FINAL REPORT

ELECTRICAL ENGINEERING RESEARCH SUPPORT FOR FDOT TRAFFIC STATISTICS OFFICE

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16. Abstract

The aim of this project was to provide electrical engineering support for the telemetered traffic monitoring sites (TTMSs) operated by the Statistics Office of the Florida Department of Transportation. This project was a continuation of project BD-543-3. The project consisted of four main efforts that are detailed in this report. The first effort was to conduct lightning surge suppression field tests to characterize the lightning surge environment of TTMS in-pavement sensors. The second effort was to develop segmented sensor interface electronics improvements for more accurate detection of segment closures on an extruded polymer segmented sensor. This effort was reduced at the request of the FDOT and funding is being sought from the Federal Highway Administration (FHWA) for continued development. The third task was to provide support for use of the Sensys wireless traffic detection system for short-term traffic count applications. The fourth effort was to monitor loop ground resistance and inductance, and piezoelectric sensor voltage outputs at 2 TTMSs. The goal of this effort was to identify the effects of sealant degradation on the electrical characteristics of the in-pavement sensors.

The results of the first task were improved characterization of the lightning surges and specification of surge suppressor requirements. The second task resulted in improved modeling of the extruded sensor. The third task resulted in an instruction manual for using the Sensys system in short-term traffic count applications. The fourth task is ongoing but has already demonstrated differences in sealant performance and maintenance procedures.

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Judith Lesika

Executive Summary

The Florida Department of Transportation (FDOT) currently monitors about 7,000 traffic count sites including over 300 permanent telemetered traffic monitoring sites (TTMSs). The monitoring equipment generally consists of traffic-actuated sensing devices imbedded in the pavement and classification equipment that captures the traffic volumes, vehicle classifications, and truck weights. The information captured by the field monitoring devices is thereafter downloaded and processed to get information on annual average daily traffic (AADT), K-factor, T-factor, truck weight, and other pertinent information. This information is used in various forms by different FDOT departments for planning, designing, operations, and maintenance activities relating to both highway pavements and bridges.

The FAMU-FSU College of Engineering (COE) was contracted to provide electrical engineering support to the Transportation Statistics Office of the FDOT in improving the accuracy and reliability of the TTMS sensors and communication equipment. The principal investigator for the project was Dr. Bruce A. Harvey of the Department of Electrical and Computer Engineering. The project was conducted from December 10, 2008 to March 30, 2010. The following major efforts conducted under this project:

1. Lightning Surge Suppression Field Tests
2. Segmented Sensor Interface Electronics Improvements
3. Sensys System Support for Short-Term Traffic Count Applications
4. Monitoring Loop Ground Resistance and Piezoelectric Sensor Outputs

Lightning Surge Suppression Field Tests

Lightning surge current count and measurement field tests were continued in this project with the goal of characterizing the lightning surges experienced by in-pavement sensors at TTMSs. The data collected demonstrates the need for surge suppressors to protect the count and classification equipment at the sites. These suppressors need to be able to protect the equipment from lightning surges of at least 3,000 amps and to endure thousands of surges.

Segmented Sensor Interface Electronics Improvements

Previous research demonstrated that a segmented sensor can improve the accuracy of vehicle classification. Also demonstrated was the feasibility of using a more durable extruded polymer segmented sensor. In this effort, electrical characterization of the extruded sensor was begun with the goal of developing an electronic interface capable of more accurately detecting segment closures. This effort was reduced at the request of the FDOT in order to apply more resources to other efforts in this project. Funding from the Federal Highway Administration (FHWA) is being sought to continue this research and development.

Sensys System for Support for Short-Term Traffic Count Applications

The Sensys wireless traffic count system was investigated and tested to determine if and how this system can be used for temporary traffic count applications. The concept included installing permanent wireless detectors in the count site and using a mobile Sensy access point to collect the count data. This effort resulted in the identification of the appropriate access point (AP240S) and the appropriate procedures for using the Sensys system for temporary traffic count applications. An instruction manual was compiled and is included in Appendix A.

Monitoring Loop Ground Resistance and Piezoelectric Sensor Outputs

This research team in cooperation with a research team led by Dr. Ren Moses monitored the electrical characteristics (inductance, ground resistance and voltage output) of in-pavement sensors at Sites 112 and 352 over a period of about 6 months. The goal of the effort was to monitor the effects of sensor sealant degradation on the electrical performance of the sensors. This ongoing effort is helping the FDOT identify appropriate sealants to use for in-pavement sensor installation, and to help the FDOT develop effective maintenance procedures to prolong the useful life of in-pavement sensors.

Benefits to the FDOT

All of the efforts under this project are helping the FDOT improve accuracy and reliability of traffic data collection, reduce maintenance cost of TTMS installations, and identify new technologies to aid in the collection of traffic data statistics.

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1. Introduction

The Florida Department of Transportation (FDOT) currently monitors about 7,000 traffic count sites including over 300 permanent telemetered traffic monitoring sites (TTMSs). The monitoring equipment generally consists of traffic-actuated sensing devices imbedded in the pavement and classification equipment that captures the traffic volumes, vehicle classifications, and truck weights. The information captured by the field monitoring devices is thereafter downloaded and processed to get information on Annual Average Daily Traffic (AADT), K-factor, T-factor, truck weight, and other pertinent information. This information is used in various forms by different FDOT departments for planning, designing, operations, and maintenance activities relating to both highway pavements and bridges.

The Department of Electrical and Computer Engineering at the FAMU-FSU College of Engineering (COE) was contracted to provide support to the Transportation Statistics Office (TSO) of the FDOT in improving the accuracy and reliability of the TTMS sensors and communication equipment. The major efforts conducted under this project were

1. Lightning Surge Suppression Field Tests,
2. Segmented Sensor Interface Electronics Improvements,
3. Sensys System Support for Short-Term Traffic Count Applications, and
4. Monitoring Loop Ground Resistance and Piezoelectric Sensor Outputs.

In addition to the major efforts, the COE also provided technical support for the TSO as needed throughout the project.

2. Lightning Surge Suppression Field Tests

Protection of the over 300 permanent TTMS installations from the damaging effects of lightning is of critical importance to the FDOT. Sites damaged by lightning result in the reduction of statistical information collected on the number and classification of vehicles operating on Florida's highways. Also, the cost of repairing the sites damaged by lightning is considerable. Florida is known as the lightning capital of North America and thus much of the state (particularly central Florida) is subject to more lightning than the rest of the United States.

To address the problem of lightning protection for TTMSs this research project continued the efforts of a previous research projects (Project No. BC-596, "Improving Operation of FDOT Telemetered Traffic Monitoring Sites" and Project No. BD-543-3, "Electrical Engineering Support for Telemetered Traffic Monitoring Systems"). In this task, more sensors and loggers were acquired to expand the testing to a greater number of sites and sensors. More interface circuits were also constructed to accommodate the number of sensors (current transformers). Each of the sensors, loggers and interface circuits will be tested and calibrated in the laboratory using the MIG0606 surge generator. Each of the sensors and interface circuits will be calibrated to measure surges of 70 amps to 4,000 amps; a range that has worked well in past field tests. During the peak lightning season in the summer of 2009, these lightning current measurement systems were installed in TTMSs along the I-4 corridor.

Activities Conducted

Discussions were held with Rick Reel and Kip Jones to determine the extent of the measurements to be conducted. In the previous project (BD-543-3) 2 surge current measurement systems were assembled consisting of a Campbell Scientific CR-800 data logger, 2 Model 101 Pearson Electronics current sensors and 2 custom sensor interface boxes. This allowed the detection and measurement of the lightning surge currents on 2 sensor leads in each of 2 TTMS locations over the summer of 2008. The data collected in 2008 indicated that the surge currents may differ depending on whether the currents are measured on the active lead of the piezoelectric sensors or the ground leads. More measurements were needed to determine the validity of the difference.

Discussions with the FDOT concluded that an additional 3-sensor current measurement system was to be added to the two existing 2-sensor measurement systems. This will enable the collection of date from an additional TTMS location and the comparison of surge currents on the active and ground leads of a piezoelectric sensor. Therefore, 3 Model 101 Pearson Electronics current sensors and an additional Campbell Scientific CR-800 data logger were acquired. The sensor interface boxes used in 2008 had been modified several times so it was decided to build seven new sensor interface boxes for the 4 existing sensors and the 3 new sensors. All the surge current measurement systems were completed, calibrated and programmed.

The sites chosen for installation of the surge current measurement systems were TTMS Sites 0086 and 0162 near Tampa, and Site 0060 on US98 in Franklin County. The sites near Tampa each had a 2-sensor surge current measurement system installed, and the 3-input system was installed in Site 0060.

The schedule of lightning surge suppression field tests conducted in 2009 was as follows:

TTMS Site 0060

- June 11, 2009: Current measurement system with 3 current sensors installed. One current sensor was connected to monitor the surge current on Loop 4. Two current sensors were connected to monitor the currents on the active and ground leads of Piezo WB.
- July 14, 2009: Data downloaded from the CR800 logger. No surges recorded. The op-amps were replaced (previous experience indicates these are the most vulnerable to failure). Removed the batteries for charging.
- July 15, 2009: Charged batteries placed back in the cabinet and logger restarted.
- August 19, 2009: Data downloaded from the logger. Only 2 surges recorded. All equipment removed for testing. No problems found when equipment tested in the lab.
- September 4, 2009: Current measurement system reinstalled at the site. Same configuration used as was used in June.
- October 16, 2009: Data downloaded from the logger. All equipment was removed from the site and the field test was ended. Total number of days monitored at Site 0060 was 110 days.

TTMS Site 0086

- June 14, 2009: Current measurement system with 2 current sensors installed. One current sensor was connected to monitor the surge current on Loop 8 and the other monitoring the ground lead on Piezo 4.
- July 20, 2009: Downloaded data from the CR 800 logger and removed batteries for charging. On Loop 8 there were 9 periods of lightning surge activities. On Piezo 4 there were 6 periods of lightning surge.
- July 21, 2009: Charged batteries placed back in the cabinet and logger restarted.
- August 17, 2009: Downloaded the data from the logger and the batteries were replaced. On Loop 8 there were 8 periods of lightning surge activities since July 21st. On Piezo 4 there were also 8 periods of lightning surge since July 21st.
- October 19, 2009: Data downloaded from the logger. All equipment was removed from the site and the field test was ended. Total number of days monitored at Site 0086 was 126 days.

TTMS Site 0162

- June 14, 2009: Current measurement system with 2 current sensors installed. One current sensor was connected to monitor the surge current on Loop 4 Red and the other monitoring the active lead on Piezo 4 Black.
- July 20, 2009: Downloaded data from the CR 800 logger and removed batteries for charging. On Loop 4 Red there were 6 periods of lightning surge activities recorded. On Piezo 4 Black there were 5 periods of lightning surge activity.
- July 21, 2009: Charged batteries placed back in the cabinet and logger restarted.
- August 17, 2009: Downloaded the data from the logger and the batteries were replaced. On Loop 4 Red there were 7 periods of lightning surge activities recorded since July 21st. On Piezo 4 Black there were also 7 periods of lightning surge activity since July 21st.

- October 19, 2009: Data downloaded from the logger. All equipment was removed from the site and the field test was ended. Total number of days monitored at Site 0162 was 126 days.

Results of Lightning Surge Suppression Field Tests

A summary of the lightning surges recorded during the field test in 2009 are tabulated in Figure 2.1.

Site # (#days)	Sensor	# Surges	Max. Surge Current	Ave. Surge Current
0060 (110)	Loop 4	15	546 A	219 A
	Piezo WB – Ground Lead	24	471 A	176 A
	Piezo WB – Active Lead	27	466 A	167 A
0086 (126)	Loop 8	464	1007 A	253 A
	Piezo 4 – Ground Lead	221	886 A	190 A
0162 (126)	Loop 4 Red	357	679 A	113 A
	Piezo 4 Black – Active Lead	443	845 A	116 A

Figure 2.1: Summary of Lightning Surges Recorded in 2009

One of the primary objectives for the data collection at Site 0060 was to determine if the number and magnitude of lightning surges differed between the active and ground leads of a piezoelectric sensor. For this test there was little difference between the active and the ground leads of Piezo WB at Site 0060. Figure 2.2 shows the recorded surges and demonstrates the similarity of the surges recorded on the active and ground leads of the piezo sensor. The only difference was 2 small surges recorded on the active lead on August 15 and September 15, 2009.

There were relatively few surges recorded at Site 0060 (in comparison with site 0086 and 00162). Site 0060 recorded approximately 1 surge every 4 days on each of the sensors monitored. Sites 0086 and 0162 had between 1.75 and 3.7 surges per day recorded on the sensors monitored. While the data at site 0060 showed little difference between the surges recorded on the active and ground leads of a piezo sensor, the amount of data collected was small and hence the data is not thoroughly conclusive. Further testing is needed.

The total number and magnitude of surges per sensor recorded during 2009 were both lower than were recorded in 2008. In 2008, 3 loops were monitored for a total of 380 days recording an average of 7.77 surges per day, and 1 piezo sensor was monitored for 127 days recording an average of 32.7 surges per day. The peak surge recorded in 2008 was 2,679 amps. In 2009, 3 loops were monitored for a total of 362 days recording an average of 2.31 surges per day, and 3 piezo sensors were also monitored for a total of 362 days recording an average of 1.90 surges per day. The peak surge recorded in 2009 was 1007 amps.

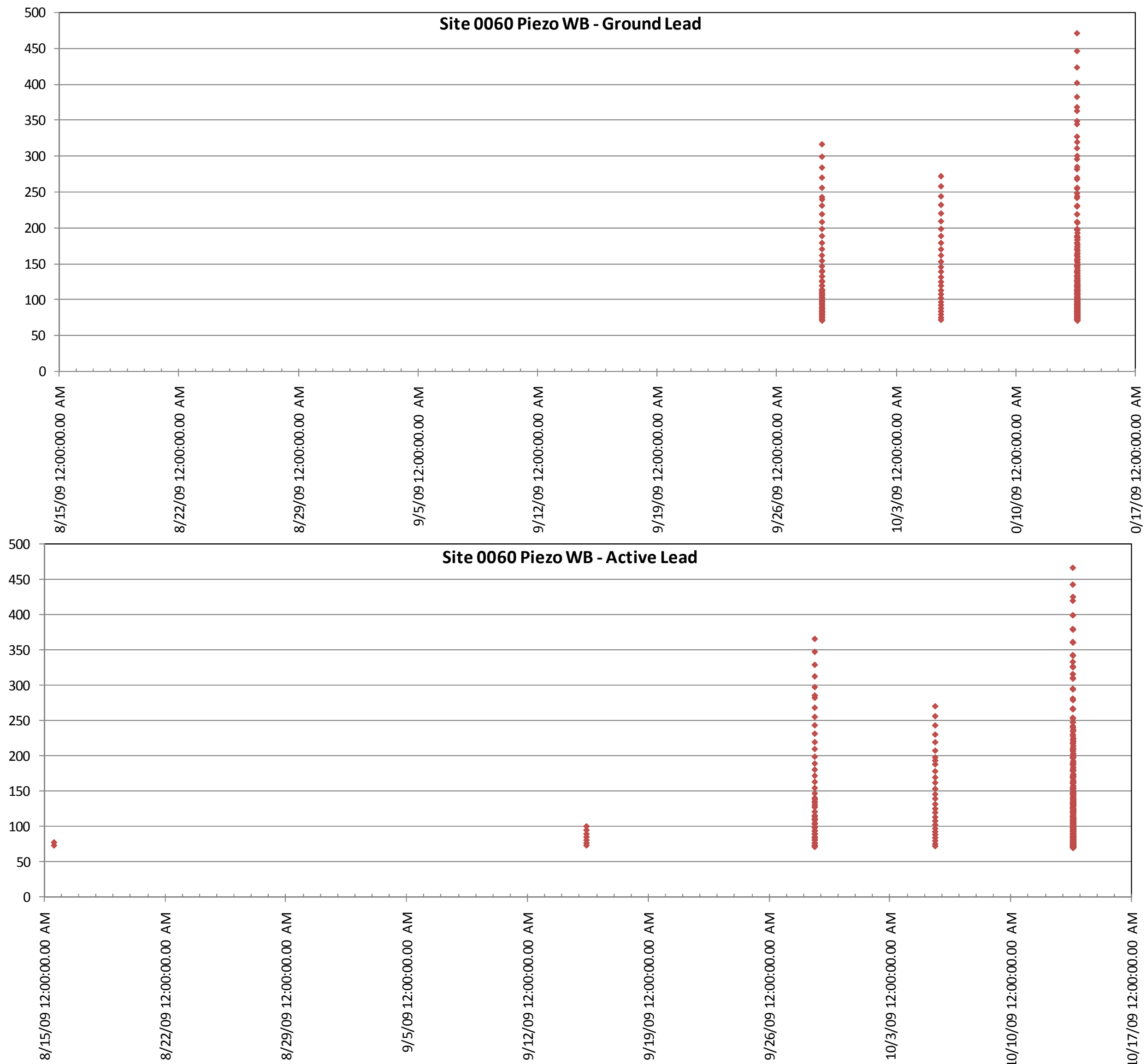


Figure 2.2: Comparison of Surges Recorded on the Piezo Sensor Active and Ground Leads

Analysis and Recommendations

Although the lightning surges were lower in 2009 than in 2008, the results were fairly consistent. Peak surges were in the low 1,000s of amps and multiple surges per day were averaged. The Lightning surge current measurement system developed and used in these tests is providing significant insight into the number and magnitude of lightning surges experienced by the TTMS in-pavement sensors. These results will help the FDOT choose the appropriate surge suppressors to protect the TTMS equipment from lightning damage. The result will be lower maintenance costs and higher reliability data collection. It is recommended that testing continue to improve the quality, quantity and variety of the data collected to more accurately quantify the lightning surge environment for the TTMS sensors.

3. Segmented Sensor Interface Electronics Improvements

The Florida Department of Transportation currently maintains over 300 telemetered traffic monitoring sites (TTMSs) throughout the state to monitors traffic operations on the state highway system. Most of these TTMSs employ inductive loop detectors and piezoelectric axle sensors to determine the number of axles, axle spacing and length of individual vehicles. This information is used to attempt to determine the classification of the vehicles. Vehicle classification statistics are used to estimate pavement wear and traffic patterns, and to plan maintenance and improvements of the roads. Thus accurate classification of vehicles is critical to the FDOT.

Classification of vehicles using number of axles, axle spacing and length alone can result in a significant number of classification errors. For example, a long-bed pickup truck with all single tires (Class 3) can easily have the length and axle spacing of some smaller trucks with 2 axles and 6 tires (Class 5). Class 5 vehicles are generally heavier and carry larger loads than a Class3 pickup truck. Such misclassifications lead to inaccurate pavement loading statistics.

Classification algorithms can be improved if the axle sensor had the ability to detect single versus dual tires on each axle. This information would greatly reduce misclassifications of vehicles such as the Class 3 –Class 5 errors. John Reed of PET Corporation proposed a design for a segmented axle sensor that can provide an estimate of the tire width and thus discriminate between single and dual tire axles. This effort was designed to determine if the segmented axle sensor is feasible and if the identification of single and dual tire axles can improve vehicle classification accuracy.

Background

This effort is a continuation of efforts conducted under a previous research project (FDOT Project BD-543-3). Initial design of the electronics interface for a segmented axle sensor were conducted and field tests were performed to demonstrate the feasibility of using segmented axle sensors to improve vehicle classification and to test the performance of the sensors and interface electronics.

The effort was conducted in two phases. First, PET Corporation produced a prototype sensor using metallic conductors. The segment lengths were designed with the aid of a study of tire footprints conducted on a separate research project by Dr. Ren Moses. An electronics interface was designed and constructed to sense the segment closures and transmit the closure information via a serial port to a classification algorithm running on a laptop computer. Field tests were conducted to demonstrate the operation of the sensor and interface, and to demonstrate the improved classification accuracy using the tire width information.

The metallic sensor was implemented to provide a proof of concept before proceeding to the second phase of the project. In the second phase of the project PET Corporation constructed a prototype of a segmented sensor made entirely of conductive and non-conductive extruded polymers. The extruded polymers are expected to be much more durable than the metallic conductors and eventual automatic extrusion of a sensor is far more cost-effective and flexible than the manual construction required for the metallic sensors.

A new electronics interface was designed and constructed for use with the extruded sensors. The extruded polymer conductors used in the new prototype have a very high resistance that complicates the interface design. The design team modified a design originated by Dr. David Bourner of the University of Maryland. Several modifications were made to Dr. Bourner's design to improve the speed and accuracy of the electronics interface. The extruded sensors and interface electronics were field tested along with the classification algorithm to demonstrate the feasibility and benefits of the extruded sensor.

The implementation of the electronics interface and the field testing of the prototype metallic segmented sensor demonstrated that tire width estimation resulting in single versus dual tire discrimination can significantly improve the vehicle classification accuracy. The implementation of an interface for and testing of the prototype extruded segmented sensor demonstrated the feasibility of the design and interfacing of an extruded segmented sensor. However, the field test also demonstrated the limitations of the existing design. The electronics interface used with the extruded sensor had a limited frequency response and could not always properly identify the closed segments.

Activities Conducted

The goal of this effort was to re-design the interface electronics for the extruded segmented sensor. The previous approach was to detect closures by measuring the direct (DC) current through each input/output pair. This approach was slow due to the high resistance and capacitance of the sensor itself. Also, the approach also could not differentiate between certain patterns of closures. To overcome these shortcomings, the research team will investigate new designs using a continuous signaling approach that uses frequency diversity, code diversity and/or time-of-arrival techniques. These techniques can improve the speed at which a closure is detected, and have the potential to improve discrimination between certain patterns of closures that led the previous interface electronics to report false (shadow) closures.

A 16-segment axle sensor made of extruded polymers was received from PET Corporation. The sensor was tested to determine the bandwidth of the sensor that could be used for a frequency diversity detection scheme. It was found that due to the resistance and capacitance inherent in the sensor the frequency of test signals transmitted through the sensor needed to be no higher than about 2 kHz in order to differentiate between open and closed segments. Therefore the initial plan is to build a 4-input system where sinusoids are transmitted at different frequencies to each of the sensor's quartets of segments. The return signals on the 4 individual segment lines will be filtered to identify the frequency of the returned signal. The combination of return line and frequency will uniquely determine the location of a single closed segment on the sensor.

The multi-frequency method for detecting segment closures in the extruded sensor was found to be very limiting and complex to implement. Capacitive links between conductors in the sensor severely complicated the accurate detection of closed segments. Also, discussions for future applications indicated that sensors with significantly more segments are desirable for some applications. Other techniques including pulse size variations and time-of-arrival pulse techniques were also briefly investigated through laboratory testing with mixed results. It was determined that a more accurate model of the sensor was needed in order to accelerate the design process through simulation.

The modeling of the extruded sensor was begun by measuring resistance of the various conductors internal to the sensor. This was facilitated by John Reed who supplied an unassembled extruded sensor on which measurement could be made. The following resistances were determined as the nominal resistances internal to the sensor:

Resistance of Extruded Conductor:	R_C	=	25 kΩ per 6" segment
Resistance of Conductor and Contact:	R_{CC}	=	3.4 kΩ per 6" segment
Resistance of Conductors to Connector:	R_E	=	3 kΩ each connector

Using these empirical values for resistance a DC or resistive model of the sensor was developed. This model is depicted in Figure 3.1. Note that some of the resistors in the circuit of Figure 3.1 are combinations of measured resistors. For example, $R_{35} = 4.7\ k\Omega = R_E + 0.5 * R_{CC}$.

The DC model was simulated using several different DC stimulating (applying voltages or currents) and sensing approaches to see if all combinations of closures can be accurately detected based solely on the DC voltages and currents. Figure 3.2 shows an example of one of the stimulating and sensing approaches attempted. It was found that in all approaches tried there were still patterns of segment closures that could not be accurately detected; even patterns that would be common during use in the roadway. Single segment closures and multiple closures within a segment group (quartet) can be accurately detected. However, none of the techniques analyzed can provide highly reliable closure detections when closures occur on more than one segment group at the same time.

At the request of Rick Reel the efforts under this task were stopped at this point in the research. Rick Reel, John Reed from PET Corporation and Dr. Harvey were working on getting the effort funded through an Federal Highway Administration (FHWA) grant. An FHWA grant would provide greater resources to complete the research and development of interface electronics for the extruded segmented sensor. The project resources were applied to other efforts in the project.

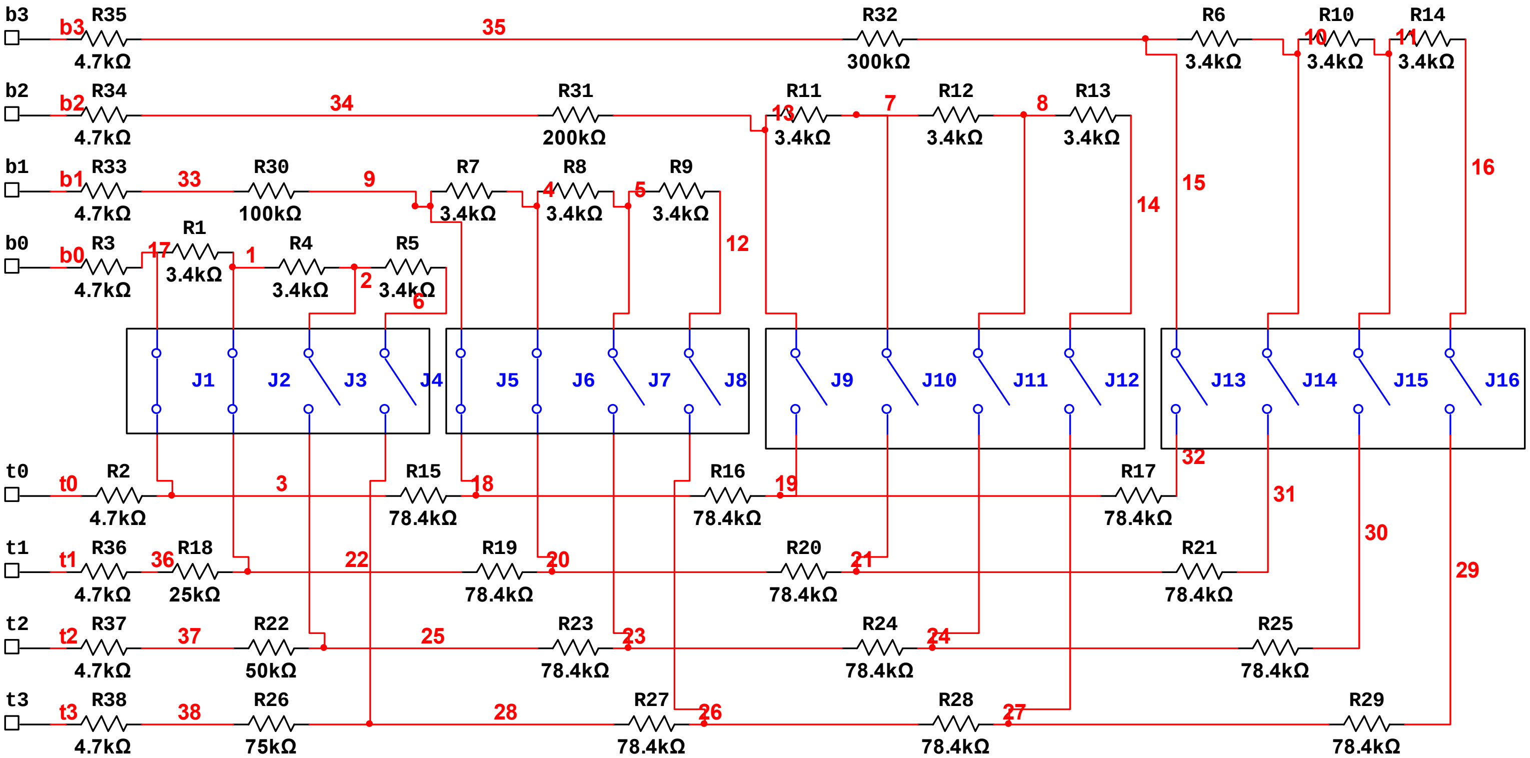


Figure 3.1: DC or Resistive Model for the Extruded Segmented Sensor

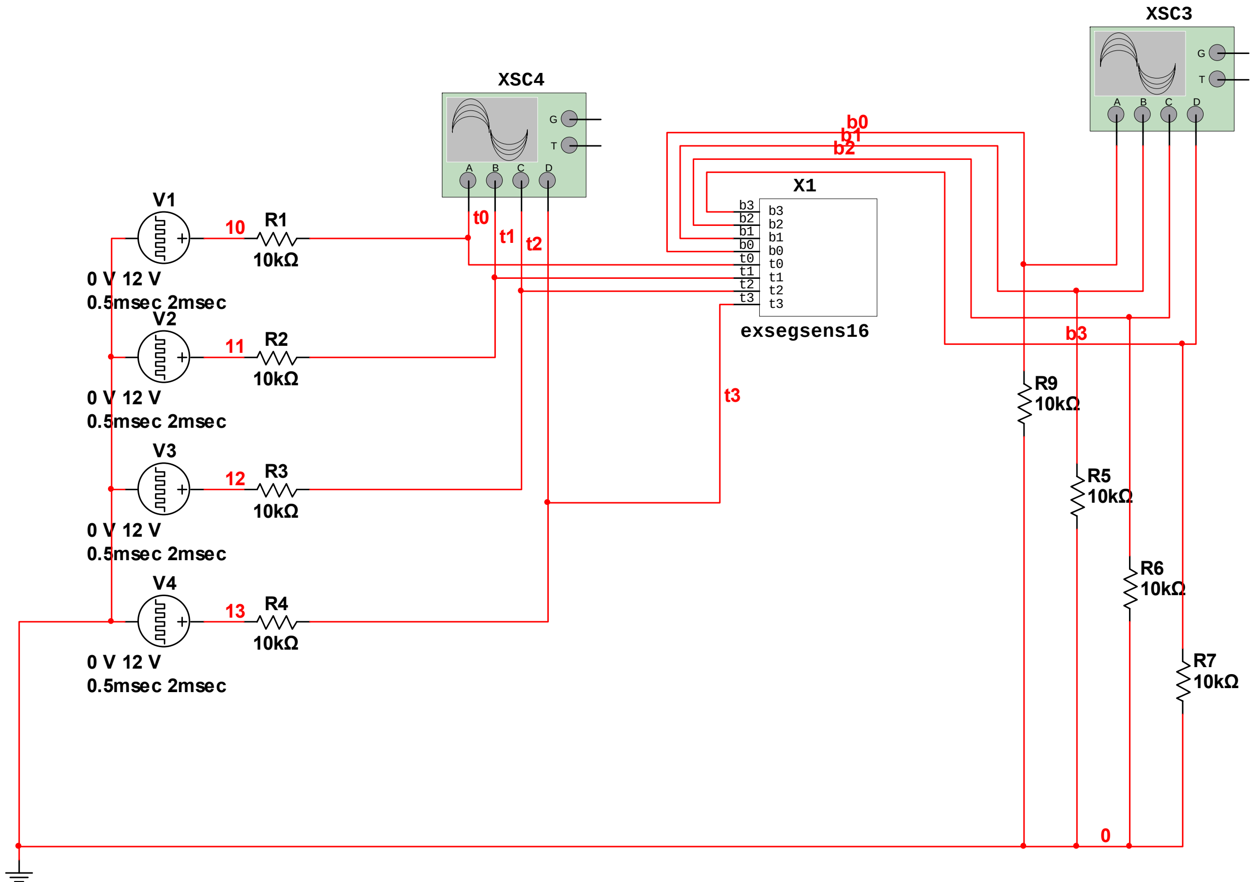


Figure 3.2: Example DC Stimulating and Sensing Approach to Detecting Closed Segments

4. Sensys System Support for Short-Term Traffic Count Applications

The FDOT tasked the project team to determine if a Sensys wireless detection system can be used to efficiently conduct short-term traffic counts. In particular, the project team was to identify easy methods to program the Sensys counters and to retrieve the data from the counters. The concept was to install in-ground sensors at each of the sites used regularly for short-term traffic counts. A single access point (AP) can then be moved from site to site to record the data from the traffic sensors. The challenge is to identify the procedures needed to set up the access point for each site, and then determine how to store the set-up for the next time the access point is returned to the particular site. The Sensys access point was designed for permanent placement with access to a network connection to collect the traffic data at a central site. The Sensys access points do have some capability for local data collection and thus have the potential to be used in a temporary count site without access to a network connection.

The FDOT had a Sensys access point and in-ground sensors installed at site 3041 (in Tallahassee). The project team set up a portable computer to communicate with the access point and installed the access point management software, TrafficDOT, on the computer. A study of the Sensys manuals determined and a teleconference with Brian Fuller, Sensys technical support, confirmed that a Sensys access point can backup it's configuration to named filed on the computer. This process is an efficient way to restore the configurations for each temporary traffic count site for future use.

The access point installed at site 3041 was determined to be the model AP240U access point which is used to activate contact closures for external traffic count equipment, but not capable of storing traffic count statistics. Statistics can only be collected in an AP240 with the S (statistics) option. Brian Fuller was contacted and he was able to send a license that upgrades the AP240U to a AP240US access point which can collect binned traffic counts using the APSTAT function.

The upgraded access point has been tested to verify that it can indeed collect binned traffic counts that can easily be downloaded using an FTP connection through a standard web browser (Internet Explorer, Firefox …). The backup and restore functions have been tested and verified to enable a use to change the APs configuration (e.g. to move the access point to another site) and then to be able to restore the configuration to the previous state.

An instruction manual was compiled to assist the FDOT personnel in setting up and using a Sensys wireless detection system for temporary count and classification sites. This manual includes instructions for performing the initial set-up of an access point at a count site, backing up and restoring configurations for moving the access point between temporary sites, and other necessary instructions such as setting time and downloading data. The instruction manual is provided in Appendix A.

5. Monitoring Loop Ground Resistance and Piezoelectric Sensor Outputs

Obtaining reliable data from the piezoelectric sensors and inductive loop sensors used in the over 300 TTMSs maintained throughout the state of Florida is of major concern to the FDOT Transportation Statistics Office. Maintaining these in-pavement sensors is a continual task for the FDOT. The wear from the traffic eventually begins to compromise the sealants used in the installation of the sensors. As the sealants break down the ground resistance of the loops may drop and the output voltage of the piezo sensors may be reduced. This reduces the reliability of the sensors and the accuracy of the traffic count/classification equipment. The goals of this effort include identifying the most efficient maintenance procedures to extend the useful life of in-pavement sensors, and to identify the more reliable sealants and grouts to use during installation of the sensors.

The objective of this task was to perform a field performance evaluation of the sealants and grouts used for piezoelectric axle sensor and inductive loop sensor installations. The two sites picked for field evaluation of sealants and grouts were Site 352 on Interstate 10 (I-10), and Site 112 on Interstate 75 (I-75). This evaluation was conducted in cooperation with the research team led by Dr. Ren Moses of the Civil and Environmental Engineering Department (BDK83, TWO #977-04) Dr. Moses' team provided periodic observation of the rate of deterioration by taking photographs and videos of how the bonding materials appeared over time. The research team for this project performed electrical readings including the inductance and ground resistance of the loop sensors, and voltage outputs of the piezoelectric axle sensors. The measurements and observations were taken during both dry and wet weather conditions to determine whether there was any moisture effect on the readings.

The information and evaluations were conducted over a period of time to evaluate the deterioration of the sealants and grouts over time. Site 352 has 5 loop sensors and 4 piezo sensors installed using a variety of sealants and grouts. This site is not an active site for collecting traffic statistics, but rather a test site allowing the evaluation of the performance of sensor sealants. Site 112 is an active count/classification site where some problems with existing sealants were detected prior to the start of this effort. Some of the sensors were replaced while others were re-sealed in order to evaluate the differences in degradation for new sensor installations versus repairing sealants in sensors.

5.1 Experimental Setup

In order to get the information of interest, the following pieces of equipment were used:

- Ground Resistance and Inductance
  - Multimeters (Ohmmeter and Inductance Meter)
  - Screwdrivers
- Voltage output
  - Test Vehicle: Chrysler Town and Country
  - Datalogger: National Instrument USB-6009 Multifunction I/O

- Labview Express Software
- Laptop Computer
- Wire Probes

Recording Voltage Outputs from Piezoelectric Axle Sensors

The datalogger for measuring the piezoelectric sensor voltage output at Site 352 was the National Instrument (NI) USB-6009 Multifunction I/O (shown in Figure 5.1). The NI datalogger has four differential voltage outputs each measuring the result from one of the four piezo sensors. Each differential out has a positive and negative terminal. All the four negative terminals (CH1-, CH2-, CH3- and CH4-) from the datalogger are grounded to the earth ground attached to the equipment cabinet at site 352 on interstate 10 (I-10). The four positive terminals (CH1+, CH2+, CH3+ and CH4+) of the datalogger are connected to the positive signal connections on the piezoelectric sensors 1-4 respectively. For proper triggering, the first sensor a vehicle on the highway will encounter is connected to CH1. The datalogger is then connected to the laptop via a USB cable.

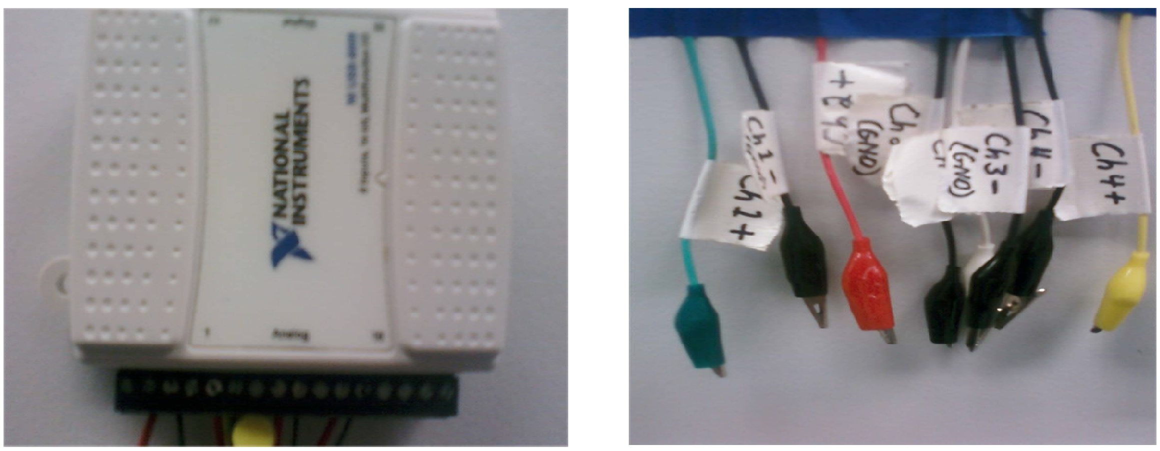
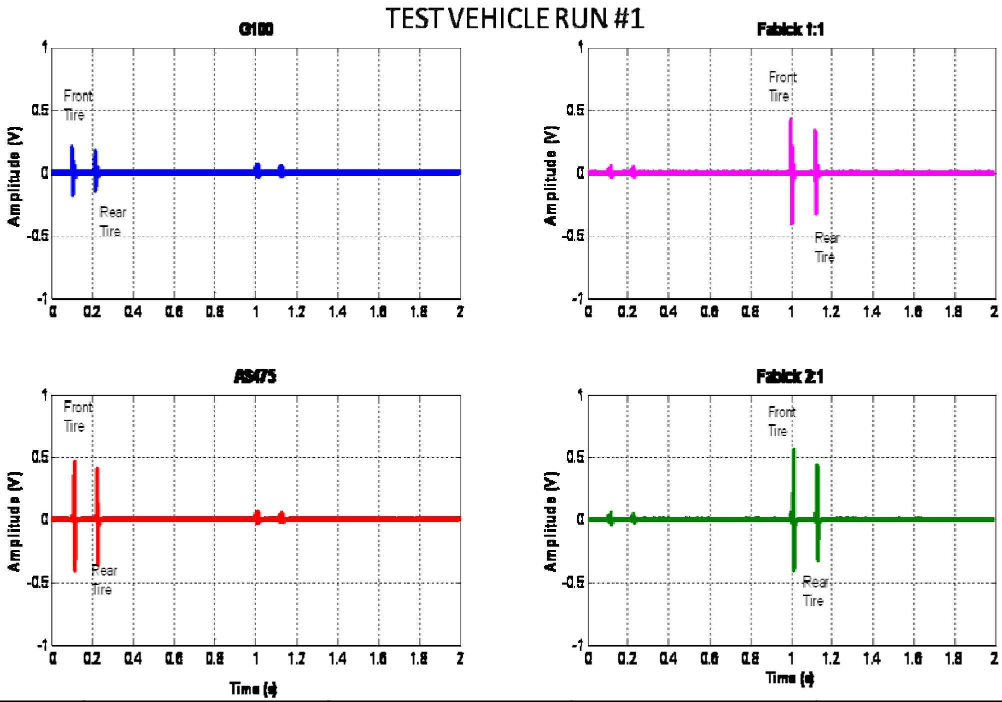


Figure 5.1: National Instrument USB-6009 Multifunction I/O and Attached Probes

After the laptop computer is turned on, the LabView software is launched and a new project is created with all the necessary parameters set. As the reference vehicle approaches the first piezo sensor the *run*, and then *record* tabs are clicked to initiate the recording of events as the vehicle goes over the sensors. The voltage outputs are time stamped and logged in a file which is then exported to MS Excel for further data analysis and processing. The process is repeated for as many different vehicles as are desired. A sample of the processed outputs is shown in Figure 5.2 representing the voltage outputs for the test vehicle, a Chrysler Town and Country Minivan.



	G100		AS 475		Fabick 1:1		Fabick 2:1	
Axle	Front	Rear	Front	Rear	Front	Rear	Front	Rear
Peak Values (V)	0.2064	0.1746	0.4603	0.4080	0.4234	0.3392	0.5587	0.4325

Figure 5.2: Example Piezo Sensor Voltage Outputs using the Test Vehicle

Ground Resistance and Inductance Measurements

A handheld multimeter was the main piece of equipment used to measure the inductance and ground resistance of the loop sensors at Site 352 on I-10 and Site 112 on I-75. Site 352 has five loop sensors labeled L1, L2, L3, L5 and L6 as shown in the site layout in Figure 5.3. Site 112 has twelve loop sensors (the Northbound and Southbound lanes have six loops each) labeled L1 to L12 as shown in the site layouts for the northbound and southbound lanes in Figures 5.4a and 5.4b, respectively.

Loop inductance measurements are conducting by connecting the multimeter (set to measure inductance) to the two ends of the loop wire. If the loops are connected to a traffic count/classify equipment, they are disconnected from the equipment prior to the measurements. The measured inductance, in microHenries (μH), is recorded for each loop in the laboratory notebook.

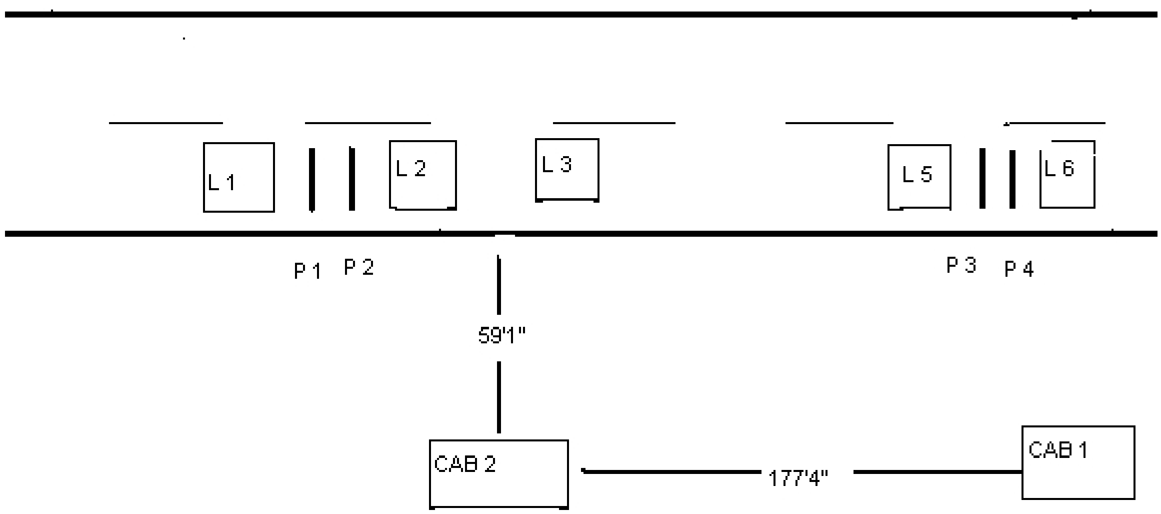


Figure 5.3: Loop layout for Site 352 on I-10

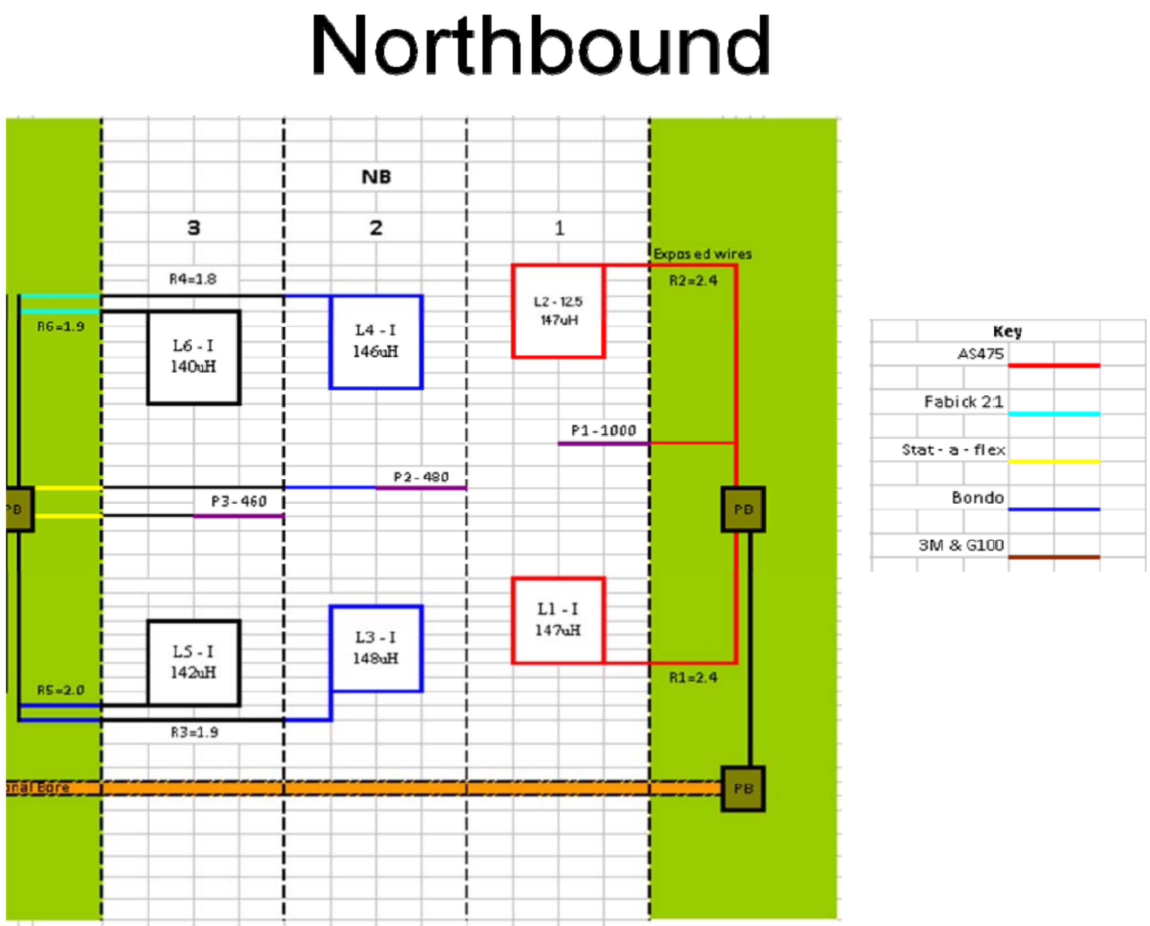


Figure 5.4a: Loop Layout for Northbound Site 112 on I-75

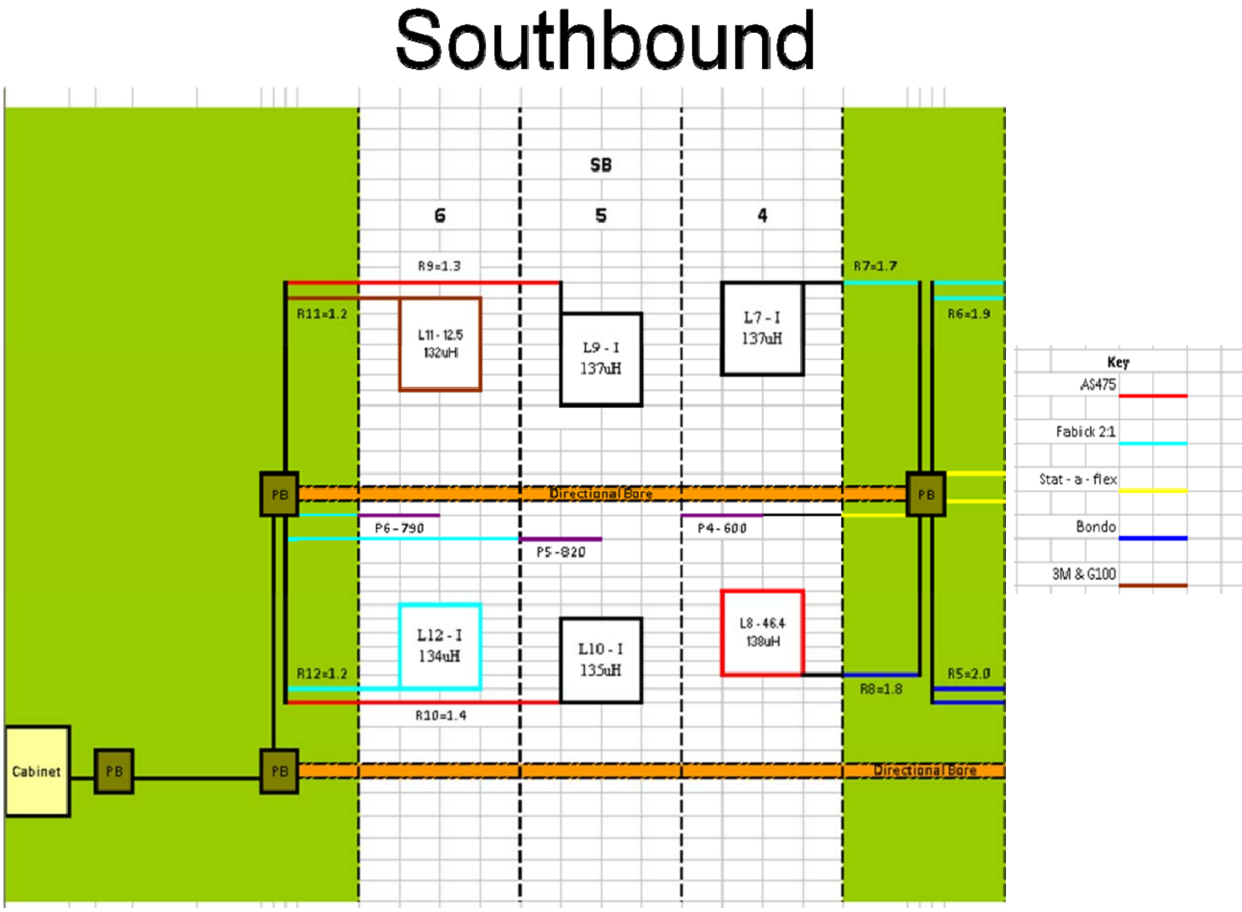


Figure 5.4b: Loop Layout for Southbound Site 112 on I-75

The ground resistance of each loop is measured by connecting the multimeter to one end of the loop and to the earth ground located in the TTMS cabinet. The multimeter is set to measure resistance, in MegOhms (MΩ), and the ground resistance is recorded in the laboratory notebook. Again, the loop must be disconnected from any traffic count/classify equipment for accurate measurement of ground resistance. Note that the typical maximum range for a handheld multimeter is 50 MΩ; any ground resistance higher than 50 MΩ is recorded as having "infinite" resistance.

To measure the inductance, the multimeter knob is tuned to the appropriate range of the inductance area and the two probes of the meter are connected to the loop sensor terminal pairs. The value of the inductance is read off the screen and recorded in a laboratory notebook. Similar procedure is repeated for the ground resistance measurements for all the loop sensors at both site 112 and 352.

A summary of the data collected for the inductance and ground resistance of the loop sensors at sites 112 and 352 in the period of February to December 2009 is shown in Figures 5.5 and 5.6.

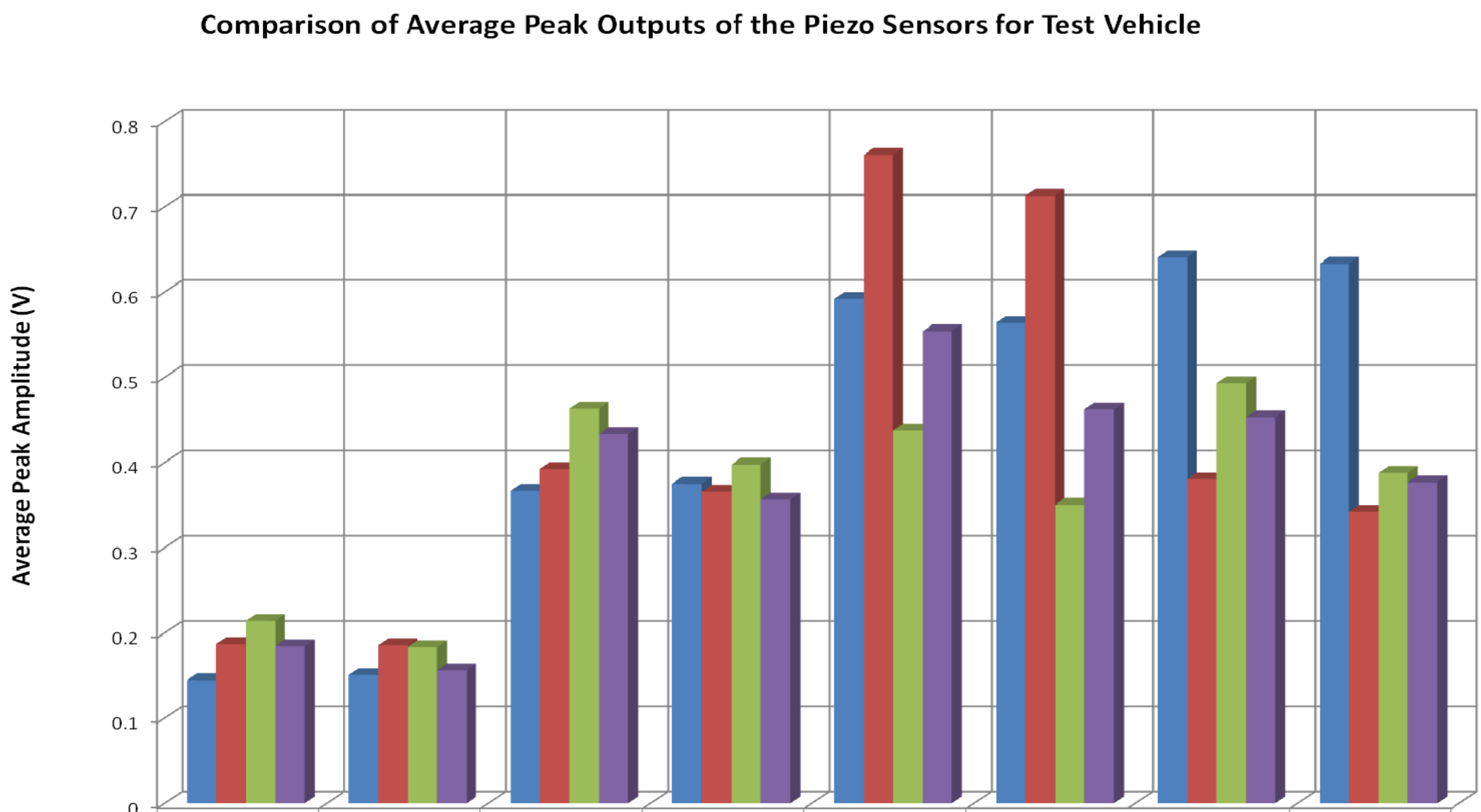
5.2 Results and Analyses of Field Tests

Several field tests were made by the research team between April and December 2009. Peak outputs from the piezoelectric sensors at Site 352 were recorded during the tests in June, July, August and October. Loop inductance and ground resistance was recorded for each loop at Sites 112 and 352 in field tests conducted in February, April, June, July, August, October and December. The data was collected on each visit was processed to identify any trends regarding the degradation of the sensors performance.

Summary of Piezoelectric Sensors Results

To test the performance of the piezoelectric axle sensors at Site 352, the peak voltage output was recorded to the front and rear tires of a test vehicle, a Chrysler Town & Country Minivan. For each field test the test vehicle was driven at 60-70 MPH across the sensors a total of five times. The average of the peak outputs for each axle of the vehicle on each piezo sensor was recorded. A summary of the average peak outputs is shown in Figure 5.5. Piezo sensor 1, installed using the G100 sealant, produced the least voltage output of all, giving a maximum output of 0.2 volts. Piezo sensor 2, installed using the AS475 sealant, produced an overall average output range of 0.35 volts to 0.45 volts. Piezo sensors 3 and 4, installed with Fabick 1:1 and Fabick 2:1 sealants, produced the largest average output range of 0.35 volts – 0.75 volts and 0.35 volts and 0.65 volts, respectively. The data collected during these tests revealed no identifiable trends in the output voltages of the piezo sensors. Any wear or degradation of the sealants used had no noticeable effect on the outputs of the sensors. Variations in the average peak output voltages appeared to be somewhat random and are more likely due to external influences such as the position of the vehicle in the lane and possibly temperature.

For comparison, the peak piezoelectric peak outputs were recorded for random Class 9 vehicles passing through the Site 352 during the field tests. Figure 5.6 charts the average peak piezo outputs for the field tests in July, August and October. In December a computer failure prevented the collection of piezoelectric output voltages. Given that there is no knowledge of the weight of these Class 9 vehicles, there is no way to identify trends due to degradation of the sensors or sealants. These measurements demonstrate the range of voltages produced by the piezoelectric sensors for heavy vehicles.

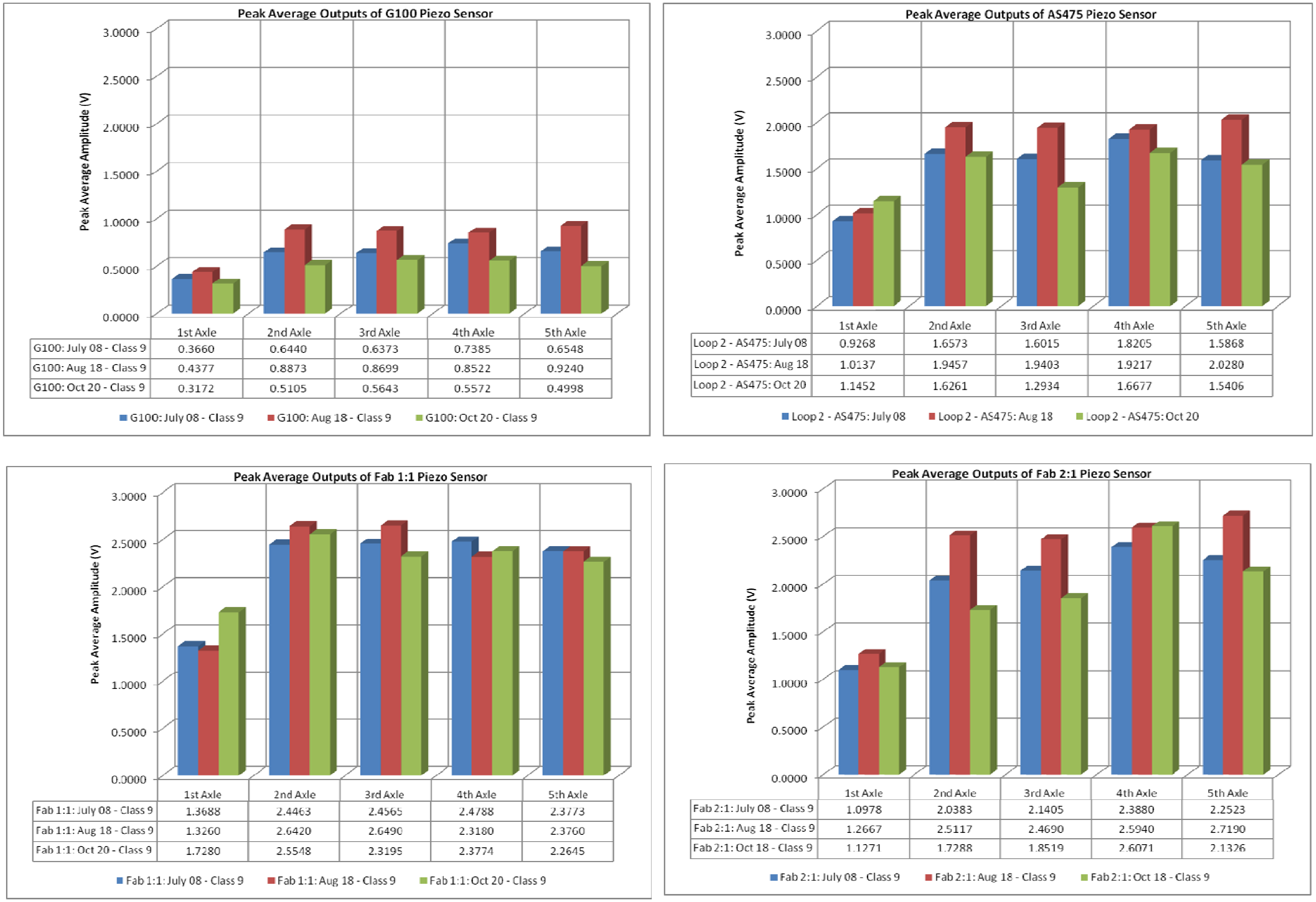


	Loop 1-G100 - FT	Loop1-G100 - RT	Loop2-AS475 - FT	Loop2-AS475 - RT	Loop3-FAB1:1 - FT	Loop3-FAB1:1 - RT	Loop4-FAB2:1 - FT	Loop4-FAB2:1 - RT
June 04 Field Test	0.1446	0.1504	0.3669	0.3751	0.5918	0.5635	0.6406	0.6333
July 08 Field Test	0.18704	0.18564	0.3923	0.36576	0.76092	0.71296	0.38014	0.3423
August 18 Field Test	0.214375	0.183325	0.463125	0.3976	0.43745	0.350375	0.493075	0.387775
October 20 Field Test	0.18446	0.15608	0.43324	0.35646	0.55402	0.4622	0.45302	0.3767

June 04 Field Test   July 08 Field Test   August 18 Field Test   October 20 Field Test

FT: Front Tire   RT: Rear Tire

Figure 5.5: Average Piezoelectric Axle Sensor Peak Outputs for Field Tests Using the Test Vehicle.



	1st Axle	2nd Axle	3rd Axle	4th Axle	5th Axle
G100: July 08 - Class 9	0.3660	0.6440	0.6373	0.7385	0.6548
G100: Aug 18 - Class 9	0.4377	0.8873	0.8699	0.8522	0.9240
G100: Oct 20 - Class 9	0.3172	0.5105	0.5643	0.5572	0.4998

	1st Axle	2nd Axle	3rd Axle	4th Axle	5th Axle
Loop 2 - AS475: July 08	0.9268	1.6573	1.6015	1.8205	1.5868
Loop 2 - AS475: Aug 18	1.0137	1.9457	1.9403	1.9217	2.0280
Loop 2 - AS475: Oct 20	1.1452	1.6261	1.2934	1.6677	1.5406

	1st Axle	2nd Axle	3rd Axle	4th Axle	5th Axle
Fab 1:1: July 08 - Class 9	1.3688	2.4463	2.4565	2.4788	2.3773
Fab 1:1: Aug 18 - Class 9	1.3260	2.6420	2.6490	2.3180	2.3760
Fab 1:1: Oct 20 - Class 9	1.7280	2.5548	2.3195	2.3774	2.2645

	1st Axle	2nd Axle	3rd Axle	4th Axle	5th Axle
Fab 2:1: July 08 - Class 9	1.0978	2.0383	2.1405	2.3880	2.2523
Fab 2:1: Aug 18 - Class 9	1.2667	2.5117	2.4690	2.5940	2.7190
Fab 2:1: Oct 18 - Class 9	1.1271	1.7288	1.8519	2.6071	2.1326

Figure 5.6: Average Piezoelectric Axle Sensor Peak Outputs for Random Class 9 Vehicles

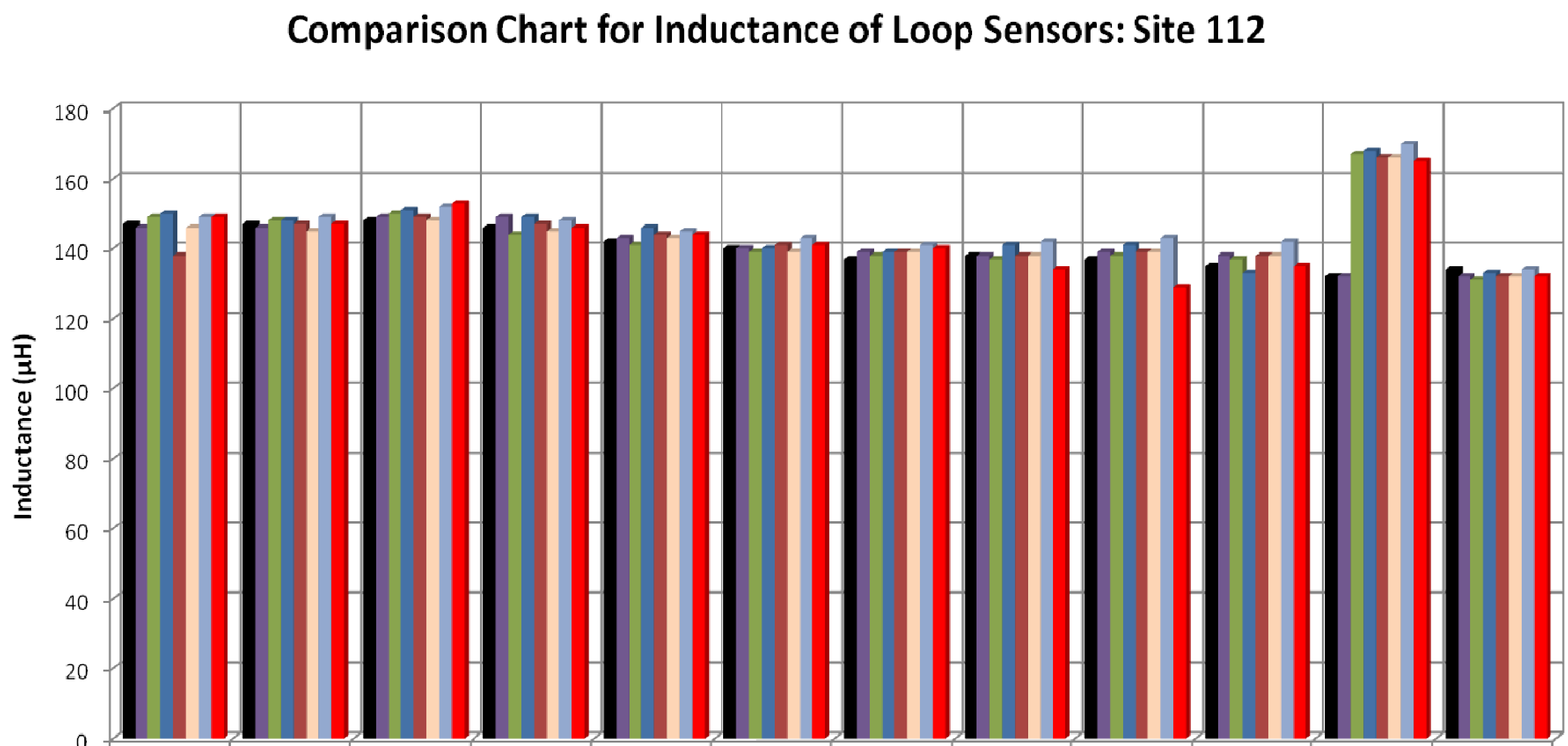
Summary of the Ground Resistance and Inductance Measurements

Prior to the start of this task, contractors working for the FDOT recorded inductance and ground resistance for the 12 inductive loop sensors at Site 112. It was noted that loops #8 and #11 had ground resistances less than 50 MΩ and that there appeared to be significant wear on the sealants used at the site. A field test was conducted on February 18, 2009 to verify the measurements and to perform a physical inspection of the site. During this field test, the inductance measurements were consistent with the earlier measurements made by the contractor, however, all of the loop ground resistance measurements were infinite (> 50 MΩ). The apparent cause for the difference appeared to be the weather during the tests. During the measurements conducted by the FDOT contractor there was wet weather, but during the February field test the weather was dry.

On March 23, 2009, the FDOT had the Site 112 repaired in an attempt to extend the useful life of this TTMS. Loop #11 was replaced; loops #1-4 and 12 were resealed. Various loop sealants were used to assess the performance the durability of the sealants. On April 6, 2009 a field test was conducted to measure the inductances and ground resistances of the loops after the site repair. The loop inductances were consistent with previous measurements with the exception of the loop that was replaced (loop #11) whose inductance increased by about 25%. All ground resistances again measured infinite (weather was dry).

Beginning in June 2009, periodic (1 to 2-month) measurements of the inductance and ground resistance of each of the loops at Site 112 and Site 352 were monitored in wet and dry conditions. Figure 5.7 charts the loop inductances measured at Site 112. All inductance measurements remained consistent throughout the tests with the exception of loop #11 which was replaced (though that loop's measurements were also consistent for all measurements after it was replaced). Figure 5.8 contains a table of the ground resistances measured for the loops at Site 112. Loop #11, which was replaced, consistently demonstrated infinite ground resistance. However, loop #12 and several other loops, most noted by Dr. Moses' team as having visible damage to the sealants, were measured as having ground resistances < 50 MΩ. The ground resistance measurements show an apparent degradation over time of the ground resistances of several loops. Also, it appears that ground resistance decreases significantly during wet weather. Note that although some of the loops had ground resistances measured below 1 MΩ, there were no apparent effects on the loop inductance and the TTMS continued to produce consistent traffic counts and classifications.

The loop inductances and ground resistances for the five loops at Site 352 are recorded in Figures 5.9 and 5.10, respectively. Loop inductances remained consistent over the length of the field tests for all the loops at the site. Loop #5 was the only loop that recorded a ground resistance < 50 MΩ at this site. This loop recorded ground resistances between 0.5 and 2.4 MΩ during each field test. This loop was noted by Dr. Moses' research team as having an exposed wire where the sealant had failed.



	Loop 1	Loop 2	Loop 3	Loop 4	Loop 5	Loop 6	Loop 7	Loop 8	Loop 9	Loop 10	Loop 11	Loop 12
Before Feb 18	147	147	148	146	142	140	137	138	137	135	132	134
Feb. 18 Field Test	146	146	149	149	143	140	139	138	139	138	132	132
April 06 Field test	149	148	150	144	141	139	138	137	138	137	167	131
June 04 field Test	150	148	151	149	146	140	139	141	141	133	168	133
July 08 Field Test	138	147	149	147	144	141	139	138	139	138	166	132
Aug. 13 Field Test	146	145	148	145	143	139	139	138	139	138	166	132
Oct. 20 Field Test	149	149	152	148	145	143	141	142	143	142	170	134
Dec. 10 Field Test	149	147	153	146	144	141	140	134	129	135	165	132

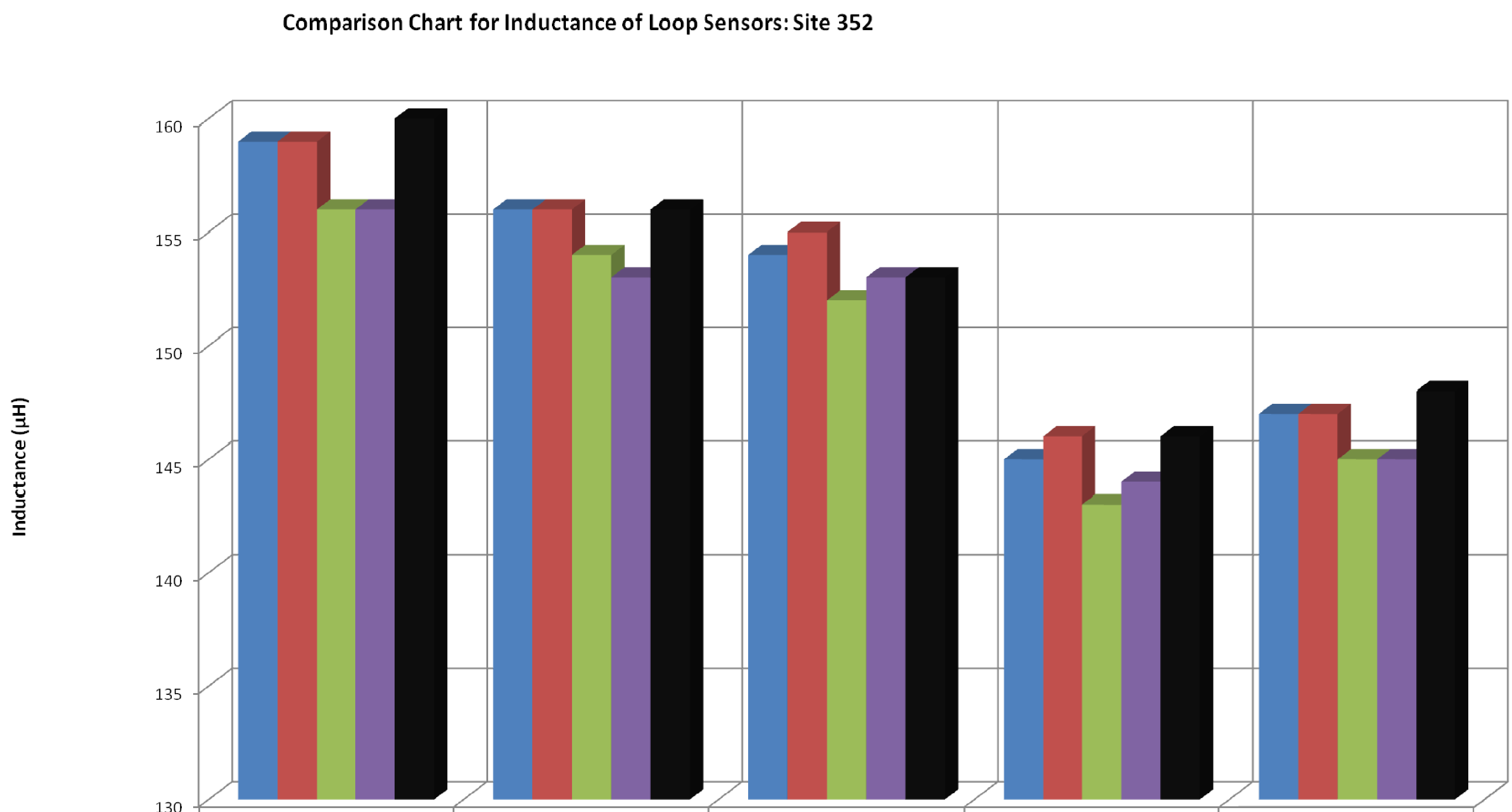
■ Before Feb 18 ■ Feb. 18 Field Test ■ April 06 Field test ■ June 04 field Test ■ July 08 Field Test ■ Aug. 13 Field Test ■ Oct. 20 Field Test ■ Dec. 10 Field Test

Figure 5.7: Inductance Measurements of Loop Sensors at Site 112 on I-75

Comparison Table for Resistance Tests for Site 112

Loop	B/4. 02:18:09 (Wet Day) (MΩ):	02:18:09 (MΩ):	03:23:09	04:06:09 (MΩ):	06:04:09 (Wet Day) (MΩ):	07:08:2009 (MΩ):	08:13:09 (MΩ):	10:20:09 (MΩ):	12:10:09 (Wet Day) (MΩ):
1	Infinite	Infinite	Resealed using AS475	Infinite	Infinite	6.90 – 10.98	5.8	8.31	0.41
2	Infinite	Infinite	Resealed using AS475	Infinite	Infinite	0.298 – 1.5	5.35	4.81	0.36
3	Infinite	Infinite	Resealed using Bondo	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite
4	Infinite	Infinite	Resealed using Bondo & shoulder using Fabcik 2:1	Infinite	Infinite	Infinite	Infinite	Infinite	22.8
5	Infinite	Infinite	Shoulder resealed using Bondo	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite
6	Infinite	Infinite	Shoulder resealed using Fabick 2:1	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite
7	Infinite	Infinite	Shoulder resealed using Fabick 2:1	Infinite	Infinite	Infinite	Infinite	Infinite	10.54
8	46.4	Infinite	Shoulder resealed using Bondo	Infinite	Infinite	Infinite	Infinite	Infinite	16.6
9	Infinite	Infinite	Shoulder resealed using AS475	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite
10	Infinite	Infinite	Shoulder resealed using AS475	Infinite	-4 (faulty) Other direction gives infinite	2.68	2.72	0.96	0.98
11	12.5	Infinite	Replaced using 3M and topped by G100	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite
12	Infinite	Infinite	Resealed using Fabick 2:1	Infinite	1st Reading: 10-17 2nd Reading: 11.6	21.4 – 24.6	5.13	13.55	8.5

Figure 5.8: Resistance Measurements of Loop Sensors at Site 112 on I-75



	Loop 1	Loop 2	Loop 3	Loop 5	Loop 6
June 04 Field Test	159	156	154	145	147
July 08 Field Test	159	156	155	146	147
August 13 Field Test	156	154	152	143	145
October 20 Field Test	156	153	153	144	145
December 10 Field Test	160	156	153	146	148

Figure 5.9: Inductance Measurements of Loop Sensors at Site 112 on I-75

Comparison Table for Ground Resistance Tests for Site 352

Loop	Sealant used	06:04:2009 (MΩ):	07:08:2009 (MΩ):	08:04:2009 (MΩ):	10:20:2009 (MΩ):	12:10:2009 (MΩ): Wet Day
1	3M	Infinite	Infinite	Infinite	Infinite	Infinite
2	3M	Infinite	Infinite	Infinite	Infinite	Infinite
3	WABO	Infinite	Infinite	Infinite	Infinite	Infinite
4	FABICK 2:1	1.45	0.466	2.35	2.2	0.84
5	FABICK 2:1	Infinite	Infinite	Infinite	Infinite	Infinite

Figure 5.10: Resistance Measurements of Loop Sensors at Site 112 on I-75

Analysis and Recommendations

The research and testing conducted under this project has demonstrated that the sensors installed to a large extent are in working condition. Through the testing and measurements conducted in the tasks and the post data processing done, the behavior of the sensors have been accurately monitored over time in determining whether or not the performance of the sensors are degrading. The results have also been useful in assessing the performance of the grouts (i.e. 3M, WABO, G100, AS 475, Fabick 1:1 and Fabick 2:1) used as sealants for the sensors. From piezoelectric sensor voltage measurements made at Site 352, the Fabick 2:1 sealant used to seal piezo sensor 4 produced the largest voltage response during the test runs, while the G100 used to seal piezo sensor 1 produced the smallest voltage response.

The loop inductance measurements made at Site 112 and Site 352 demonstrated that the inductance remained relatively stable for loops with and without degradation (as seen in dropping ground resistance measurements. Electrically, the loop inductance is not expected to be measurably affected unless the loop wire is severed, loop wires in separate turns of the loop short together, or the ground resistance of the loop gets very low (< 100 KΩ). So this result is to be expected.

The loop ground resistance measurements at Site 112 seemed to indicate that resealing a loop can improve the ground resistance of the loop, but the improvement may not last as long as replacing the loop (see loops # 8 and #11 in Figure 5.8). Also, weather conditions (wet or dry) seemed to have a significant impact on ground resistance.

Continued periodic measurement of the inductive loops and piezoelectric sensors at Sites 112 and 352 is recommended. Also, continuous logging of loop ground resistance and weather (rain and temperature) at Site 352 is also recommended to investigate the correlation between weather conditions and loop ground resistance changes. Under this project the weather equipment was acquired for the continuous monitoring at Site 352. Using the Campbell Scientific CR800 data loggers used for the lightning surge measurements, the air and pavement temperature, the rainfall amounts, and the ground resistance of all 5 loops at Site 352 can be continuously recorded. This effort will continue in future research to support the Transportation Statistics Office of the FDOT.

6. Conclusions

This project has included several efforts to support and improve the operation of the FDOT Telemetered Traffic Monitoring Systems. The major areas of support included:

1. Lightning Surge Suppression Field Tests,
2. Segmented Sensor Interface Electronics Improvements,
3. Sensys System Support for Short-Term Traffic Count Applications, and
4. Monitoring Loop Ground Resistance and Piezoelectric Sensor Outputs.

The field testing of the lightning surges experienced by the TTMS in-pavement sensors is providing the information necessary to identify the proper lightning surge protection for the traffic monitoring equipment. These tests are demonstrating the need for surge suppressors able to suppress lightning surges up to 3,000 amps and able to endure thousands of surges without failure.

The research into the segmented sensor interface improvements has demonstrated that the high resistance, intrinsic capacitance and structure of the extruded segmented sensor make a simple conductance test inaccurate for identifying segment closures. The design of the interface is now delayed pending funding through the FHWA.

The field testing and analysis of the Sensys wireless traffic monitoring system has shown that it is feasible to use it for short-term traffic count applications. The access point (AP) can be set up for a temporary traffic count site, and the setup can be stored for future use at that particular site. This will allow a single access point to be moved efficiently between temporary traffic count sites. The access point for this application must be an AP240 with the S designator to allow the access point to store traffic statistics. An instruction manual for operating the Sensys system for temporary traffic counts is provided in Appendix A.

Monitoring the electrical characteristics of loops and piezoelectric sensors at Sites 112 and 352 is providing information on the results of the degradation of sealants and grouts used to install the sensors. It is also demonstrating the differences in reliability and wear between resealed loops and replaced loops. These measurements combined with analysis by a Civil Engineering research team led by Dr. Ren Moses will help the FDOT identify the most effective maintenance procedures to extend the operating life of the sensors in a TTMS installation. It will also help to determine the most effective sealants to be used in the environment of the state of Florida. Continued research is still needed to complete the analysis of the degradation of the sensors and to identify the impacts of weather.

7. Benefits to the FDOT

The results of this project have provided four specific benefits to the FDOT.

a. The lightning field tests have led to the specification and recommendation of reliable surge suppressors to protect the sensitive electronics in the TTMSs. This has improved the reliability of the TTMSs and reduced the cost of repairs to the TTMS equipment due to failures caused by lightning surges.

b. Improved classification of vehicles using the segmented axle sensor has been demonstrated in field tests. Improving the interface electronics design for a more durable extruded polymer sensor will provide the FDOT with a tool to significantly improve vehicle classification and monitoring.

c. The Sensys wireless traffic monitoring system has been shown to be a good alternative to pneumatic tube systems for temporary traffic count applications. Use of the Sensys system will improve reliability of the sites and reduce costs using the permanent in-pavement Sensys sensors rather than pneumatic tubes.

d. Research into the effects of in-pavement sensor sealant degradation on the electrical properties of the sensors will help the FDOT reduce maintenance costs by identifying the most durable sealants and the most effective maintenance procedures to extend the life of the TTMS in-pavement sensors.

Appendix A

Instruction Manual for Operating the Sensys System for Temporary Traffic Counts

Instruction Manual for Operating the Sensys System for Temporary Traffic Counts

Contents

Abbreviations:

AP: Access Point

FTP: File Transfer Protocol

RF: Radio Frequency

Notations:

Hyperlinks, or selectable buttons and tabs will be in bold italics (e.g. ***Hyperlink***).

Labels on web pages or in software will be in italics (e.g. *Labels*).

Data to be entered into a field on a web page or in software will be in Lucida Console font (e.g. `192.168.2.99`).

1. Introduction

This Instruction Manual provides information and the procedures for using the Sensys System, which was initially designed to operate in a server controlled network, for temporary traffic counts.

The instructions will allow the user to fully understand the Sensys Networks Vehicle Detection System, properly configure the Sensys access point (AP) for the traffic count site, and retrieve the traffic count data from the access point.

The instructions provided here are to accomplish the following tasks:

1. System Components and Requirements
2. Configuration of Field Laptop Computer
3. Configuration of the Sensors
4. Initial set up of Access Point
5. Backup and Restore of Access Point for multiple site application
6. Downloading Statistical Data & Exiting TrafficDOT Application

Notes:

1. Some of the contents have been summarized from the Sensys Online Reference Manual. If more clarification will be needed, view the Sensys Online Reference Manual at www.sensysnetworks.com in the Dealer Login section or the Sensys Reference Guide in the Technical Docs section..
2. These instructions are applicable to the Windows XP operating system.

2. System Components and Requirements

The implementation of the Sensys system for temporary traffic counts requires the following components for its basic operation:

- Sensys Wireless Sensors

  These are pavement mounted magnetometers equipped with wireless radio transmitters to detect the presence and movement of vehicles.

- Sensys Access Point

  This is an intelligent device that establishes overall time synchronization of the system, transmits configuration commands and message acknowledgements and receives and processes data from the sensors. For the statistics –processing purpose of this project, the version of access point to be used should be AP240 including the upgraded S version such as the AP240US or AP240ES. Any other S-version could be used as well.

- TrafficDOT Software

  This is monitoring application software from Sensys network that provides graphical user interface (GUI) to the components of Sensys Traffic count system. (Installation will be explained in Section 2).

- Laptop Computer with an Ethernet port.

  The instructions on this manual are based on Windows XP Operating System. The Mac, Unix, Linux or other Windows can also be used based on a different instruction set. Minimum requirements are: 40GB HDD, 1.8GHz CPU, 1024MB Memory, and the Mozilla Firefox web browser.

- Ethernet Cable

  Use a Cat 5 or a better Ethernet cable that is at least 1.5m long terminated with male RJ 45 connectors on both ends.

3. Configuration of the Field Laptop Computer

The laptop computer used to communicate with the Sensys access point must meet the following requirements:

1. Laptop must be configured to a fixed IP address.
2. Laptop must have TrafficDOT application software installed

3.1 Configuring the Laptop to a Fixed IP Address

The IP Address is found under ***Network Connections***.

- On the laptop computer click on ***Start*** menu→ ***My Network Places*** and then click on the link ***View Network Connections*** which is on the left side of *My Network Places* window.

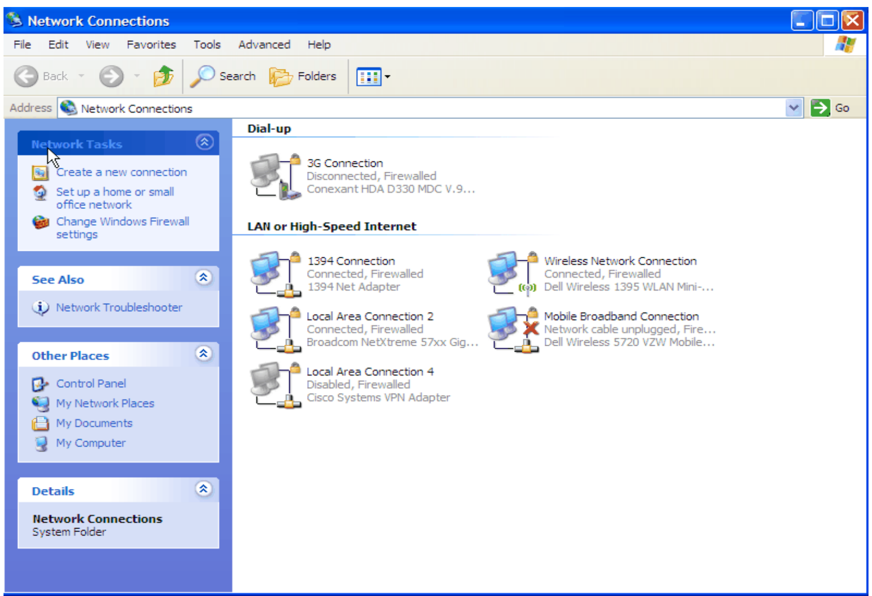


Figure 3.1: Network Connection Window

- Right click on the desired Local Area Connection (LAN) and select ***Properties*** (see Figure 3.1).

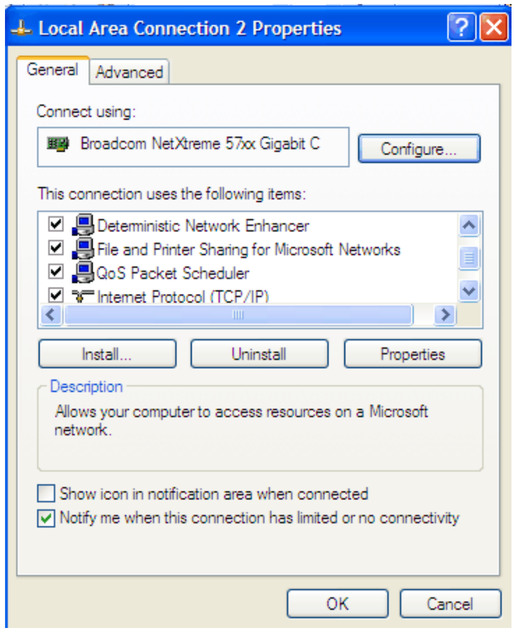


Figure 3.2: Local Area Connection Properties Window

➢ Double Click on ***Internet Protocol (TCP/IP)*** (see Figure 3.2).

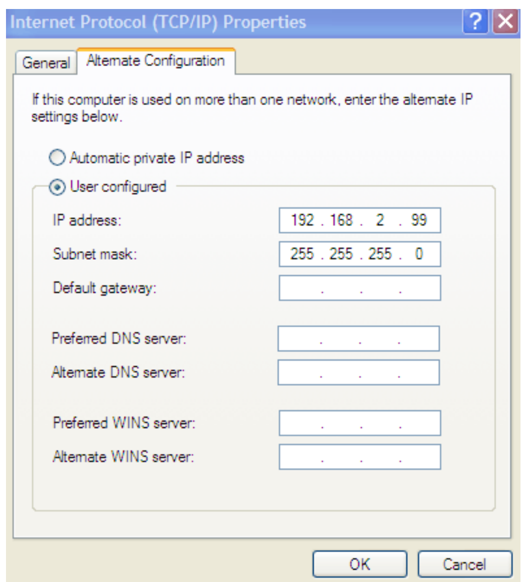


Figure 3.3: Internet Protocol Properties Window

➢ If the ***Alternate Configuration*** (see Figure 3.3) tab is available, select ***User Configured***, and fill out the *IP Address* and the *Subnet mask* as shown. Click ***Ok***.

This will enable you to connect up at any time without needing to reconfigure the IP port in the future.

➢ If the ***Alternate Configuration*** is not available, then you will need to change the *IP address* as shown Figure 3.4. Note the original settings prior to making any changes.

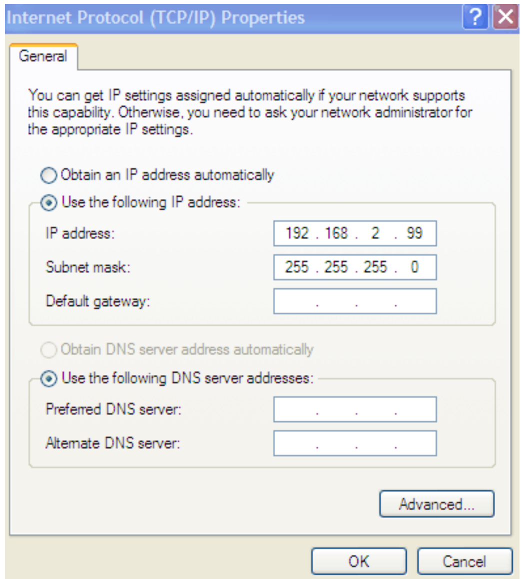


Figure 3.4: Internet Protocol Properties/General Window

You will need to perform this step (and reverse it back after completing use of TrafficDOT) every time you use the laptop with the system.

3.2 Installation Procedure for TrafficDOT Application Software

- Put the TrafficDOT software media (CD) for windows version in the CD drive of the laptop.

  Note: The Software can also be downloaded from the Dealer's page on Sensys website.

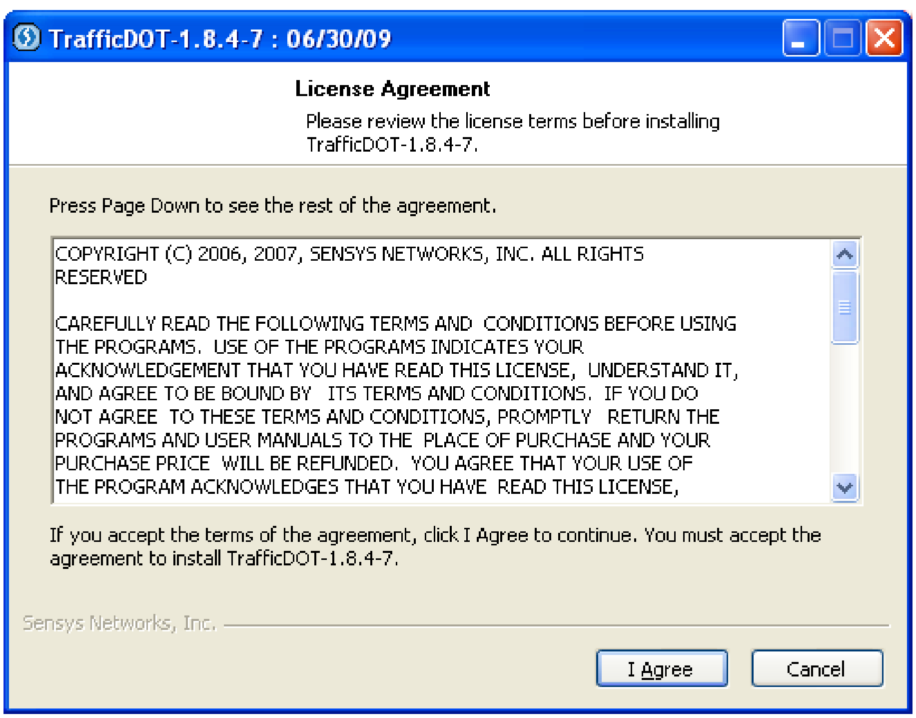


Figure 3.5: Installation License Agreement

- Continue by clicking on the ***I Agree*** button (see Figure 3.5).

- Install all components of TrafficDOT by checking all the boxes in the *Choose Components* screen (see Figure 3.6).

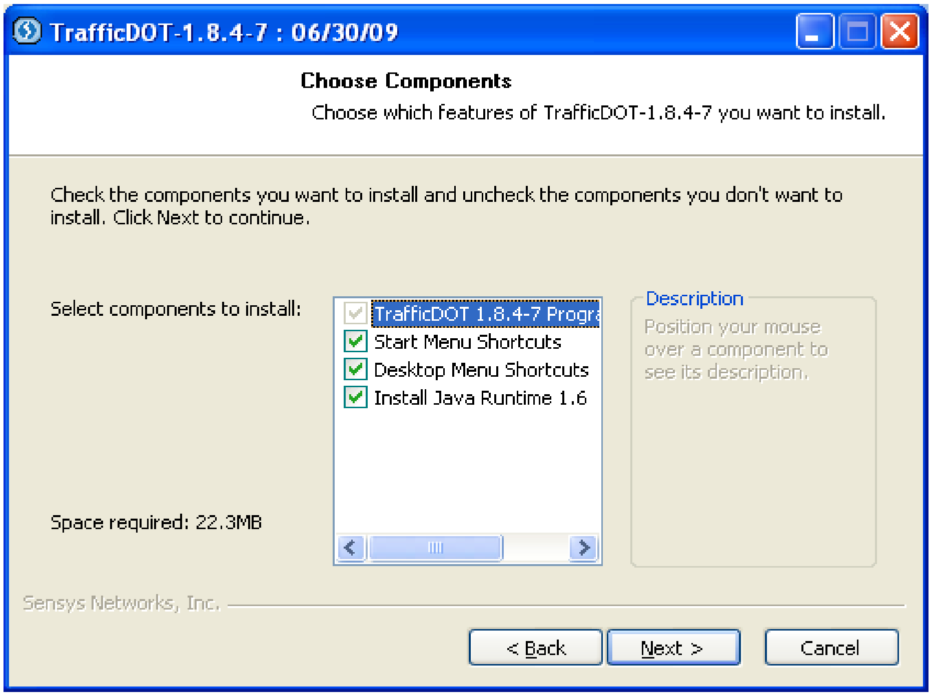


Figure 3.6: Choose Installable Components Windows

- Click the ***Next*** button.

- If desired, change the *Destination Folder* for the software on the *Choose Install Location* window (see Figure 3.7).

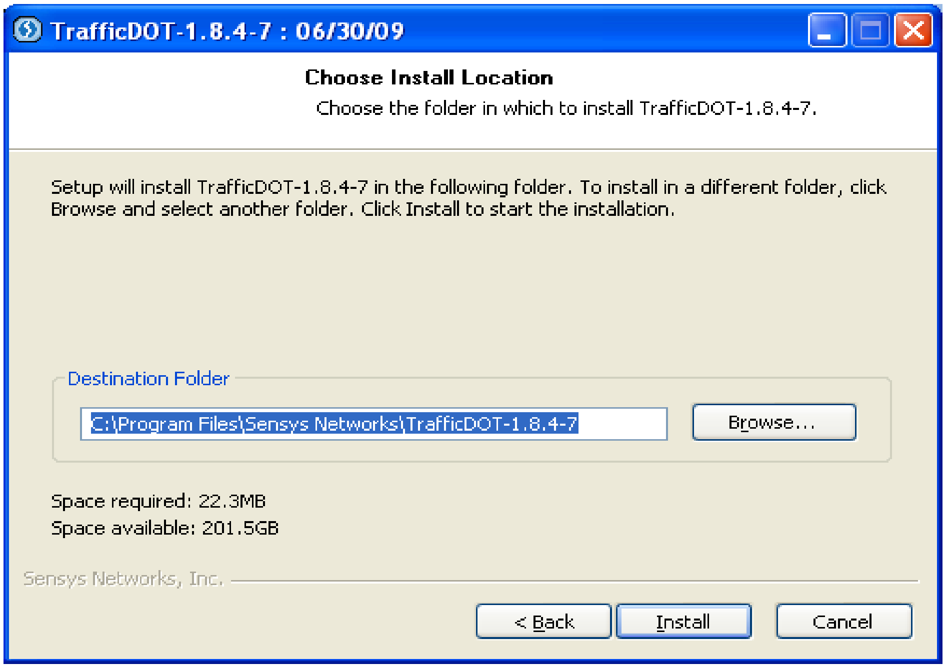


Figure 3.7: Choose Install Location Window

- Click the ***Install*** button to begin the installation.
- The progress of the installation will be reported on the *Installing* window (see Figure 3.8).

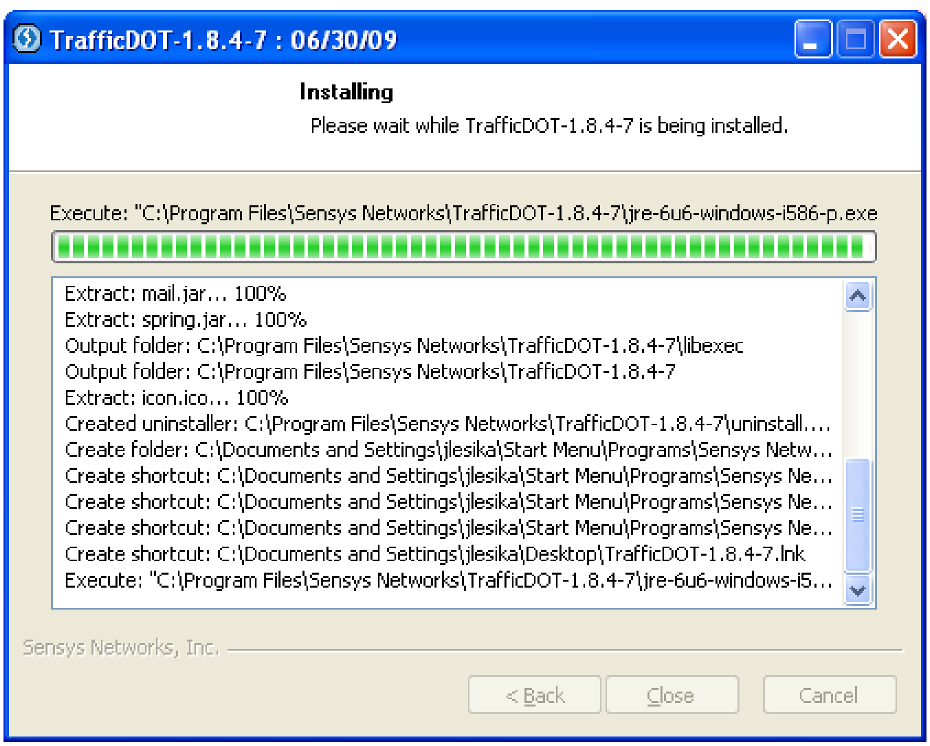


Figure 3.8: Installation Status Window

Note: If the Java Runtime Environment is required, a separate installation process occurs. Accept the Terms and Conditions to continue. Wait for the installation to complete. Click on the ***Finish*** button.

➢ The results of the installation will appear on the installation window (see Figure 3.9).

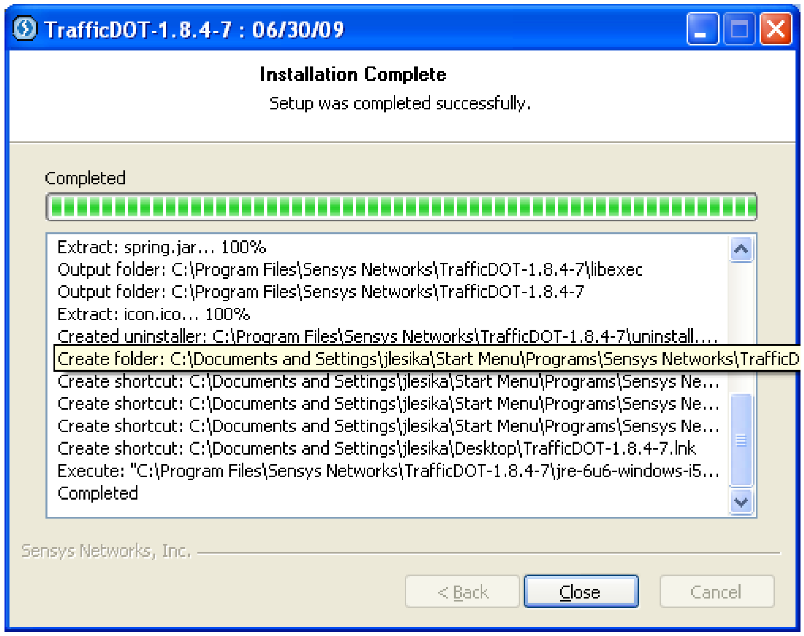


Figure 3.9: Installation Completion Window

➢ Complete the TrafficDOT software setup wizard by clicking on the ***Close*** button.

4. Configuring the Sensors Using the TrafficDOT Application Software

Sensors ship with a factory default configuration for count applications. In most cases, the configuration is modified to fit the specific needs of an installation. However, once set, a sensor's configuration typically requires no further changes.

Sensor configuration involves selecting values for the following parameters:

- Operating mode
- Radio Frequency Channel

From the main TrafficDOT window, select the ***Configure*** menu and click ***Sensors*** (see Figure 4.1).

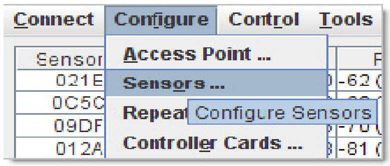


Figure 4.1: Configure Sensors Window

The *Sensor Configuration* window appears (see Figure 4.2).

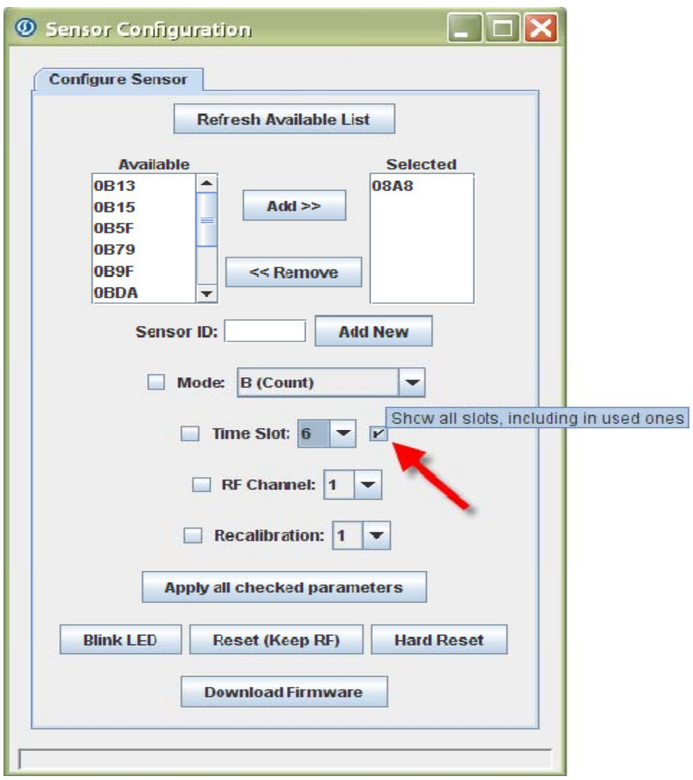


Figure 4.2: Sensor Configuration Window

Click ***Refresh Available List*** button and all the available sensors will be displayed.

4.1 Selecting Sensors to Configure

Sensors are selected by moving their IDs from the *Available* list to the *Selected* list as follows:

From the *Available* list, click one or more sensor IDs. (Note: On Windows platforms hold down the SHIFT key while clicking to select multiple entries in series.)

- Click the button labeled ***Add* >>.** The sensor ID(s) appear in the *Selected* list.

To remove IDs from the *Selected* list, do the following:

- From the *Selected* list, click one or more sensor IDs.
- Click **<< *Remove***. The sensor IDs are removed from the *Selected* list and appear in the *Available list.*

4.2 Setting a Sensor's Operating Mode

The sensor's operating mode defines the type of detection data it transmits. To set the operating mode, do the following after selecting the sensors to be configured:

- Fill the check box to the left of the label *Mode* by clicking it.
  (The entries on the *Mode* drop-down list are the operating modes available for sensors.)
- Select an entry from the list by clicking it.
  (Select *Count (B)*, for the statistical count application).

4.3 Setting a Sensor's RF Channel

All sensors associated with an Access Point must use the same frequency as the Access Point. To set the RF channel, do the following:

- Fill the check-box to the left of the label *RF Channel* by clicking it.
- The entries in the *RF Channel* drop-down list correspond to the 16 frequencies available for use. Select an entry from the list by clicking it. Note: The factory default channel is zero.
- Click ***Apply all checked parameters***.

4.4 Managing Sensor Tables and Lane Names

Access Points store information describing sensor locations and relative positions in two databases. The databases are:

- Sensor Table – also referred to as the “dots” configuration table. This database stores an entry for each sensor in the network including its lane position.
- Sensor-Pair Table – also referred to as the “dot pairs” configuration table. This database includes one entry for each sensor-to-sensor relationship forming a speed pair (pair of sensors used to measure vehicle speed).

4.4.1 Adding a Dot (Sensor Table) Configuration Entry

To add a new entry, do the following:

From the ***Configure*** menu, navigate to ***Sensors*** and then click on the ***Dot Table*** in order to display the table (see Figure 4.3).

- Position the cursor in the *DotId16* column on a blank row. Type the 4-character HEX Id (hexadecimal identification number) of the sensor.

- If the sensor is used with a traffic controller, supply the card address in the column *Address 170*. If the sensor is not used with a signal controller, type a zero into the field.

- Type into the *Lane* field a short text description of the lane in which the sensor resides.

- Type into the *Position* field an integer between 0 and 2 that indicates the sensor's relative position in the lane.

  Note: Positions are determined by counting up from zero in the direction of the traffic's travel. That is, a vehicle will first drive over sensor zero, then sensor one and then sensor two. There is a maximum of three sensors per lane. The sensor in position zero must be defined before the sensor in position one, and position one must be defined before position two.

- The check box at the left edge of the row designates the sensor as being included (or ignored) by statistical or other applications. The check box is filled by default which indicates the sensor will be included hence do not uncheck.)

- Click ***Apply*** from the *Operations* menu to add the entry.

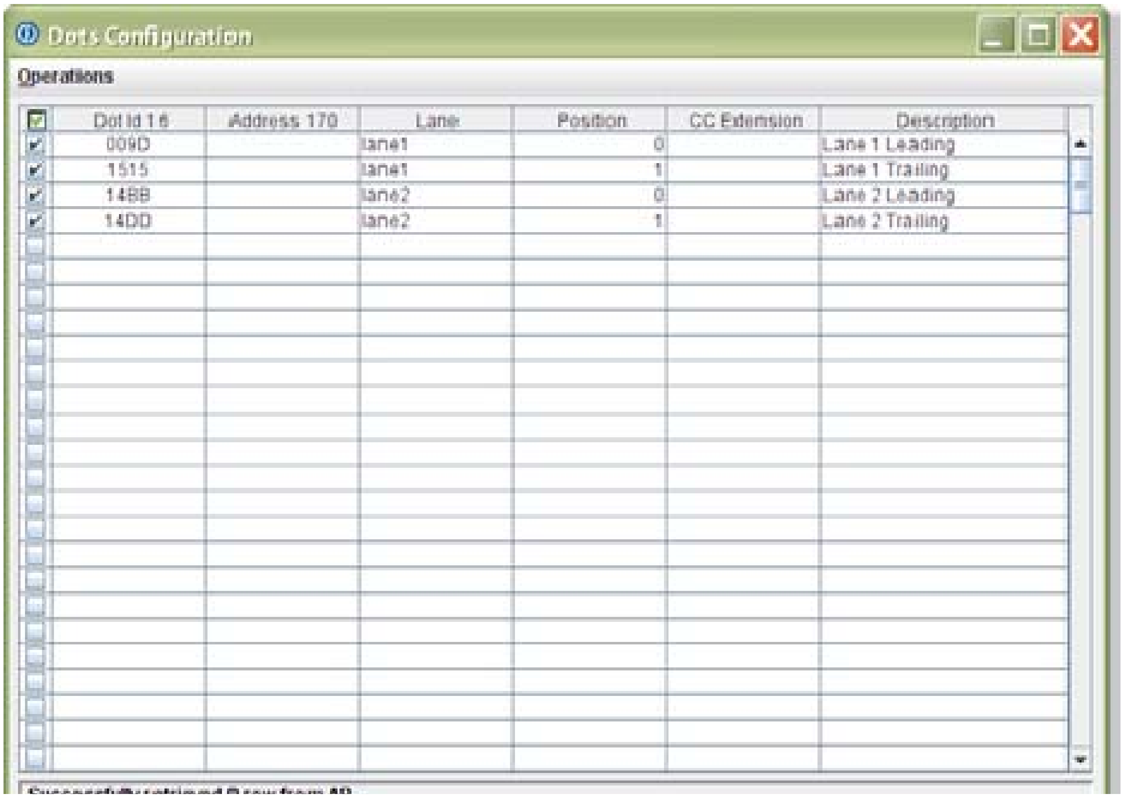


Figure 4.3: Sensor Table (Dots Configuration table)

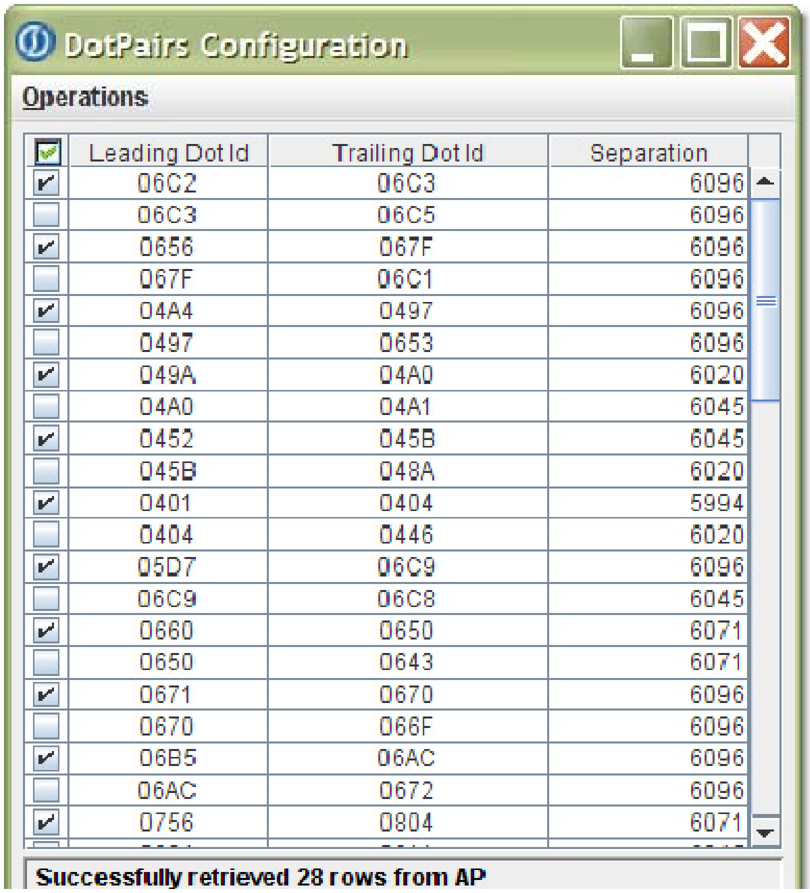
4.4.2 Adding a DotPairs (Sensor-Pair Table) Configuration Entry

The data contained in this table gives value added information from the detection events. For instance, speed, length gap and other values can be derived only by knowing the relative position and distance between two sensors. To add a new entry, do the following:

- From the ***Configure*** menu, navigate to ***Sensors*** and then ***Dot Pair Table*** (see Figure 4.4).
- Fill the check-box to the left of the *DotPairs Configuration* table.
- Position the cursor in the *Leading Dot Id* column on a blank row. Type the 4-character HEX Id of a sensor.

  Note: A leading sensor is the sensor that a vehicle first passes over when traveling in the direction of normal traffic flow.
- Type into the *Trailing Dot Id* field the 4-character HEX Id of a sensor.

  Note: A trailing sensor is the sensor that a vehicle passes over second when traveling in the direction of normal traffic flow.
- Type into the *Separation* field a decimal value (in millimeters) specifying the physical distance between the leading and trailing sensors.



☑	Leading Dot Id	Trailing Dot Id	Separation
☑	06C2	06C3	6096
☐	06C3	06C5	6096
☑	0656	067F	6096
☐	067F	06C1	6096
☑	04A4	0497	6096
☐	0497	0653	6096
☑	049A	04A0	6020
☐	04A0	04A1	6045
☑	0452	045B	6045
☐	045B	048A	6020
☑	0401	0404	5994
☐	0404	0446	6020
☑	05D7	06C9	6096
☐	06C9	06C8	6045
☑	0660	0650	6071
☐	0650	0643	6071
☑	0671	0670	6096
☐	0670	066F	6096
☑	06B5	06AC	6096
☐	06AC	0672	6096
☑	0756	0804	6071

Figure 4.4 - DotPairs Configuration Window

➢ Click ***Apply*** from the ***Operations*** menu to add the entry.

5. Initial Set up of the Access Point

The Access Point has to be correctly configured so as to be able to perform the statistics count application.

5.1. Connecting the Laptop to the Access Box

Before you can set up/configure an Access Point, a connection between the laptop computer and the access point (AP) must be established.

- Turn on the laptop.
- Plug one end of the Ethernet cable to the Ethernet -port of the laptop and the other end to the Ethernet port of Access Box (See Figure 5.1).

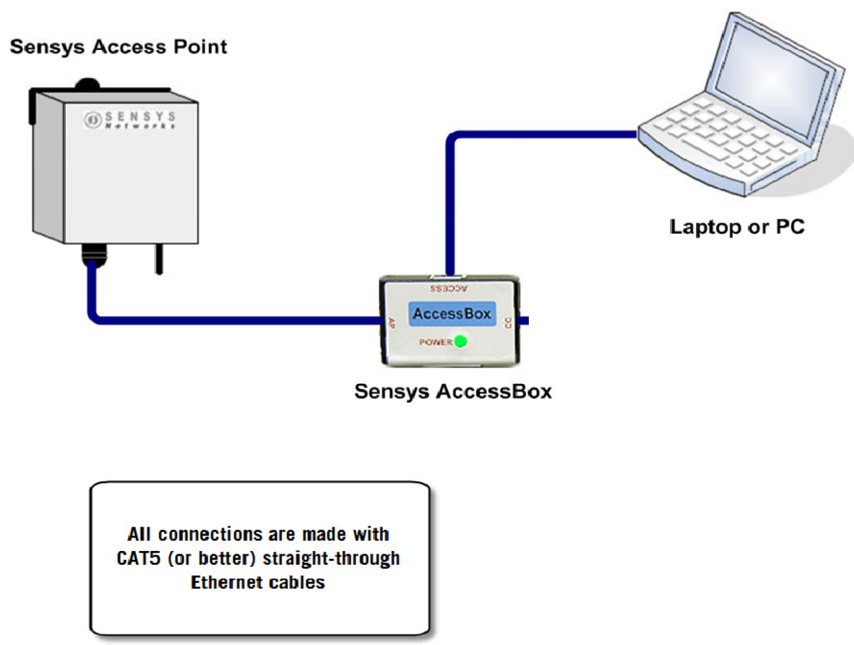


Figure 5.1: Connecting an IP Device (Laptop) to a Sensys Access Box

5.2. Connecting to the Access Point via TrafficDOT Application

- Double-click on the TrafficDOT icon on the desktop (shortcut).
- Type the access point's *IP Address* and *TCP Port* (See Figure 5.2).
  Default IP address: `192.168.2.100`
  Default TCP port: `10000`

Note*:* It is recommended to use the default IP address and port number.

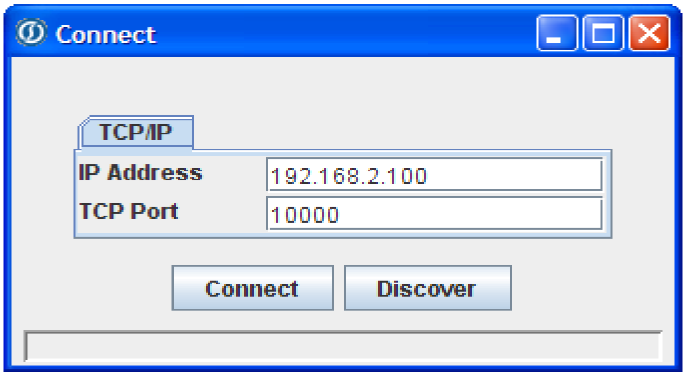


Figure 5.2: TrafficDOT Application Connection Window

➢ Click the ***Connect*** button.

Note: If the IP address of the access point is not known, click on ***Discover*** button. The ***Discover*** button queries the local network and opens a window that lists All the Access points on the network. Make a note of the IP address of the access point you wish to connect to. Click on ***Dismiss*** button to close the window and return to connect window.

5.3 Configuring the Access Point

➢ To configure an Access Point, access the ***Configure*** menu and click ***Access Point*** (See Figure 5.3).

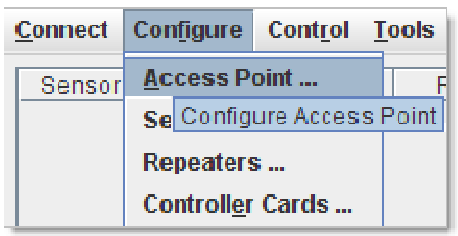


Figure 5.3: Configure Access Point Menu

The *Access Point Configuration* window appears with the current configuration data loaded into its tabular display (See Figure 5.4).

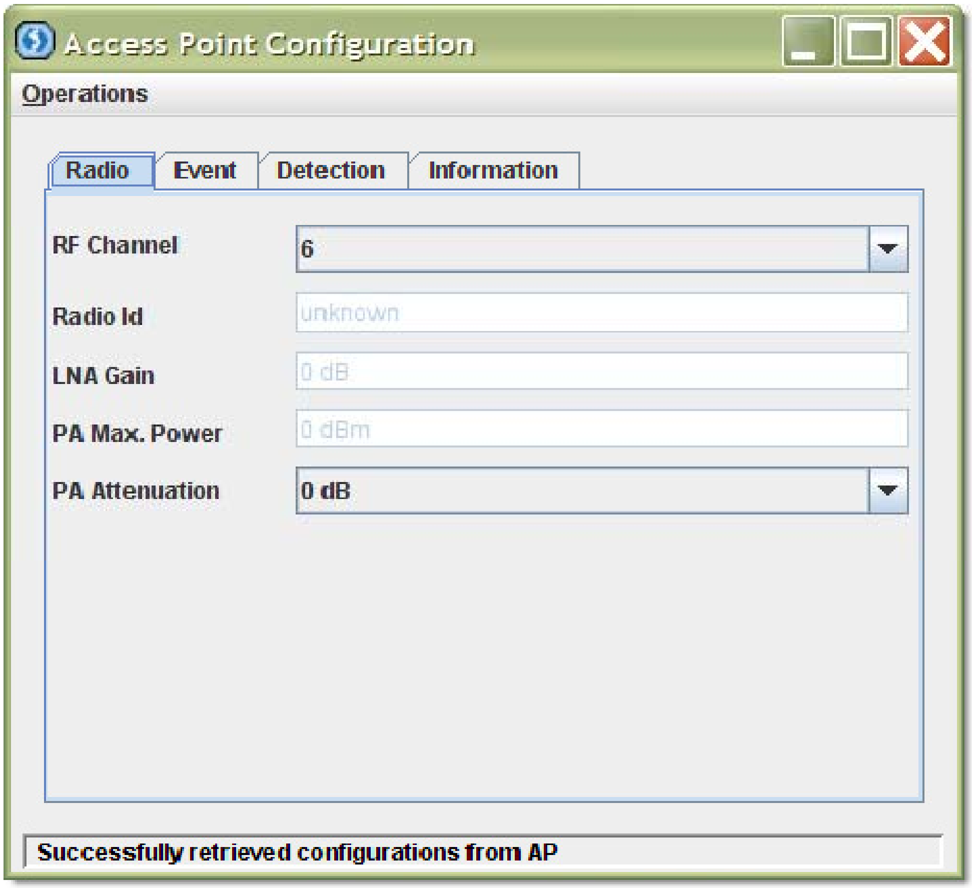


Figure 5.4: Access Point Configuration Window

5.3.1 Setting the RF Channel

To set the RF channel, do the following:

- The entries in the *RF Channel* drop-down list correspond to the 16 frequencies available for use. Select an entry from the list by clicking it. Note that the factory default channel is zero. The value set on this section should correspond to the value set on the sensors' configuration in Section 3.

- Click ***Apply*** from the *Operations* menu to apply the change or continue configuring the Access Point.

5.3.2 Setting User ID and Password for FTP Services Hosted by the Access Point

Access points contain a local ftp server to provide a means of file transfer and disk access to authorized users. The *Access Point* tab collects the user identifier and password string for the ftp user.

- From the ***Configure*** menu, click ***Preference*** (See Figure 5.5).

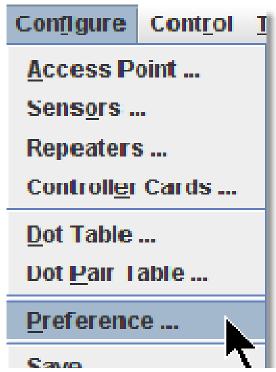


Figure 5.5: TrafficDOT Configure / Preference Menu

➢ Click on the ***Access Point*** tab (See Figure 5.6).

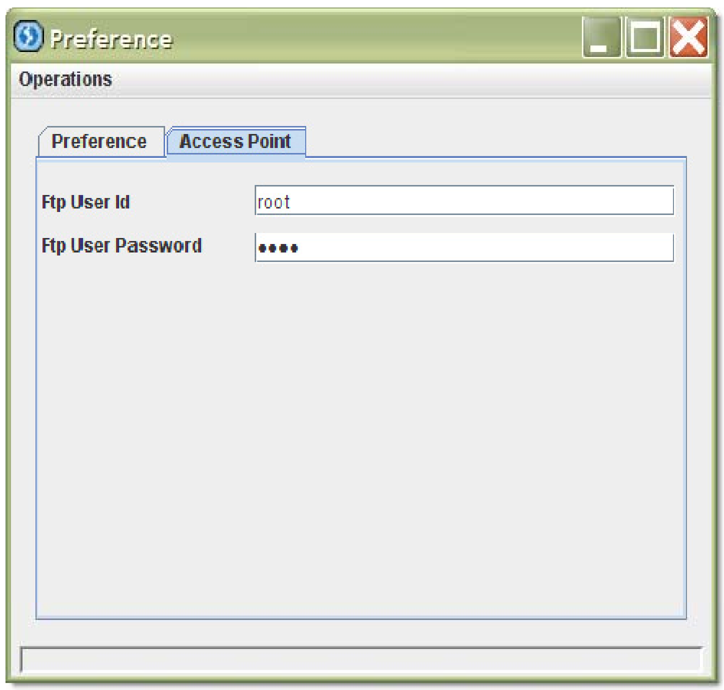


Figure 5.6: User ID and Password

➢ Set the desired *User ID* and *Password*.

➢ Go to *Operations* then click ***Save***.

5.3.3 Setting Up the Configuration for Bin Data Collection

After all the connections and set ups for the sensors have been completed, the configurations for bin data collection can then be performed. From the main window of TrafficDOT go to the ***System*** -> ***Configuration*** menu and perform the following:

➤ Go to the ***Push*** tab (see Figure 5.7).
Push refers to movement of processed sensor statistical data from one host to another initiated by an access point.

➤ Enter the *1st Destination IP*. Enter the fixed IP address of the laptop as configured in Section 3 "Configuration of the Field Laptop Computer." The IP address used was `192.168.2.99`.

➤ Specify the *Destination Port (required)* (typically `10250` however any other port above 10000 can be used).

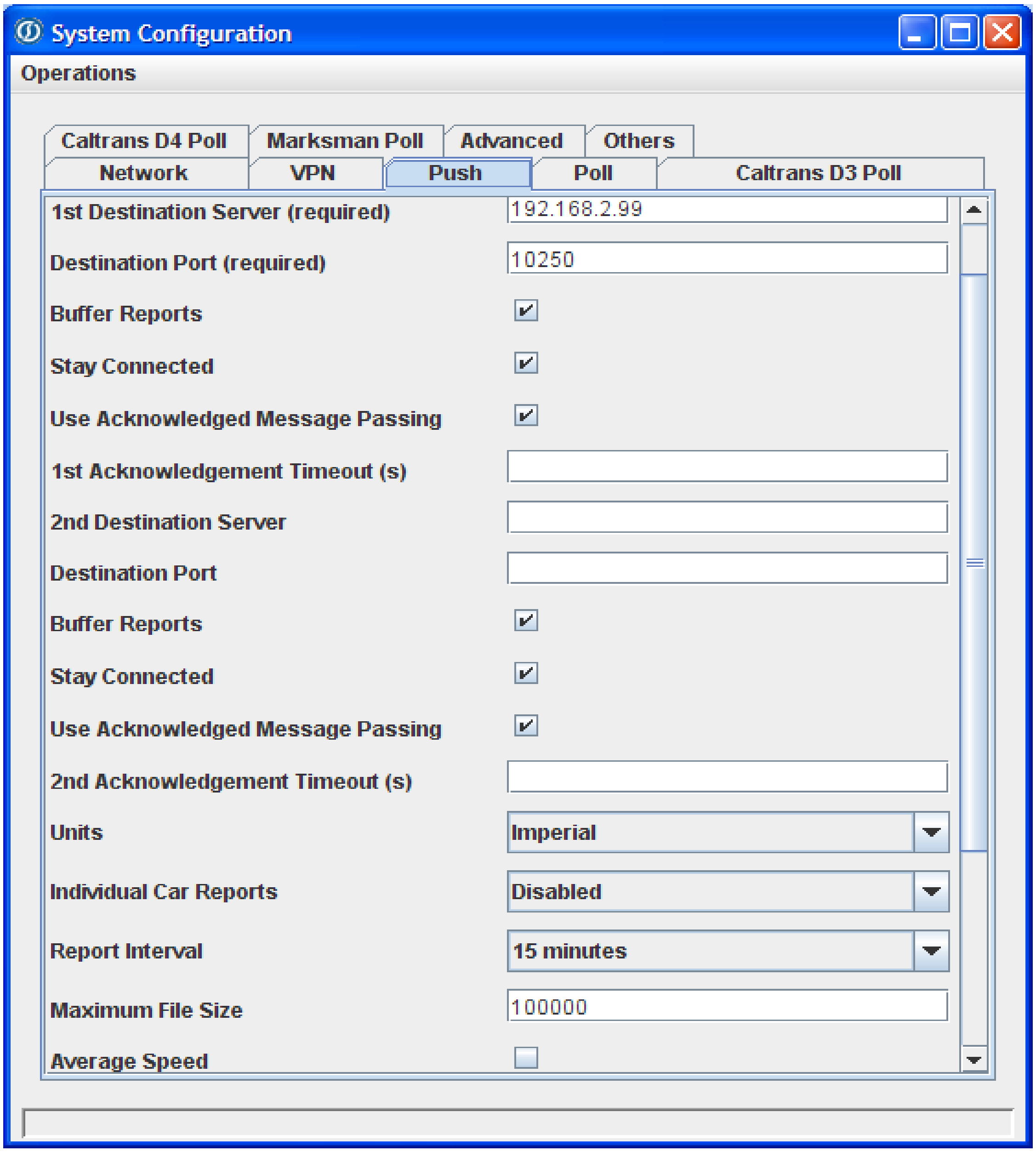


Figure 5.7: System Configuration Window

- Verify that the following options are checked:
    - *Buffer Reports*
    - *Stay Connected*
    - *Use Acknowledged Message Passing*

- The following entries should be left blank:
    - *1st Acknowledgement Timeout (s)*
    - *2nd Destination Server*
    - *Destination Port*
    - *2nd Acknowledgement Timeout (s)*

- Uncheck *Average Speed*.

- Set the *Units* to *Imperial*.

- Verify that the *Individual Car Reports* entry is set to *Disabled*.

- Set the *Report Interval* for bin collection to *15 minutes*.

- Set the *Maximum file size* to 300kB by entering `300000`.
  Note: Maximum file can be set up to 500kB. File size is determined by the number of lanes and the length of time to be recorded.

- While still on the *System Configuration* window, click on the ***Poll*** Tab (see Figure 5.8).

- Set the *TCP Port (required)* to `1050`.

- Set the *Operating Mode* as *Connection-based Polls* using the dropdown menu.

- Set the *Units* to *Imperial*

- Set the *Report Interval* to *15 minutes*.

- Set the *Individual Car Reports*, the *Speed Histogram*, and the *Length Histogram* to Disable.

- Set the *Timestamp Option* to *End of Interval*.

- Set the *Maximum file size* to 300kB by entering `300000`.
  Note: Maximum file can be set up to 500kB. File size is determined by the number of lanes and the length of time to be recorded.

- Verify that the following are unchecked:
- *Average Speed*
- *Use Diagnostic to correct Averages*
- *Display Diagnostics*

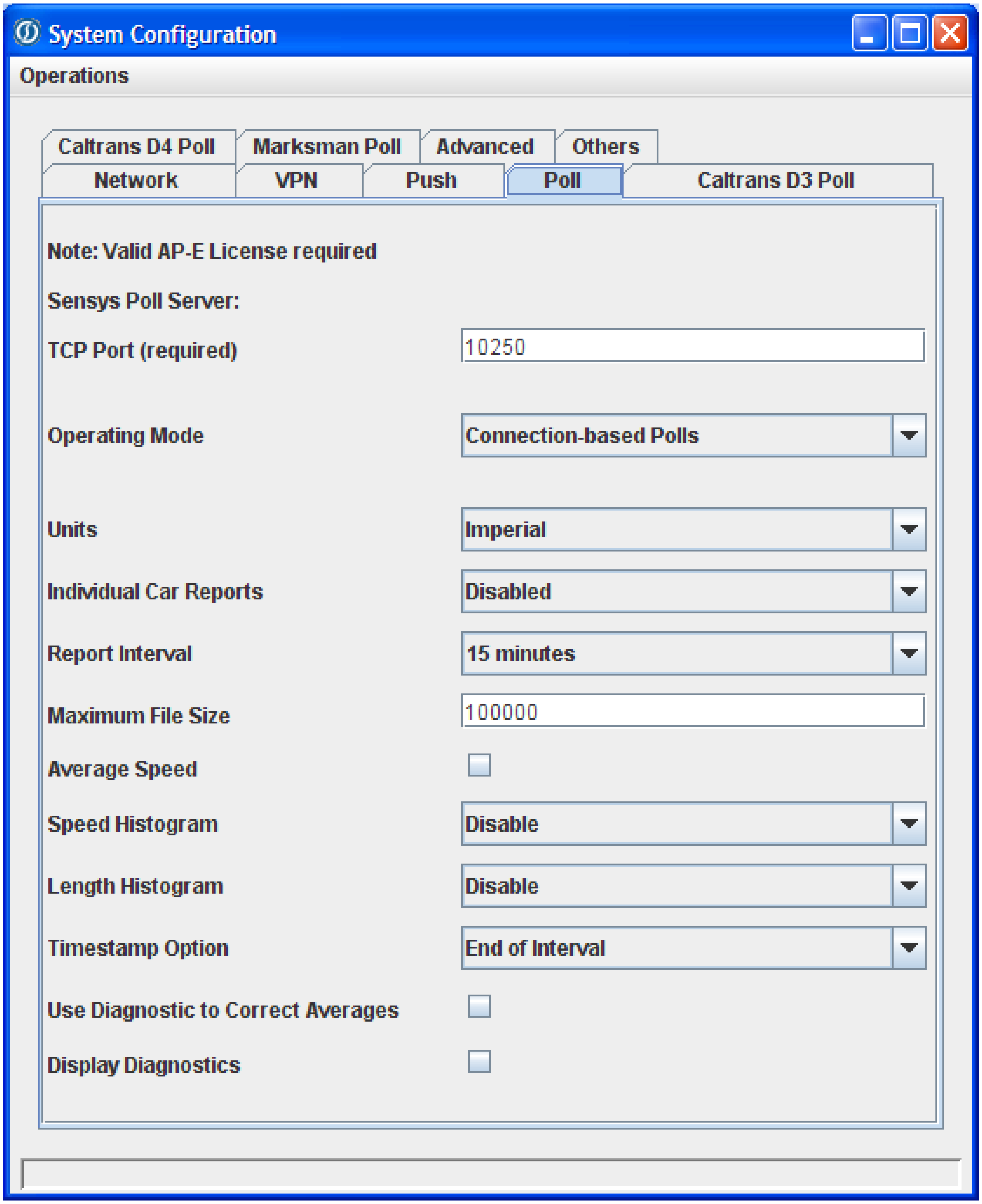


Figure 5.8: System Configuration Window

5.3.4 Setting the Date via TrafficDOT

Click on the ***Others*** tab (see Figure 5.9) and do the following:

- Specify *Free running* in the *Time Synchronization* drop down menu.
- Set the correct time zone.

- Set *Serial Mode* to *RS485*.

  Note: RS485 sets the port for communications with traffic signal control equipment via a contact closure card from Sensys Networks. This setting is mandatory for using the access point with signal controllers.

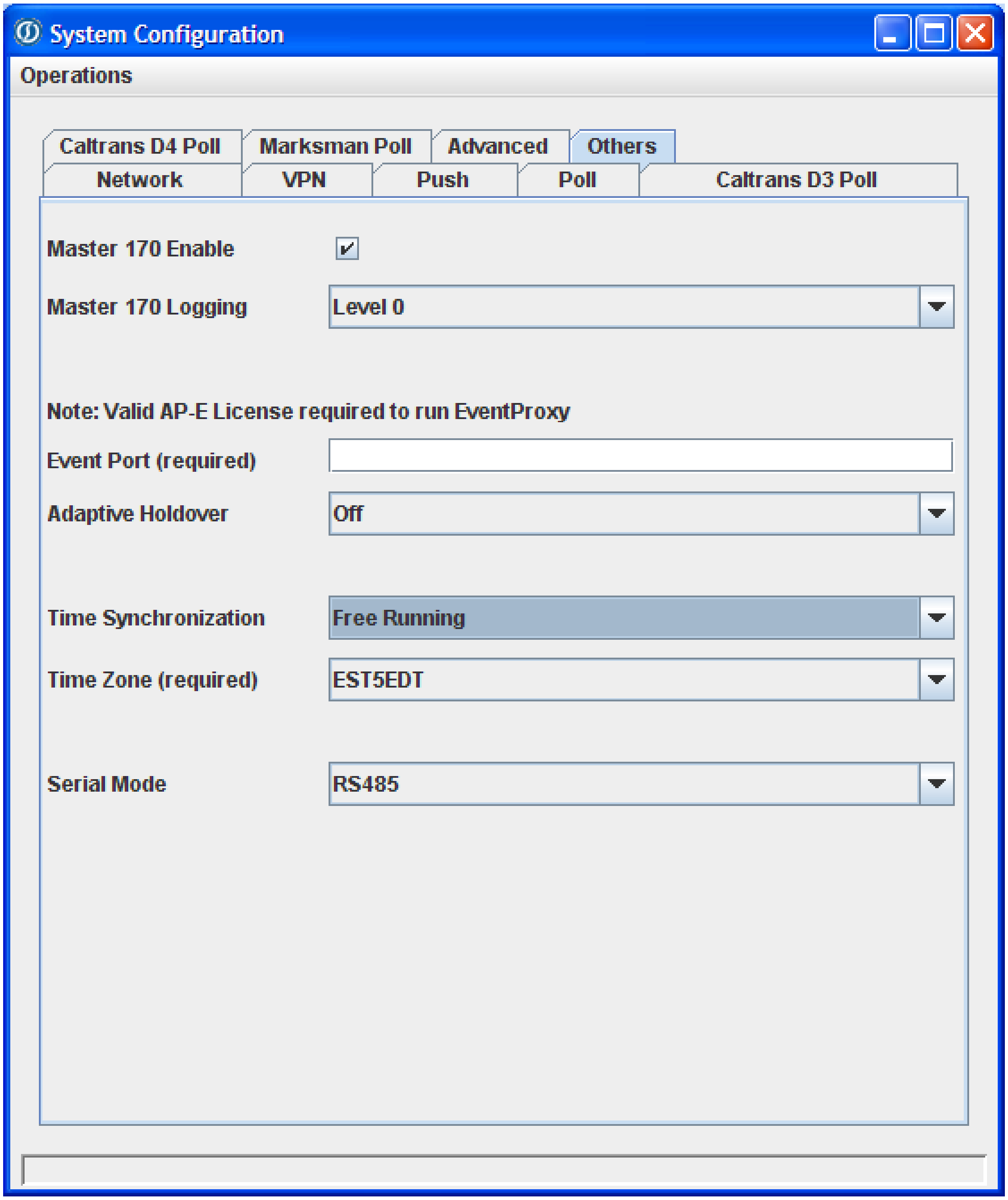


Figure 5.9: System Configuration Window->Others

5.3.5 Saving the Configurations

- Click on ***Operations***.
- Click on ***Save***.
- Click on ***Dismiss*** when finished saving (see Figure 5.10).

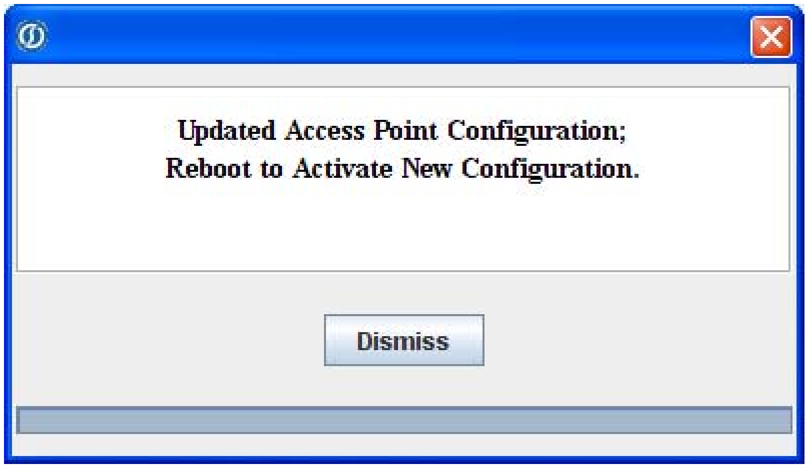


Figure 5.10: Successfully Saved Configuration Window

5.3.6 Rebooting the Access Point.

After all the configurations have been made to the access point, it has to be rebooted so as the changes to take effect. This is very important and it is done via TrafficDOT's ***Control*** menu (see Figure 5.11).

- Click on ***Control*** from main window and then select ***Reboot***.

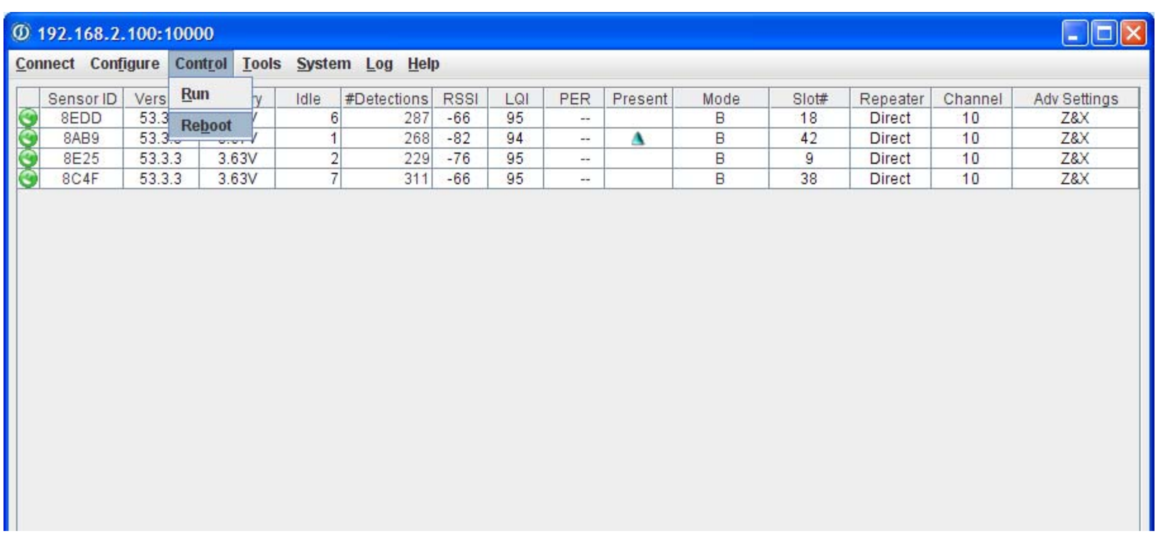


Figure 5.11: System Control Window

5.3.7 Setting Date and Time via Telnet

- Reconnect the access point via TrafficDOT Application.
- Click on windows ***Start*** button and then click ***Run***.
- Type `telnet 192.168.2.100` into the *Open* dialog box (see Figure 5.12) and then click ***OK***. This should open a new DOS window with prompt to log in (see Figure 5.13).

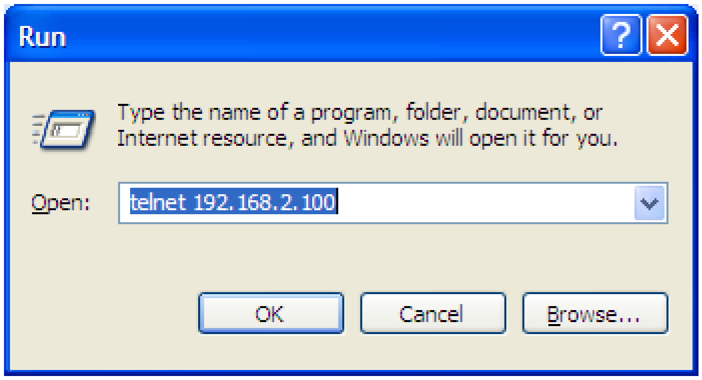


Figure 5.12: Performing a Telnet Connection in the Run Window

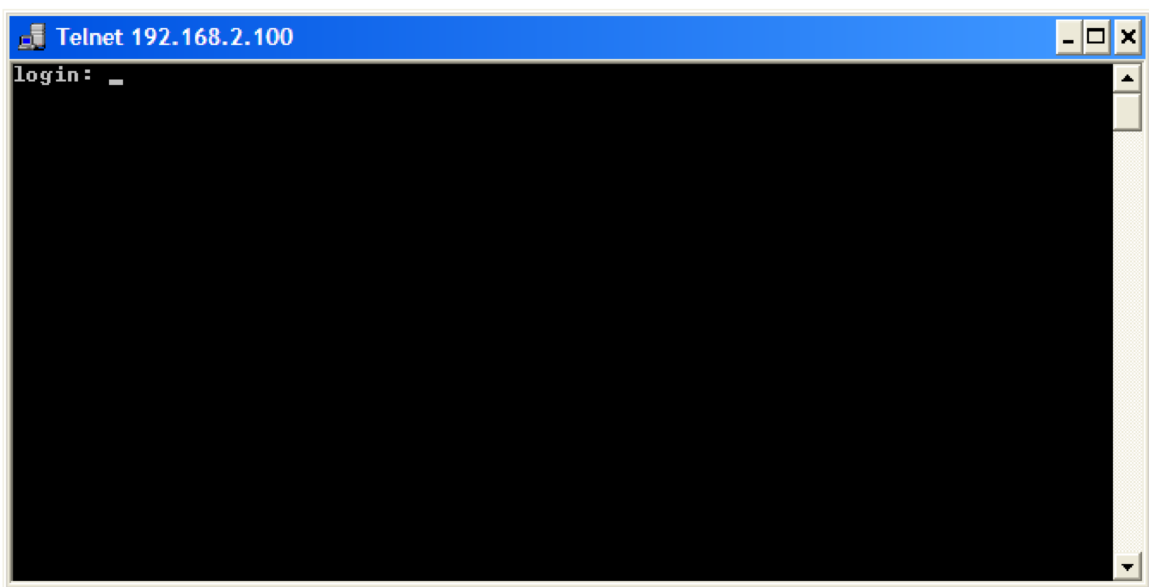


Figure 5.13: Telnet Login Window 1

- Type the username (default login username is `root`) and then press ENTER on the keyboard.
- Type the correct password (see Figure 5.14).

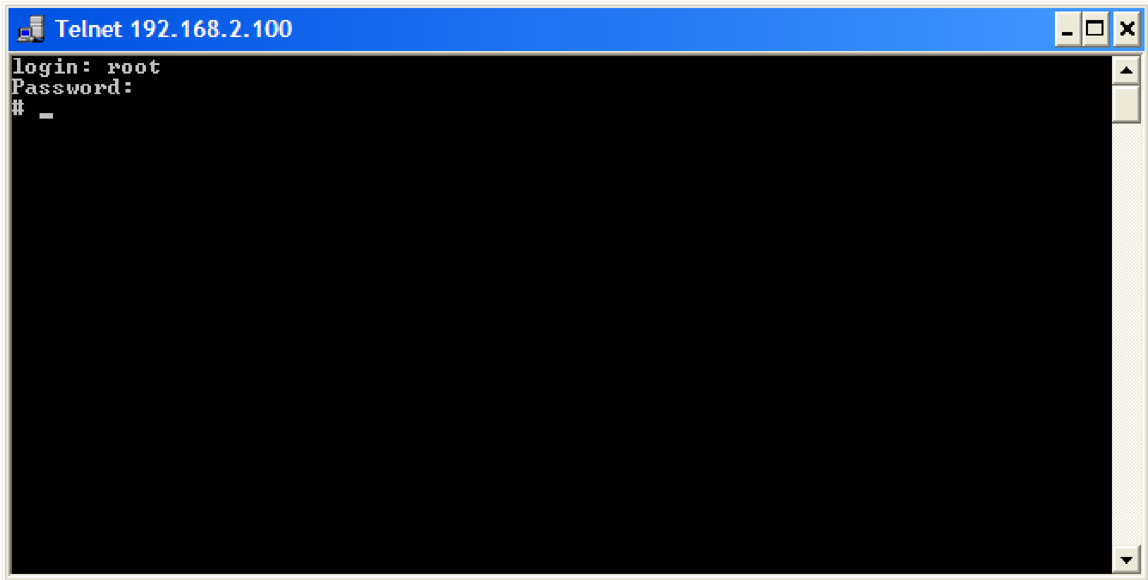


Figure 5.14: Telnet Login Window 2

- To set the date and time type “date-s YYYY.MM.DD-HH.MM” substituting YYYY, MM, DD, HH and MM with the correct year, month, day, hour (24 hour clock) and minute, respectively. The time entered should be in Greenwich Mean Time (GMT). For example, to set the date and time to October 13, 2009 at 3:15PM EDT (Eastern Daylight Savings Time), type `date-s 2009.10.13-19:15` at the prompt (see Figure 5.15).

  To adjust eastern time zone to GMT use the following:

  1. For EST, add 5 hours (1 PM EST is 18:00)
  2. For EDT, add 4 hours (1 PM EDT is 17:00)

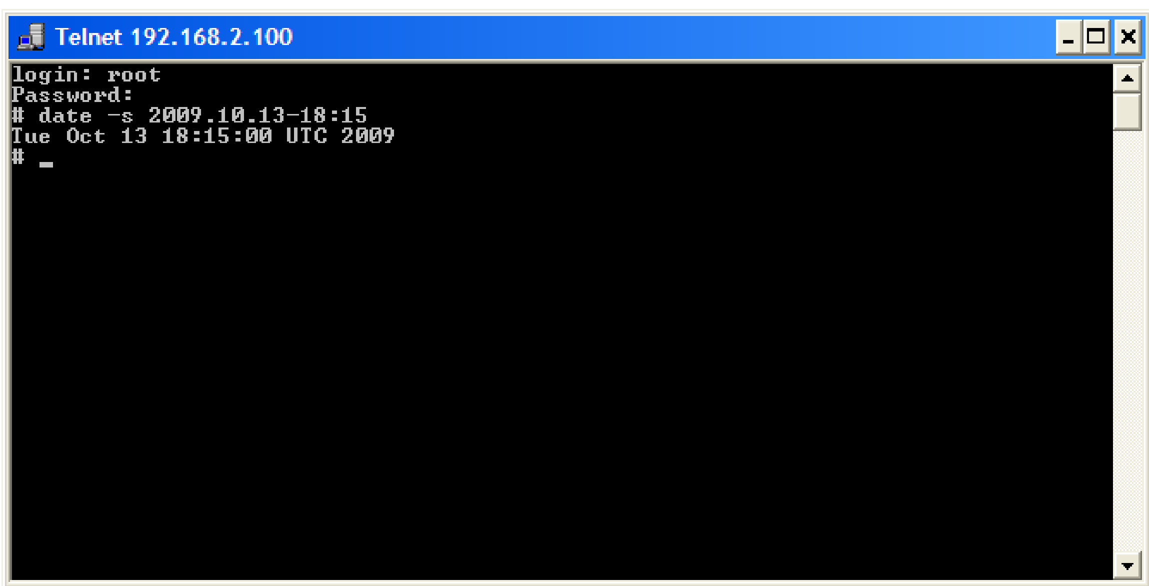


Figure 5.15: Telnet Window for Date and Time Set Up

6. Backing Up and Restoring the Access Point for Multiple Sites

This section is very important as it will enable the user to be able to store (back-up) a site configuration to use the access point at another site. When returning to the original site, the user can restore the configuration of the original site without having to repeat the lengthy setup. This can be extended to storing the configurations for multiple temporary traffic count sites by using a naming convention that allows the user to identify the back-up files from each traffic count site.

6.1 Backup of the Access Point Configuration

Backup activities are initiated from the ***System*** menu. Once the settings for a certain location have been backed up, they can be retrieved next time when collecting data from that particular backed up site. *Note:* Always perform back up for every first time site visit. To backup the current access point configuration, do the following:

- Go to the TrafficDOT main window and select ***System*** -> ***Backup*** (see Figure 6.1).

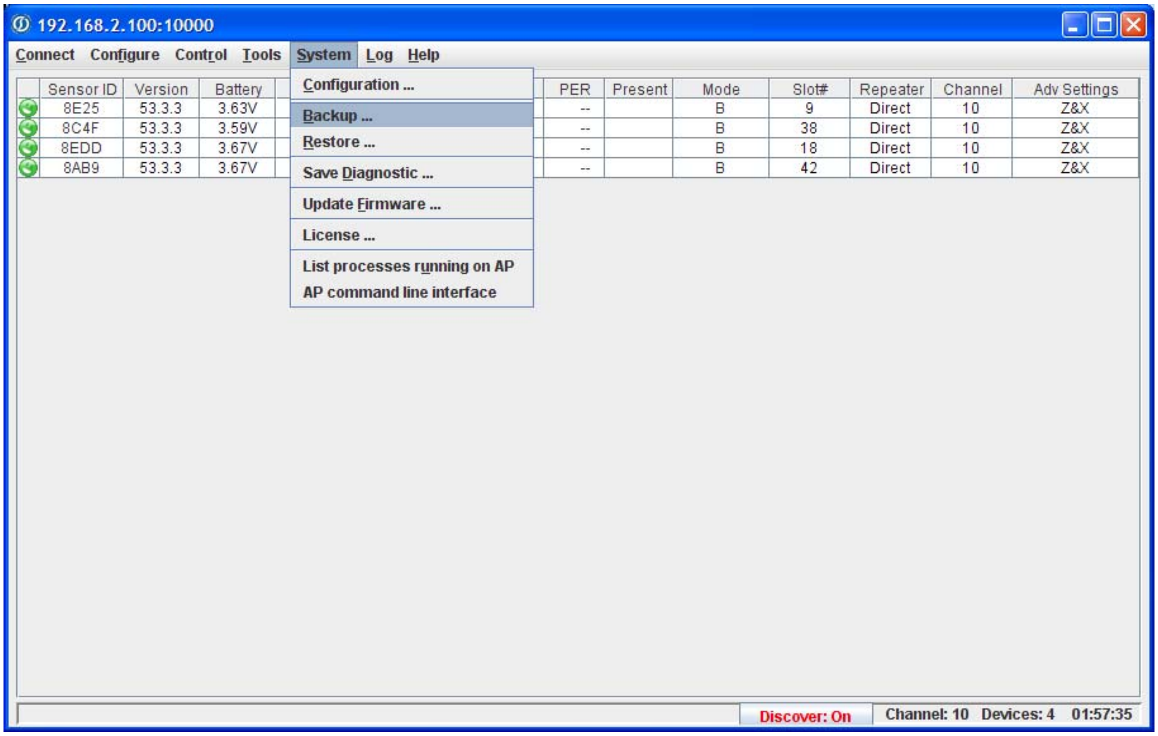


Figure 6.1: TrafficDOT's System Menu

The *Backup VDS240* window will appear (see Figure 6.2).

- Name the file by typing the site name on the *File Name* text box. A good choice of file name should identify the data collection site such as `AP_site_3041`. Optionally, store the file to a different folder than the default.

- Click ***Save*** to backup the access point configuration to the file.

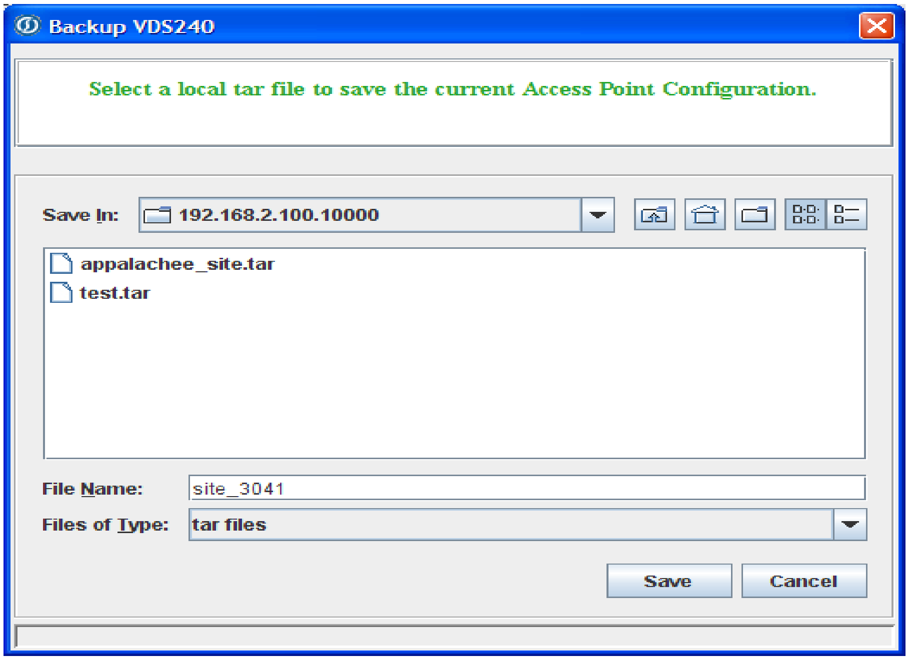


Figure 6.2: Back-up VDS window

➢ Wait for back up to complete and click D***ismiss*** (see Figure 6.3).

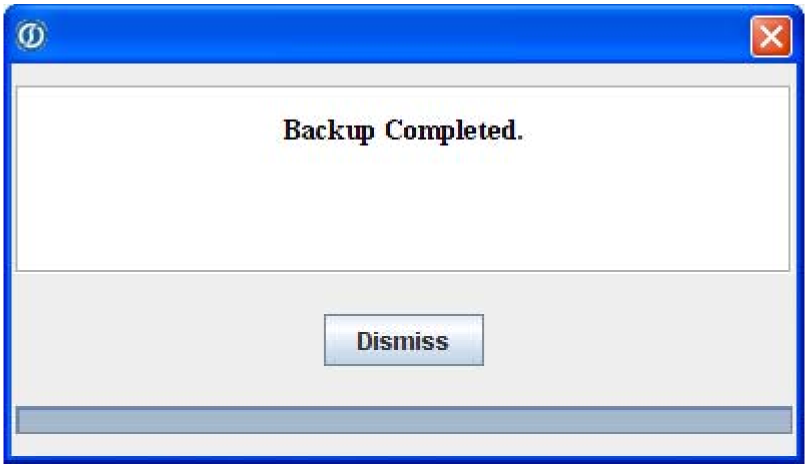


Figure 6.3: Back-up Completion Window

Note: The same procedure will be followed when backing up the configurations for all other temporary traffic count sites. Using unique filenames including the site number will simplify identifying the correct file to restore when the access point is again used at each site.

6.2 Restoring the Configurations

The restore function in TrafficDOT can be used to quickly restore an access point to a site configuration that has been saved using the backup function. To restore a previously saved site configuration, connect to the access point using TrafficDOT and perform the following steps:

- Click ***Restore*** from the ***System*** menu. The *Restore VDS240* window appears (see Figure 6.4).

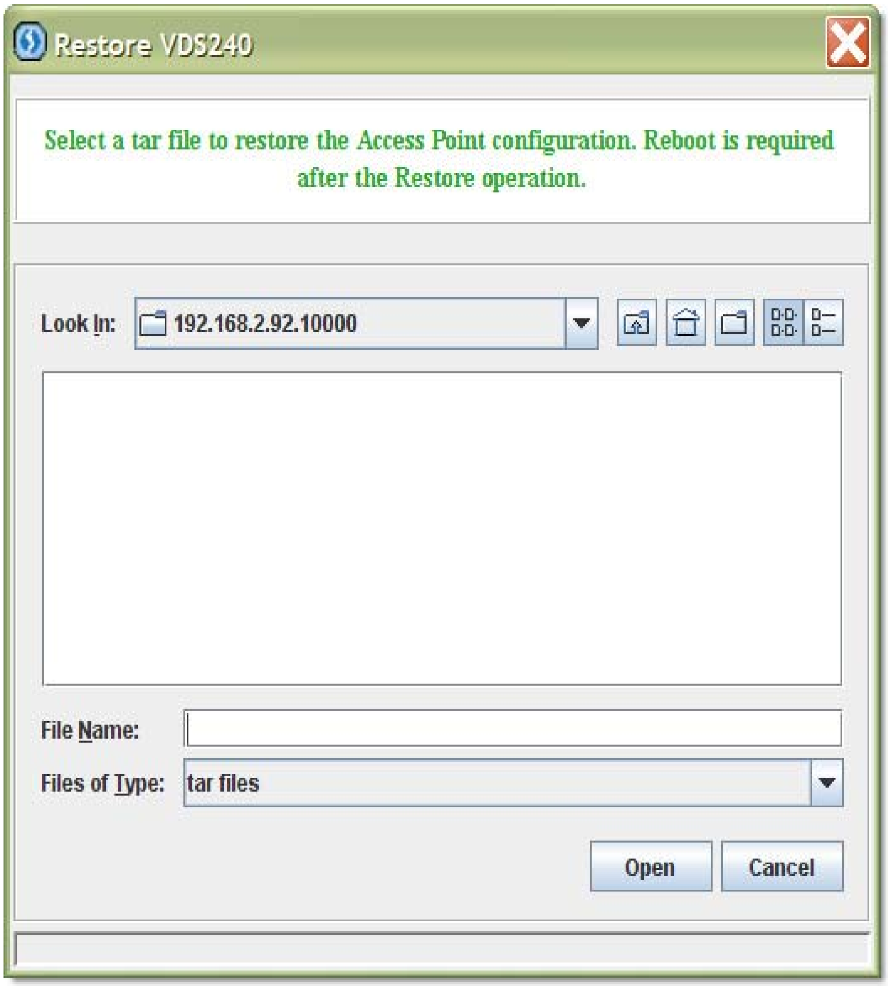


Figure 6.4: Restore VDS240 Window

- Select the file that contains the backup that will serve as the source for the restore. Optionally, navigate to a different folder than the default.

- Click ***Open*** to restore the Access Point from the file.

- Reboot the access point by clicking on ***Control*** from main window and then selecting ***Reboot***.

7. Downloading Statistical Data and Exiting TrafficDOT

The Statistical data collected by the access point can be downloaded for the analysis via the web browser using ftp connection between the laptop computer and the Access point.

7.1 Downloading Data

➢ Go to your Web browser (Recommended: Mozilla Firefox web browser).

  Note: Microsoft Internet explorer could also be used. Prior to using the Microsoft Internet Explorer for downloading the data, perform the following:

  - Open Internet Explorer. Select ***Tools*** > ***Internet Options*** from the menu bar (see Figure 7.1).

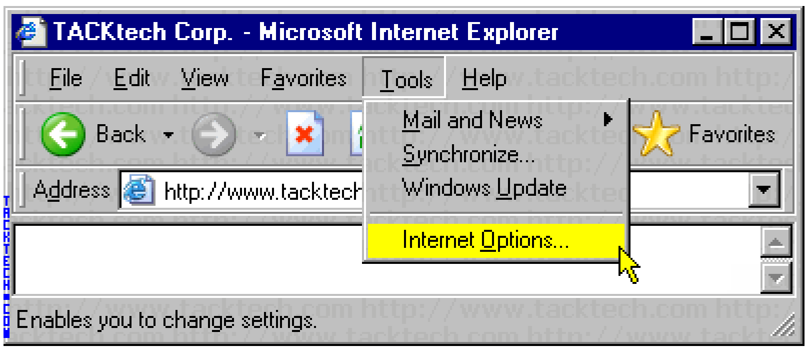


Figure 7.1: Internet Options

  - Click on the ***Advanced*** tab. Uncheck the *Enable folder view for FTP sites* option. Click the ***OK*** button (see Figure 7.2).
  - Close Internet Explorer.
  - Re-open Internet Explorer to apply the changes.

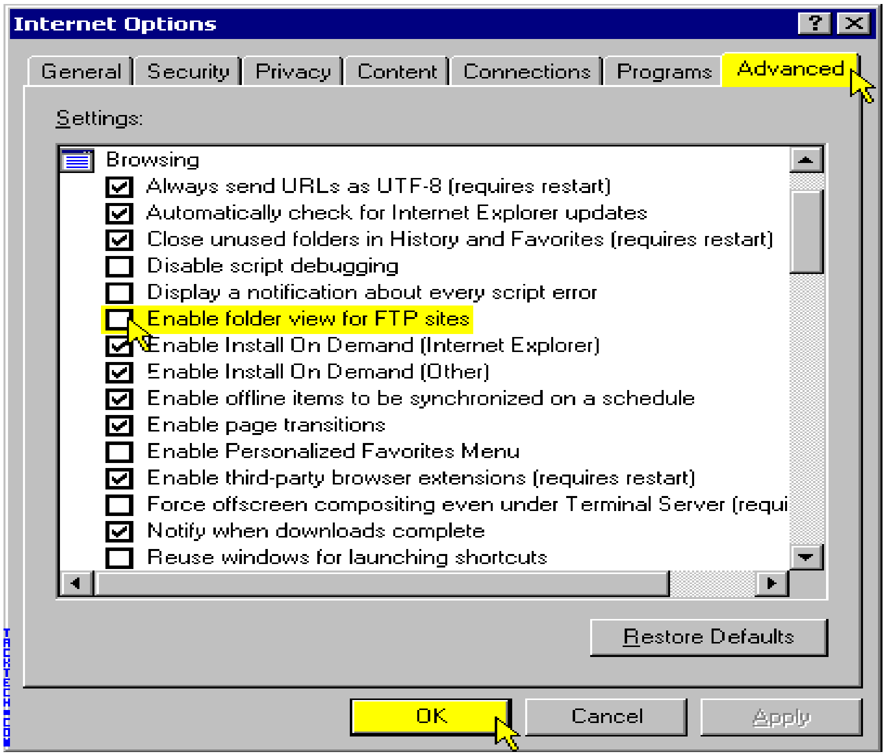


Figure 7.2: ***Enable folder view for FTP Sites*** option.

- On the web browser address bar, type "ftp://<username>@<ip address>" substituting <username> with the username configured for the access point and <ip address> with the configured IP address of the access point. For example, if the default IP address and username were configured in the access point then type "ftp://root@192.168.2.100" into the address bar.

- A pop up window asking for password should appear (see Figure 7.3).

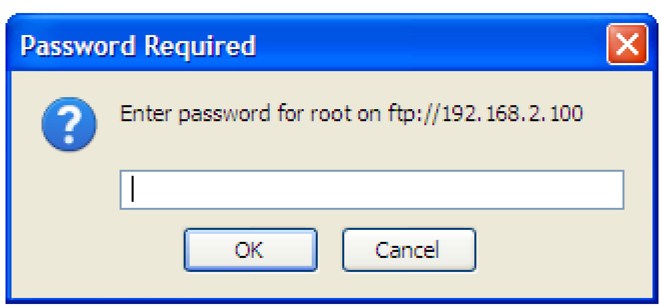


Figure 7.3: Password Request Pop up Window

- Type the correct password and click ***OK***. A list of folders will be displayed (see Figure 7.4).

- Navigate to ***var/apstat_poll_tcp***. A list of files will be available labeled using date format, double click a file to open.

- Select all the text in the file by pressing Ctrl+A on the keyboard, and then copy the text by pressing Ctrl+C on the keyboard.

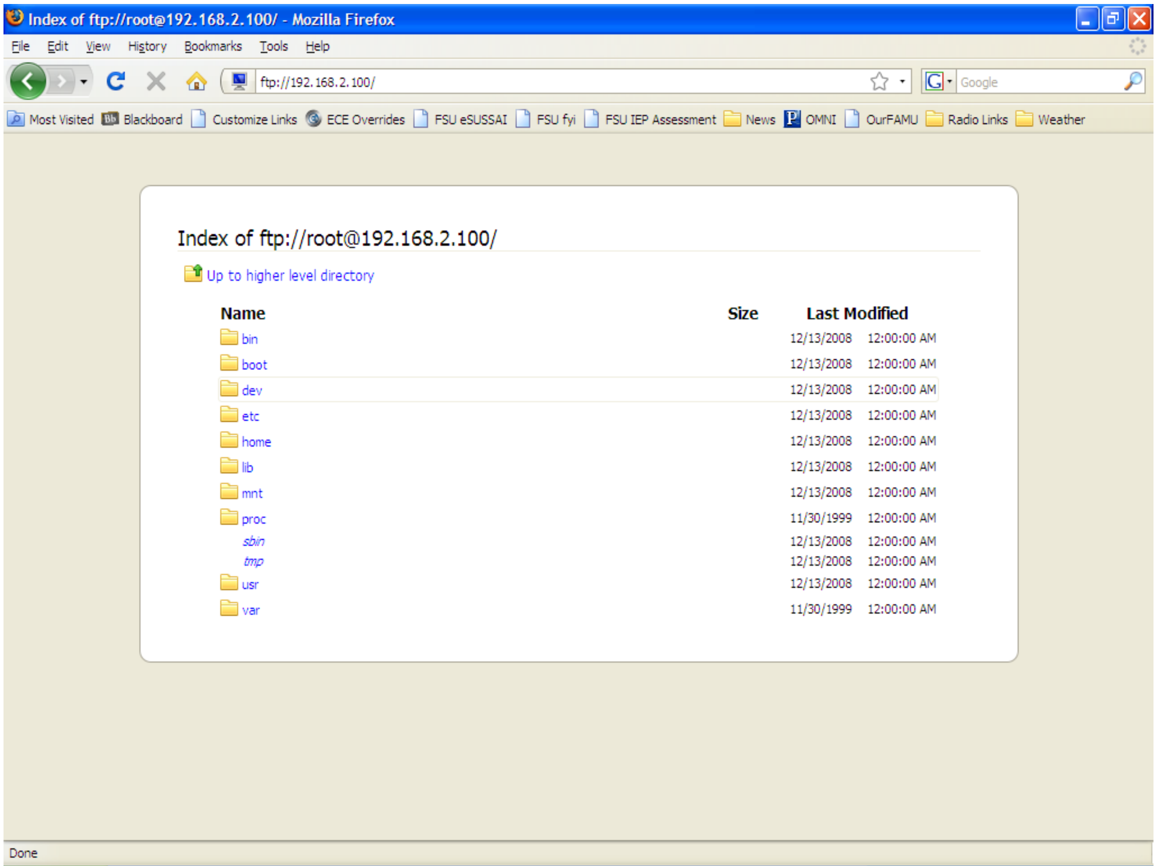


Figure 7.4: Available Folders List Window

- Open a new file using notepad or Microsoft Word
- Paste the text into the file by pressing Ctrl+V on the keyboard.
- Save the file and close it.

Note: The files should be saved one after the other according to the dates they were created.

7.2 Exiting TraffficDOT

To end TrafficDOT session, do the following:

- From the ***Connect*** menu on the TrafficDOT main window, click ***Disconnect***.
- Then click ***Exit***.

Alternatively, you can close TrafficDOT by clicking the close window control in the upper right-hand corner of the *Access Point Control Center* window.