Excel Technology Co Pty Ltd

Loop Feeder Length

'*discussion*'

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The Loop Feeder Factor in Detector performance

Definition of the loop feeder function: "The feeder cable transforms the variations in loop inductance that occur when a vehicle passes through the in-pavement loops electromagnetic field."

> ***This document considers the effect of length and the inherent electrical characteristics of the feeder cable on vehicle detection performance of in-pavement loops.***

Please refer to the following documents for further information concerning vehicle detection performance relating to the loop, loop tails and loop feeder components of the vehicle detection

AS-2703-xxxx Vehicle Loop Detector Sensors
AS-2276:2:xxxx Cables for Traffic Signal Installations – Part2: Feeder Cable for Vehicle detectors
Engineering Note: ETGENG:2007:L120.1.A – Loop Wire Industry information
Engineering Note: ETGENG:2007:L120.2.A – Loop Wire Specification

It is generally noted that long feeder lengths reduce sensitivity. The maximum loop feeder length as per AS 2276:2 Section 4.1 is 200mts however various road authority documents state a maximum of 300mts which introduces an element of ambiguity into interpretation and subsequent site design. This document attempts to address the ambiguity through describing the characteristics and inherent performance limitations associated with loop feeder cable. It is postulated that that an appropriate decision concerning an acceptable loop feeder length and loop specification may be determined to ensure performance of real time motorway detection and vehicle classification sites.

'Sensitivity' is in effect a measurement of variation of change in inductance which not only is altered by physical, environmental and site issues but is directly related to the metal mass of the vehicle. For example, a bicycle 'change' is typically 200 times less than a large standard vehicle. Similarly a 'High Bed' truck has significantly less change when the high bed section of the vehicle passes through the loops electromagnetic field. A low value of inductance change associated with a large loop is comparable to reduced sensitivity as a consequence of long feeder lengths. . The challenge therefore is to minimise the factors and parameters that the equipment and site design must contend with in order to better handle the variation in vehicle mass which the detector has no control over.

An example;
If we presume that in general, feeder cable has an inductance of 0.6 μH per metre (or 33 μH per 50metres) and a 4 turn 2 metre square loop has an inductance of 220 μHs, then the total inductance including a 50 metre feeder length is equal to approximately 250 μH. Ultimately performance is related to sensitivity and sensitivity is a consequence of the relationship between the loop and the feeder cable.

The inductance measurement of the loop should always be high with respect to the inductance measurement of the feeder – simply stated the feeder has a fixed loss which can be compensated for by an increased loop inductance. This is achieved by increasing the windings or number of turns in the loop. An industry standard suggests that minimum ratio of 4:1 means that the detector will measure 80% of the change caused by the vehicle mass transgressing the loop. The table on the following page provides an indication of the significant decrease in 'Q' when longer feeders are included in the circuit.

This does not take into consideration the proportion of the mass that transgresses the loop or any other factors recognised as 'uncontrollable' variables in the site design. While these may be recognised they are largely ignored because while they can not be compensated for in performance analysis they should be considered as constant for the test i.e., same vehicle passes over the same position in respect to the loop.

The following calculations displaying a decrease in sensitivity associated with feeder length has been reprinted from the Traffic Detector Handbook: Third Edition – Volume 1 FHWA-HRT-06-108.

SINGLE LOOP EXAMPLE

1. What is the loop sensitivity at the pull box assuming a high-bed vehicle (4-ft (1.2-m) undercarriage) passes over the loop? Figure 2-17 illustrates this case and gives the lead-in wire lengths. The equivalent electrical circuit is shown in Figure 2-18.

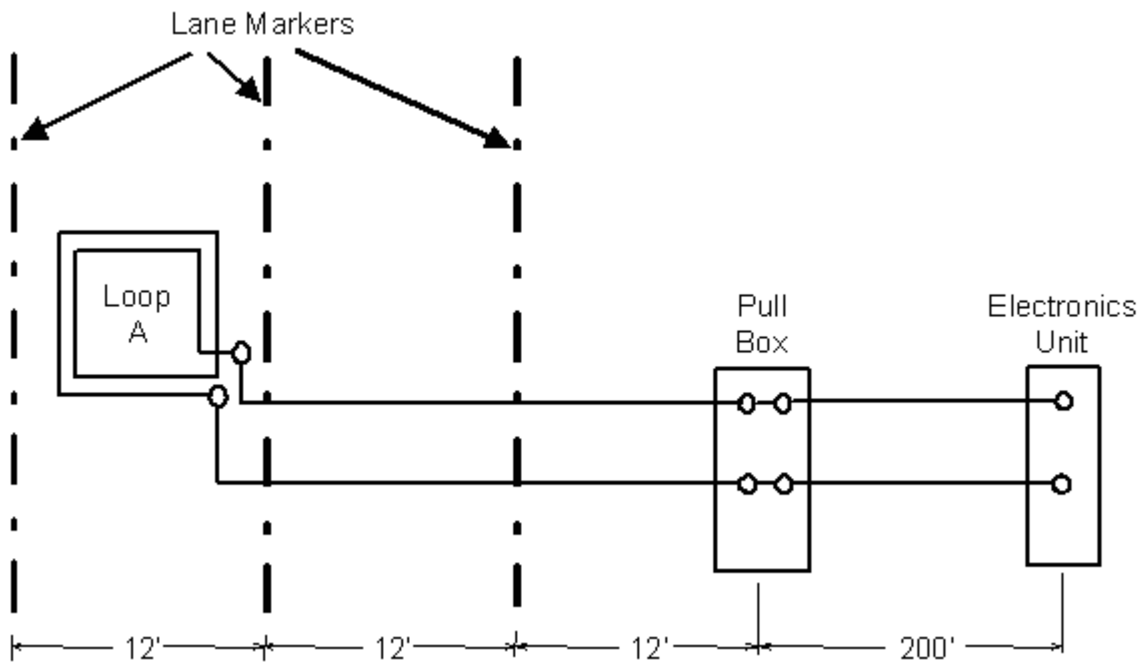

Figure 2-17. Single inductive loop connected to a pull box and electronics unit.

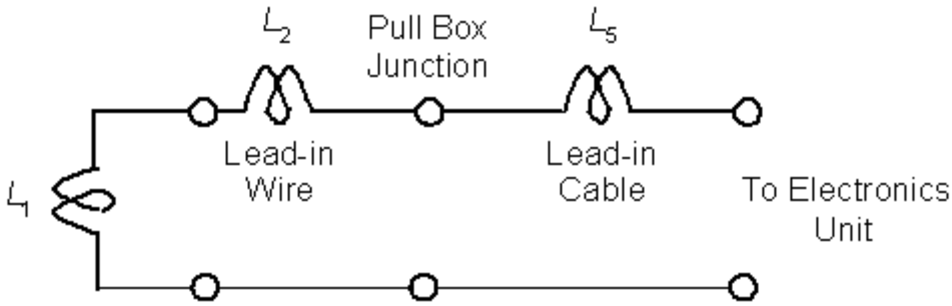

Figure 2-18. Equivalent single loop electrical circuit.

The sensitivity S_L for a 4-ft (1.2-m) high undercarriage and a three-turn, 6- x 6-ft (1.8- x 1.8-m) loop of #14 AWG wire is 0.1 percent from Figure 2-11. The twisted loop wires form an approximately 24-ft (7.3-m) lead-in wire to the pull box. The inductance per foot for #14 AWG loop wire with 5 twists per foot is 0.22 μH/ft (0.7 μH/m). The lead-in inductance L_S is

$$L_S = (0.22\,\mu\text{H/ft}) \times (24\text{ ft}) = 5.3\,\mu\text{H} \qquad \textbf{(2-27)}$$

The self inductance L_L of a three-turn, 1.8-1.8-m (6- x 6-ft) loop of #14 AWG wire at 20 kHz from Appendix C is 74 μH. Therefore, the sensitivity S_P (in percent) at the pull box is

$$S_P = \frac{S_L}{1+\frac{L_S}{L_L}} = \frac{0.1\%}{1+\frac{5.3\,\mu\text{H}}{74\,\mu\text{H}}} = 0.093\% \quad \textbf{(2-28)}$$

2. What is the inductive-loop system sensitivity at the input terminals of the electronics unit with a 200-ft (61-m) length of Type 8720 shielded lead-in cable between the pull box and the electronics unit?

From Table 2-6, the inductance of type 8720 cable is 0.22 μH/ft. The total series inductance between the loop and the input terminals of the electronics unit is

$$L_S = [(0.22)\times(24)] + [(0.22)\times(200)] \quad \textbf{(2-29a)}$$

$$L_S = 5.3\,\mu\text{H} + 44\,\mu\text{H} = 49.3\,\mu\text{H} \quad \textbf{(2-29b)}$$

Then the sensitivity S_D at the input terminals of the electronics unit is

$$S_D = \frac{S_L}{1+\frac{L_S}{L_L}} = \frac{0.1\%}{1+\frac{49.3\,\mu\text{H}}{74\,\mu\text{H}}} = 0.060\% \quad \textbf{(2-30)}$$

3. What is the inductive-loop system sensitivity at the input terminals of the electronics unit with a 200-ft (61-m) length of Type 8720 shielded lead-in cable between the pull box and the electronics unit if a four-turn, 6- x 6-ft (1.8- x 1.8-m) loop #14 AWG wire is used?

The sensitivity S_L for a 4-ft (1.2-m) high undercarriage and four-turn, 6- x 6-ft (1.8- x 1.8-m) loop is 0.1 percent. From Appendix C, the loop self inductance is 125 μH at 20 kHz. The series inductance is the same as in the previous example.

Therefore

$$S_D = \frac{S_L}{1+\frac{L_S}{L_L}} = \frac{0.1\%}{1+\frac{49.3\,\mu\text{H}}{125\,\mu\text{H}}} = 0.072\% \quad \textbf{(2-31)}$$

Information from Traffic Detector Handbook: Third Edition – Volume 1 FHWA-HRT-06-108

Implications for feeder length

Queensland Transport & Main Roads Detector Feeder Cable Characteristics Schedule

Length of Loop Feeder	Resistance Ω	Inductance µH
50Mts	0.7	33
100Mts	1.4	67
150Mts	2.0	100
200Mts	2.7	133
250Mts	3.4	167
300Mts	4.1	200

For every meter of feeder, you would increase the "feeder" Inductance (Microhenries) by 0.62, therefore, for a feeder length of 500m the inductance in the feeder will be approximately 300 microhenries (a little over) . Feeder resistance is a significant contributor to reducing ‘Q’ which determines the performance of the loop. Feeder resistance increase by about .7ohms per 50 metres of installed feeder cable.

The detection performance implications for feeder inductance in this example means that the loop itself has to exceed 300 Microhenries otherwise the feeder induction will cancel out the loop induction. A final loop inductance (after the feeder ‘loss’ is taken into consideration) should be approximately 180 to 320 microhenries. This varies according to the number of turns, size of loop and to some extent the road sub-base. The Engineering note related to loops provides a more in-depth analysis of the relationship between loops and inductance.

Length of Feeder	Increase Resistance	Increase inductance	Decrease ‘Q’
50Mts	0.7ohms	33uhenries	-3
100Mts	1.4ohms	67uhenries	-5
150Mts	2.0ohms	100uhenries	-7
200mts	2.7ohms	133uhenries	-9

“Q” decrease primarily as a consequence of resistance

Optimum Cable Specification

Refer to AS2276:2:xxxxx for details relevant to a screened, twisted balanced twin feeder cable suitable for interconnection between an inductive type vehicle detector loop and vehicle detector equipment.

Operational Temperature Range -10ºC to +70ºC
Nominal Cross Sectional Area 1.5mm^2 (drain wire nominal cross sectional area of 0.35mm^2
Core Lay – helical configuration not exceeding 50mm twist or a maximum of 8 turns per metre
Metallic Screening conductive material – Aluminium or Copper tape 0.075mm or laminate 0.025mm
DC core Resistance 1.5mm^2 13.6 ohms per kilometre (Ω/km) maximum
DC Drain resistance 0.35mm^2 54.4 ohms per kilometre (Ω/km) maximum
Mutual Capacitance Range 65pF/m to 80pF/m
Nominal Inductance 33µH/m

Appendix A – information concerning site environmental and other variables that impact on vehicle detection performance.

The inductance of a loop installation is determined by:
The size and geometry of the loop
The number of loop windings ie., number of 'turns' in a given loop
The length of loop feeder (interconnecting cable) connecting the loop to the loop detector
The presence of any ferrous material in the vicinity of the loop wires (for example steel reinforcing in concrete, metal drains, pavement manholes & metal pipes)

Best results are achieved
Loop feeders > 50mts best served by paired screen cable.
Solder all connections and seal in "joint epoxy"
Feeder lengths 100-150mts
Loop Sensitivity is seriously effected by ferrous metal objects in the vicinity of the loop

Water Penetration – produces mutual capacitance which effects loops performance
Water Variables - relate to pure or mineralised contaminated water