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16. Abstract

Today, modern traffic control systems are necessary to obtain maximum possible efficiency from our freeway systems. In order for the traffic controller to respond to the needs of the traffic, it must be able to sense traffic conditions at all times. A major component of a vehicle detection system is the induction loop detector (ILD). This research effort evaluated the methods by which crosstalk in loop detectors could be controlled effectively in a freeway management situation and, thereby, make the most efficient use of induction loop detectors.

The researchers conducted tests to evaluate the distance at which no crosstalk was observed between two adjacent ILDs. Tests were also conducted to measure the potential of crosstalk in twisted and untwisted lead wires, and between parallel lead wires. As a part of this ongoing research, the potential for crosstalk within the controller cabinet itself was also evaluated. Researchers observed that there was no crosstalk between ILDs placed in 3.65 meter (12 foot) and 3.35 meter (11 foot) wide lanes. However, crosstalk may exist in loop detectors that are placed in 3.05 meter (10 foot) wide lanes. No false detections were recorded over twisted or untwisted lead wires. It was observed that a spacing of 50 mm (2 inches) or more eliminates the lead wire crosstalk. No evidence of crosstalk was measurable in the controller cabinet.

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INDUCTION LOOP DETECTOR SYSTEMS CROSSTALK

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Research Report 1392-2
Research Study Number 0-1392
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Sponsored by the
Texas Department of Transportation
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TEXAS TRANSPORTATION INSTITUTE
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IMPLEMENTATION STATEMENT

This research provides a more reliable basis for the application of induction loop detectors by the Texas Department of Transportation and local governmental units. With the increasing development of freeway management systems, this research provides the designer with practical information as to the minimum distance that should be maintained between two loops to avoid crosstalk between them. Since efficient performance of the detection systems is much sought-after, recommendations regarding the potential for crosstalk between two parallel lead wires, between twisted lead wires, and within the controller cabinet itself, is important.

This report contains pioneering work done on the problem of crosstalk in induction loop detectors. There was no crosstalk between two 1.8 m by 1.8 m (6 ft by 6 ft) loops placed in 3.65 m (12 ft) or 3.35 m (11 ft). But, crosstalk may exist in loop detectors that are placed in 3.05 m (10 ft) lanes. In such cases, reducing the widths of the loop detectors to 1.5 m (5 ft) would be of great help in reducing the possibility of crosstalk. Though the findings ensure methods of eliminating crosstalk in adjacent loop detectors, thorough testing of the procedures is recommended before any implementation takes place.

Crosstalk between untwisted and twisted lead wire was controlled by a 50 mm (2 in) separation of the saw cuts. No measurable crosstalk potential could be measured within the controller cabinet.

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration or the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. Donald L. Woods (P.E. # 21315) was the principal investigator for the project.

ACKNOWLEDGMENT

The research reported herein was performed as part of a study entitled "Effective Detector Placement for Computerized Traffic Management" by the Texas Transportation Institute and sponsored by the Texas Department of Transportation. This study was conducted in cooperation with the U.S. Department of Transportation and the Federal Highway Administration. Dr. Donald L. Woods, (P.E. #21315) of the Texas Transportation Institute served as the research supervisor, and Dr. Carroll J. Messer served as a co-investigator of the research.

The authors wish to acknowledge the role of the research assistants and technicians at the Texas Transportation Institute who helped in the collection, reduction, and analysis of data for this report.

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SUMMARY

A research study to determine the occurrence of crosstalk between inductance loop detectors was conducted under controlled conditions at the TTI test facility at the Riverside Campus, Texas A&M University. The study was conducted using 1.8 meter by 1.8 meter (6 ft by 6 ft) loops and three vehicle types: large car, small car, and pickup truck.

The findings of the study showed that crosstalk is mainly a loop-to-loop problem. Crosstalk between lead-in wires, whether twisted or untwisted, and cabinet circuitry was not a problem. Crosstalk occurred when two loops were placed too closely. Required distances between loops to prevent crosstalk are 0.6, 0.9 and 1.2 meters (24, 36, and 48 inches), respectively, when the detector is set on low, medium, and high sensitivity settings.

Spillover, due to vehicles in adjacent lanes, may occur when the spacing from vehicle to loop edge is less than 1.1 meters (42 inches). To avoid crosstalk or spillover situations, 1.5 meter (5 feet) loops may be used without seriously affecting the electromagnetic field of the loop.

Loops will not crosstalk when they operate at frequencies differing by 10 kHz or more. Frequencies may be varied by hooking inductors in series with the loop.

Crosstalk was not observed when lead-in wires were spaced at 50 mm (2 inches) or more. There was no difference in twisted and untwisted lead wires.

1.0 INTRODUCTION

In modern traffic control systems and traffic management systems, it is necessary to have factual data to make proper decisions and thus achieve maximum possible efficiency in the traffic control strategies. To collect the necessary data, traffic detectors are used extensively, and they must provide accurate information at all times and in every detector application. Most detectors employed in traffic control systems are of the induction loop type. Induction loop detectors are the easiest to install and are most economical. Even though they are widely used, there is a lack of factual information about the characteristics and behavior of induction loop detectors. This research study is one of several efforts to provide additional information on detector applications.

This research study addresses the general characteristics and problems associated with the use of inductance loop detectors in gathering traffic data. The nine reports of this study deal with such subjects as detector placement, response time, detector form, loop crosstalk and applications in speed traps. The study also addressed wire types and the manner in which a loop is formed. This particular part of the study dealt with "crosstalk," which is the occurrence of two adjacent loops interfering with each other, causing errant detections.

1.1 PROBLEM STATEMENT

Crosstalk causes serious problems in the operation of the induction loop detectors and produces false detection of vehicles when there are no vehicles in the detection zone. Crosstalk primarily occurs when the resonant frequency of one loop detector matches the resonant frequency of a neighboring loop detector. Proximity of the two loops is the principal consideration in the cause of crosstalk. However, there are some other possible causes that must be explored to determine if, in fact, they are factors, including the use of unshielded lead-in wire in the same conduit with other detectors, or two lead-in wires sharing the same saw slot. Other causes of crosstalk may include poor splices and improper connection of the cable shields, or coupling between closely spaced wires in the cabinet.

1.2 OBJECTIVES

The primary objectives of the proposed research are to experimentally determine the following:

- Minimum spacing between the loops required to prevent crosstalk in ILDs;
- Potential for false detection over twisted and untwisted lead wires;
- Potential for crosstalk between parallel lead wires; and
- Potential for crosstalk in the controller cabinet.

1.3 ANTICIPATED BENEFITS

This research provides a more reliable basis for the application of induction loop detectors by the Texas Department of Transportation and local governmental units in Texas. This research should provide the designer with practical information as to the minimum spacing that should be maintained between two loops to avoid crosstalk between them.

2.0 STUDY DESIGN

This study was conducted in a controlled environment at the Texas Transportation Institute testing area, located at the Texas A&M University Riverside campus.

2.1 CONSTRUCTION OF TEST SITE

The test site consisted of four 1.8 m by 1.8 m (6 ft by 6 ft) induction loop detectors installed on a concrete runway. The ILDs were located 5 m (15 ft) from the edge of the pavement in the center of a 4 m (12.5 ft) panel, as shown in Figure 1. The construction team cut the loop into the concrete pavement with a 35 horsepower concrete saw using a diamond tip blade. All of the saw cuts were 50 mm (2 in) deep, with the width of the cut varying from 6.25 mm (1/4 in) to 12.5 mm (1/2 in) depending on the type of wire used. The spacing between the loops was 6, 15, and 24 m (20, 50, and 80 ft), measured from the front edge to the front edge of each loop. From the edge of the pavement, the loop wire ran underground through a 25 mm (1 in) diameter PVC pipe to the pullbox.

The composition of loops A, B, and C consisted of six turns of #12 THHN stranded wire. Loop D consisted of six conductor (three pairs), #18 AWG stranded copper, AMW style 2464, PVC jacketed cable. A movable loop (1.8 m by 1.8 m) (6 ft by 6 ft), with three complete turns and three individual turns, was constructed using a wooden frame represented by Loop A' in Figure 1. The first three loops were constructed with leads from the three complete turns and the leads for the three individual turns all meeting in the pullbox. Loop D was constructed similarly, except that the three turn loops were connected in the pullbox since the wire was six conductor unshielded cable. The loops were sealed within the saw cuts using "Permanent Sealer 974" sealant.

The team made four saw cuts along the lead wires of loops A and B for a length of 3 m (10 ft) at a uniform spacing of 50 mm (2 in) to conduct the lead wire crosstalk study.

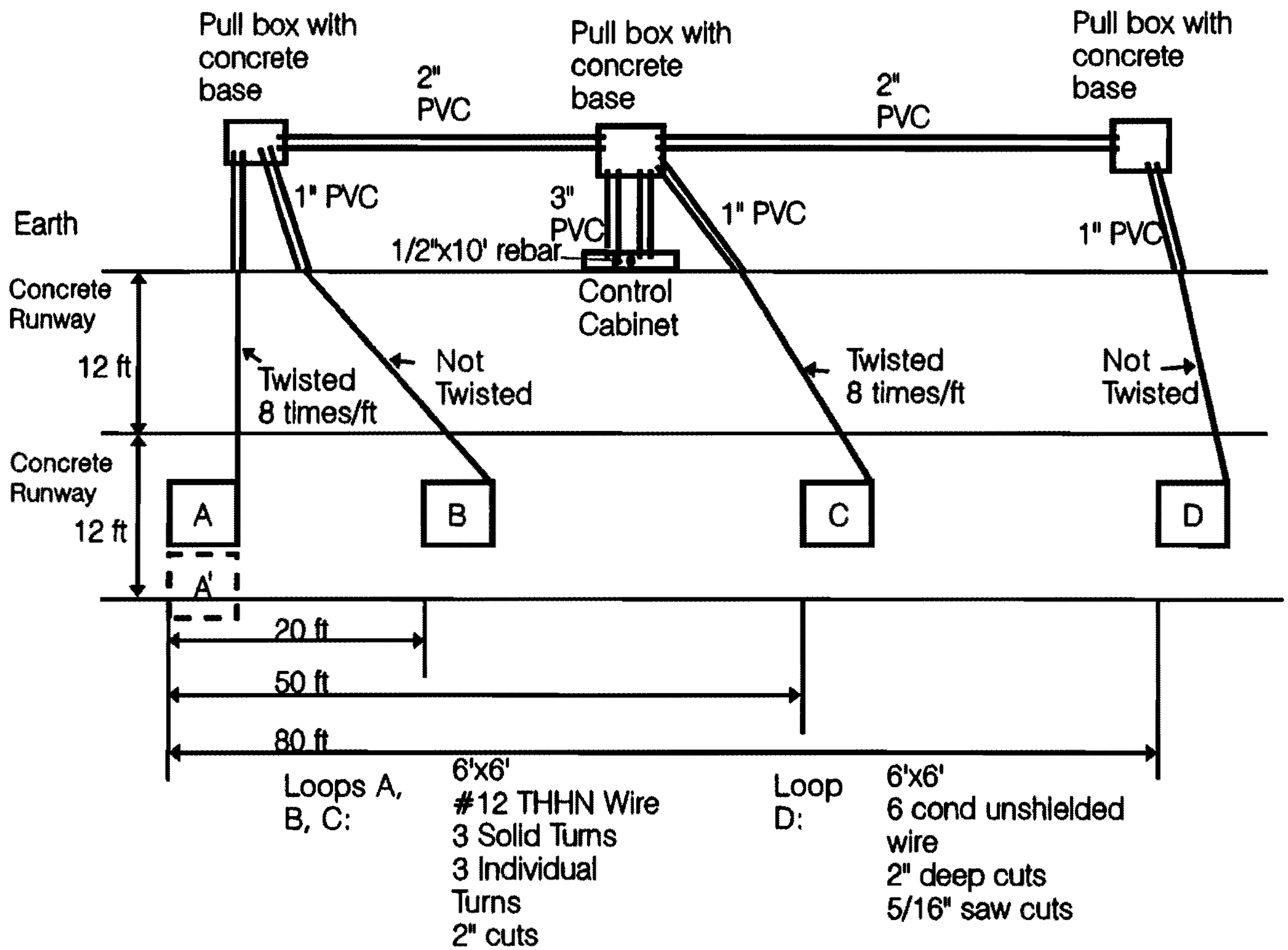

Figure 1. Test Site

2.2 STUDY OF CROSSTALK BETWEEN TWO LOOPS

The crosstalk study between two loops utilized loop detector A and a movable 1.8 m by 1.8 m (6 ft by 6 ft) loop detector A'. The two loops were connected to two separate detector units. Both detector units were set to medium frequency. The sensitivity for each detector unit was set at the same level for each test. Researchers then moved the movable loop (loop A') with respect to loop A and obtained the distance at which the crosstalk occurred.

The above tests were conducted for two different types of detector units, and each run was repeated ten times. A particular set of tests was stopped when the incidence of crosstalk was no longer observed. To ensure that the loops were working in good condition, with adequate Q-factor, a frequency meter was used to measure the frequency of the loop system; the loop system included the loop wire, the lead wire, and the detector unit. Completion of this series of tests determined the minimum distance that could be successfully used for accurate vehicle detection while avoiding the problem of crosstalk in a freeway management system.

2.3 FALSE DETECTION BY CROSSTALK BETWEEN LEAD WIRE

As a part of the crosstalk project, researchers studied the potential for crosstalk between the lead wires of two inductive loops placed adjacent to each other in two different lanes. This part of the study utilized loop detectors A and A'. Both detectors A and A' were set on medium frequency, and at the same sensitivity for each test. Two different detector units were tested with two design vehicles (a large car and a small car), as identified in Table 1. The spacing between the two lead wires was increased at 50 mm (2 in) increments, and a particular test was stopped when crosstalk was no longer observed between the lead wires. This decision was based on the following premise: if crosstalk is not observable at a uniform spacing of X^{in} between the untwisted lead wires, it will not, therefore, be observed at a spacing of $(X+2)^{in}$ for a particular sensitivity setting. Each vehicle made ten passes over Loop A at 32, 65, and 97 km/h (20, 40, and 60 mph). Each detector was tested in the presence mode of operation, so an accurate detection required the detector unit to hold the call while the vehicle was within the loop.

Table 1. Classification of Design Vehicles

Classification	Vehicle	Height above Pavement	Vehicle length	Front vehicle width
Small car	1987 Honda Civic	225 mm (9")	3.9 m (12'10")	1.6 m (5'1")
Large car	1991 Ford Crown Victoria	213 mm (8.5")	5.3 m (17'3")	1.9 m (6'3")

To find out whether the lead wires contributed to errant vehicle detection, researchers performed tests by activating all four loops — A, B, C, and D — which were separated by distances of 6, 15, and 25 m (20, 50, and 80 ft) from the front edge of loop A, and by running the test vehicle over the lead wires to see if the vehicle was detected. The entire test series was completed ten times for each design vehicle and for three detector sensitivity settings: low, medium, and high.

2.4 STUDY OF CROSSTALK POTENTIAL IN THE CONTROLLER CABINET

This study measured the potential for crosstalk in the controller cabinet itself. Researchers were especially concerned about crosstalk caused by the cabinet wiring and the long unshielded ends of the lead-in wires as they are connected to the controller and the detector units.

Three "Detector Systems" detector units and loops A, B, and C were energized, with the fourth loop connected to a dummy detector in the cabinet. The dummy consisted of a 0.91 m (3 ft) shielded, two-wire cable terminated with a 560 ohm resistor. A high sensitivity oscilloscope ("Model Tetronics # 214 Storage") was connected across the dummy load resistor to measure the voltage. Researchers energized the three active loops and measured the dummy load voltage and frequency at 2 millivolts in the absence of a vehicle.

2.5 USE OF DIFFERENT TYPES OF DETECTOR UNITS

Because of their lower costs, rack-mounted detector units are very widely used and are preferred over the relatively more expensive stand-alone detector units. As a part of this ongoing research, the team made an effort to compare the performances of stand-alone detector units and rack-mounted detector units.

In order to conduct a fair comparison between both counterparts, it was important to determine the corresponding sensitivity settings for the two types of detectors at which the percent change in inductance of the detector unit was the same for both types of detector units. Table 2 presents the results of this comparative study. In Table 2, "Detector Systems" sensitivity settings 2, 5, and 8 are comparable with the sensitivity settings 3, 6, and 9 of "Naztec" rack-mounted detector units. These two sets of sensitivity settings indicate the same amount of inductance change in "Detector Systems" and "Naztec" detector units upon the detection of a vehicle.

Table 2. Equivalent Sensitivity Settings in Detector Systems and Naztec Detector Units

Sensitivity Setting	Average % Change in Inductance	
	Detector Systems	Naztec
0	0.96	
1	0.63	1.202
2 Low	0.28 Low	0.718
3	0.16	0.364 Low
4	0.08	0.213
5 Med	0.045 Med	0.125
6	0.036	0.061 Med
7	0.029	0.040
8 High	0.017 High	0.024
9	0.016	0.015 High
10		0.015
11		0.008
12		0.008

3.0 RESULTS

3.1 RESULTS OF CROSSTALK STUDY

For safe and efficient use of induction loop detectors, it is important to take proper preventive measures in order to avoid crosstalk. Crosstalk in loop detectors can be controlled in two different ways. First, crosstalk may be controlled by providing enough physical distance between the ILDs that their individual inductance fields do not interact. Second, crosstalk may be controlled by altering the ILD's operating frequencies enough that the loops have no opportunity of resonating within the other loop's frequency range.

Researchers also conducted tests to evaluate the possibility of crosstalk in the controller cabinet itself and in the twisted and untwisted lead wires.

3.2 EVALUATION OF MINIMUM DISTANCE OF NO CROSSTALK

In this research, test runs were conducted using portable loop A' and loop B installed in the pavement. Both loops, i.e., loop B and portable loop A', were connected to two different detector units of the same type. Using the same sensitivity-settings on both detectors, various lateral distances between the loops were used and the distance at which there was no crosstalk was determined. It was observed that at low, medium, and high sensitivity settings, the distance with no crosstalk occurrence for "Detector Systems" stand-alone detector units was 0.6, 0.9, and 1.2 m (24, 36, 48 in), and 0.6, 0.75, and 1.1 m (24, 30, 42 in), respectively, for "Naztec" rack-mounted detector units as shown in Figure 2. The recommended minimum separation to prevent crosstalk is presented in Figure 3.

3.3 ELECTRONIC SEPARATION OF INDUCTION LOOP DETECTORS

When two induction loop detectors placed in two adjacent lanes are operating at similar frequencies, they begin to resonate with one another; as a result, crosstalk can occur. If the operating frequencies of these two loop detectors were altered by a significant amount, crosstalk would be effectively controlled.

The frequency of an induction loop detector is usually controlled by a frequency-setting switch in the front panel of the detector unit. The various frequencies that may be set by using this frequency-setting switch for a "Detector Systems" stand-alone detector unit are listed in Table 3.

Table 3. Observed Frequencies for Different Frequency Settings (Using "Detector Systems" Detector Unit)

Frequency Setting	Frequency (in kHz)
High	44.07
Medium High	39.91
Medium Low	36.38
Low	33.91

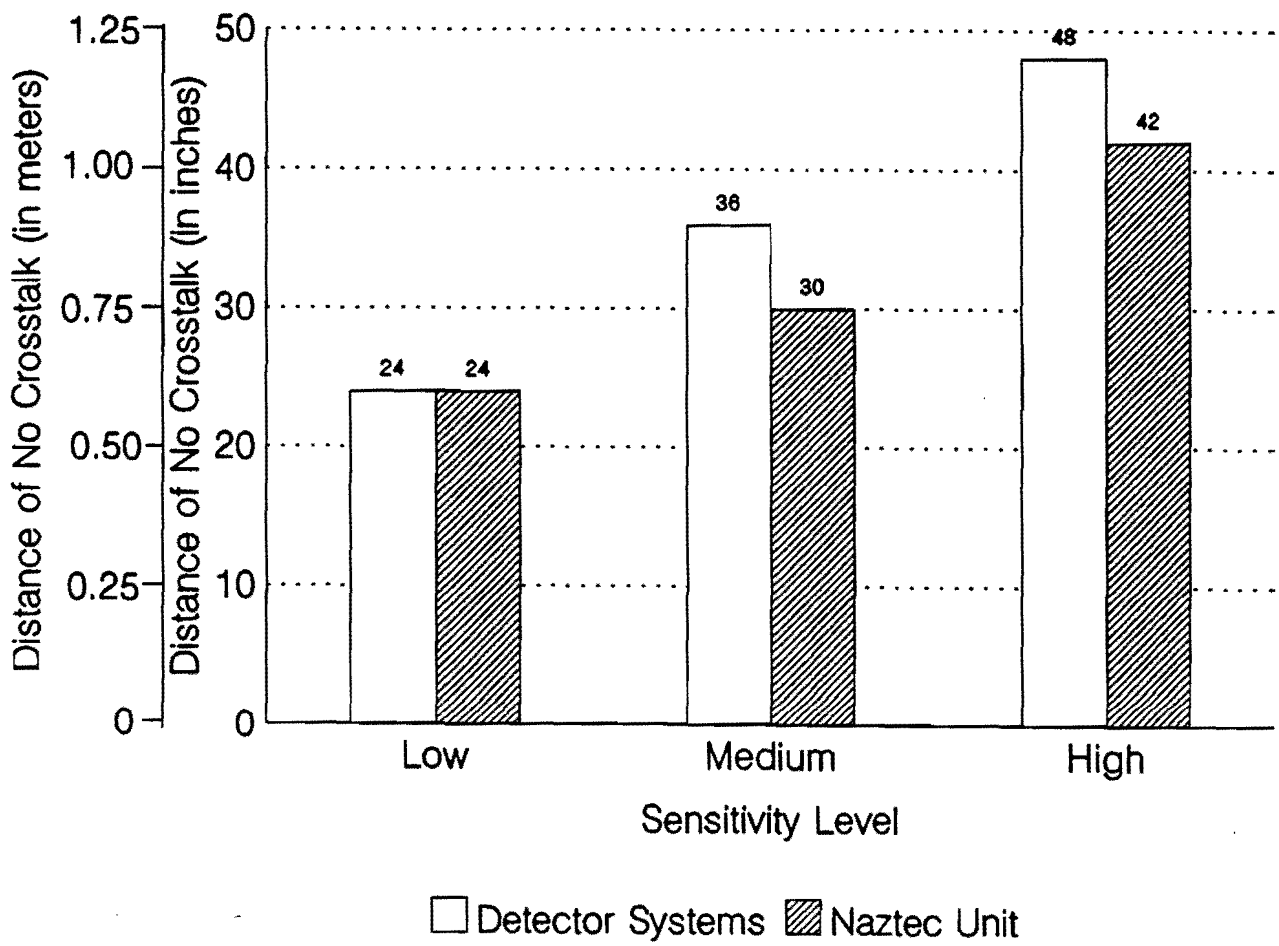

Figure 2. Distance of Minimum Crosstalk (Bar Charts)

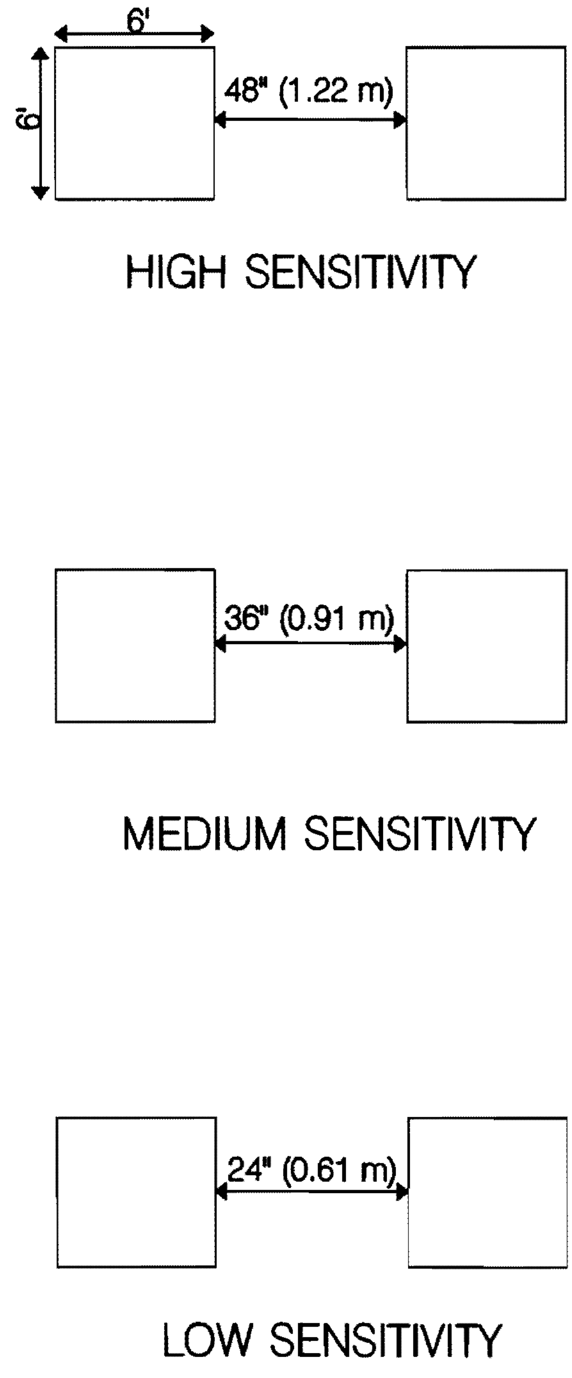

Figure 3. Distance of Minimum Crosstalk (Schematic)

From Table 3, note that a maximum difference of approximately 10 kHz in the operating frequencies of two induction loop detectors could be obtained by using high and low frequency settings. With this difference as an objective, different frequency combinations could be achieved by placing inductors in series with the loop circuit so that a difference of at least 10 kHz exists in the operating frequencies of two adjacent loop detectors. An experiment was designed to provide different values of inductance to be connected in series with the loop detector circuit, and the resulting induction loop detector frequency was measured with a frequency meter. The results of this study are shown in Table 4. The results are also illustrated graphically in Figure 4. A careful inspection of Figure 4 indicates that one such possible combination could be achieved by creating a difference of 200 μH in the inductances of the two ILDs, causing the operating frequencies of two induction loop detectors to differ by 10 kHz. This difference in inductance of the two ILDs would create operating frequencies different enough to avoid crosstalk from occurring.

Since the frequency of an ILD is also a function of capacitance, a shift of 10 kHz could also be obtained by changing the capacitance of the two adjacent ILDs. As illustrated in Figure 5, one such shift could be obtained by creating a difference of 0.3 μF (microfarads) in the capacitance of the two ILDs.

Table 4. Observed Frequency and Capacitance for Different Inductances

Added L, ΔL (in μH)	$L_T = \Delta L + L_{Loop}$*1 (in μH)	Frequency, f (in kHz)	ΔC (in microfarads)
51	150	34.46	0.073
53	152	34.35	0.075
57	156	33.98	0.081
60	159	33.65	0.085
62	161	33.51	0.087
66	165	33.25	0.092
69	168	32.98	0.097
74	173	32.61	0.103
77	176	32.48	0.106
83	182	31.99	0.114
87	186	31.73	0.119
100	199	30.94	0.134
103	202	30.58	0.139
132	231	29.07	0.173
150	249	27.92	0.197
166	265	27.37	0.214
194	293	26.23	0.246
220	319	25.32	0.275
222	321	25.36	0.275
278	377	23.32	0.346
330	429	22.59	0.385
470	569	19.36	0.563
680	779	17.53	0.726

[1] Inductance of the test loop was measured to be 99.1 μH at 45 Khz

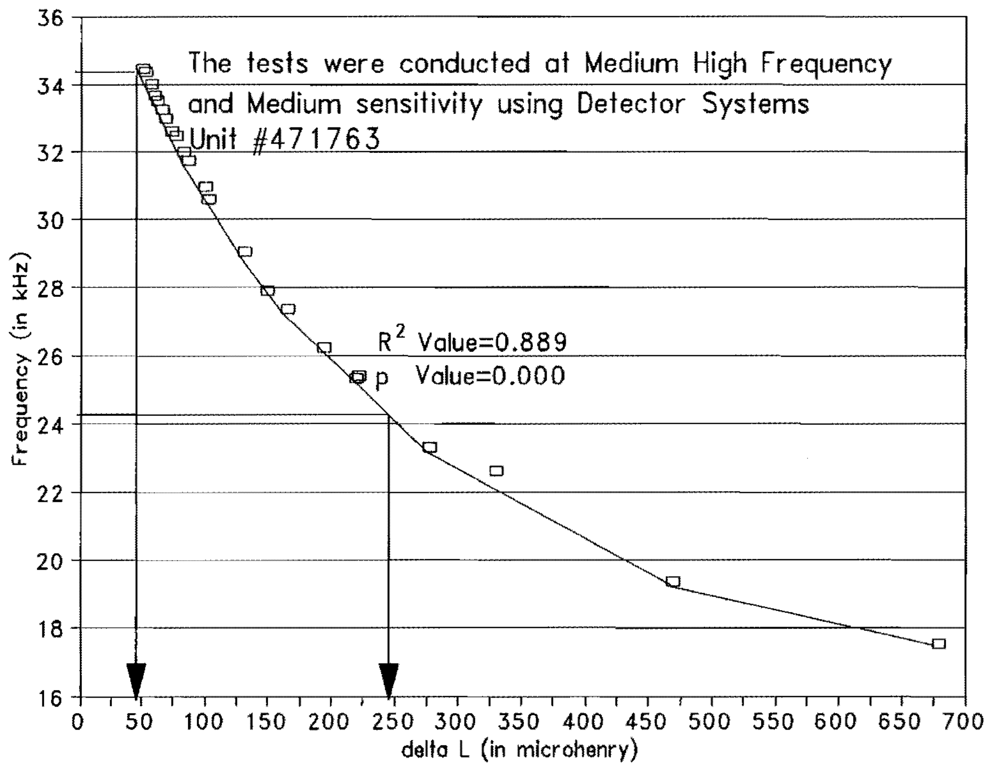

Figure 4. Relationship between Frequency and Inductance

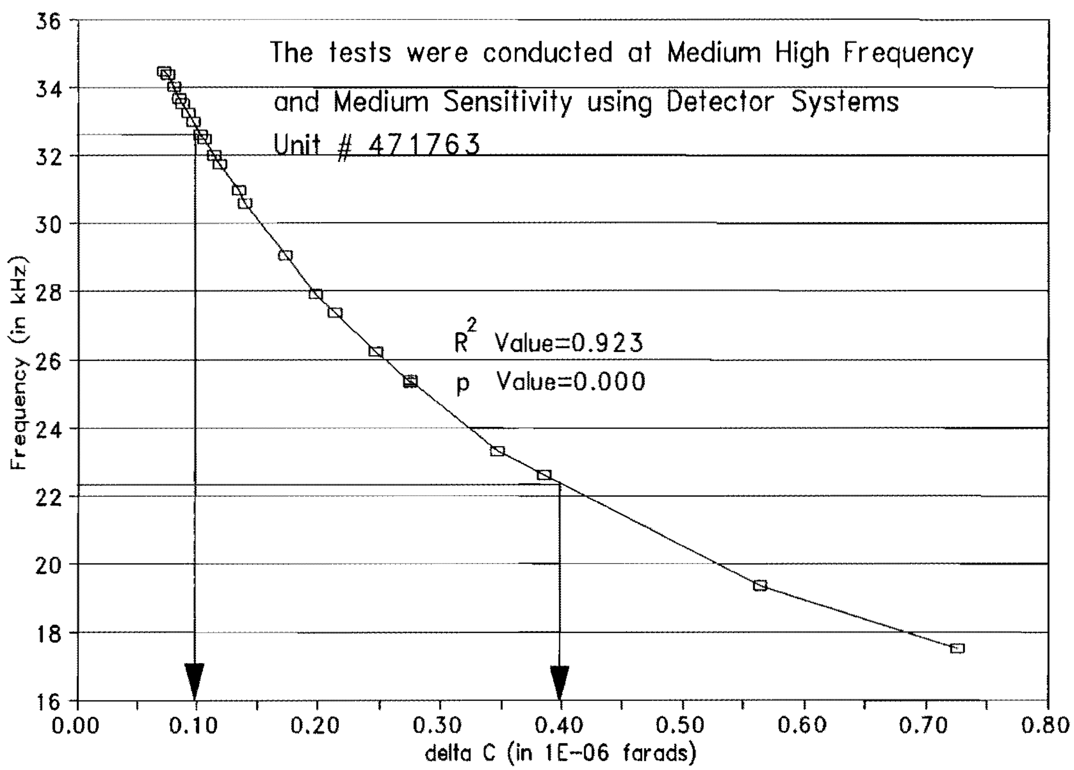

Figure 5. Relationship between Frequency and Capacitance

The different values for ΔC, shown in Table 4, were calculated by using the following equations:

$$\Delta C = C_{Loop} - C_{Combined}$$

Where: ΔC = Difference in the Capacitance of two ILDs, in farads

$$C_{Loop} = \frac{1}{(2 \pi f)^2 \cdot L_{Loop}}$$

Where:

C_{Loop}	=	Capacitance of test loop, in farads
f	=	Frequency of test loop, in hertz
π	=	3.14159
L_{Loop}	=	Inductance of test loop, in henries
	=	99.1 μH at 45 kHz

$$C_{Combined} = \frac{1}{(2\pi f)^2 \cdot L_T}$$

Where:

$C_{Combined}$	=	Total Capacitance of the test loop due to added inductance, in farads
f	=	Frequency of test loop, in hertz
L_T	=	Loop inductance + added inductance, in henries

Using the above equations, various frequency combinations could be derived that differ by 10 kHz or more. One example of such combinations is tabulated in Table 5. In a five-lane freeway environment with one loop detector in each lane, there is not enough difference in lead length to provide a significant change in loop frequency. Combining a variable number of turns of wire with a carefully selected application of capacitors or inductors can ensure satisfactory operation without crosstalk. The patterns shown in Table 6 and Table 7 illustrate this approach.

3.4 CROSSTALK BETWEEN PARALLEL LEAD WIRES

Three saw cuts, each 50 mm (2 in) deep, were made parallel to the lead wire of loop B, at a spacing of 50 mm (2 in). Both lead wires were energized and tested at the sensitivity settings of low, medium, and high. The results of this part of the study indicate that no crosstalk occurs when the parallel wire leads are 50 mm (2 in), apart. The results were the same whether the leads were twisted or untwisted.

3.5 CROSSTALK BETWEEN TWISTED AND UNTWISTED LEAD WIRES

In this part of the study, all four loop detectors (A, B, C, and D) were connected to four Detector Systems stand-alone detector units. Different runs were made using low, medium, and high sensitivity settings over the four lead wires at the speeds of 32, 64, and 97 km/h (20, 40, and 60 mph) using a small car, a large car, and a pickup truck. The same experiments were repeated using Naztec rack-mounted detector units.

The results of this study found no indications of false detections over either the twisted or untwisted lead wires at all sensitivity settings.

Table 5. Various Frequency Combinations Using Inductors and Capacitors

No. of wire turns	Added Inductance in Series (in μH)	Added Capacitance in Series (in μF)	Frequency (in kHz)
2 turns	-	-	67
3 turns	-	-	65
4 turns	-	-	63
2 turns	200	-	57
3 turns	200	-	54
3 turns	400	-	44
2 turns	-	0.6	53
3 turns	-	0.6	51
4 turns	-	0.6	46

Table 6. Frequencies of Adjacent ILDs Using Inductors in a Five-Lane Freeway Environment

Lane No.	Loop Combination with Inductor/Capacitor in Series with Loop Circuit	Frequency (in kHz)
Lane 1	3 turns	65
Lane 2	3 turns + 220 μH	54
Lane 3	3 turns + 470 μH	44
Lane 4	4 turns + 100 μH	29
Lane 5	4 turns + 330 μH	20

Table 7. Frequencies of Adjacent ILDs Using Capacitors in a Five-Lane Freeway Environment

Lane No.	Loop Combination with Capacitor in Series with Loop Circuit	Frequency (in kHz)
Lane 1	3 turns	65
Lane 2	3 turns + 0.3 μF	55
Lane 3	4 turns	62
Lane 4	4 turns + 0.6 μF	46
Lane 5	3 turns	65

3.6 CROSSTALK IN THE CONTROLLER CABINET

The three active loops — A, B, and C — were energized, and the dummy load voltage and frequency were measured at 2 millivolts with approximately 40 kHz. Researchers determined the source of this signal to be from the loop nearest the dummy. The source of the signal or crosstalk was either loop-to-loop, cable-to-cable, or internal to the cabinet. To eliminate one condition at a time, portable loop A' was connected to the dummy with the same initial crosstalk indications. The first condition to be eliminated was "cable-to-cable." This was achieved by rerouting the lead cable to the dummy loop away from any other cables. This action had little or no effect on the 2 millivolt reading. The second condition to examine was cabinet wiring. This was performed by removing the dummy loop cable and dummy resistor lead from the cabinet terminal strip and terminating them outside the cabinet. This also had no effect on the 2 millivolt reading. Finally, the dummy loop was eliminated by shorting the lead wires at the loop end while all other connections remained normal. This eliminated the voltage across the dummy resistor.

This experiment showed that crosstalk, in the Riverside campus experimental setup, is primarily loop-to-loop. Cabinet wiring or cable-to-cable wiring has little effect and is of no significance.

4.0 FINDINGS AND RECOMMENDATIONS

The findings of this phase of the research are summarized as follows:

1. The crosstalk problem is primarily a problem of loop-to-loop crosstalk.

2. Crosstalk between lead wires was eliminated when the lead wires were spaced at 50 mm (2 in) or more.

3. There was no appreciable crosstalk measured within the controller cabinet.

4. Vehicle passage over the lead wires did not result in crosstalk, regardless of whether the leads were twisted or untwisted.

5. The threshold spacing at which crosstalk no longer occurred was 0.6, 0.9, and 1.2 meters (24, 36 and 48 inches), respectively, for low, medium, and high sensitivity settings. Some differences were observed for rack-mounted detectors, but spacings were less than those listed above.

6. Crosstalk can be reduced by operating adjacent loops at frequencies that differ by at least 10 kHz. This may be accomplished by placing inductors in series with the loop.

7. Spillover, or detection of vehicles in an adjacent lane was essentially eliminated when the vehicle was 1.1 meter (42 inches) from the edge of the loop.

8. For narrow lanes and other unique situations, spacing between loops, and between loops and lane lines may be increased by reducing the loop width to 1.5 meters (5 feet). A reduction to 1.5 meters does not appreciably alter the loop field. Any reduction below this value tends to reduce the height of the electromagnetic field and, thus, reduces the probability of detecting and holding a detection on high-profile vehicles.

APPENDIX: CROSSTALK STUDIES

CROSSTALK STUDIES

Frequency Setting: High

Sensitivity Setting: High

Number of Turns of Wire= 4

Detector 1 (Permanent)
SN - 471765
Type - 813-103SS
Manufacturer: Detector Systems

Detector 2 (Movable)
SN - 471766
Type - 813-103SS
Manufacturer: Detector Systems

Distance m (ft.)	Detected	Not Detected	Total
.9 (3)	5	0	5
1.1 (3.5)	3	3	6
1.2 (4)	0	5	5

Frequency Setting: High

Sensitivity Setting: High

Number of Turns of Wire= 5

Frequency of the Permanent loop = 32.068 kHz

Frequency of the Movable loop = 33.112 kHz

Equipment Used: Frequency Probe

Detector 1 (Permanent)
SN - 471765
Type - 813-103SS
Manufacturer: Detector Systems

Detector 2 (Movable)
SN - 471766
Type - 813-103SS
Manufacturer: Detector Systems

Distance m (ft.)	Detected	Not Detected	Total
.9 (3)	2	3	5
1.1 (3.5)	0	5	5

Frequency Setting: High

Sensitivity Setting: High

Number of Turns of Wire= 6

Detector 1 (Permanent)
SN - 471765
Type - 813-103SS
Manufacturer: Detector Systems

Detector 2 (Movable)
SN - 471766
Type - 813-103SS
Manufacturer: Detector Systems

Distance m (ft.)	Detected	Not Detected	Total
.9 (3)	4	2	6
1.1 (3.5)	2	5	7
1.2 (4)	5	7	12
1.4 (4.5)	0	5	5
1.5 (5)	0	5	5

Frequency Setting: High

Sensitivity Setting: Medium

Number of Turns of Wire= 4

Detector 1 (Permanent)
SN - 471765
Type - 813-103SS
Manufacturer: Detector Systems

Detector 2 (Movable)
SN - 471766
Type - 813-103SS
Manufacturer: Detector Systems

Distance m (ft.)	Detected	Not Detected	Total
.5 (1.5)	3	4	7
.6 (2)	0	5	5
.8 (2.5)	2	4	6
.9 (3)	0	5	5
1.1 (3.5)	0	5	5

Frequency Setting: High

Sensitivity Setting: Medium

Number of Turns of Wire= 6

Detector 1 (Permanent)
SN - 471765
Type - 813-103SS
Manufacturer: Detector Systems

Detector 2 (Movable)
SN - 471766
Type - 813-103SS
Manufacturer: Detector Systems

Study Types

Distance m (ft.)	Detected	Not Detected	Total
.6 (2)	1	5	6
.8 (2.5)	0	5	5
.9 (3)	0	5	5
1.1 (3.5)	0	5	5
1.2 (4)	0	5	5

Frequency Setting: High

Sensitivity Setting: High

Number of Turns of Wire= 3

<u>Detector 1</u> (Permanent)
SN - 471765
Type - 813-103SS
Manufacturer: Detector Systems

<u>Detector 2</u> (Movable)
SN - 471766
Type - 813-103SS
Manufacturer: Detector Systems

Study Type: Untwisted lead wire crosstalk

Distance mm (in.)	Detected	Not Detected	Total
50.8 (2)	6	2	8
76.2 (3)	3	3	6
101.6 (4)	7	1	8
152.4 (6)	1	5	6
203.2 (8)	1	6	7

<u>Note</u>: The lead wire for the movable loop consisted of two separate sets of wires that were not separated by a constant distance. Because of this, inductance developed around the two wires so that crosstalk was observed.

Frequency Setting: High

Sensitivity Setting: Low

Number of Turns of Wire= 3

Detector 1 (Permanent)
SN - 471765
Type - 813-103SS
Manufacturer: Detector Systems

Detector 2 (Movable)
SN - 471766
Type - 813-103SS
Manufacturer: Detector Systems

Study Type: Untwisted lead wire crosstalk

Distance mm (in.)	Detected	Not Detected	Total
76.2 (3)	0	5	5

Note: The lead wire used for the movable loop in this test consisted of two individual wires that were not separated with a constant distance.

Frequency Setting: High

Sensitivity Setting: Medium

Number of Turns of Wire= 3

<u>Detector 1</u> (Permanent)
SN - 471765
Type - 813-103SS
Manufacturer: Detector Systems

<u>Detector 2</u> (Movable)
SN - 471766
Type - 813-103SS
Manufacturer: Detector Systems

Study Type: Untwisted lead wire crosstalk

Distance m (ft.)	Detected	Not Detected	Total
.9 (3)	1	4	5
1.2 (4)	0	6	6

<u>Note</u>: The lead wire used for the movable loop in this test consisted of two individual wires that were not separated with a constant distance. There was, therefore, an inductance field around the two wires and, thus, crosstalk was observed.

Frequency Setting: High

Sensitivity Setting: High

Number of Turns of Wire= 3

Detector 1 (Permanent)
SN - 471765
Type - 813-103SS
Manufacturer: Detector Systems

Detector 2 (Movable)
SN - 471766
Type - 813-103SS
Manufacturer: Detector Systems

Study Type: Untwisted lead wire crosstalk

Distance mm (in.)	Detected	Not Detected	Total
50.8 (2)	0	5	5

Note: The lead wire for this study consisted of an extension cord which separated the two wires by a constant distance (zero). There was, therefore, no mutual inductance between them and, thus, no crosstalk was observed.

Frequency Setting: High

Sensitivity Setting: High

Number of Turns of Wire= 6

Detector 1 (Permanent)
SN - 471765
Type - 813-103SS
Manufacturer: Detector Systems

Detector 2 (Movable)
SN - 471766
Type - 813-103SS
Manufacturer: Detector Systems

Study Type: Untwisted lead wire crosstalk

Distance mm (in.)	Detected	Not Detected	Total
50.8 (2)	0	5	5

Note: The lead wire for this part of the study was an extension cord. The spacing of the individual wires was constant and so there was no mutual inductance field around them and hence no crosstalk was observed. Since no crosstalk occurred between the loops with 3 turns of loop at a spacing of 2" between the two lead wires (permanent and movable), the data collection was terminated.