

# **EVALUATION OF INTRUSION DETECTION TECHNOLOGIES FOR HIGH SPEED RAIL GRADE CROSSINGS**

## **Final Report**

by

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16. Abstract  <p>The rail industry is in the process of developing a prototype system for high speed rail. One of the concerns when using high speed rail is the danger of obstructions on the track. This level of danger is much higher than with traditional railway vehicles because the high speed passenger equipment is both lighter and faster moving than traditional equipment. It is therefore more vulnerable to serious damage and derailment by objects on the track.</p> <p>The goal of this project was to evaluate methods for detection of objects on railway track where they are crossed by a roadway. Two existing traffic monitoring technologies were tested for their potential in railway intrusion detection: video and microwave.</p> <p>Laboratory test results indicated that both systems appeared to have good potential for use in railroad intrusion detection. The video system was tested in indirect natural light, medium intensity artificial lighting and low level artificial lighting. Object detection was independent of color, composition, and direction of entry but was a direct function of detection zone size. Spheres as small as 4 inches (102 mm) in diameter, were consistently detected by the video system at distances of 15-25 feet (4.6-7.6 m). The microwave system consistently detected 4 inch (102 mm) spheres at the same distances, and results were independent of material, color, entry direction and zone size.</p> <p>Field test results of both of the technologies were mixed. The video system was subject to detection problems during the day due to the much greater complexity of the field environment and at night due to light reflections from smooth surfaces. The microwave detection system reliably detected large objects such as automobiles, even in a complex field environment, but it did not reliably detect objects smaller than an auto. The ability of this system to detect smaller objects appeared to be severely compromised from confounding features such as metal objects that can reflect microwaves. The distance of objects from the detection unit may have also been a factor in its poor field performance.</p> <p>The study concluded that existing video and microwave-based traffic monitoring systems may have potential for use in a railroad intrusion detection application, but further refinement of the technologies is needed.</p>					
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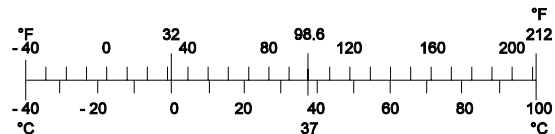
## SI\* (MODERN METRIC) CONVERSION FACTORS

### APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
<b><u>LENGTH</u></b>				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
<b><u>AREA</u></b>				
in <sup>2</sup>	square inches	645.2	millimeters squared	mm <sup>2</sup>
ft <sup>2</sup>	square feet	0.093	meters squared	m <sup>2</sup>
yd <sup>2</sup>	square yards	0.836	meters squared	m <sup>2</sup>
ac	acres	0.405	hectares	ha
mi <sup>2</sup>	square miles	2.59	kilometers squared	km <sup>2</sup>
<b><u>VOLUME</u></b>				
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft <sup>3</sup>	cubic feet	0.028	meters cubed	m <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.765	meters cubed	m <sup>3</sup>
NOTE: Volumes greater than 1000 L shall be shown in m <sup>3</sup> .				
<b><u>MASS</u></b>				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
<b><u>TEMPERATURE (exact)</u></b>				
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

### APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
<b><u>LENGTH</u></b>				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
<b><u>AREA</u></b>				
mm <sup>2</sup>	millimeters squared	0.0016	square inches	in <sup>2</sup>
m <sup>2</sup>	meters squared	10.764	square feet	ft <sup>2</sup>
m <sup>2</sup>	meters squared	1.196	square yards	yd <sup>2</sup>
ha	hectares	2.47	acres	ac
km <sup>2</sup>	kilometers squared	0.386	square miles	mi <sup>2</sup>
<b><u>VOLUME</u></b>				
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m <sup>3</sup>	meters cubed	35.315	cubic feet	ft <sup>3</sup>
m <sup>3</sup>	meters cubed	1.308	cubic yards	yd <sup>3</sup>
<b><u>MASS</u></b>				
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
<b><u>TEMPERATURE (exact)</u></b>				
°C	Celsius	1.8C+32	Fahrenheit	°F



\*SI is the symbol for the International System of Measurement

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# EVALUATION OF INTRUSION DETECTION TECHNOLOGIES FOR HIGH SPEED RAIL GRADE CROSSINGS

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## 1.0 INTRODUCTION

The rail industry is in the process of developing a prototype system for high speed rail. One of the concerns when using high speed rail is the danger posed by obstructions on the track. This level of danger is much higher than with traditional railway vehicles, because the high speed equipment is both lighter and faster moving than traditional equipment. It is therefore more vulnerable to serious damage and derailment by objects on the track.

The highest risk area for objects on the track is at intersections with roadways. When vehicles cross the track something may fall off of a truck or farm vehicle, or someone may drop something from the vehicle. The goal of this project was to evaluate methods for detection of objects on railway track where they are crossed by a roadway.

Several factors contribute to making remote detection of objects on a track a particularly difficult problem. The size of object that must be detected may be quite small, such as a length of pipe or a piece of equipment. The conditions under which objects must be detected will vary as a function of time of day and season of the year and will include variables such as natural versus artificial light, fog, rain, snow covering the ground, etc. Also important is the fact that, while the detection of potential hazards must be as close to 100% as possible, the number of false detections requiring attention must be kept to a minimum.

The specific objective of this project was to evaluate existing technologies for detection of objects, for their usefulness in monitoring railroad-roadway intersections. The tasks included identification of potential technologies, evaluation of those technologies on paper for their applicability, selecting the most promising for tests, and then physically evaluating the hardware both in the laboratory and in the field.

The identification of potential technologies was addressed in a 1997 study prepared for the Oregon Department of Transportation (ODOT) by the Transportation Research Institute at Oregon State University. This study took a comprehensive look at possible grade crossing treatments for a potential high speed rail corridor (*Bell, et al. 1997*). One facet of this research project was to review possible methods for the detection of objects on railroad tracks. However, the work was limited to identification of technologies that might be used, without making comparisons or reaching conclusions about their appropriateness for this application. The technologies identified in this study as having potential for intrusion detection included video image processing, inductive loop, infrared, and sonar-based systems.

In 1998 a national workshop was held on Intruder and Obstacle Detection Systems for Railroads (*Carroll, et al. 1998*). The primary focus of this workshop was the issue of what constitutes an intruder or obstacle that needs to be detected and, once detected, how it should be reported. The workshop also included a review of potential technologies for detection, an effort similar in its objective to the 1997 study. The list resulting from this workshop included radar detectors, laser detectors, infrared detectors, ultrasonic detectors, millimeter microwave, magnetic, buried

coaxial, video motion detectors, seismic, fiber optic, perimeter fence detection, and photoelectric beam.

A recent review of potential technologies for intrusion detection at rail crossings was completed in 2001 (*Reynolds 2001*). A variety of technologies was examined, including infrared, microwave/radar, passive acoustic, ultrasonic, and video. The research report provided an updated comprehensive summary of these technologies. The examination of each technology included a description of the method of detection, strengths, weaknesses, and potential difficulties for the technology such as installation, weather, maintenance, etc. The technologies are summarized in Table 1.1, which notes the ability to detect large stationary objects, accuracy in doing so, environmental effects, and device sensitivity.

**Table 1.1: Detection technology comparisons**

Detector Type	Detect Stationary Vehicles?	Accuracy*	Affected By Environment?	Sensitivity
Infrared	Variable			Variable
Passive	Yes	97%	Yes	Fair
Active	Yes			Good
Microwave	Variable			
Continuous Wave Doppler	No	97%	No	Fair
Frequency Modulated CW	Yes			
Ultrasonic	Yes	90-96%	Yes	Good
Passive Acoustic	Yes	90-96%	Yes	Fair
Video	Yes	97%	Yes	Good

\*Compared to inductive loop data

This report recommended that Frequency Modulated Continuous Wave (FMCW) microwave, ultrasonic, and video imaging showed the most promise, but it noted that no single system would meet all of the requirements for a rail crossing application. The FMCW microwave systems tend to undercount in low volume conditions and also have limited sensitivity. The ultrasonic devices also have been shown to undercount, have limited sensitivity, and are affected by weather conditions, air turbulence, and the reflectivity of the detection surface. The video imaging systems have problems in adverse weather conditions and in transitions between daylight and darkness.

An important point about all of these studies is that the reported evaluations were based on vehicle detection (automobiles). This is understandable in the sense that the technologies tested are designed for that application. On the other hand, the usefulness of the research for the current study is limited, because much smaller objects than a vehicle may be hazardous for high speed rail.

Based on these reports and a final review of current manufacturers' data sheets, the decision was made to pursue video imaging and microwave detection for testing. At the time the technology selection decision was made, these were the two types of technology that showed the most promise for detecting smaller objects that might be found at a rail-roadway crossing, such as farming tools or a shopping cart, and pedestrians.

In addition to technology selection, technology vendors also had to be identified. Many of the vendors who were contacted did not show an interest in participating in the research project. The two that were selected as being most promising were a video detection system manufactured by Traficon<sup>1</sup> and a microwave detection “Remote Traffic Monitoring System” made by E.I.S.<sup>2</sup>

Several video systems were available and were considered. The Traficon system was selected for final evaluation based on its listed sensitivity, the availability of local support, and cost. During an on-site demonstration by the vendor, an additional consideration was presented. Traficon was developing a system designed specifically for pedestrian detection, one which would presumably provide greater sensitivity for smaller objects than the vehicle sensing system. Final selection of the Traficon video detection system was made after a one month trial period of testing in the OSU laboratories.

In microwave detection, E.I.S. was the only manufacturer of a system that had the capability of detecting stationary objects. The E.I.S Remote Traffic Monitoring System (RTMS) was therefore the only commercially available choice for a microwave detection system for objects left on a railroad bed. In addition, a local representative was available and interested in supporting the project. Prior to the final decision to use this system the vendor presented a demonstration and also visited the test site to assist in identifying options for installation of the detection equipment.

The following chapters describe the testing that was done to evaluate these systems for detection of objects at railroad-roadway crossings. It includes a description of the systems to be tested along with the test methods used and the results for both laboratory and field tests. It concludes with a summary describing the potential for both the video and microwave systems as railroad intrusion detection devices.

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<sup>1</sup> Traficon NV, Meensesteenweg 449/2, B-8501 Bissegem, Belgium, Europe

<sup>2</sup> EIS Electronic Integrated Systems Inc. 150 Bridgeland Avenue, Toronto, Ontario, Canada M6A 1Z5



## **2.0 THE SENSING EQUIPMENT**

The two detection systems evaluated in this research were both originally designed for traffic monitoring. Both have been demonstrated to be reliable through many in-service traffic monitoring applications. Their use for railroad intrusion detection, although theoretically within the capability of these systems, is substantially beyond their design basis. The sections that follow present a brief description of the equipment being evaluated, its setup, and its operating parameters.

### **2.1 THE TRAFICON VIDEO SYSTEM**

The Traficon “VIP/I - Incident monitor” video system uses as its basic sensor a conventional video camera mounted above the region of interest to provide a clear video image of the area. The signal from this camera is sent to a video image processor card. The output of the processor card is both the original video image and, superimposed on the display, an image of the zones being monitored. The processor card also includes discreet digital outputs that can be connected to lamps, computer inputs, or other devices to signal when a stationary object has been detected.

The functioning of this system relies on a combination of built-in video processing software and the skill of the operator in setting up this software. The latter is essential to maximize the system accuracy and sensitivity in detection of stationary objects in the detection area. The primary parameters requiring setup are as follows:

- **Zone Size and Shape:** Each video image may have up to seven detection zones superimposed on it. Each of these seven zones can be located anywhere on the image, including overlapping each other. Each zone has four sides and may have any size or shape.
- **Detection Delay Time:** When an object enters a detection zone the processor card detects it immediately. However, it is not recognized as an object of interest until it has been in the zone for a specified period of time, the delay time. The default delay time of four seconds helps prevent unwanted detection of transient objects such as flying birds or blowing leaves.
- **Zone Direction Sensitivity:** Sensitivity to the direction of entry of an object can be specified. A zone can be made to detect objects entering from only one direction while ignoring entry from another. A zone can also be set to detect entry from any direction.

Other variables that can be adjusted to improve detection for a particular application include a detection sensitivity setting, video camera lens zoom (for wide angle or narrow angle coverage), video level, and video quality detection threshold (for camera failure detection).

The Traficon system was originally designed for use in monitoring vehicles and includes features for providing traffic data (volume, speed, speed discrimination, density, occupancy, and

concentration), incident data (high speed density or occupancy, queue or inverse direction detection, stopped or slow moving vehicle detection, and strange object detection), and presence data (presence or approach of vehicles to an intersection, count of vehicles passing through a zone, queue length measurement). Based on success in traffic monitoring, the system was subsequently adapted to pedestrian detection and monitoring with similar capabilities. It is the pedestrian system which was used in this research.

The primary advantage of this system is the combination of detection with video monitoring capability. For the automatic incident detection required in this project, this system would detect an object and provide a discreet signal to the operator indicating the presence of a stationary object intruding on the railroad tracks. The operator could then use the video image provided by the system to either confirm the need for a response or, if no problem is evident, reset the signal.

The principle disadvantage of this system is that it is subject to the same problems associated with any outdoor video system – i.e., the need for artificial lighting at night and difficulties obtaining a good image during inclement weather such as rain, fog or snow.

## **2.2 THE REMOTE TRAFFIC MONITORING SYSTEM (RTMS)**

As with the video-based system, the RTMS is designed for vehicular traffic monitoring. Specifically, it is intended to provide an inexpensive, reliable replacement for multiple inductive loop sensors. The system has a combination of digital outputs to simulate loop signals and also output to a computer where software can be used for collecting advanced traffic flow data.

The RTMS operates on a fundamentally different principle than the video system. Whereas a video system is passive and collects information from ambient conditions, the RTMS is an active system. It sends out microwaves and interprets the resulting reflections to detect changes in the zone of interest. The RTMS system is unique in that its sensing is based on a frequency modulation continuous wave principle rather than the Doppler shift sensing more common to microwave and radar systems. This allows it to detect objects that are stopped, while Doppler systems can only detect moving objects.

The system is typically mounted on a pole to provide the desired coverage. There are two ways of describing the coverage area: the actual (physical) method used by the RTMS and the programmed coverage area in which individual detection zones are defined. Physically, the coverage area is an elliptical area divided into 32 range slices. These range slices are the physical areas in which the system is checking for objects. In terms of detection zones, the coverage area can be broken into a maximum of eight zones. Each zone may be changed in its distance from the detector and in its width.

The detection zones are set up using a computer program and fed into the RTMS unit through a serial (RS-232) interface. In addition to defining the zones, the setup program includes the following elements which are key to this application:

- The Mode tells the program whether the detector is physically arranged to monitor a highway by looking across it (side-fired), whether it is set to monitor a highway by

looking along the direction of traffic (forward looking), or whether it is looking at an intersection.

- The Sensitivity sets the level of target signal necessary for detection.

This unit has many more parameters in its setup menu, but virtually all others are related to traffic information: speed alarms, traffic counts, statistics, etc. The system is also designed specifically to provide traffic information for monitoring, freeway traffic management, advanced traveler information systems, ramp-metering, speed and red-light violation enforcement, etc. Its use for detection of objects other than vehicles has not been previously reported.

The output of this system is a digital signal indicating whether an object has entered a zone or not. This output is delivered to a computer where software interprets the signal and indicates a “hit” on the zone display. It also triggers a switch closure that can be used with an external device for responding to the detection.

An important advantage of this system is its high resolution. Also important is its insensitivity to ambient conditions including lighting (or lack thereof), and weather (snow, rain, fog, etc.). A potentially important disadvantage of this system is the inability to physically see the demarcation of the zones being monitored. In traffic applications this difficulty is overcome by using the passage of vehicles to check the appropriate setup of monitoring zones. In a rail-roadway crossing application some other technique must be used to ensure correct coverage of the area to be monitored.





### **3.0 LABORATORY EXPERIMENTAL PROCEDURE**

Development of an experimental procedure followed an extensive period of familiarization with the video detection and microwave detection systems. These systems were originally designed for a specific application – traffic monitoring. As a result, the available information and operating instructions provided very little guidance for use of these systems in detecting objects that might pose a threat to high speed rail.

After initial familiarization and extensive conversations with factory representative experts on the systems, a list of variables for consideration in the development of an experimental procedure was compiled. The authors hypothesized numerous variables that may affect the sensitivity of the detection equipment: lighting, object material, weather (fog, rain, snow), object shape and orientation, distance from detection equipment, angle from detection equipment, background color, object color, shadows, and entry direction. A full parametric study of even this partial list of variables was not possible within the resources and time frame of this investigation. Thus the decision was made to quantitatively study the key variable of size and to qualitatively study other variables during the course of the research.

In addition, in an attempt to differentiate between inherent equipment capabilities and limitations resulting from multiple confounding variables, tests were performed first in a “clean” laboratory environment. Field testing to simulate actual in-service operation of the equipment followed at a nearby rail crossing.

#### **3.1 EQUIPMENT FOR LABORATORY TESTS**

The experiments took place in the large laboratory space in Graf Hall on the Oregon State University campus. An area approximately 25 feet square (58 m<sup>2</sup>) was prepared for the detection zone. The surface was painted a neutral gray, and the detection equipment was mounted approximately 20 feet (6 m) above one corner of the test area.

##### **3.1.1 Video detection equipment**

For these laboratory tests, the video detection system camera was mounted above a corner of the detection zone, as shown in Figure 3.1. The camera was at the top of the mast and the video transmission equipment was in a box mounted immediately below the camera.

This camera was hard wired directly to the video image processor module and a television monitor located in an adjacent office. In the field, the video signal can be transmitted to a monitoring station via wireless modem to the detection module.



Figure 3.1: Laboratory set up of video camera and transmission equipment

### **3.1.2 Microwave detection equipment**

The microwave sensor and detection module comprised a single package that was mounted adjacent to the video detection camera in the corner above the detection area. This unit was hard wired to a computer in the office which operated the RTMS software to present a graphic display of the detection zones and corresponding output from the sensor indicating detection of an object.

The microwave detection system is shown in Figure 3.2. As indicated above, both the sensor and detection hardware are contained in the box. The cable coming out the bottom includes the RS-232 computer connection and the discreet switch connections. In this photograph the unit has been shimmed to point downward at a steeper angle than recommended by the manufacturer. This was done as part of a familiarization test of the system to consider its sensitivity to installation angle.



Figure 3.2: Laboratory set up of microwave detection system

### 3.1.3 Test objects

The objects to be detected in the quantitative tests were developed after considerable qualitative experimentation. The investigators wanted a standard set of objects that could be used to provide a direct comparison between the optical and the microwave-based systems. The resulting object was a roughly spherical metallic shape constructed to several diameters, starting at 2.5 inches (63.5 mm) and increasing in regular increments to a diameter of 16 inches (406 mm). They consisted of cardboard forms covered with aluminum foil. A sphere was chosen because it presented a uniform shape to the detector regardless of its orientation, the viewing angle of the detector, or the direction from which the sphere entered the detection zone. Figure 3.3 shows the objects used to test the system detection capabilities.



Figure 3.3: Target objects used in laboratory testing of the detection devices

## **3.2 LABORATORY EXPERIMENTAL PROCEDURES**

As with the development of the test objects, experimental procedures were the result of considerable qualitative testing of the systems: rate of entry into the detection zones was evaluated; time for objects to be absorbed into the detection system's background was varied; the effect of lighting for the video system was tested; the importance of the detection beam angle for the microwave detection system was tested; and the effect of varying direction of entry of objects into the test area was evaluated.

The video detection and microwave detection systems differ enough in their detection schemes that slightly different procedures could have been adopted. For example, the video detection system can be set to detect objects entering from one direction only; the microwave detection system does not sense direction of entry. However, the time required for setup was the main factor in total testing time. Thus, performing the first test for each setup would take considerable time, but subsequent repeat testing would take little additional time. Because of this, it was decided to use essentially the same procedure for each system.

### **3.2.1 Video detection procedure summary**

This procedure was designed to characterize the sensitivity of the video detection system as a function of its setup. This was a more involved procedure than originally anticipated but was determined during preliminary qualitative testing to be essential. The qualitative testing indicated a large variation in sensitivity as a function of the programmed zone size and zone shape. Specifically, it was clear from the qualitative testing that smaller zones were more sensitive – i.e., the smaller the zone, the smaller the object that could be detected. Therefore zone size and shape were included as a part of the test procedure.

A very basic description of the procedure is as follows:

- Set detector parameters to define the size, shape (rectangular), orientation, and sensing characteristics (directional/non-directional) for the zone to be evaluated.
  - Starting with the 2.5 inch (63.5 mm) sphere, test the detection capability for the particular detection setup.
    - Test by pulling sphere into detection zone from direction of camera
    - Test by pulling sphere into detection zone in a direction perpendicular to a line from the camera to the opposite end of the test area.
    - Test by pulling sphere into detection zone diagonally.
  - Repeat procedure with all spheres through 16 inch (406 mm) diameter.
- Set detection system to next set of parameters and repeat.

In the course of qualitative testing it was determined that evaluation of detection as a function of zone characteristics should focus on the two likely zone configurations for the rail monitoring application: square and rectangular. As presented in the results, the above experimental procedure was applied to a variety of cases for each for these zone shapes.

### **3.2.2 Microwave detection procedure summary**

The microwave detection system was much less flexible in its programming capability. This situation resulted in a considerably shorter basic test procedure. The qualitative testing phase demonstrated no difference in detection as a function of target entry point or direction; if an object was detected, it occurred at the point of entry into the detection zone regardless of what location on the border or in what direction it was moving. Nevertheless, to be consistent with the video detection tests, the same basic procedure was used:

- Set detector parameters to define the number of zones to be used.
  - Starting with the 2.5 inch (63.5 mm) sphere, test the detection capability for the particular detection setup.
    - Test by pulling sphere into detection zone from direction of camera
    - Test by pulling sphere into detection zone in a direction perpendicular to a line from the camera to the opposite end of the test area.
    - Test by pulling sphere into detection zone diagonally.
  - Repeat procedure with all spheres through 16 inch (406 mm) diameter.
- Set detection system to next set of parameters and repeat.

Due to the nature of the microwave detection zone and the limited space in the laboratory area, testing was effectively limited to the use of one detection zone. However, the zone used in testing was representative of the size that is appropriate for application to a rail crossing.

### **3.2.3 Other comments about the testing procedure**

For both the video and the microwave detection systems, the criterion for defining a sphere of a particular size as being detectable required that detection be 100% successful on a minimum of ten successive tests. A larger number of trials would be necessary for conducting statistical analyses, but, with very few exceptions, an object was either detectable or not. Qualitative observations indicated that there was no “occasional” detection or occasional failure to detect, which would indicate the need for a more sophisticated data collection method in these laboratory tests.



## **4.0 LABORATORY RESULTS**

The results of the laboratory tests suggested that both of the systems tested, although designed for detection of vehicles, had sufficient sensitivity to be capable of meeting the requirements for detection of potentially hazardous objects on railway tracks. Each system had its strengths and weaknesses. The video-based system was capable of high sensitivity but only if the detection zone size were minimized. The microwave-based system had high sensitivity over a large area but significant limitations in tailoring the detection zone for a specific application.

The detailed results are presented first for the video detection system and then for the microwave detection system. In each case the nature and results of the qualitative testing are presented prior to details of the quantitative testing.

### **4.1 VIDEO-BASED OBJECT DETECTION SYSTEM**

The video detection system was the first installed for testing. Because of the very flexible setup software, this system required a great deal of qualitative testing and experimentation, both to develop a skill in operating it to best advantage and to develop an understanding of the intent of the system designers. The system used was a variant of the commercially available traffic monitoring system. It was modified for use in pedestrian traffic monitoring and crosswalk signal control. This version had fewer detection zones but better sensitivity for objects smaller than a vehicle.

All initial qualitative tests were conducted using white discs laid on the test floor and pulled across the test area by a string. These discs were selected to provide a good contrast and uniform dimension from the point of view of the camera. A variety of sizes was used to obtain an initial estimate of the sensitivity of this system.

The setup software allows the user to define the size and shape of the detection zone(s) to be used. The shape can be any closed quadrilateral polygon. The zone size can be anything up to the entire field of view of the video camera. After experimenting with parallelogram detection zones of various shapes, sizes, and angles, it was decided as a matter of practicality that only rectangles would be used in the quantitative portion of the tests.

Figure 4.1 shows an example setup as seen from the video camera. The six defined rectangular zones are superimposed on the video image by the detection module.



Figure 4.1: Laboratory video detection zone setup

In addition to the shape and size of the detection zone, the video detection software allows the user to select a directional sensitivity so that objects will be detected only if entering from a selected side of the detection zone. This feature was tested qualitatively as part of the process of developing familiarity with the system capabilities. However, because all directions of entry must be considered for railroad intrusion detection, this feature was not used in the quantitative tests.

#### 4.1.1 Video detection qualitative test results

Initial experimentation with the video detection system provided some important insights about the video detection software logic and the importance of using good setup techniques to detect objects. In particular, it became clear that:

- The system sensitivity is a function of detection zone size. When a zone is defined, the software automatically imposes a grid in the defined space, and objects must cross at least two lines of that grid to be detected. If a zone of 10 ft by 10 ft (3 m x 3 m) was defined, for example, the corresponding grid resolution made it possible to consistently detect an 8-inch (203 mm) diameter object. When the zone dimensions were halved, to dimensions of 5 ft by 5 ft (1.5 m x 1.5 m), the corresponding grid resolution doubled with the result that the minimum diameter disc that could be consistently detected was 4 inches (102 mm).<sup>3</sup>
- The feature of directional sensitivity does define whether or not an object will be detected as a function of its direction of entry into the detection zone, but it does not greatly affect the sensitivity to object size. This is a feature of value when using object detection for signal control but it has no obvious value for this application.

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<sup>3</sup> Based on our understanding of how detection is accomplished, it seems likely that it would be possible to increase the sensitivity for large areas. The software is proprietary and originates in Europe. We therefore did not pursue the possibility of changes to better suit this application.



- In the application of object detection for the railroad, additional circuitry will most likely be required to “lock-in” the detection signal to allow sufficient time for an appropriate response. Locking in a signal is necessary because after a specified period of time, typically 15 minutes, the video detection algorithm allows detected objects to become part of the background with the result that the output of a detection signal is turned off. Any object detection system operates on this principle, since the basis for detection is a change in an otherwise constant picture, the background. In the case of this unit there is a switch output which can be used to trigger a lock-in circuit, indicating an intrusion in the detection area. The intrusion could thus be flagged until appropriate action is taken (e.g., review of the video picture) and the signal is cleared.

Following this first set of tests, qualitative tests for materials, color, lighting, and shape were conducted. The results of these tests were as follows:

- Detection using video images was independent of the material of which the object was made. The system successfully detected objects made of wood, metal, and plastic. It was also consistently successful at detecting people as they walked through the detection area, a result that would be assumed for a pedestrian detection system.
- Detection was independent of color, except when the object was the same color as the background. Initial tests were run using white targets. Subsequent tests were run on targets of black, gray, and various colors. The system could not identify cardboard targets of the same shade of gray as the background floor, but no colors were identified which were undetectable.<sup>4</sup>
- It is a fact of visible light video-based detection that there must be light for detection to take place. In the facility where the testing was conducted, extensive testing of light levels was not possible. However, tests were conducted using both natural light and fairly low level incandescent light. The artificial lighting was richer in color than a fluorescent or sodium vapor lamp, but the levels were of the same order of magnitude as what might be found at an illuminated railroad crossing. The results of this qualitative testing showed that object detection would take place in artificial light with the same reliability as in natural light. Field testing would be appropriate both during the day and at night. If significant differences in sensitivity are found, a more extensive evaluation of lighting requirements would be justified. However, based on these qualitative tests, the need for such an evaluation was not considered likely.
- Detection was independent of shape. Shape was tested by moving all manner of objects into the test zone from different directions to determine whether or not the system would detect them. This included tools, containers, building materials, rags, etc. The only shape that was not detected was a length of irrigation pipe moved into the detection zone parallel to the direction of view for the camera. Objects used in this qualitative test generally had a larger dimension than the spheres used in the quantitative tests. The important exception was the irrigation pipe, which had a diameter of 4 inches (102 mm). It was not clear whether the failure to detect this pipe was primarily a function of its shape or its color. It seemed likely due to a combination of factors, because the pipe was

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<sup>4</sup> A more detailed test using precision contrast gray targets might be valuable for applications with a uniform color background. For this application, however, the background would not be a uniform color and the probability of an object being low enough in contrast with the background so as to be undetectable appeared to be very low.

always detected at a different orientation than parallel to the direction of view, and it was also always detected at the same orientation but when lit slightly differently.

#### 4.1.2 Video detection quantitative test results

The quantitative test results for the video image-based detection system are summarized in Tables 4.1 and 4.2. These tables indicate reliable detection of a sphere as a function of:

- a. Detection Zone Size – dimensions range from 4 ft (1.2 m) to 20 ft (6.1 m) square, with sides oriented parallel and perpendicular to the camera viewing direction
- b. Sphere Diameter – a range of sizes from 2.5 inches (63.5 mm) to 16 inches (406 mm) in diameter
- c. Detection Zone Entry Direction
  - a. Parallel to camera viewing direction
  - b. Perpendicular to camera angle viewing direction
  - c. At an angle of 45 degrees from parallel to camera viewing direction

Reliable detection required a 100% success rate in a series of 10 tests and is indicated by an “X” in the table. Given a small enough detection zone size, the video detection system was capable of reliably detecting a test object as small as 4 inches (102 mm) in diameter.

**Table 4.1: Object detection with the video-based device, using square detection zones with sides oriented parallel and perpendicular to the camera viewing direction**

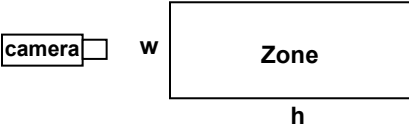
Square Zones							
Zone Size (ft)	Entry to Detection Zone	Sphere Size (in)					
		2.5	4	6	8	12	16
20 X 20	Parallel						X
	Perpendicular						
	at 45°					X	X
10 X 10	Parallel					X	X
	Perpendicular					X	X
	at 45°				X	X	X
5 X 5	Parallel			X	X	X	X
	Perpendicular			X	X	X	X
	at 45°			X	X	X	X
4 X 4	Parallel		X	X	X	X	X
	Perpendicular			X	X	X	X
	at 45°		X	X	X	X	X

X = 100% detection of the object in 10 trials.

**Table 4.2: Object detection with the video-based device, using rectangular detection zones with sides oriented parallel and perpendicular to the camera viewing direction**

Rectangular Zones		Sphere Size (in)					
Zone Size w x h (ft)	Entry to Detection Zone	2.5	4	6	8	12	16
10 X 20	Parallel					X	X
	Perpendicular					X	X
	at 45°					X	X
5 X 10	Parallel				X	X	X
	Perpendicular			X	X	X	X
	at 45°			X	X	X	X
3 X 5	Parallel		X	X	X	X	X
	Perpendicular		X	X	X	X	X
	at 45°		X	X	X	X	X

X = 100% detection of the object in 10 trials  
w = width (Perpendicular to camera view)  
h = height (Parallel to camera view)



### 4.1.3 Microwave-based object detection system

The microwave detection system differed from the video system both in the basic detection system and in the approach to providing user information. While the video system required, for all practical purposes, no separate computer interface, the microwave detection system required a personal computer on which to run proprietary software to interpret the information being sent by the detection system and represent it schematically on the computer monitor. Rather than physically seeing the detection zones in relation to the background, as it was with the video system, the computer display simply signaled which zone was detecting an object.

All initial tests were completed using the aluminum spheres developed for tests on the video system. These spheres were pulled through the test area from different locations and in different directions. Also, a variety of sizes were used to obtain an initial estimate of the sensitivity of this system.

The setup software for the microwave detection system is defined strictly in terms of vehicle monitoring, whether on highways or at intersections. It allows the user to select a mode to define whether the unit is situated such that it is looking down a highway, across a highway, or at an intersection. The user may also select the number of zones to be monitored, their distance from the sensor, and their depth (e.g., one car length).

For this application a standard forward looking highway setup was selected, and the microwave detection unit was mounted using the recommended viewing angle. The theoretical shape for zones in the test area is show in Figure 4.2.

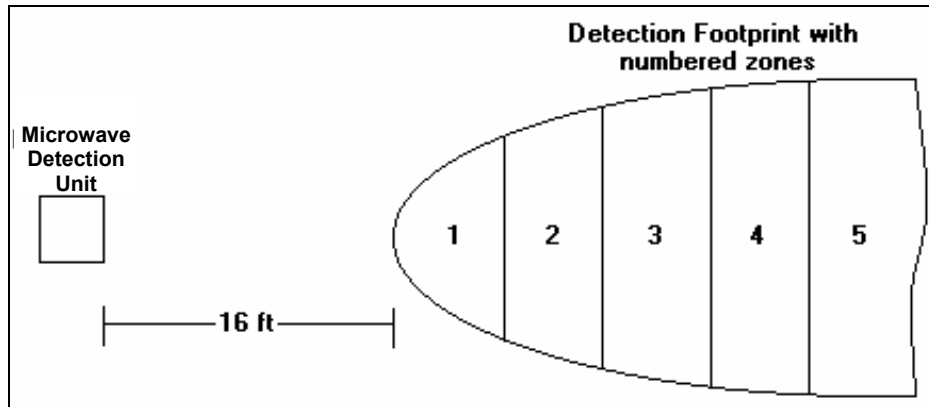


Figure 4.2: Detection zones for the microwave detection device

Since the actual footprint for detection with the microwave detection unit could not be observed (as with the video system), the outline of the footprint was determined by moving a large test sphere towards the detection area until detection occurred. By moving into the area from different starting points, an outline of the detection area footprint was obtained. Figure 4.3 shows one side of the detection area with its characteristic parabola-like shape. The point at the bottom is the apex and the line from that point through the sphere in the photo represents the line of symmetry for the footprint.

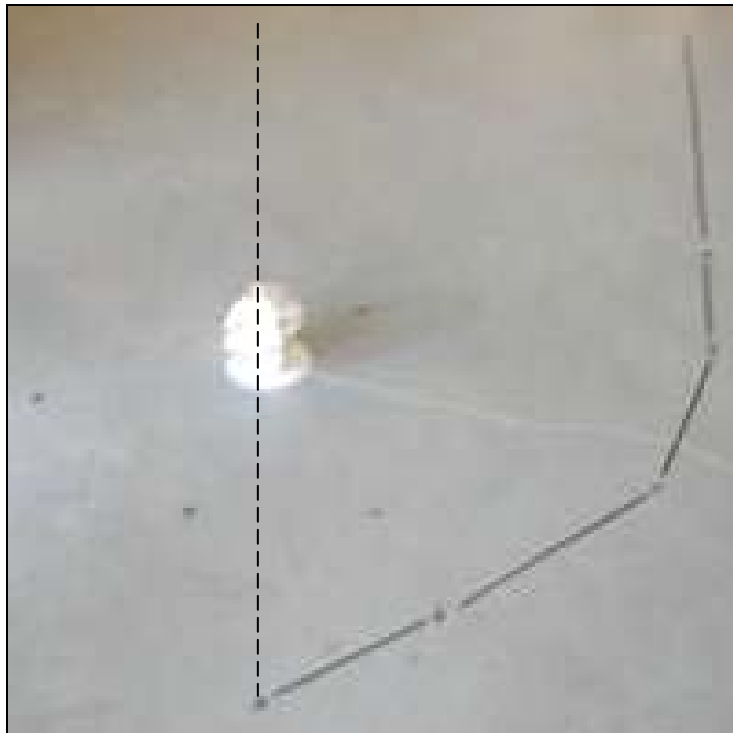


Figure 4.3: Demarcation of one half of the detection area for the microwave detection unit, showing the line of symmetry for the other half of the area.

#### 4.1.4 Microwave detection qualitative test results

The results of initial experimentation with the microwave detection unit provided some important insights about the strengths and weaknesses of the system when used to detect smaller and less uniform objects. In particular, it became clear that:

- The system sensitivity, a parameter that could be varied during setup, was not designed to be used to aid in detection of small objects. When this setting was increased above a certain level (13-14 on the sensitivity scale) the system developed a tendency to report false positives in detection. It appeared that the sensitivity setting was a calibration used to describe the difference between overall background signal and overall detection signal. It could be used when it is necessary to compensate for a “noisy” background and eliminate false positive detections. It did not appear that the device sensitivity could be adjusted for the size of an object.
- The microwave detection system did not appear to have any particular directional sensitivity. Detection was strictly a function of whether an object was in the detection zone or not. Its route of entry into that zone did not affect performance.
- As was the case for the video system, the microwave detection system had individual switches associated with each detection zone. In the application of object detection for the railroad, additional circuitry would most likely be required to lock-in the detection signal because the microwave detection algorithm allows detected objects to become part of the background in a matter of minutes, typically about 15 minutes.

Following this first set of tests, qualitative tests for materials, color, lighting, and shape were conducted. The results of these tests were as follows:

- Detection using the microwave detection system was independent of the material of which the object was made. The system successfully detected objects made of wood, metal, and plastic. It was also consistently successful at detecting people as they walked through the detection area. It is well established that some materials provide a better return signal for microwaves than others. This test indicated that for common materials in the size range being tested, differences in microwave reflectivity did not appear to be a significant factor in the system’s ability to detect objects.
- Detection was independent of color. For microwaves, visible “color” does not affect performance.
- Detection was independent of lighting. The microwave detection sends out its own “light” in the form of microwaves and it is the reflection of this signal that is interpreted by the detection unit.
- Detection was independent of shape. Shape was tested by moving all manner of objects into the test zone from different directions to determine whether or not the system would detect them. This included tools, containers, building materials, rags, etc. Objects used in this qualitative test generally had a larger dimension than the smallest sphere used in the quantitative tests.

#### **4.1.5 Microwave detection quantitative test results**

The quantitative test results for the microwave-based detection system are summarized in Table 4.3. This table indicates reliable detection of a sphere as a function of:

- a. Sphere Diameter – A range of sizes from 2.5 inches (63.5 mm) to 16 inches (406 mm) in diameter
- b. Detection Zone Entry Direction
  - a. Parallel to microwave sensing direction
  - b. Perpendicular to microwave sensing direction
  - c. At an angle of 45 degrees from parallel to microwave sensing direction

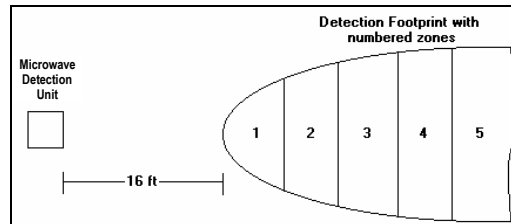
The microwave detection unit was mounted at 17 feet (5.2 m) above the detection surface, and aimed at a 14° down angle. Reliable detection required a 100% success rate in a series of 10 tests and is indicated by an “X” in the table. The microwave detection system was capable of reliably detecting a test object as small as 4 inches (102 mm) in diameter.

It should be noted that because of laboratory space limitations it was not possible to test the sensitivity of the microwave detection system as a function of zone size. However, the zone size used is one which would be appropriate for use in the proposed application for object detection on rail tracks.

**Table 4.3: Object detection with the microwave device**

Detection Zone		Sphere Size (in)					
Zone Number	Entry in Relation to Detection Unit	2.5	4	6	8	12	16
		1	Parallel		X	X	X
Perpendicular at 45°			X	X	X	X	X
				X	X	X	X
2	Parallel		X	X	X	X	X
	Perpendicular at 45°		X	X	X	X	X
				X	X	X	X
3	Parallel		X	X	X	X	X
	Perpendicular at 45°		X	X	X	X	X
				X	X	X	X
4	Parallel		X	X	X	X	X
	Perpendicular at 45°		X	X	X	X	X
				X	X	X	X
5	Parallel		X	X	X	X	X
	Perpendicular at 45°		X	X	X	X	X
				X	X	X	X

X = 100% detection of the object in 10 trials.







## 5.0 FIELD TEST EXPERIMENTAL PROCEDURE

### 5.1 EQUIPMENT FOR FIELD TESTS

Both the video system and the microwave system were installed at a railroad crossing on the campus at Oregon State University. The monitoring stations were remotely located as would be the case in a typical field installation. A schematic of the grade crossing is shown in Figure 5.1. Physical features of this location included the following:

- Standard crossing gates
- Crossing control house
- Single light pole to illuminate intersection at night
- Road width is greater than likely at a remote crossing
- Sensing equipment pole is different than lighting pole

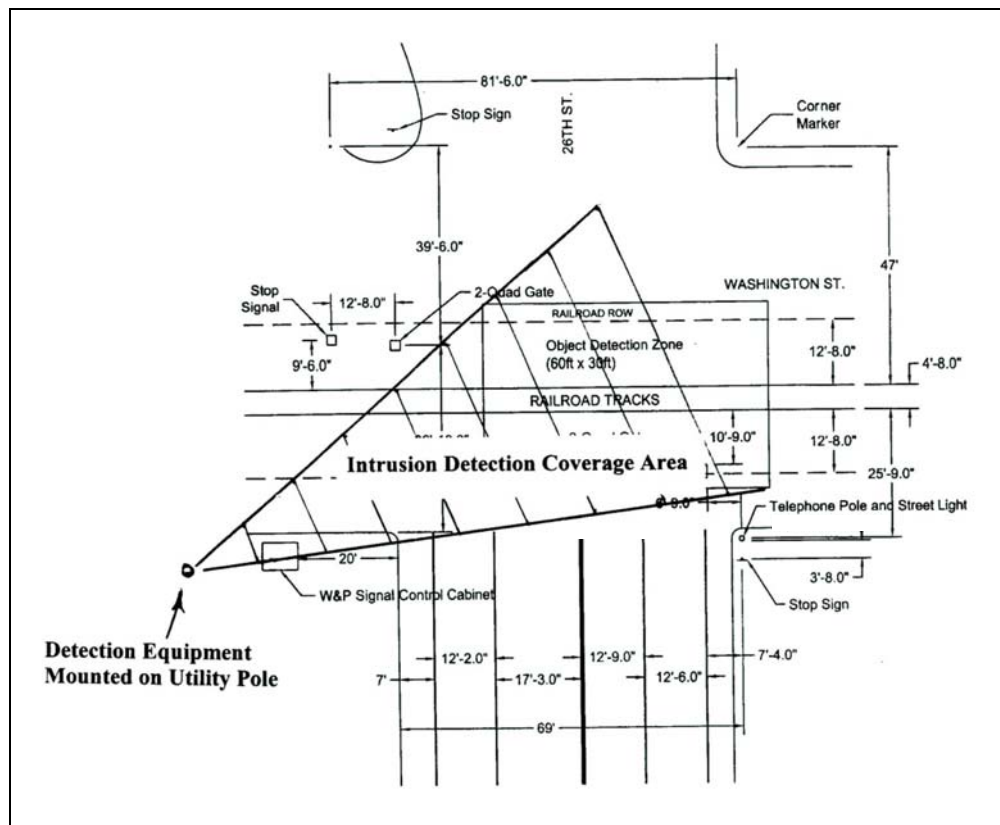


Figure 5.1: Schematic of field test site

Figure 5.2 shows a view of the intersection used for the field tests with the video camera in the foreground. Note the metal signal control box on the near side of the intersection to the right of the tracks. Also note the location of the near signal arm within the detection area.



Figure 5.2: View of the field test site from the video camera location

As shown in Figure 5.3, both the video camera and the microwave device were mounted in the same location. The pole used was located nearly 100 feet (30 m) from the intersection and had a height of approximately 25 feet (7.6 m). There were no direct (line-of-sight) obstructions from the camera location to the intersection.

The video camera was mounted at the top of a mast that was attached to the existing pole. Also mounted on the mast (starting immediately below the camera and working down) were the antenna for transmitting the video signal, the video signal transmission equipment, and the antenna for transmitting the microwave system data.

The microwave system was mounted near the top of the existing pole using the provided mounting hardware. The microwave detection power supply and wireless modem were mounted on the pole below the sensor box. As noted above, the antenna for transmitting the modem output to the remote receiver was located on the video system mast which was strapped to the original pole.

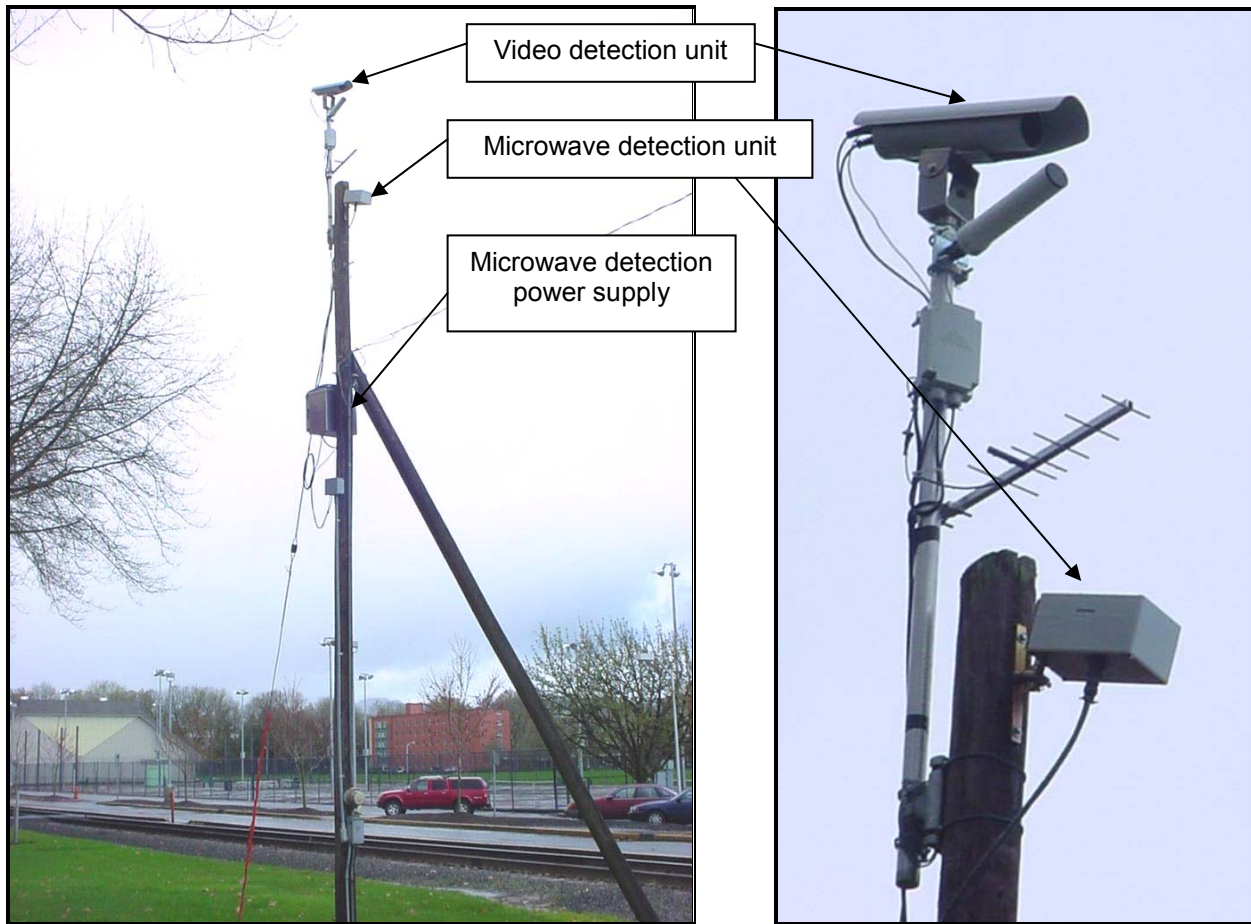


Figure 5.3: Field test installation of detection equipment: a) utility pole with equipment; b) close-up photo

The final piece of the field test equipment was the remote monitoring station. This was located approximately one-fourth mile (400 m) east of the railroad crossing intersection in the office of the OSU Department of Public Safety. Receiving antennas were mounted on the roof of the building to provide the required line-of-sight access to the transmitting antennas, and cable was routed through an existing roof penetration to a desk in the office. For the video system this was a straight run of coax cable from the antenna to the video image processing module. For the microwave system a wireless modem was mounted at the antenna and a twisted pair RS-232 connection was routed to the office.

The monitoring station setup is shown in Figure 5.4. The video detection module was connected to a video monitor and the microwave detection output was displayed on a computer screen. Since the field test area was remote, on-site verification of conditions and events required wireless communication between personnel stationed at the monitoring station and the test site, or the investigator would have to travel between the two locations.



Figure 5.4: The microwave detection display (left) and the video detection display (right); a corner of the video detection module is also visible (center, behind the video monitor)

The significance of the separation of the test site from the monitoring station first became apparent when aligning the microwave system. As was the case in laboratory testing, it was necessary to identify the boundaries of the microwave detection envelope. It thus required two people, radio communications, and nearly a full day of testing to accomplish this stage of the equipment setup.

## 5.2 FIELD TEST EXPERIMENTAL PROCEDURES

Because a great deal of knowledge about the characteristics of the two detection systems had already been developed in the laboratory, the intent of the field tests was to perform a limited number of qualitative tests to confirm our basic understanding of those characteristics and then to move directly to quantitative tests. After the tests for the video system had been started, the planned tests had to be changed rather dramatically to obtain meaningful data.

A key to understanding the reason changes were made to the originally planned procedures is to recall the idea of a background picture. When first installed, both the video system and the microwave system must take some time to establish the normal characteristics of the area they are monitoring. Detection of objects is then a matter of comparing the (almost constant) background stored in memory with the current picture. If there is a significant difference, then the system concludes that an object has entered the monitored area. The basic reason for the



procedure changes was the fact that the field test site had a very busy and complex background compared to the very uniform, smooth, gray, concrete background of the laboratory.

### **5.2.1 Video detection field test procedure**

This procedure was designed to characterize the sensitivity of the video detection system as used in the field. Based on the results from the laboratory tests, the planned field test procedure took into consideration the primary variables of object size and detection zone size. The time of day during which the tests were conducted was a third variable that could be controlled, and weather was a fourth variable. The test procedure is summarized as follows:

1. Identify the smallest object that could be consistently detected using a typical setup.
  - a. Mark the length of the railroad track from the edge of the test section nearest the camera to the farthest one in 10 ft (3 m) increments.
  - b. Use the detection zones for the video system as set up by the factory representative.
  - c. Starting with pedestrians and work down through the spheres used in the laboratory study, to identify the smallest sphere regularly detected. Do all work in good lighting conditions with no interfering weather.
    - i. Starting at the nearest point to the camera, identify the smallest object that can be detected. Do this by placing the object on one of the tracks and checking the monitor to see if it is registered as a stationary object. Work down in size to the smallest object that is detected.
    - ii. Test that same object at each 10 ft (3 m) mark along the tracks to determine if the video sensitivity is adequate to detect this object at greater distances.
    - iii. If the object is detected, repeat the test but starting at the second 10 foot (3 m) increment mark, i.e. starting 10 feet (3 m) farther from the camera for the next test.
    - iv. Continue until the smallest detectable object has been identified for each 10 foot (3 m) increment along the test zone.
  - d. For each of the video zones, check for consistent detection
    - i. Select from the previous results the smallest object detectable in one of the video zones.
    - ii. Place that size object anywhere along the track within the video zone being tested and check for detection.
    - iii. Repeat Steps i and ii for a minimum of 50 tests and evaluate results for consistency.
    - iv. Repeat Steps i, ii, and iii, for each of the other video zones.
2. After completing tests using the setup provided at installation, revise the video detection configuration to a more optimized setup (e.g. smaller video zones, higher sensitivity, etc.). Repeat all of the above testing with the revised setup.
3. With a minimum detectable size established for an optimized setup, repeat Step 1d for other conditions.
  - i. Night time with artificial lighting
  - ii. Rainy conditions
  - iii. Other potentially interfering weather conditions as available

This procedure was designed to establish the suitability of the video system for detection of objects on railroad tracks with a good degree of reliability. During the pedestrian detection phase of this test (step 1c), however, an event occurred which suggested that object contrast with the background could have a significant effect in field conditions. The system detected clothing that contrasted sharply with the background, while it did not detect a pedestrian with less contrasting clothing color. This sensitivity to jacket color was unexpected because of the relative insensitivity to contrast differences observed in the laboratory.

Since it was clear that the adequacy of the video system for intrusion detection could be severely compromised by the apparent sensitivity to contrast, the field test procedure was modified accordingly. The majority of field testing for the video system was therefore conducted in the following fashion:

1. Set up the video system for maximum sensitivity.
  - a. Define six video zones and minimize video zone size.
    - i. Each zone covered about 14 feet (4.3 m) in length (parallel to the railroad tracks) and was 4 feet wide (perpendicular to the railroad tracks).
    - ii. The detection area was 2 zones wide by x 3 zones long. Each of the two rails was therefore covered by three zones over the length of the area being monitored.
  - b. Set detection sensitivity as high as possible without false signals (approx. 55)
2. Test detection of standard rectangular samples at all locations.
  - a. Use 5 samples of approximately 18 in by 30 in (457 mm x 762 mm), each of which was a different color, ranging in shades of gray from black to white. These samples were cut from Crescent brand poster-board and included the following colors: Raven Black (989), Photo Gray (1019), Gibraltar Gray (1074), Regent Gray (3310, and Arctic White (3297).
  - b. Test for detection at distances from 90 to 130 feet (27.4 to 39.6 m) from sensor pole in 10 foot (3 m) increments.
    - i. Record current date, time, weather, lighting, and names of data collectors.
    - ii. Start with color 1 (black) and the test zone at 90 feet (27.4 m).
      1. Wait until traffic will not be using the test zoned for at least 1 minute.
      2. Walk through test zone and on the way through, leave the sample in the zone across a rail.
      3. Monitor the video display for 1 minute or until the object is detected, whichever comes first.
      4. Remove the sample and wait for the video system to reset to its background status (no object detected).
      5. Repeat Steps 1 through 4 until detection for sample color 1 has been tested five times in each test zone – at 90, 100, 110, 120, and 130 feet (27.4, 30.5, 33.5, 36.6, and 39.6 m).
    - iii. Repeat Steps 1-5 for colors 2, 3, 4, and 5.
3. Test consistency of detection at 120 feet (36.6 m) from pole. For these tests, two tests were run at once (one on each rail) to speed data collection.

- a. Use the same 5 samples from black to white.
  - b. Do multiple tests of each color at 120 foot (36.6 m) location on track.
    - i. Start with color 1, black. (Note: there are two samples of each color.)
      - 1. Wait until traffic will not be using the test zoned for at least 1 minute.
      - 2. Walk through test zone and on the way through, leave 1<sup>st</sup> sample on south rail and 2<sup>nd</sup> sample on north rail.
      - 3. Monitor the video display for 1 minute or until each object is detected, whichever comes first.
      - 4. Record results for each rail.
      - 5. Remove the samples and wait for the video system to reset to its background status (no object detected).
      - 6. Repeat steps 1 through 4 until detection for sample color 1 has been tested a minimum of 25 times at the 120 foot (36.6 m) distance.
    - ii. Repeat Steps 1 through 6 for colors 2, 3, 4, and 5.
4. Test detection at night under very limited artificial lighting
- a. Use the same 5 samples from black to white.
  - b. Do multiple tests of each color at 120 foot (36.6 m) location on track.
    - i. Start with color 1, black. (Note: there are two samples of each color.)
      - 1. Wait until traffic will not be using the test zoned for at least 1 minute.
      - 2. Walk through test zone and on the way through, leave 1<sup>st</sup> sample on south rail and 2<sup>nd</sup> sample on north rail.
      - 3. Monitor the video display for 1 minute or until each object is detected, whichever comes first.
      - 4. Record results for each rail.
      - 5. Remove the samples and wait for the video system to reset to its background status (no object detected).
      - 6. Repeat Steps 1 through 4 until night detection for sample color 1 has been tested a minimum of 10 times at the 120 foot (36.6 m) distance.
    - ii. Repeat Steps 1 through 6 for colors 2, 3, 4, and 5.

Note that for all tests, current lighting conditions and weather conditions were observed and recorded.

## **5.2.2 Microwave detection field test procedure summary**

Based on the success of the microwave detection laboratory tests, the same basic procedure was planned for the field tests. In summary:

- 1. Set detector parameters to define the number of zones to be used.
  - a. Starting with the 2.5 inch (63.5 mm) sphere, test the detection capability for the particular detection setup.
    - i. Test by pulling sphere into detection zone from direction of camera

- ii. Test by pulling sphere into detection zone in a direction perpendicular to a line from the camera.
    - iii. Test by pulling sphere into detection zone diagonally.
  - b. Repeat with all spheres through 16 inch (406 mm) diameter.
2. Set detection system to next set of parameters and repeat.

As was discussed in the section on laboratory experimental procedures, this microwave system has fixed detection “slices” but how those detection slices are arranged into zones can be programmed if desired. Prior to setting up the specific detection zones to be used in these tests, preliminary qualitative tests were conducted to establish the operating characteristics of the microwave detection system in the field. Various objects were moved through the detection area, including the aluminum spheres from the laboratory, square pieces of galvanized sheet metal up to 3 ft by 3 ft (0.9 m x 0.9 m), and automobiles.



## 6.0 FIELD TEST RESULTS

The results of the field tests were quite different from those of the laboratory. The more complex environment encountered in the field appeared to reduce the reliability of detection to a point where neither system performed as expected for use in railroad intrusion detection. The video-based system showed serious shortcomings in its ability to deal with low contrast between the object and the background; the microwave detection performance was impaired by the electromagnetically complex environment. The detailed results are presented first for the video detection system and then for the microwave detection system. For the video system, the qualitative test results are presented followed by quantitative test results. For the microwave system, only qualitative results are presented.

### 6.1 VIDEO-BASED OBJECT DETECTION SYSTEM

The initial configuration of detection zones for the video system was set by the installer. This was a typical setup that might be used in a pedestrian detection application. The intersection was covered by four zones. Each was wide enough to cover the tracks and about one fourth of the track-length in the intersection. In the discussions that follow, these detection zones should not be confused with the “target location.” The target locations are defined by the distance from the pole on which the sensing equipment is mounted. There can therefore be tests involving the same zone but different target locations. The test results showed that a given zone may or may not detect an object depending on where it is placed in the zone.

The first qualitative tests used the system to detect pedestrians. Conditions were full daylight, overcast skies, and no precipitation. A person in radio communication with the remote monitoring station was directed to position himself in the different zones and wait until detection was verified. The results from this first testing were as follows:

- In all zones at all times, pedestrians were successfully detected using this system.
- In addition, approximately 20 passers-by either stopped or walked slowly enough to be detected during this test.

The second round of qualitative tests made use of the spheres from the laboratory tests. The conditions included full daylight, overcast skies, and no precipitation. The following observations were made:

- It was important for the person at the intersection to walk quickly through the zone, leaving the sphere on the way through. Otherwise, the person might be detected as a stationary object rather than testing for detection of the sphere.
- The video system consistently detected the 16 inch (406 mm) sphere in all zones.
- The system did not consistently detect smaller spheres in any zone.

During this test the investigators observed by chance that the color of a person's clothing affected the video performance. The observation that the color or contrast of an object affected the performance of the system led to a new series of tests to determine the sensitivity to contrast. These involved the use of poster-board targets of different shades of gray. The targets were approximately 18 inches wide and 30 inches long (457 mm wide by 762 mm long). Each was a uniform color and there were 5 shades of gray (1 = black to 5 = white).

These tests were conducted at 90, 100, 120, and 130 feet (27.4, 30.5, 33.5, 36.6, and 39.6 m) from the pole where the camera was mounted, and each shade was tested at least 5 times at each distance. To better understand the question of contrast in this field testing, the tests at 100 feet (30.5 m) were repeated twice during this test series. Multiple tests at other distances were not performed because of the length of time required to collect the data. Both automotive and pedestrian traffic became a challenge, causing delays of up to 10 minutes for each test.

The results of these tests are shown in Table 6.1. Successful detection is indicated by a "Y" and shading. Results and observations from these tests can be summarized as follows:

- Light colors were more detectable than dark in this environment.
- At 100 feet (30.5 m), the detection rates were 0%, 20%, 60%, 94%, and 80% for colors 1 through 5 respectively.
- There was something different about the detection at 120 feet (36.6 m). At other distances there was detection of multiple shades of gray but at 120 feet (36.6 m), only white (Color 5) was consistently detected.
- The results of the series of three tests done at 100 feet (30.5 m) suggested that another variable was involved. The results vary quite a bit from good detection of only Colors 5 and 4, to good detection of Colors 5, 4, and 3, to fair detection of Colors 5, 4, 3, and 2.

**Table 6.1: Results of testing to determine the effect of contrast on object detection by the video system in the field. The right two columns summarize the data taken at a distance of 100 feet (30.5 m) and show the increase in sensitivity as the color gets lighter.**

Weather/Lighting:		Overcast, No Shadows								
Color	Trial	Distance From Pole (ft)						# of Y at 100 ft	% Detected at 100 ft	
		90	100	100	100	120	130			
1	1	N	N	N	N	N	N	0	0.0%	
	2	N	N	N	N	N	N			
	3	N	N	N	N	N	N			
	4	N	N	N	N	N	N			
	5	N	N	N	N	N	N			
2	1	Y	N	N	N	N	Y	3	20.0%	
	2	Y	N	N	Y	N	Y			
	3	Y	N	N	N	N	Y			
	4	Y	N	N	Y	N	Y			
	5	N	N	N	Y	N	Y			
3	1	N	N	Y	N	N	Y	9	60.0%	
	2	N	Y	N	Y	N	Y			
	3	N	N	Y	Y	N	Y			
	4	N	N	Y	Y	N	Y			
	5	N	N	Y	Y	N	Y			
4	1	N	N	Y	Y	N	Y	14	93.3%	
	2	Y	Y	Y	Y	N	Y			
	3	Y	Y	Y	Y	Y	Y			
	4	Y	Y	Y	Y	N	Y			
	5	Y	Y	Y	Y	N	Y			
5	1	Y	Y	Y	Y	Y	Y	12	80.0%	
	2	Y	Y	Y	Y	Y	Y			
	3	Y	Y	N	Y	Y	Y			
	4	Y	Y	N	Y	Y	Y			
	5	Y	Y	Y	N	Y	Y			

Y = detection of test object  
N = no detection of test object

Color key: 1 = Raven Black (Crescent #989)  
2 = Photo Gray (Crescent #1019)  
3 = Gibraltar Gray (Crescent #1074)  
4 = Regent Gray (Crescent #3310)  
5 = Arctic White (Crescent #3297)

The third set of tests for the video system was designed to clarify the results of the first two. The goal in this case was to determine more accurately the sensitivity of this system to contrast between the object and the background. Also, the test zones were modified to maximize sensitivity.

All tests were conducted at a distance of 120 feet (36.6 m), and all five shades of gray were used. A total of 200 tests was completed during the day, and an additional 50 were completed at night under artificial lighting. To speed the testing, two tests were run simultaneously; one used the zone covering the north track at a distance of 120 feet (36.6 m), and one used the zone covering the south track at a distance of 120 feet (36.6 m). Table 6.2 shows the results of both the daytime and nighttime tests.

The results of the daytime test and corresponding observations are as follows:

- The only color that was consistently detected was black. This was detected in all tests on both tracks.
- The second most detectable was the darkest gray closest to black, but it was detected only 68% of the time.
- The least detectable color was the one midway in the range between black and white.

These results were the opposite of the first tests performed. In those it was white which was best detected. The only substantive difference noted was that for this third round of tests the sky was clear and sunny and there were strong shadows, whereas the earlier test was done in conditions of overcast skies and no shadows.

The night tests had some different results which are summarized as follows:

- All colors were well detected in all tests.
- There were only three cases of non-detection out of the 50 tests run. One was with black and the other two were with the darkest shade of gray.
- There were several cases noted of “false positive.” The video system registered object detection when there was nothing on the tracks.

This last observation was explained when it was noticed that the system was registering a “detection” whenever a car approached the tracks from a direction in line with the camera. The system was in fact detecting the reflection of the car’s headlights on the tracks, as shown in Figure 6.1. Figure 6.2 is a photo showing the reflection of streetlights on the tracks, to show how such reflected light can appear to be a light colored object on a normally dark background.

**Table 6.2: Results of daytime and nighttime tests on video system**

Distance From Pole: 120 Feet											
Color	Weather	Sunny	Sunny	Sunny	Sunny	Sunny	Sunny	Sunny	Sunny	Night	Night
	Trial	North Track	South Track	North Track	South Track	North Track	South Track	North Track	South Track	North Track	South Track
1	1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	2	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
	3	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	4	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	5	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2	1	Y	Y	Y	N	N	Y	Y	Y	N	Y
	2	Y	N	N	N	Y	N	Y	Y	Y	Y
	3	Y	Y	Y	N	N	N	Y	Y	N	Y
	4	Y	N	Y	N	Y	N	Y	Y	Y	Y
	5	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
3	1	N	N	N	N	N	Y	N	N	Y	Y
	2	N	N	N	N	Y	Y	Y	N	Y	Y
	3	N	N	N	N	N	N	N	N	Y	Y
	4	N	N	N	Y	Y	N	N	N	Y	Y
	5	N	N	N	N	N	N	Y	N	Y	Y
4	1	N	N	N	Y	N	N	Y	Y	Y	Y
	2	N	N	N	N	Y	N	Y	N	Y	Y
	3	N	Y	N	N	Y	N	Y	Y	Y	Y
	4	N	Y	N	N	Y	N	Y	Y	Y	Y
	5	N	Y	N	N	N	N	N	Y	Y	Y
5	1	Y	Y	N	Y	Y	N	Y	Y	Y	Y
	2	N	Y	N	Y	Y	N	Y	Y	Y	Y
	3	N	Y	N	Y	Y	N	N	N	Y	Y
	4	N	N	N	N	Y	N	Y	Y	Y	Y
	5	N	Y	N	N	Y	N	N	N	Y	Y

Y = detection of test object  
 N = detection of test object

Color key: 1 = Raven Black (Crescent #989)  
 2 = Photo Gray (Crescent #1019)  
 3 = Gibraltar Gray (Crescent #1074)  
 4 = Regent Gray (Crescent #3310)  
 5 = Arctic White (Crescent #3297)



Figure 6.1: An example of a false positive generated on the video system at night. The solid rectangles indicate that an object has been detected. Note the car headlights in the upper left corner. When this car was farther away, its lights reflected off of the track and were interpreted by the video system as a white object on the tracks.



Figure 6.2: A photo of the tracks taken at night and showing the reflection of street lights on the track. It is easy to see how the video system could interpret these reflections as a light colored object on the tracks.

## **6.2 DISCUSSION**

Based on the laboratory tests, the field tests, and discussion with the vendor, it appears that the effects of contrast between object and background are very much dependent on the lighting conditions. This video system is at its best when the lighting conditions are constant and uniform (i.e., minimal shadows). The artificial lighting at night, although nearly monochromatic and of low intensity, provided conditions most nearly resembling those in the laboratory. Hence, among all field tests, the results of those conducted at night were the most similar to the results of the lab tests.

From the standpoint of the video detection system, daylight varies considerably more than the artificial night light. Daylight can quickly vary in intensity according to cloud cover. At the same time, shadows can go from being non-existent to being very strong. This means that the system must have less sensitivity to variance in the background in strong sunlight than in overcast conditions.

A final note that should be made about the video detection system is that the transmission system for getting the signal from the field site to the monitoring station worked very well. No problems were ever observed with either the quality or reliability of the signals being received.

## **6.3 MICROWAVE-BASED OBJECT DETECTION SYSTEM**

The microwave detection system was the subject of a great deal of preliminary qualitative testing and virtually no follow-up quantitative testing. The quantitative testing was not conducted because the field test location contained many confounding factors for a microwave system, factors which rendered the system unreliable for all but the largest of objects.

Upon installation of the microwave detection system, it was noted that an object was being detected at distance of about 75 feet (23 m) (see Figure 6.3). Although it was initially assumed that this was part of the start-up process and that this “hit” would be assimilated into the background after about 30 minutes, this “object” was in the display throughout most of the entire test period. During this startup phase it was also noted that automobiles seemed to be detected reliably but that pedestrians were not.

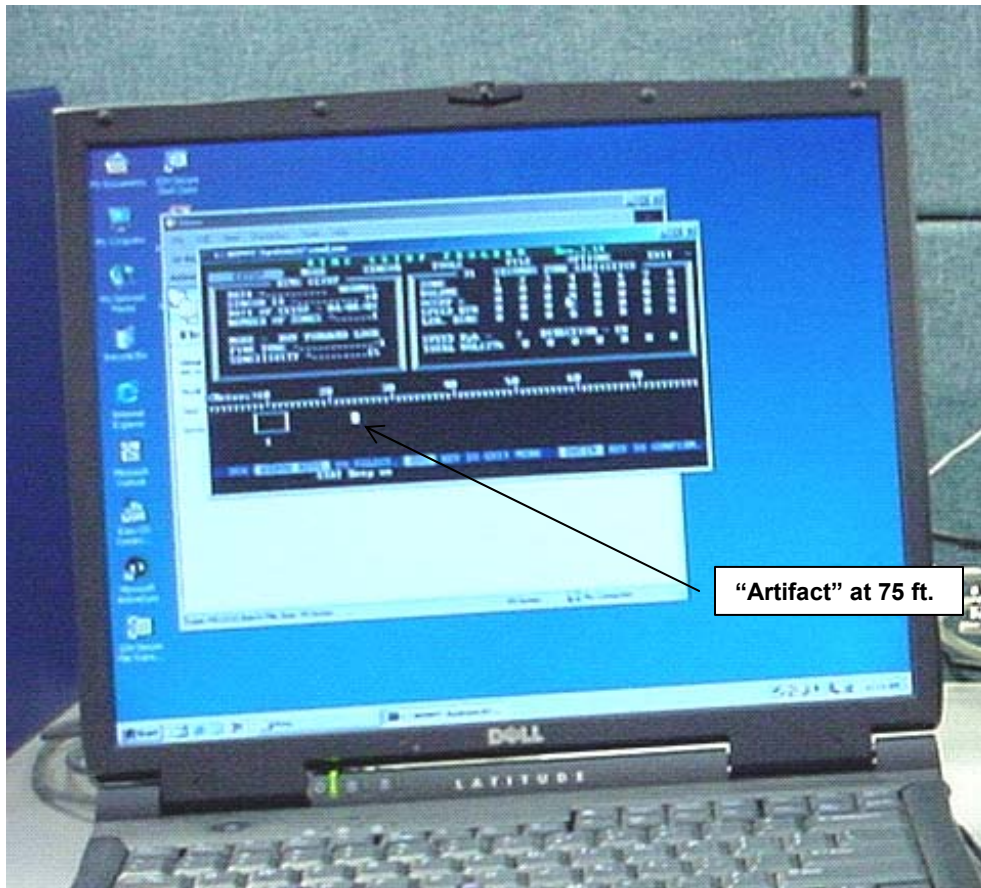


Figure 6.3: A photo of the microwave detection computer display showing the artifact that was displayed throughout the testing of this system. This artifact was “detected” at a distance of approximately 75 ft. (23 m) from the sensor.

Initial tests of the microwave system followed the planned procedure. The spheres used in the laboratory were used to determine the sensitivity of the microwave system in the field. After finding that none of the spheres, including the largest (16 inch (406 mm) diameter), was being detected, some larger targets were fabricated out of sheet metal. These initial test results and observations are summarized as follows:

- The microwave system was unable to detect any of the targets including the largest, a 3 ft by 3 ft (0.9 m x 0.9 m) square of sheet metal, when they were placed in the test region (90-130 ft) (27.4-39.6 m).
- Pedestrians, who were reliably detected in the laboratory, were generally not being detected by the system in the field, although occasionally there would be a detection.
- The display continued to show an object being detected at about 75 feet (23 m) from the pole on which the unit was mounted.

At this point, although the laboratory tests had generated a fair amount of confidence in our understanding of the setup and operation of this system, we attempted to map the detection



envelope, i.e. to define the parabolic area in which the system would detect objects. To accomplish this, the largest target (3 ft by 3 ft) (0.9 m x 0.9 m) was used at a distance of approximately 20 feet (6.1 m) from the base of the pole. This was a region that was outside of the planned test area but where the large target was being detected by the microwave detection system. This target was pulled from a location outside the detection zone towards the centerline of the zone. When it was detected, the point was noted as being an edge of the detection zone. Unfortunately, attempts to repeat this test resulted in a significantly different edge location every time.

In a final attempt to at least verify that the detection zone included the railroad tracks, an automobile was used to define the edges of detection at a distance of approximately 120 feet (37 m) from the base of the pole. A car was driven on the road from the north towards the tracks until it was detected. That spot was noted and the test repeated starting from the south. This test was repeatable and confirmed that the unit was correctly aimed at the crossing.

After having such good success in the laboratory with this system, the inability of the unit to detect any but the largest of targets was puzzling. One difference between the laboratory and this field installation was the complexity of the environment to be considered background. There were the crossing gate arms, the crossing control house, and the rail tracks, all of which were metal. To assist in understanding the effects these items might have on the system, an expert in microwaves was consulted. Based on the layout diagrams and descriptions of the field site, it was confirmed that the arrangement at the crossing would be difficult for a microwave system. The reason given was the likelihood of errant reflections from the various objects that make up the crossing. The problem could probably be worked around by installing various microwave absorbers and reflectors at key locations but that it would take a fair amount of work to get it right.

Also during this time, the display was monitored at night and it was discovered that the “object” at 75 ft (23 m) would sometimes disappear. A check of distances and a visual inspection of conditions led to a tentative conclusion that this “object” was in fact the near crossing arm moving with either the wind, as a result of traffic moving nearby, or both. Because of the more serious detection problems of the microwave system, this tentative conclusion was not explored in more detail for verification.

Another difference between the laboratory and this field installation was the distance between the detection equipment and the test area. With the video detection system this distance resulted in decreased sensitivity, i.e., a larger threshold size necessary for objects to be detected. It may also be that the greater distance adversely affected the performance of the microwave detection system as well. Further research is warranted to explore whether reducing this distance would result in field performance that more closely corresponds to the results of the lab tests.

Based on the preliminary results and the expert opinion regarding the intersection, tests on the microwave detection system were discontinued. The system continued to be monitored while taking data on the video system, but the purpose was to look for any informative events that may have taken place.

The results and observations for the microwave detection system as tested in the field are as follows:

- Objects that are standard for a rail crossing – the crossing arms and the metal box containing the controls and battery backup – can present significant challenges for a microwave-based system.
- In this installation, with both the metal box and one of the crossing arms between the detector and the test zone, the microwave system sensitivity to objects was severely compromised. It was still able to consistently detect automobiles, the objects for which it was designed. It was not able to consistently detect smaller objects.
- The background in this field installation included an object (the crossing gate) which the system could not identify as constant due to its intermittent movement, with the result that an object was shown as being detected almost continually even though the tracks were clear.
- The challenges presented by not being able to “see” what the microwave system sees (i.e., to not have an image to look at, which corresponded to the field of detection) were considerably greater in the field than they were in the laboratory. It would take more time and testing of a field installation to be certain that the required coverage was being provided.

## **7.0 CONCLUSIONS AND RECOMMENDATIONS**

The results of testing for object detection capabilities of the Traficon video detection system and the RTMS microwave detection system were mixed. Both technologies clearly showed promise for use in detection of small objects in a laboratory setting, but the performance of both systems was considerably less when tested in the field.

### **7.1 VIDEO-BASED DETECTION SYSTEM**

#### **7.1.1 Conclusions from laboratory testing**

This system has some strong points to be noted:

- It offers extraordinary flexibility in defining detection zones.
- It is quite insensitive to a range of lighting and colors.
- It is capable of detecting objects with a significant dimension as small as four inches (102 mm).
- Because of the flexibility in defining detection zones, this system is relatively insensitive to mounting location.
- Because the system is video-based, when an object is detected it is possible to look at the video display and see what it is. It is also possible to either continuously or selectively record the image from the sensing camera.

This system also has some weaker points:

- Because of the flexibility in setup and because of the need to customize a setup for each installation, a person that is very familiar with the system must be involved to insure that the system setup is appropriate to maximize sensitivity for the intended application.
- To detect the smallest objects requires a small zone size. For the specific hardware tested, there would not be enough zones available to cover a railroad crossing area and still have the zones small enough to detect a four-inch (102 mm) object. Coverage could be provided, however, by using additional units or by changing the acceptable minimum detectable object to a larger size (approximately 8 inch (203 mm) significant dimension).
- There is no computer interface of any significance. The unit is programmed either by a keypad or by using a mouse to click on an identical keypad on the computer display.

#### **7.1.2 Conclusions from field testing**

- As predicted by the laboratory testing, the system sensitivity in the field is inversely related to zone size.
- In an actual field installation with widely varying lighting conditions, the sensitivity of this system is affected by the contrast between an object to be detected and the background. This is an important difference in comparison to the laboratory results.

- The effect of object-to-background contrast on system sensitivity varies considerably with lighting conditions. Detection characteristics are very different depending on whether lighting is bright sunlight, indirect natural light from overcast skies, or artificial lighting from street lights.
- With a constant lighting source such as artificial lighting at night, the video system's detection of objects is substantially more reliable.
- The video system is subject to false detection at night due to light reflections from smooth surfaces.
- At the distance from camera to intersection used in these tests (90-130 ft) (27.4-39.6 m) and with the number of detection zones available, objects must have a cross section of about 5 sq ft (0.5 m<sup>2</sup>) to be reliably detected under the best of conditions. (Note: This is consistent with the inverse linear scaling effect of sensitivity to zone size as determined in the laboratory tests).

## **7.2 MICROWAVE-BASED DETECTION SYSTEM**

### **7.2.1 Conclusions from laboratory testing**

This system, like the video system, has some strong points to be noted:

- The setup using the computer program is very fast and could be done for any given installation by a person with a very modest amount of training.
- The detection capability of this system is quite good. Using a zone size appropriate for the railroad project, the microwave detection was consistent in detecting targets with a significant dimension of 4 inches (102 mm).
- The system is inherently insensitive to lighting and to color of the object to be detected. It is also reasonably insensitive to object composition and shape.
- The system has the direct ability to record detection events at the computer. External counters using the event switches are not necessary.

Some of the weaker points of this system include the following:

- The system has limited capability for programming zone coverage.
- The nature of a detected object cannot be determined without adding a video camera system.

### **7.2.2 Conclusions from field testing**

- The microwave detection system reliably detects large objects such as automobiles, even in a complex field environment.
- The ability of this system to detect smaller objects is severely compromised when the environment includes confounding features such as metal objects that can reflect microwaves. The performance of the system may also be affected by the distance between the detection equipment and the detection area, but this hypothesis was not tested.

- The system should operate with a consistent detection performance in all ambient conditions including darkness, rain, snow, and fog. (However, the system was not tested under these conditions.)

### **7.3 OVERALL CONCLUSIONS AND RECOMMENDATIONS FOR RAILROAD INTRUSION DETECTION**

The focus of this research was the evaluation of two existing technologies deemed most likely candidates for application in railroad intrusion detection, a video detection system and a microwave detection system. Both technologies showed good promise when tested in a laboratory environment; both technologies showed significant shortcomings when tested in the field.

Although the sensing technologies are very different for the two systems, the evaluation of the signals is very similar in principle and is the underlying source of difficulties for both systems in the field testing. They both identify a new object by recognizing a change in a stored image of the background. To do this they must have a stable image of what is supposed to exist in the area being monitored (the background) and good capabilities for identifying changes in that image (i.e., an intrusion). For this to work, the background must be as constant as possible. For the video system, changes in lighting changed the background enough that sensitivity to new objects was substantially decreased. For the microwave system, the existence of multiple reflectors in the field being monitored made the background seem unstable and resulted in a much decreased sensitivity to new objects.

Neither of these technologies is adequate for railroad intrusion detection at the current state of technology. It may be possible to improve the technologies to a point where they will perform at an acceptable level. However, before investing in efforts to bring these technologies to a level where they would be acceptable, it would be appropriate to revisit the full range of possibilities that exist for intrusion detection.

Available technologies should be evaluated by developing a design matrix for the needs of this particular application. It should be based on both what are labeled “customer requirements” and on engineering requirements. This set of requirements would provide a definitive basis for evaluation of existing technologies and new ideas. Next, the review of existing technologies, including the two that were subjects of this study, should be updated. All of these technologies, along with any new ideas, should be evaluated using the design matrix. This would result in a strong basis for a second generation effort at testing candidates for railroad intrusion detection.



## 8.0 REFERENCES

Bell C.A., Hunter-Zaworski K.M. and Zaworski D.D. *Low Volume Highway-Rail Grade Crossing Treatments for the Oregon High Speed Rail Corridor*. Salem, OR: Oregon Department of Transportation. Report No. FHWA-OR-RD-97-08. April 1997.

Carroll Anya, Meltzer N. and Carpenter J. *Intruder and Obstacle Detection Systems (IODS) for Railroads – 1998 Requirements Workshop*. Washington, DC: U.S. Department of Transportation. Report No. DOT-VNTSC-FRA 00-07. December 2001.

Reynolds A. *Locked Gate: An Analysis of Non-Intrusive Detection Systems for Low Volume, High Speed Railroad Crossings*. Unpublished master's thesis. Bozeman, MT. Department of Civil Engineering, Montana State University. 2001.





## **APPENDICES**



# APPENDIX A: TRAFICON SPECIFICATIONS

## Description of the TRAFICON System

The purpose of the Traficon Video Image Processor Px (VIP/P2x) is to detect the presence of pedestrians on sidewalks. This is done by defining optical detection zones, which are placed on a standard video image. The desired outcome of this research is to determine whether this technology will work for detecting objects at remote railroad crossings.

The VIP/P2x has two video inputs and the user can define up to seven detection zones per video image. The zones can be designed as global or directionally sensitive. The VIP/P2x detects objects by their contrast with the surrounding area or background.

The zones will be triggered in the following situations:

- Whether the zones have a direction or not, they all act as presence zones. This results in the zone being triggered when an object is in the zone for a certain length of time. That length of time is referred to as the Delay Time and is set to four seconds by default. It can be adjusted in the Output Mode menu. Having the Delay Time set to an appropriate length of time will help to prevent the detection of flying birds or leaves, etc.
- Making a zone direction sensitive will only trigger the zone when an object enters the zone in the direction of the arrow. This will happen independently of the Delay Time. Objects passing through the zone perpendicular to the arrow will not be detected.

## TRAFICON Technical Specifications

➤ Dimensions	<ul style="list-style-type: none"> <li>• 2.34W x 4.50H x 7.00D inches, excluding the handle</li> </ul>
➤ Communication	<ul style="list-style-type: none"> <li>• RS-232C service ports for setup</li> <li>• RS-485 communication within a rack for data collection</li> </ul>
➤ Inputs	<ul style="list-style-type: none"> <li>• Composite video 75Ω - 1 Vtt CCIR/EIA</li> <li>• Power Supply</li> <li>• Reset button on front panel</li> </ul>
➤ Outputs	<ul style="list-style-type: none"> <li>• Analog video output with overlay of system info data &amp; detection lines or zones</li> <li>• Auto diagnostic LED indicators</li> <li>• 4 optically isolated open-collector outputs</li> </ul>
➤ Connector	<ul style="list-style-type: none"> <li>• Double row 22 pins EDGE, according to the NEMA Standards Publication TS 2-1992</li> </ul>
➤ Power Supply & Consumption	<ul style="list-style-type: none"> <li>• +10.8V DC to +26.5V DC (150mA)</li> </ul>
➤ Environmental	<ul style="list-style-type: none"> <li>• -34°C to +74°C</li> <li>• 0 to 95% relative humidity → non-condensing</li> </ul>



# APPENDIX B: EIS REMOTE TRAFFIC MICROWAVE SENSOR (RTMS) SPECIFICATIONS

## Description of the RTMS System

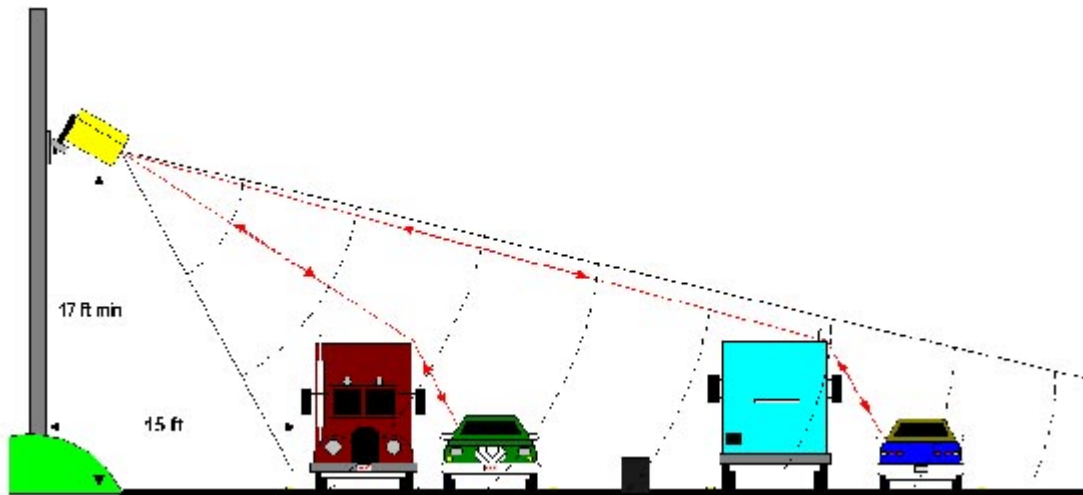
The RTMS (Remote Traffic Microwave Sensor) radar is a low-cost, general-purpose, all-weather traffic sensor which detects presence and measures traffic parameters in multiple independent lanes.

The RTMS is a true presence traffic detector providing presence, volume, occupancy, speed and classification information in up to 8 discrete user-defined detection zones up to 60 m (200 ft.) away. Output information is provided to existing controllers via contact pairs and to computer systems via a RS-232 serial communications port.

The RTMS is uniquely designed for side-fired operation. It is usually mounted on existing side-of-the-road poles, is easy to install and remove, and is fully programmable to support a variety of applications.

The RTMS requires no maintenance and was proven to be the only multi-zone traffic detector unaffected by any type of weather. In many tests performed by traffic professionals worldwide, this presence radar technology has been recognized as the best for almost all traffic management applications.

The RTMS is a miniature radar operating in either of two microwave bands, employing the FMCW (Frequency Modulated Continuous Wave) principle. It transmits a low-power microwave signal of constantly varying frequency in a fixed fan-shaped beam.



The beam "paints" a long elliptical footprint on the road surface. Any non-background targets will reflect the signal back to the RTMS where the targets are detected and their range measured.

The RTMS range measurement resolution of 2 meters (7 ft.) allows the "slicing" of the footprint ellipse into 32 range-slices. The user can define a number (1 - 8) of detection zones, each consisting of one or more range slices.

The RTMS internal microcomputer controls in real-time 8 opto-isolator relays corresponding to the detection zones. Relay contacts are closed when a target is present within the respective detection zone. The contact-pairs can be connected directly to traffic controllers. In addition, short-term statistical data on each zone are accumulated and transmitted by the RTMS via its serial port. Typically, every 30 to 300 seconds a message containing the Volume, Occupancy, Average Speed and Long Vehicle Volume in each detection zone is transmitted.

The long microwave wavelength and the range-measurement capability make the RTMS immune to all weather effects and to most occlusion situations.

## Technical Specifications for the RTMS Model “X”

➤ Microwave signal and area coverage	<table> <tr><td>Center Frequency</td><td>10.525 GHz</td></tr> <tr><td>Bandwidth</td><td>45 MHz</td></tr> <tr><td>Power Output</td><td>10 mW</td></tr> <tr><td>Beam Width (Azimuth)</td><td>15°</td></tr> <tr><td>Beam Elevation Opening</td><td>45°</td></tr> <tr><td>Range</td><td>10-200 ft (3-60 m)</td></tr> <tr><td>Number of Detection Zones</td><td>8</td></tr> </table>	Center Frequency	10.525 GHz	Bandwidth	45 MHz	Power Output	10 mW	Beam Width (Azimuth)	15°	Beam Elevation Opening	45°	Range	10-200 ft (3-60 m)	Number of Detection Zones	8
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➤ Interfaces	<p>The RTMS provides eight contacts for the indication of presence in the detection zones and a ninth contact used for RS-232 RTS or Power-On indication. Contacts are rated for 100ma and 350V AC or DC. Opto-isolation protects internal circuits against surges.</p>														
➤ Power Requirements	<table> <tr><td>RTMS Standard Power Requirement</td><td>12-24V AC or DC</td></tr> <tr><td>Maximum (peak) Voltage</td><td>33 VDC or 24 VAC</td></tr> <tr><td>Commercial AC Power Option</td><td>115±20V AC @ 50-60 Hz, 80mA</td></tr> <tr><td>Power Consumption (Std. Power)</td><td>6 watts</td></tr> <tr><td>Auto Power Failure Recovery</td><td>within 5 seconds</td></tr> </table> <p>Power may be provided by the following sources:</p> <ul style="list-style-type: none"> <li>- DC or Low Voltage AC from transformers in controller cabinets. Recommended transformer for one RTMS unit: 16-20 Volts 10VA.</li> <li>- Commercial AC option (115±20V)</li> <li>- Batteries – Recharging by lighting sources (at night), solar panels, scheduled replacement</li> </ul>	RTMS Standard Power Requirement	12-24V AC or DC	Maximum (peak) Voltage	33 VDC or 24 VAC	Commercial AC Power Option	115±20V AC @ 50-60 Hz, 80mA	Power Consumption (Std. Power)	6 watts	Auto Power Failure Recovery	within 5 seconds				
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➤ Surge Immunity	<p>The RTMS withstands ± 1kV surge (rise time = 1.2 µsec, hold = 50 µsec) applied in differential mode to all lines, power and output, as defined by IEC 1000-4-5 and EN 61000-4-5 standards.</p>														
➤ Reliability	<p>Mean time between failures of the RTMS in its operating environment is 90000 hours (10 years)</p>														

