Excel Technology Co Pty Ltd

Loop Detector
'Xtalk'

Original Publication L100.8 Rev A ENGNOTE_Loop_Detector_Xtalk Jan 2012

What is Loop Detector Xtalk ?

Definition of the problem: "When two frequencies coincidentally align with each other spurious and erratic operation may result – coincidental alignment results from loops tuned to the same frequency, frequency fluctuations when a vehicle traverses the loop and long term environmental drift.

A simple description of the more problematic loop detector Xtalk issue is the coupling of 'energy' between loop tails (wires) associated with in-pavement loops when both loops have a similar excitation frequency. This manifests in the vehicle detector as 'ghost' vehicles or false triggering of detector channels and 'locked-on' detectors. A 'locked-on' detector channel may remain on for a 10 minute period because the detector channel will retune after 10 minute periods – Australian Standard requirement.

Detector 'Xtalk' can be thought of in this manner: A radio station broadcasts (transmits) on a carrier frequency of 105.3Mhz. On your radio receiver you move the frequency selection to 105.3Mhz and you 'pickup' (receive) the transmission of music/speech etc which is transferred on that carrier frequency. When the receiver and the transmitter are 'tuned' to the same carrier frequency then the voice, music etc is transferred 'coupled' into your radio. When the radio receiver is not tuned to 105.3Mhz you don't receive the transmission. This is a simple example of the nature of transferring energy via tuned circuits.

Similarly when in-pavement loops operate at very similar frequencies a vehicle actuation can be 'coupled' to another detector input (ghost vehicle or false trigger results). This will only occur when the loop frequencies are the same (or very similar) and the two loops are active at the same time **and** the unshielded wires are in close proximity ie., same road slot. This can not occur when a single 8 channel scanning detector card is used as two loops will not be excited simultaneously as each channel is excited in sequence from 1-8. However when more than one card is used, the probability of a loop from each card being excited simultaneously increases as two or more cards are exciting loops in a cyclic rate around 250-300microseconds per channel. Good design practices ensures that the unshielded loop tails are not in close proximity however if loop tails are in close proximity then there is a likelihood that energy will be coupled and Xtalk will occur.

While environmental drift and detection fluctuations may be eliminated in detector firmware, the Xtalk problem is compounded by installing loops in motorway applications which are electrically the same ie., 2 Metre square loops with 4 turns which present similar electrical characteristics (inductance&resistance) and therefore will operate at similar excitation frequencies. Also vehicle detector technology with improved performance and greater accuracy is dependent on individual loop scanning periods of around 300 millionths of a second – this naturally increases the probability of channels from different cards being excited simultaneously due to the higher sampling rate. This requires more attention to site design and separating loop tail wires in road saw cut slots.

The paradox of high performance / high accuracy detectors is high speed scanning. ETG vehicle detectors can provide an accuracy of +-1khr in 100 khr. Vehicle length is derived from vehicle speed and loop occupancy. The ETG design is focussed on these determinants having high levels of accuracy in order to provide accurate vehicle length. Therefore the scanning period for individual channels is between 250-300millionths of a second. This unfortunately increases the probability of 'Xtalk' – the following pages present means for reducing and eliminating Xtalk.

Refer to Appendix A for information concerning Accurate Speed & Vehicle Length Determination requiring a high resolution scan rate of typically 250microseconds.

Eliminating / Reducing Xtalk between loop based vehicle detector channels

Xtalk can only occur when a chassis has more than one vehicle detector module – channels on a single sequencing detector will never couple energy because only one channel is on at a time. Xtalk results from the coupling of energy between unshielded loop channel wires laid in close proximity to each other when the loops are excited by separate cards.

Xtalk reduction through modifying Capacitance

There is an argument which promotes changing Capacitance or 'C' to adjust loop tuning frequency as the loop is generally a fixed value of inductance and 'C' may be modified easily within the circuit within the detector. Resonant frequency change is the basis of inductive vehicle detection ie., measuring a variation in frequency determines a vehicle actuation.

ω is the frequency in radians/sec

For a resonant circuit:

ω = 1 / SQRT(LC)

Therefore ω is proportional to 1/SQRT(L) or L^-0.5

In other words any variation in L of X% translates to a much smaller variation of ω. However, this variation is not affected by C. C only affects the absolute value of ω.

What does all this mean?

Changing the resonant frequency point for a fixed inductor (a loop) requires changing the capacitance 'C'.

Since C is not related to the change in ω when L changes - it can be stated that doing so is a pointless exercise unless the frequency is be shifted by at least 5Khz and the device must easily accommodate site variations while incurring preset incremental capacitance steps.

Xtalk minimalisation through software algorithms

ETG vehicle detectors incorporate software algorithms which attempt to ensure that multiple cards are not scanning in synchronisation and monitor vehicle actuations to determine if the actuations occur simultaneously in less than a 10 millisecond period – indication of Xtalk. Ultimately this activity is based on the probability of reducing the potential for Xtalk induced errors and therefore can not be considered absolute.

Xtalk elimination through backplane card synchronisation

This method involves controlled sequenced operation of vehicle detector cards. For example, a chassis may have four detector cards and a supervisory function controls the sequenced selection of each card ensuring that only one card is enabled 'switched-on' at a time. However, this method has significant performance limitations because the controlled sequence means that loop sampling is delayed which introduces significant speed determination errors. Refer to Appendix A for information concerning Accurate Speed & Vehicle Length Determination which assumes only one card is functioning. This error is compounded by the further time delays associated in sequencing cards. Due to these limitations this method is not used in ETG equipment.

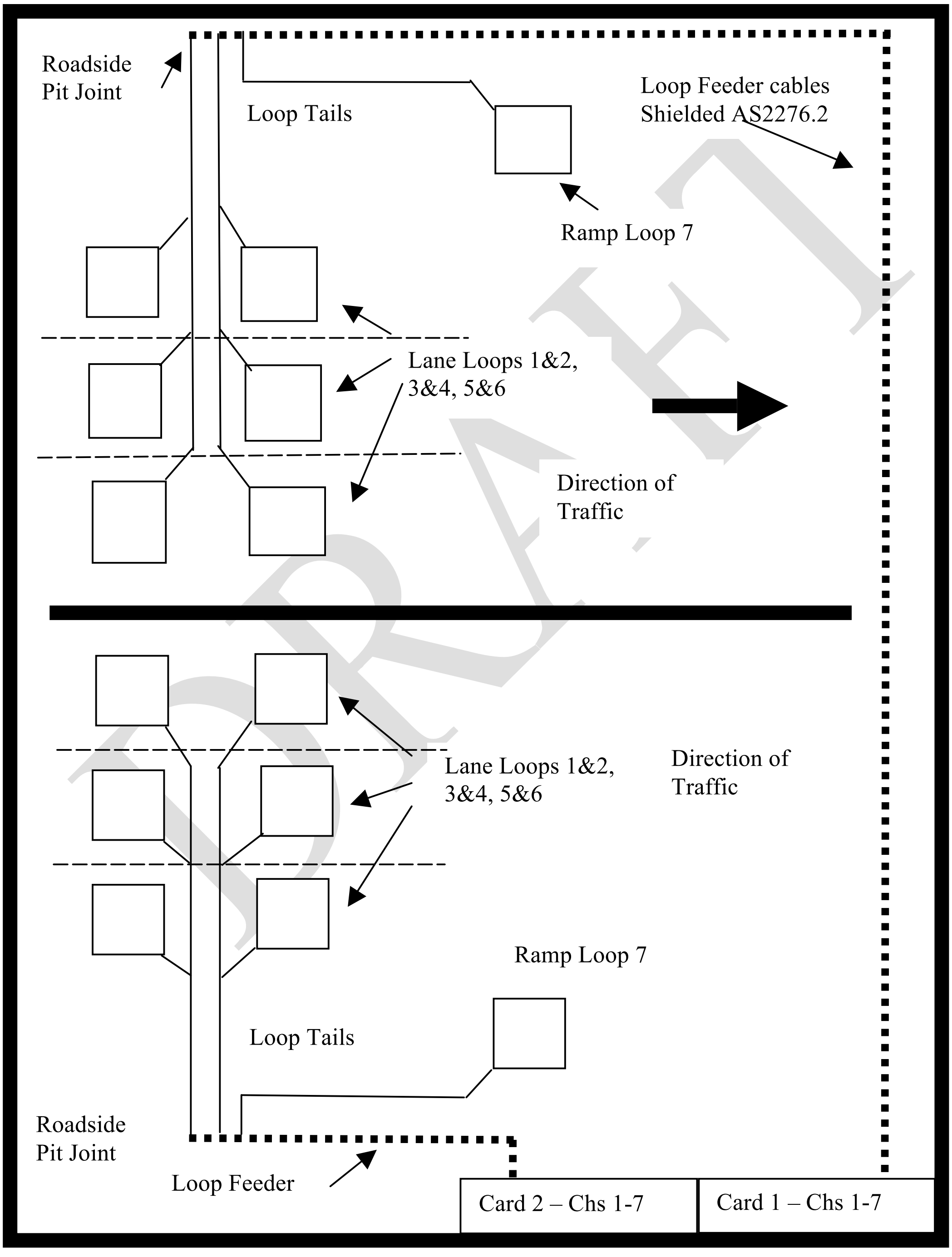
Xtalk elimination through work practices

Laying unshielded loop tails in the same slot should be avoided at all times. While it is not a desirable practice, it is permissible to lay loop tails associated with the same detector card in the same slot however under no circumstance should loop tails associated with different detector cards be installed in the same slot. This practice in respect to intersection loops ceased in the 1980s. Also it is desirable to keep the shielding associated with Loop Feeder cable (ASNZS 2276.xx Loop Feeder Cable) as close to the bared cable ends of the insulated wires located within the cable for maximum protection when terminating the loop feeder cable into the Field Termination Panel connectors.

Xtalk elimination through site design

Best work practice site design eliminates Xtalk problems by ensuring feeder wires are not located in the same slot inadvertently or otherwise during installation.

For example, a site has 3 lanes inbound and 3 lanes outbound. A 12 channel detector chassis (card ONE being 8 channels & card TWO being 4 channels) is chosen for installation. The design allocates channels 1-6 (card ONE) to inbound lanes and channels 7&8 (card ONE) to an outbound lane. A poor design locates the feeder wires from Channels 7 & 8 (card ONE) in the same slot as channels 1- 4 of Card TWO. This will cause Xtalk. A good design nominates that the loop tails for Channel 7&8 be run in their own slot and separated from the tails from Card TWO. Alternatively an 8 channel card be allocated to a single six lane direction and the unused 7&8 be allocated to ramp monitoring is required.



Appendix A – Accurate Speed & Vehicle Length Determination requires a high resolution scan rate of typically 250microseconds.

Scan rate

The speed of a vehicle is calculated using the time taken to travel from the leading loop to the lagging loop and the loop spacing, using the following formula:

Speed (s) = Loop Spacing (d) / Time Between Loops (t)

The ETG detector uses four time measurements (two time periods) to calculate time between loops:

- Activation of loop 1 (t_{i1}) to activation of loop 2 (t_{i2})
- Clearing of loop 1 (t_{o1}) to clearing of loop 2 (t_{o2})

These measurements are then averaged to find the time between loops.

Therefore $t = [(t_{i2} - t_{i1}) + (t_{o2} - t_{o1})] / 2$

Assuming a worse case scenario, the scan rate for the loops is ~2.5ms. The detector measures time with 1ms precision. Therefore there is an error in each time measurement of 0 to 3 milliseconds. This error can be modelled as a uniform random variable e where e is an element of [0,3].

Therefore:

$$t = \{[(t_{i2} - e_{i2}) - (t_{i1} - e_{i1})] + [(t_{o2} - e_{o2}) - (t_{o1} - e_{o1})]\} / 2$$
$$t = [(t_{i2} - t_{i1}) + (e_{i1} - e_{i2}) + (t_{o2} - t_{o1}) + (e_{o1} - e_{o2})] / 2$$
$$t = [(t_{i2} - t_{i1}) + (t_{o2} - t_{o1})] / 2 + E; \text{ where } E = (e_{i1} - e_{i2} + e_{o1} - e_{o2}) / 2$$

Figure 10a on the following page shows the probability density function (p.d.f.) for E when the typical one set of measurements is used (left graph); compared to the p.d.f. for E when the ETG two measurement method is used. It can be seen that the two measurement method gives a higher probability of an accurate result.

Since Measured Speed (s') = Loop Spacing (d) / Measured Time (t')
And t' = Actual Time (t) + E
Then s' = d / (t' + E)

Thus the percentage error in speed (e_s) is:

$$e_s = 1 - s'/s \times 100\%$$
$$e_s = 1 - \{[d / (t' + E)] / [d / t]\} \times 100\%$$
$$e_s = 1 - [t / (t' + E)] \times 100\%$$

A car travelling at 100km/h takes 180ms to travel 5m. If loops are spaced 5m apart, then the maximum speed error due to scan rate will be 1.67%. However the probability of this error is low and we can therefore assume that the majority of readings will be within 1% of the actual speed.

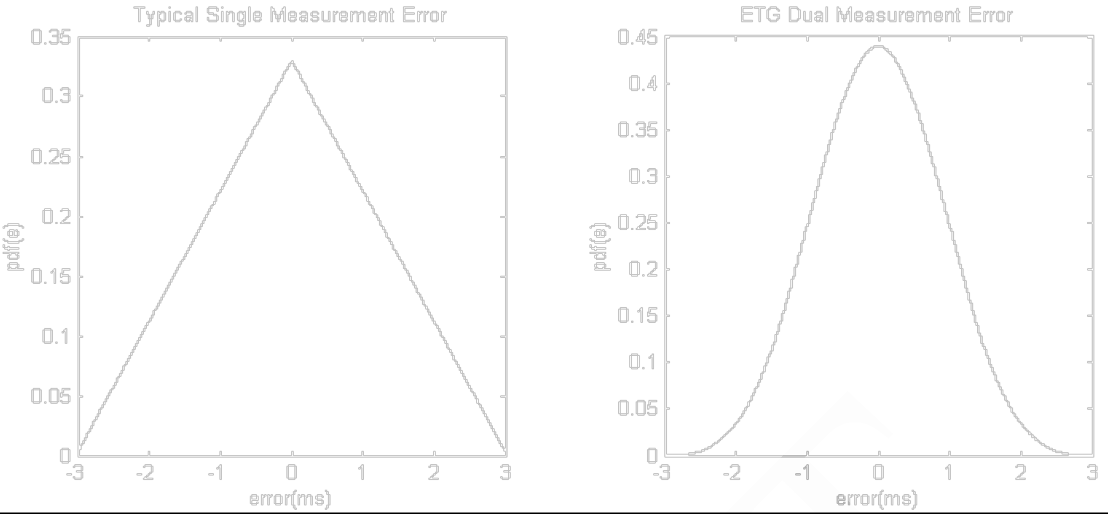


Figure 10a: Single Measurement Error

Averaging the speed measurements decreases the error probability. Figure 10b shows the average speed error p.d.f. for 100 cars travelling at 100km/h measured over a 5m spaced loop pair:

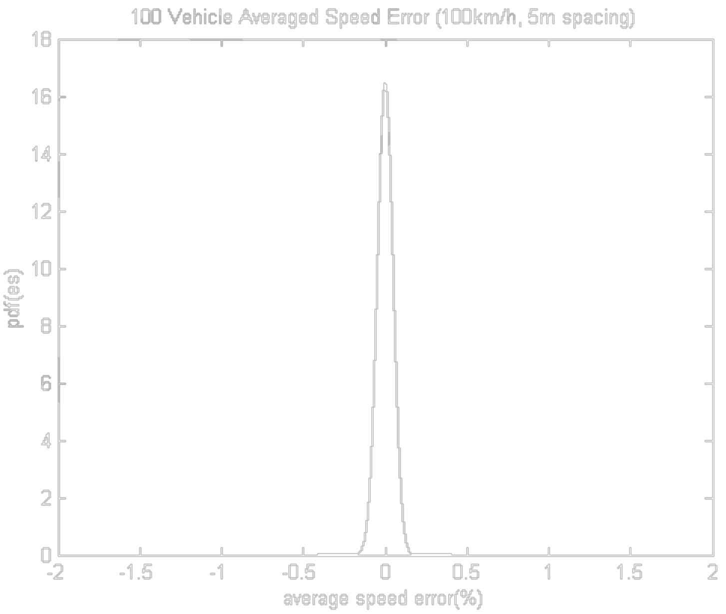


Figure 10b: 100 Vehicle Average Measurement Error

Loop Spacing

The speed error due to loop spacing is proportional to the error in the loop spacing.

Measured Speed (s') = {Loop Spacing (d) ± Loop Spacing Error (e_d)} / Time Between Loops (t)

Therefore percentage speed error (e_s) = 1 – s' / s × 100%

$$e_s = 1 - \{[(d \pm e_d) / t] / [d / t]\} \times 100\%$$
$$e_s = 1 - (d \pm e_d / d) \times 100\%$$
$$e_s = \pm e_d / d \times 100\%$$

Thus a ±10cm loop spacing error on a loop pair of proper length 5m will result in a speed error of ±2%. To avoid this error care should be taken to make sure the loop spacing is correct. This error does not diminish with averaging.

Vehicle Length an compounding error

The length of a vehicle is calculated using the speed of the vehicle, the loop length and the average occupied time of both loops:

Length (l) = Speed (s) × Occupied Time (t) – Loop Length (d_l)

The ETG detector uses four time measurements (two time periods) to calculate the loop occupancy:

- Activation of loop 1 (t_{i1}) to clearing of loop 1 (t_{o1})
- Activation of loop 2 (t_{i1}) to clearing of loop 2 (t_{o2})

These measurements are then averaged to find the average occupancy.

Therefore $t = [(t_{o1} - t_{i1}) + (t_{o2} - t_{i2})] / 2$

As in Section 0 we can express the total error of this measurement as the summation of four uniform random variables, E, where $E = (e_{o1} - e_{i1} + e_{o2} - e_{i2}) / 2$. The p.d.f. for E is therefore the same as shown in Figure 10a.

To calculate the overall length error p.d.f. is complicated as it is related to the speed error, and is beyond the scope of this manual. A worst case analysis will give a rough idea of the error however.

Assume a 5m long vehicle travelling at 100km/h (27.78m/s) drives over a 2m loops spaced 5m apart. From Section 0 we know the speed error is ± 1.67 km/h (0.46m/s); and simple maths tells us that the time over each loop should be (2m + 5m) / 27.78m/s = 0.252s.

Therefore: Length (l) = Speed (s) × Occupied Time (t) – Loop Length (d_l)

$$l = (27.78m/s \pm 0.46m/s) \times (0.252s \pm 0.003s) - 2m$$
$$l = 7.00m \pm 0.12m \pm 0.08m - 2m$$
$$l = 5m \quad \pm 0.2m$$

Thus the length error is ± 0.2m.