Excel Technology Co Pty Ltd

In-Pavement Loop Electromagnetic Field Analysis

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Document: L100.5 Rev B "Loop Field Analysis"

Inductive Loop Sensors for Vehicle Classification

Introduction:

Inductive loop sensors work by creating an oscillating magnetic field in the loop coil. When a vehicle travels over the loop, the loop field creates eddy currents in the metal of the vehicle. The magnitude of the eddy currents is determined by the magnetic field density and therefore the distance of the metal from the loop and orientation in the loop field. The eddy currents create a magnetic field that opposes the loop field, which is seen as a change in inductance of the loop.

The change in inductance is therefore:
- decreased when further from the loop (trucks etc)
- increased when more metal area is over the loop
- increased when the loop field is stronger

A 2m x 1m loop has a slightly higher peak field strength than a 2m x 2m loop at close heights above the loop - (< 1m). At 1m the peak field strength is the same, and above 1m the 2m x 2m loop has a higher peak field strength. The problem is compounded as the peak field points move from the corners of the loop to the centre of the loop as the height above the loop increases. Basically, if a loop is made too big, a dead spot appears in the centre of the loop at small heights, and if a loop is made too small then the loop field is weak at large heights.

Since the 2m x 1m loop is half the size of the 2m x 2m loop, the metal area of any vehicle over the loop is decreased by half. This means the change of inductance is lower, and so **more of the vehicle will have to be over the loop** for it to register as a detection. Thus the detection starts later and ends earlier, giving less occupied time, and **therefore a smaller calculated length than is true**. This affects vehicle classification and HiOcc alarms, as HiOcc alarms require accurate occupancy times.

It is also our experience that a 2m x 1m loop may not detect articulated trucks reliably. The decreased peak loop field strength at > 1m further decreases any inductance change when compared to a 2m x 2m loop (this is demonstrated in th enclosed graphs). With high bed trucks, this may result in the loss of detection when the gap between the ‘Cab’ or prime mover section and the trailer rear axle assembly is over the loop, and therefore two smaller vehicles will be detected instead of one.

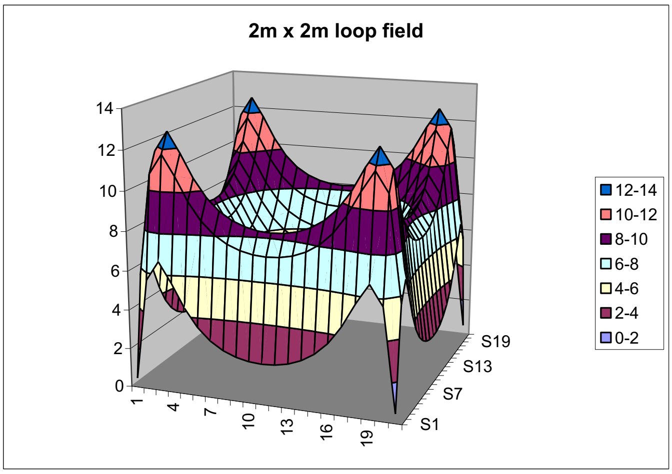
We have found 2m x 2m loops to be a global industry standard for classification. This appears to be the optimum size from both field observation and theoretical data extrapolation as follows. The 2 x 2 mt 4 turn loop provides maximise area performance versus field strength, provides a more accurate HiOCC result and gives accurate length measurements which therefore provides more accurate vehicle classification.

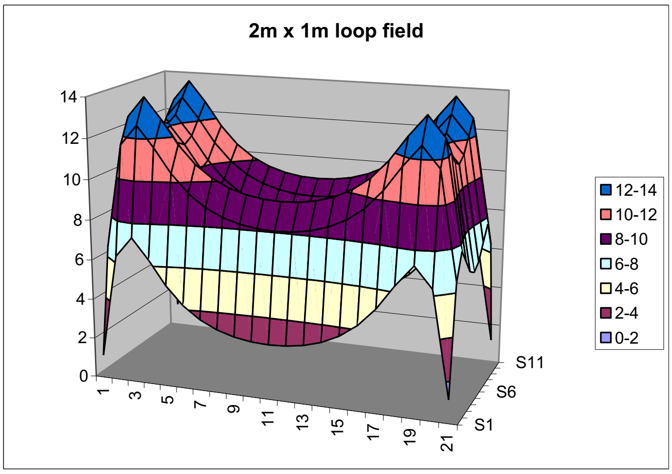
The following theoretical presentation is based on a data set configured into a Microsoft Excel spreadsheet.

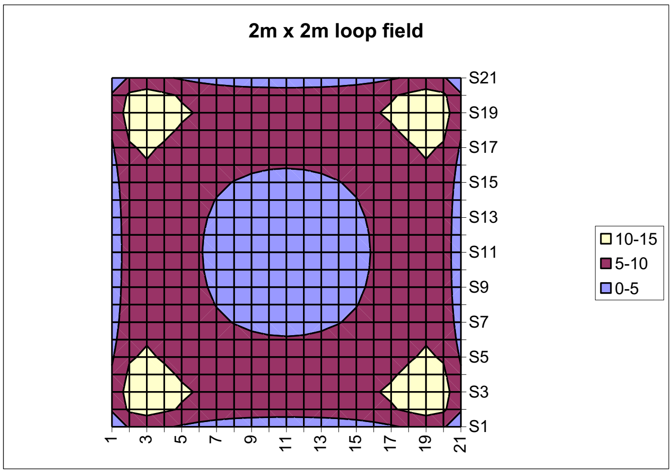
The following graphs show the relative magnetic field strengths for 2m x 2m and 2m x 1m for a plane (i.e. a vehicle's metal chassis) at 0.25m above the ground.

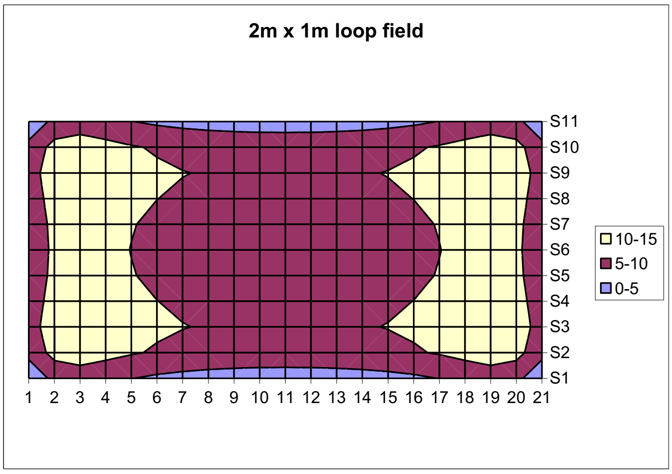
Furthermore the detection edge is shown, it is a relative indicator of how many field lines intersect the vehicle as it moves from before the loop to completely over the loop. Thus the detection edge corresponds to a relative indication of the change of inductance.

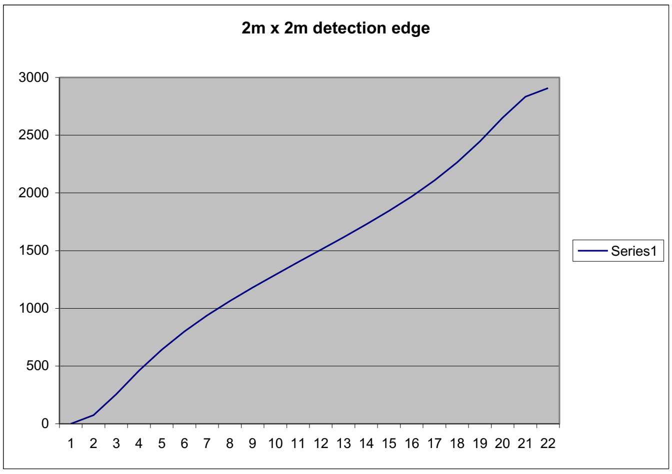
Enter height above loop (m): 0.25

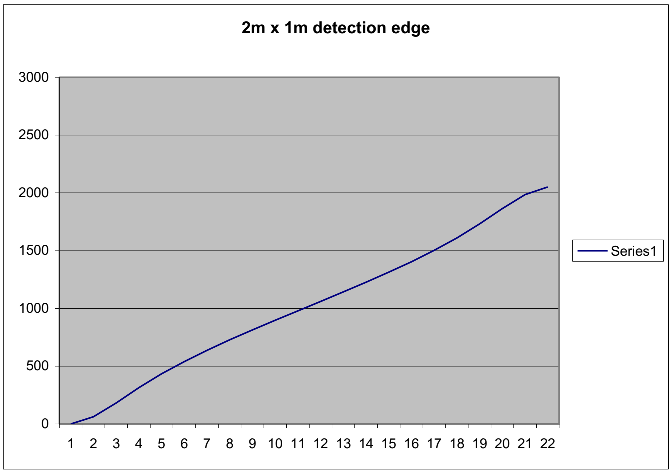












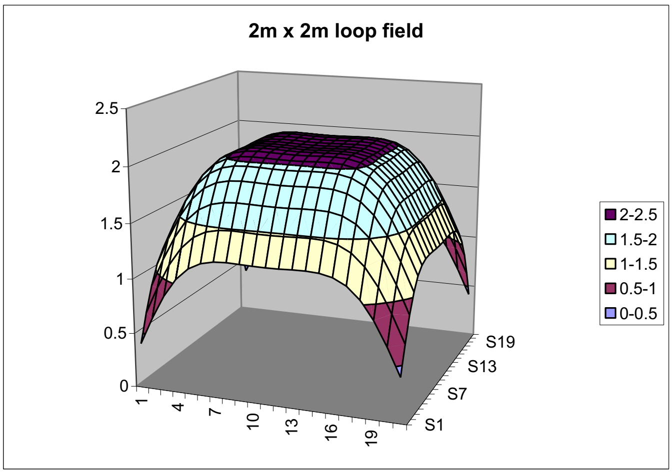
The graphs show that while the 2m x 1m loop has a higher peak field strength, the change of inductance is faster for a vehicle moving over the 2m x 2m loop. This means the 2m x 2m loop will give a more accurate detection, however since the change for both is quite rapid the difference in accuracy would be small for general detection.

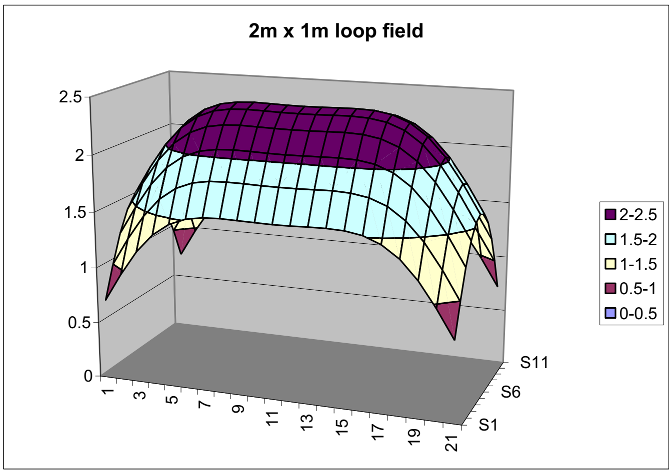
Document: L100.5 Rev B "Loop Field Analysis"

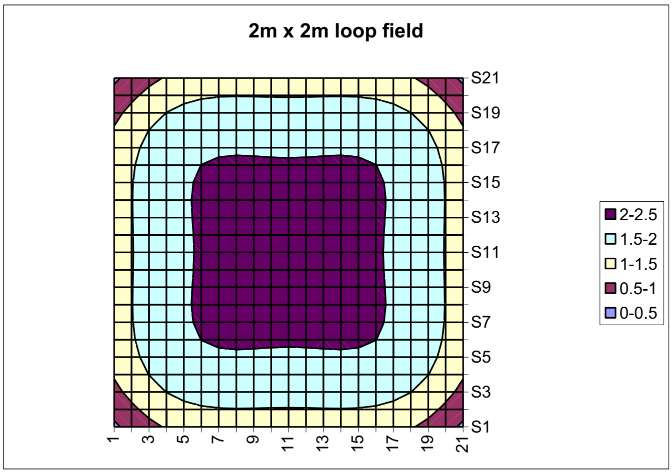
The following graphs show the relative magnetic field strengths for 2m x 2m and 2m x 1m for a plane (i.e. a vehicle's metal chassis) at 0.75m above the ground.

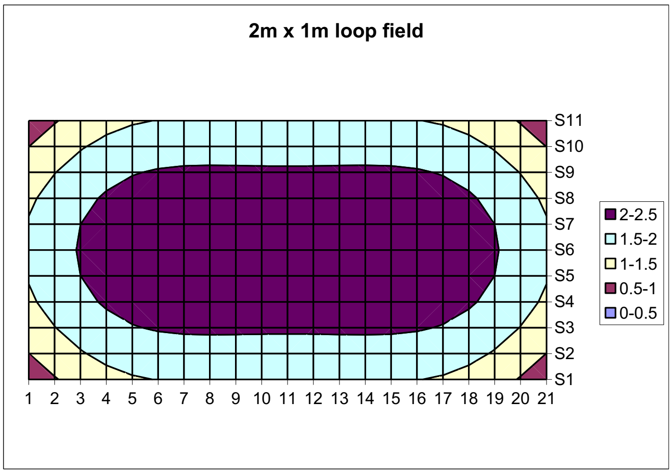
Furthermore the detection edge is shown, it is a relative indicator of how many field lines intersect the vehicle as it moves from before the loop to completely over the loop. Thus the detection edge corresponds to a relative indication of the change of inductance.

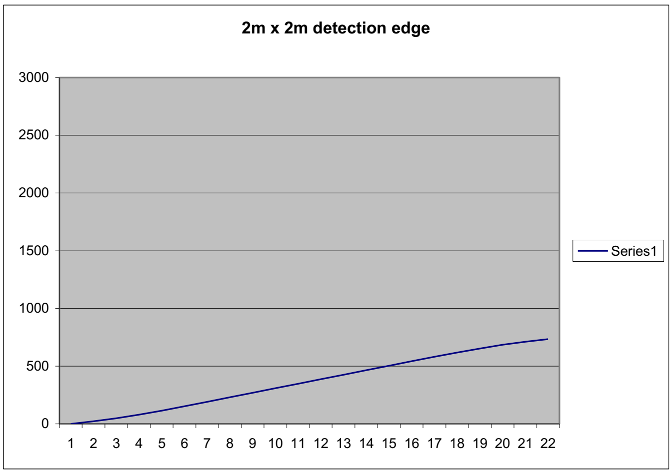
Enter height above loop (m): 0.75

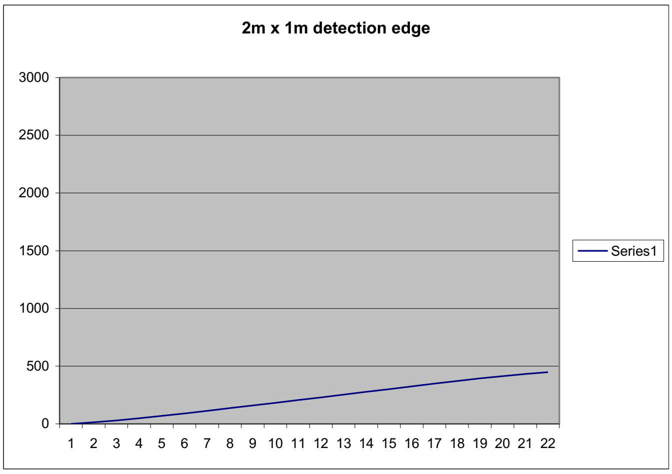












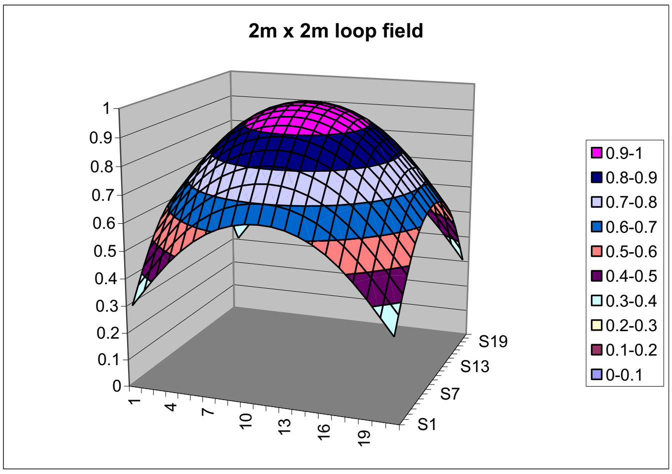
The graphs show that while the 2m x 1m loop still has a higher peak field strength, the change of inductance is faster for a vehicle moving over the 2m x 2m loop. This means the 2m x 2m loop will give a more accurate detection, resulting in more accurate length values.

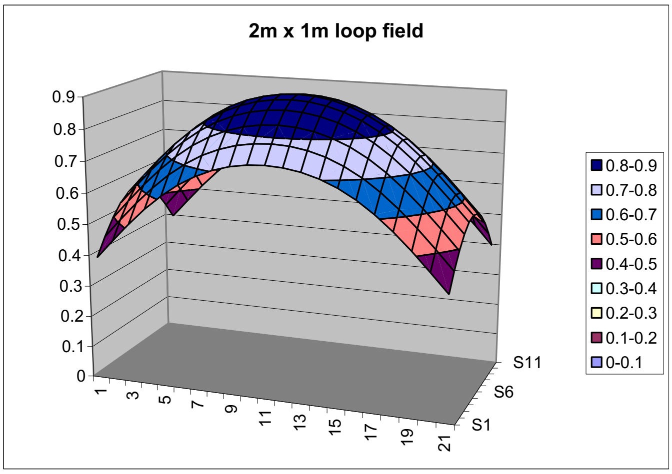
Document: L100.5 Rev B "Loop Field Analysis"

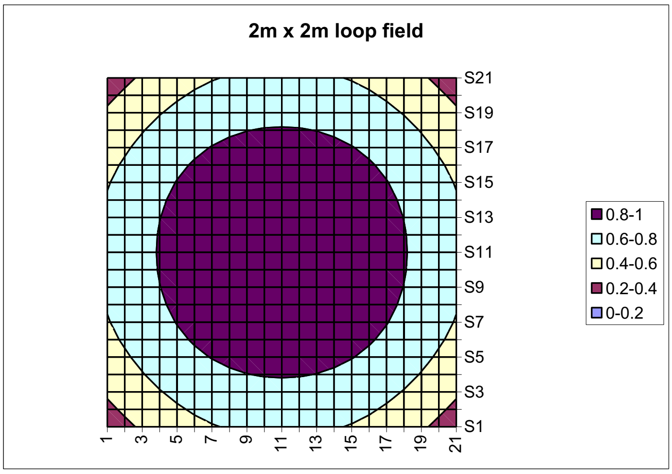
The following graphs show the relative magnetic field strengths for 2m x 2m and 2m x 1m for a plane (i.e. a vehicle's metal chassis) at 1.25m above the ground.

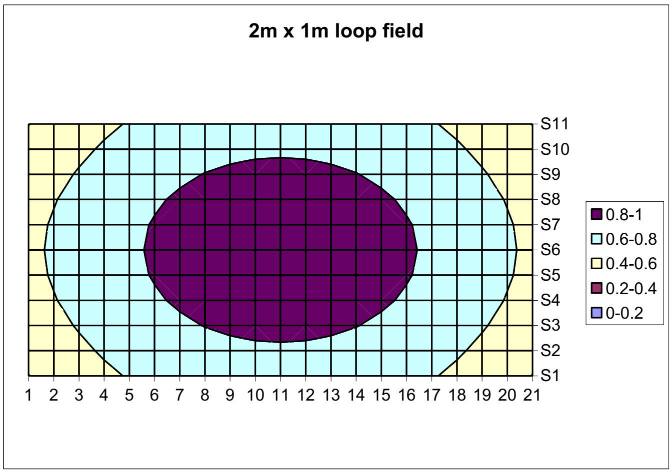
Furthermore the detection edge is shown, it is a relative indicator of how many field lines intersect the vehicle as it moves from before the loop to completely over the loop. Thus the detection edge corresponds to a relative indication of the change of inductance.

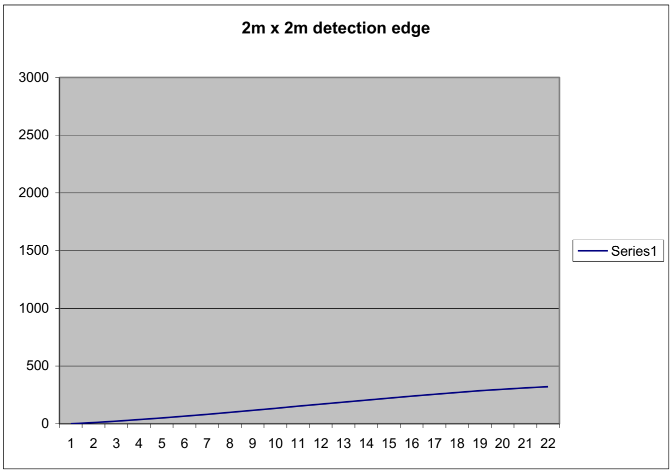
Enter height above loop (m): 1.25

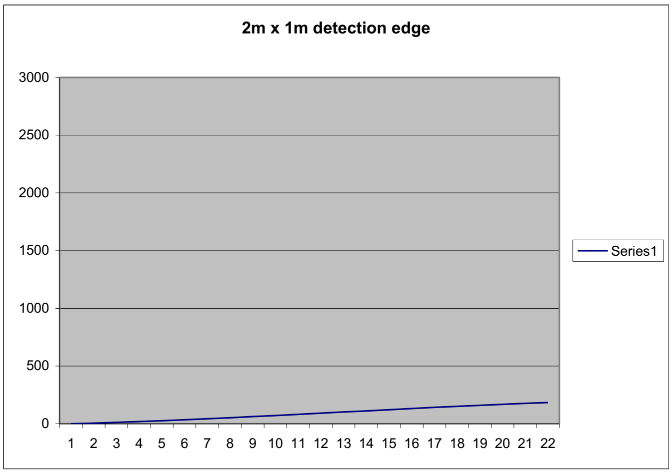












The graphs show that now the 2m x 2m loop has a higher field strength, the change of inductance is faster. This means the 2m x 2m loop will give a more accurate detection, resulting in more accurate length values. It is unlikely however that the front of a vehicle will be 1.25m off the ground. Of more concern is the middle of articulated trucks where the bed of the truck is around this height or higher. The decreased field strength of the 2m x 1m loop as well as the smaller size of the loop creates the possibility of losing the detection.

Document: L100.5 Rev B "Loop Field Analysis"

Simplifications:

In this analysis some simplifications were used. A vehicle was simplified to be a plane of metal at a certain height over the loop, and the field outside of the loop was ignored.

A real vehicle would be expected to cause an even greater change in induction for the 2m x 2m loop, as the engine and bonnet are higher off the ground.

The field outside the front edge of the 2m x 2m loop is always approximately twice as strong as the 2m x 1m loop. Therefore the 2m x 2m loop should have a much greater initial change in induction when a vehicle travels over it, giving sharper detection edges and therefore greater length accuracy. However if the change of inductance is lower, **more of the vehicle will have to be over the loop** for it to register as a detection. Thus the detection starts later and ends earlier, giving less occupied time, and **therefore a smaller calculated length than is true**. This affects vehicle classification and HiOcc alarms, as HiOcc alarms require accurate occupancy times.

It is therefore expected that if an analysis was performed with out simplifications, the results would support the 2m x 2m loop as being better performing.

Field Results:

Excel Technology Group specifies 2m x 2m loops for all loop vehicle classification applications. In one instance in Ireland, smaller loops approximately 2m x 1m wide were used by the client in one lane because of poor site location. This lane was found to have classification inaccuracies due to articulated trucks losing detection while over the loop, and being counted as two small vehicles. Another brand of equipment was trialled at the same location and the lane was found to exhibit the same problem.

Conclusion:

Field experience and scientific analysis leads us to recommend 2m x 2m loops, because of the greater detection, length calculation and classification performance of 2m x 2m loops when compared to 2m x 1m loops.