop does not, about 0.5% of the total. Some of these false positives (relative to the loop) are single quarter second detections. It may be that some vehicles travelling in the opposite direction and turning right at the junction just clip the detection zone of the Heimdall, but not the loop.*”

Very occasionally the Heimdall remains in the detect state considerably longer than does the loop. A few of the false negatives are due to the loop detecting two vehicles whilst the Heimdall is continuously on, detecting only one. On the other hand there is also a slight query over the loop as there are an appreciable number of instances of it being on for exactly 3.5 seconds, but never longer in the data that we (TRL) have looked at, although in previous tests at the site longer periods of continuous occupancy were recorded.

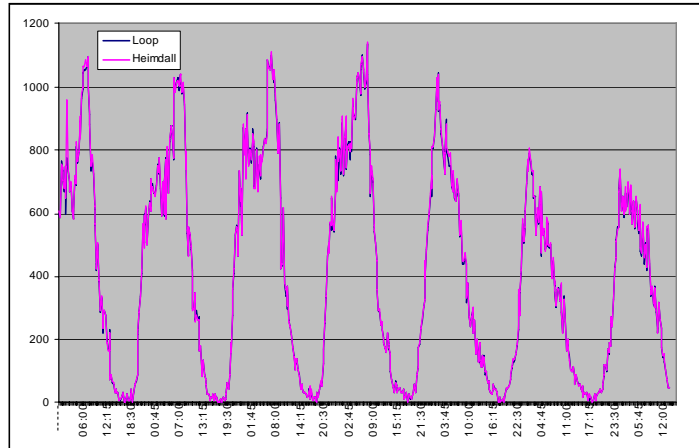


Figure 5

In general it looks as though the Heimdall effective detection zone is somewhat less than that of the loop leading to lower total occupancy, however, the difference is not large enough to be a problem for SCOOT and will be allowed for in the validation of saturation occupancy."

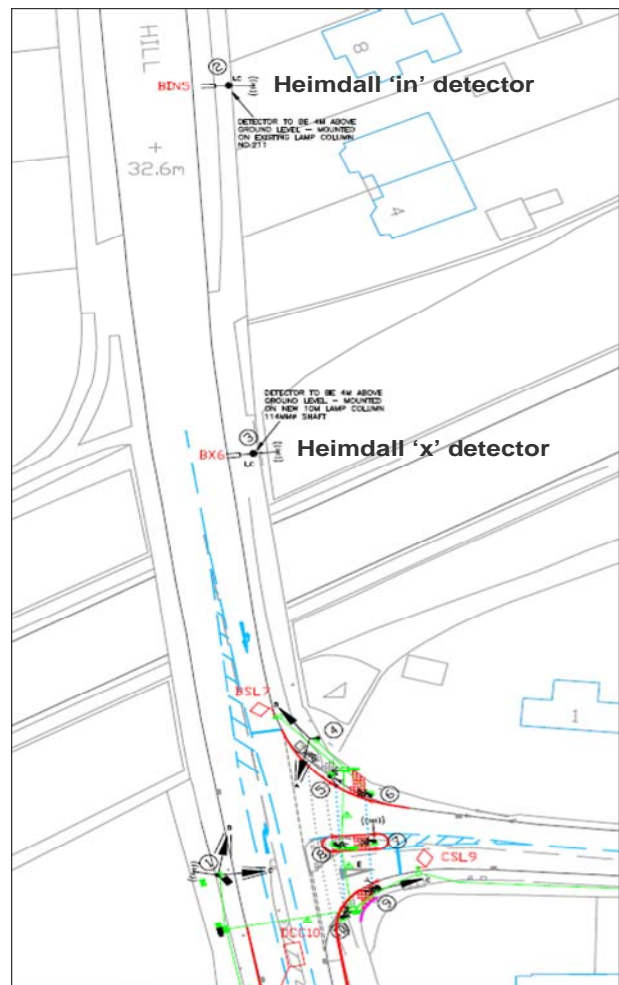
## MOVA trial site (Willett Arms – Wimborne)

This is a new MOVA intersection which was commissioned in February 2009 and the approach utilising the Heimdall detectors includes a bridge over the A31, preventing loops being cut and cable connections to the detectors. Consequently detector data is transmitted to the controller via Smartlink.

The site has been commissioned and validated by Siemens Design Services staff and as there are no reference loops possible in this case the validation has been used to assess the performance of the Heimdall detection.

Throughout the trial period the detectors and the intersection have been subjected to three validations.

The first validation confirmed that during commissioning all the loops/detectors are operating as expected. The second validation confirmed that there had been no changes or variation since the initial validation and the third proved a longer term confirmation that the performance of the Heimdall detectors had not altered during the trial period.



An additional check to compare the count of vehicles passing the Heimdall 'In' loop with those passing over the associated stop line loop resulted in a count deviation of less than 0.5%.

One observation from this trial (and the trials at the Poole test site) is that the Heimdall detector does have a constant delay of about 200mS between vehicles passing over the detection zone and the detector activating its outputs.

However TRL have indicated that detection delays less than 500mS is adequate for MOVA detection performance so this is not considered to be a significant issue.

## Conclusions

The Heimdall detector is shown, within this paper, to provide good correlation to an actual loop for both count and SCOOT Link Profile Unit generation. There are some variances but these variances are small enough not to affect the SCOOT performance of a junction.

It must be stressed however, that correct installation is important to ensure optimum performance. The key points being, installation must be perpendicular to traffic flow, the installation angle must be such that only the near lane being monitored should be illuminated. The handbook provides full information along with suggested setup angles.

The detector performance for a MOVA installation has also been evaluated and has been shown to be fully compatible for MOVA junction installation and operation.

It should also be noted that the detector will detect pedestrians. Therefore care should also be taken when identifying a suitable detector location. Detector positioning close to a pedestrian crossing or pedestrianised area will inevitably produce an unknown number of false positives as and when pedestrians cross the detection zone.