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# **Performance Evaluation of the Pilot Study of Advisory On-board Vehicle Warning Systems at Railroad Grade Crossings**

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16. Abstract <p>The Pilot Study of Advisory On-Board Vehicle Warning Systems at Railroad Grade Crossings was conducted to provide roadway vehicles approaching the specially equipped grade crossings with an on-board/advisory warning of a train approaching or occupying the grade crossing. The system design was composed of a trackside transmitter assembly (TTA) and in-vehicle receiver (IVR). The TTA sent a K-band signal to the IVRs when a train was approaching or occupying the crossings. The existing Metra grade crossing controller activated the trackside system. The system was installed at five railroad grade crossings in the northern Chicago suburbs. Approximately 300 IVR units were installed in the vehicles of 38 participating organizations. This report documents issues with the operation of the overall system and corrective measures that were taken. The performance history of the pilot study is presented in a chronological order. Overall, the system performance did not meet study expectations even though replacing the original IVRs were helpful to some degree. The off-the-shelf technology used in this pilot study did not provide adequate reliability for the study environment. The concept of an on-board warning system has potential to work if a more reliable technology is used to activate the warning system. There were other challenges such as the complexities of multi-agency coordination that required time, effort, and approval from various agencies. Also, with 38 participating organizations, the pilot study encountered a number of challenges in coordinating the installation of IVRs and driver training along with retraining several hundred participant drivers when the IVRs were replaced.</p>			
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## **1. INTRODUCTION**

The Pilot Study of Advisory On-Board Vehicle Warning Systems at Railroad Grade Crossings was undertaken by the Illinois Department of Transportation (IDOT), Intelligent Transportation Systems Program Office. This pilot study sought to provide roadway vehicles approaching railroad grade crossings with an on-board/advisory warning of a train approaching or occupying the grade crossing. The primary emphasis of the study was to evaluate driver perceptions of the on-board warning system's effectiveness, including the in-vehicle receiver (IVR) position, warning display methods and modes and overall system reliability.

IDOT selected a contractor team led by Raytheon Company to design, install, operate and maintain the Pilot Study Advisory Warning System. Raytheon Company subcontracted with Cobra Electronics who designed and provided the IVRs and roadside transmitters for the project. Raytheon Company also subcontracted with two other firms; Metro Transportation Group (MTG) for design, installation and operation of the trackside control cabinets and Calspan SRL for a human factors analysis to determine the placement of the in-vehicle receivers in participant vehicles. The University of Illinois at Urbana-Champaign (UIUC) is the independent evaluator for the pilot study. This evaluation will emphasize driver perceptions and understanding of the advisory on-board warning information provided. The UIUC used four surveys to measure drivers' perception and acceptance of the system.

## **2. SYSTEM DESIGN SUMMARY**

The system design was composed of a trackside transmitter assembly (TTA) and the IVR. The TTA sent a K-band signal to the IVR when a train was approaching or occupying the crossing. The trackside system was activated by the existing Metra grade crossing controller. When the Metra gates were activated, the trackside transmitter emitted a dual carrier radio frequency signal for the duration of the grade crossing event. This dual carrier signal was used to reduce the likelihood of false alarms.

The trackside subsystem consisted of the trackside controller (TC) assembly and TTA. The TC assembly was an Eagle EPAC300 actuated unit. The TTA was designed by Cobra Electronics. Once the Metra controller determined that a train was within the warning range, the TC received 110 volts of AC current for the duration of the controller's signal cycle. The receipt of the signal triggered a relay to the "on" position. This energized the transmitter via a 24-volt DC current and the transmitter began transmitting a dual carrier, omni-directional, K-Band (24.1 Ghz) warning

signal. The designed-for-broadcast range of the transmitter was 800 to 1,200 feet from the transmitter.

The trackside controller recorded up to 40 events including input signals from the Metra controller and failure alarms. Battery backup provided continuous operation for a minimum of 6 hours in case of power loss. A remotely located computer monitored and archived all the activity at the trackside subsystem.

## **2.1. System Performance Requirements**

The Pilot Study of Advisory On-Board Vehicle Warning Systems was a project aimed at improving safety at railroad grade crossings. Therefore, the advisory warning system needed to satisfy stringent performance requirements. The system's functional and operational performance requirements were as follows:

### **2.1.1. Functional Requirements**

- 1- The IVR must operate in a temperature range of –20 to +185 F and humidity of 95%.
- 2- Total system downtime must be less than 0.001% for two years.
- 3- The system must operate 24 hours a day, 7 days a week.
- 4- In the event of a power loss, the trackside equipment must continue to function for at least six hours.
- 5- The IVR display must be within the driver's cone of vision.
- 6- IVR audible output must be 15-35 db above the ambient noise level.

### **2.1.2. Operational Requirements**

- 1- The trackside equipment must transmit the signal for a distance no less than 800 feet and no more than 1,200 feet in all directions from the grade crossing upon detection of an approaching train.
- 2- The transmitted signal must be received by the IVR regardless of environmental conditions.
- 3- The IVR must be able to pick up and maintain the signal within 800 feet of the crossing during a train event.
- 4- The IVR must continue to give the audible and/or visual warning for the duration of the train event.

5- The trackside portion of the system, and all parts, thereof, must fail "on."

The compliance of the advisory warning system with the operational and functional requirements was examined through extensive laboratory and field-testing. However, many preparatory steps were taken before the system testing and pre-deployment operations began. The next section explains the preparation process.

### **3. PILOT STUDY PREPARATION**

Important issues that needed to be considered before the start of system testing and pre-deployment operations included:

- 1- Site selection
- 2- Participating organizations profiles and selection
- 3- IVR placement
- 4- Survey preparation and considerations

#### **3.1. Site Selection**

The trackside transmitter equipment was installed at five railroad grade crossings equipped with a combination of flashers and gates along the Metra-Milwaukee North line. Study sites with different mixes of land uses and heavy train traffic were selected. The location, jurisdiction and characteristics of the sites in the pilot study were as follows:

- 1- Beckwith Road/Lehigh Avenue, Morton Grove: Residential Area
- 2- Chestnut Street/Lehigh Avenue, Glenview: Industrial Area
- 3- Shermer Road, Northbrook: Commercial Area
- 4- Dundee Road, Northbrook: Major Arterial
- 5- Greenwood Avenue/Chestnut and Park, Deerfield: Residential Area

A more frequently traversed crossing in Glenview (Glenview Road) was considered. However, due to the crossing geometry and logic, the potential existed for false alarms at a nearby grade crossing (Dewes Street).

The five selected railroad crossings handle Amtrak and freight train movements in addition to significant Metra commuter train movements. There are between 70 and 115 train movements per crossing on a typical weekday.

### **3.2. Participating Organization Profile and Selection**

Approximately 300 IVR units were installed in the vehicles of participating organizations. These organizations were chosen based on their close proximity to the study area and number of movements over the five designated crossings. A mix of public and private organizations participated in the pilot study. Private sector firms were selected by contacting the local chambers of commerce. The selection of school bus companies was based on information provided by the IDOT Division of Traffic Safety. Local governmental agencies for each of the pilot study area communities agreed to participate. A total of thirty-eight organizations participated in the pilot study.

### **3.3. In-vehicle Receiver Placement**

A human factors study was conducted in order to determine the ideal placement and optimal mounting technique for the IVR. Since the vehicle types differed among the participating organizations, on-site vehicle fleet evaluations were conducted in order to determine specific installation requirements. Installation recommendations for each vehicle type were determined according to the dashboard configuration, the driver's field of vision constraints, vehicle vibration considerations and fleet equipment restrictions. The IVR was placed within the driver's cone of vision as recommended in the human factors study and on-site vehicle evaluations.

### **3.4. Survey Preparation and Considerations**

Surveys were utilized to document drivers' perceptions of the advisory warning system. Their perceptions represent the foundation of the evaluation effort. The final evaluation is based on four surveys distributed during the pilot study. These surveys included: the base line survey distributed prior to deployment and three surveys distributed during the course of the pilot study. The baseline survey sought background information from the drivers such as their age, work experience and perception of existing railroad crossing devices. The other three surveys were related to the drivers' experience with the advisory warning system. Each driver had experience

with three modes of operation of the IVR, visual only, audible only, and a combination of visual and audible warnings.

## **4. PHASES OF PROJECT EVALUATION**

The evaluation of the Pilot Study of the Advisory On-Board Warning System is based on three sets of information. 1) Driver feedback during the pilot study, 2) Information gathered in focus groups, and 3) Performance history of the system.

### **4.1. Driver Feedback During Pilot Study**

During the nine-month operational phase of the Pilot Study, drivers' opinions about the system were gathered and examined with the help of surveys distributed during the course of study. The pilot study revealed 1) the situations where the system did not perform as required, 2) the reactions and acceptance of drivers to the advisory warning system and 3) the improvements that can be made to the system. The surveys also revealed the utility of the advisory warning system to improve railroad grade crossing safety and the future applicability of this type of system.

### **4.2. Focus Groups**

Three different focus groups were conducted. They included an operation managers focus group, a technical oversight and project management focus group, and a participating drivers focus group. The focus groups provided insights on the opinions of these project participants. The focus groups complemented the results of the driver feedback surveys by allowing the university to discuss issues specific to each group. Feedback from the drivers and focus groups are discussed elsewhere.

This section summarizes the performance of the IVR and the TTA during the pilot study. The analysis documents problems with the operation of the overall system and solutions that were taken.

## **5. PERFORMANCE HISTORY**

The Pilot Study of Advisory On-Board Vehicle Warning Systems at Railroad Grade Crossings was initiated in May 1997. Installation of IVRs in the participating vehicles began in the third quarter of 1997. The performance history of the pilot study is presented in a chronological order.

### **JUNE 1997**

Participants and villages were briefed on the project overview and system demonstration.

### **JULY 1997**

The participant vehicles were inspected by Calspan SRL to determine dashboard configuration, driver work area and obstructions to the IVR mounting. Acceptable IVR warning system locations were found for all vehicles inspected. The preliminary system design was completed. Coordination issues for utility and phone connections at the five crossings were identified.

### **AUGUST 1997**

According to a wave propagation analysis, a single transmitter configuration at the Shermer, Dundee and Beckwith locations and dual transmitter configurations at the Greenwood and Chestnut crossings were selected. Concerns were expressed about the exact transmitter installation location at the five grade crossing sites. Raytheon submitted a system design document (SDD), which provided a comprehensive review of the design and operation of the system. IDOT approved the IVR design contingent upon the unit meeting all the requirements of the Scope of Services. Cobra Electronics informed their suppliers to begin production of 350 IVRs.

### **SEPTEMBER 1997**

The SDD was approved. It was agreed that two of the five trackside pole installations would be located outside the Metra right-of-way. The in-vehicle information card and instructional training video were submitted for IDOT review. The TTAs were constructed and made ready for installation.

### **OCTOBER 1997**

For the convenience of the participants, multiple sites were made available for the installation of 350 IVRs. Utility companies gave their approval for connections at the trackside controllers. All four villages approved the trackside installation plans. Electrical plans for the trackside installations were forwarded by Metra to the Illinois Commerce Commission (ICC) for final approval.

Three hundred (300) copies of the training video were provided to IDOT for distribution to the study participants. Driver training began during the last week of October.

### **NOVEMBER 1997**

IVR installation started in early November and more than 60 percent were completed. Calspan SRL completed and submitted its human factors final report on IVR mounting/location to IDOT for approval. Metra approved the right-of-entry agreement to allow the contracting team to conduct the trackside equipment installation. The ICC and IDOT Springfield offices approved the trackside installation plan.

Several reports of false alerts (defined on pages 8-9) were reported by pilot study participants, most of which came from police officers. It appeared that the combination of the K-band police radar gun and the in-vehicle communication devices were responsible for false alerts in police vehicles. False alert reports were also received from other participants. It was suspected that these false alerts were caused by high intensity ambient microwave sources. IDOT developed false alert report forms so that participants could report the specifics (date, time, location, direction of travel, duration, etc.) of the false alerts.

### **DECEMBER 1997**

Three of the five trackside installations and remaining IVR installations were completed. Metra provided crews to perform system connections to their vital relays. Cobra initiated a study to investigate the false alert problem discovered in November.

### **JANUARY 1998**

Each equipped crossing was tested for propagation of the transmitted signals. New software that listened longer before triggering the alarm was developed by Cobra to alleviate the false alert problem. This correction was intended to fix false alerts due to ambient sources; however, it was less likely to fix the problem with the police vehicles. The two remaining TTAs were

installed. Telephone service was connected at all five sites. To assist in the provision of electrical service, Metra allowed ComEd to use existing Metra poles and right-of-way for access to the cabinets at trackside. In addition, a phone number was established by Cobra for participants to report technical problems (power on difficulties, false alerts, missed alerts, etc.)

## **5.1. False Alert Findings**

Cobra determined that there were three potential sources of false alerts in the IVRs:

### **AMBIENT MICROWAVE SOURCES**

When multiple ambient microwave sources were combined, these signals could occasionally produce signals that were similar to those signals needed to activate the IVR. In these rare occasions, the combination of signals produced a false alert. These types of false alerts were intermittent both in time and space (receivers produced repeatable false alerts in certain areas such as shopping malls). Cobra modified the IVR software to better test for signal stability before activating an alert. More than a dozen participating organizations reported problems with false alerts.

### **TWO OR MORE SOURCES WITHIN THE K-BAND FREQUENCY**

This type of false alert could occur if two K-band radar guns were used simultaneously and if the frequencies of both K-band radar guns were at the two frequencies recognized by the IVR. This occurred rarely. Cobra could not prevent this event since the signals were coming from more than one source and the combination ended up being similar to the signals needed to activate the IVR.

### **SINGLE K-BAND SOURCE COMBINED WITH IN-VEHICLE COMMUNICATION DEVICES**

A single K-band source combined with the use of in-vehicle communications devices in police vehicles could cause false alerts. This problem was noticed in the police cars operating radar guns simultaneously with high powered UHF communication equipment such as 2-way radios. As a result, the police participants were offered the option of either withdrawing from the study or allow the contracting team to relocate receivers in non-radar-equipped police vehicles.

**FEBRUARY 1998**

Power connections were made by ComEd at all five sites. Metra performed all final connections from their track circuit relays to the Pilot Study trackside controllers. All connections inside the trackside controllers were completed and the trackside system became operational at all five sites.

Receivers were moved from police to public service vehicles in Glenview and all receivers were removed from Deerfield police vehicles due to the problems noted in the false alert findings. More false alert tests were performed. The new receiver software was successful with non-police vehicles; however, it still gave false alerts with police vehicles.

System integration testing with a limited number of vehicles began on February 17. The transmission range was less than the required 800 feet at two sites (Beckwith and Shermer) due to excess cable bundled inside the radomes.

### **MARCH 1998**

The transmitter at Shermer Road was remounted on an extended mounting arm to improve signal coverage along Shermer Road southwest of the railroad crossing. Adjustments were made to the transmitters at Beckwith and Greenwood (one TTA replaced) to provide more uniform coverage within the transmitter range.

The police radar interference problem was analyzed. A possibility existed that the IVRs might not issue a warning in the presence of K-band police radar. The signal from the transmitter to the IVR was being "blocked" by the police radar. A study to determine the cause of blocking by police radar found that the K-band radar blocked the signal at any distance from the radar source. KA-band and X-band radar were found to block the signal at less than 30 feet from the source. In a "blocking" situation, an IVR-equipped vehicle in the vicinity of an equipped crossing would not receive a warning when a train was present or approaching the crossing. The contracting team indicated new receiver software that could prevent the signal blockage problem would delay the study by 6-9 months.

It was determined at the March Project Management Committee (PMC) meeting that an improved receiver not susceptible to radar interference would need to be developed for any future pilot study deployment. The PMC agreed that the "blocking" problem needed to be

completely eliminated. The only practical alternative to correct the “blocking” problem was to develop a new IVR with enhanced software.

IDOT and the PMC mandated that the system must be fail-safe because the false alert problem could have disastrous consequences. It was decided to revise the software and re-install IVRs in all vehicles. The existing IVRs remained in the vehicles until exchanged with new units. Controllers remained powered-up but transmitters were turned off.

Correspondence was sent to all project participants informing them that a significant delay would occur in system deployment due to the need for receiver redesign, manufacturing, shipping, delivery, and testing.

Copies of the Participant Training Plan were delivered to IDOT. The Calspan SRL report titled “A Human Factors Assessment of On-Board Vehicle Warning System Installation” was delivered to IDOT.

#### **APRIL 1998**

Follow-up site visits were performed by IDOT and Raytheon staff to explain the reasons behind the delay in system deployment. During these site visits, it was found that the transmitter at Chestnut and Lehigh had failed in the “on” position. However, at that time, the contracting team was not monitoring incoming alarms at the Remote Maintenance Terminal because system deployment had been postponed. In addition, none of the participating drivers had reported a “false alert” at this crossing. A re-education effort and more report forms were provided to participating organizations to improve the false alert reporting rate.

#### **May 1998**

The IVR redesign goals were set to provide a warning in the presence of interfering K-band signals and to minimize false alerts. The following changes were incorporated into the IVR redesign:

Power Up Sequence: Vehicles with an audible-only IVR received one audible iteration of the warning signal, followed by the green rectangle that indicated the IVR was powered up (operational). Vehicles with a visual-only IVR received one iteration of the “Warning Train” message, followed by the green rectangle that indicated the IVR was operational. Vehicles with

a combination audible/visual IVR received one audible iteration of the warning signal, followed by one iteration of the “Warning Train” message, and then the green rectangle that indicated the IVR was operational.

Train Warning Message: In a situation where an IVR did not register 100% certainty that a train was present because of the additional presence of interfering signals or the presence of very strong signals that overwhelmed the IVR, a unique warning tone (for audible-enabled IVRs) and a “Caution” message (for visual-enabled IVRs) was presented. In a situation where the IVR was able to distinguish unambiguously the train warning signal provided by a trackside transmitter, the warning tone (for audible-enabled IVRs) was distinguishable from the “Caution” mode. The warning message from visual-enabled IVRs was “Warning Train” rather than the previous message “Caution”.

Two project participants – Master Brew Beverages and Underwriters Laboratories expressed a willingness to participate in a four-week beta test of the new receivers, once prototypes were produced. Their offer was accepted.

### **June 1998**

On June 8, the contracting team demonstrated the operating system to IDOT officials. Concerns over several items were expressed by IDOT as a result of this demonstration. On June 18-19, IDOT officials tested the system operation at each of the five crossings in two modes. The transmitter was placed in a continuous on position in the first mode so that the vehicles received a warning upon approaching a crossing regardless of a train approaching or occupying the crossing. In the second mode, the transmitter was placed in the deployment mode and the vehicles received a warning only when a train was approaching or occupying the crossing. During these tests, it was observed that IVRs nulled (loss of warning) on several occasions, primarily caused by dead spots and receiver range problems. Based on the results of the field testing, it was decided that there was a problem with the operation of the in-vehicle warning system. The system failed to provide a consistent and continuous warning at all times when a train was approaching or occupying the crossing. The field tests also showed that the new IVRs should be designed to solve the problem of nulling and minimize intermittent signals through obstructions. IDOT stated that “the variability of the problem areas based upon the IVR, the direction of travel and the mode of operation requires greater analysis to identify and correct the problem areas”. Trackside acceptance could not take place until full system reliability could

be demonstrated. Cobra was asked to postpone ordering new IVRs until the results of the beta test were accepted by IDOT and the contracting team. Cobra implemented a new IVR design and retrofitted 25 existing IVRs for use in the beta test. IDOT recommended that these field tests (beta tests) be performed utilizing the enhanced IVRs.

### **July 1998**

Twenty (25) IVRs were updated with a new software version and installed in Master Brew Beverages and Underwriters Laboratories vehicles in preparation for a beta test with the new IVR capability. A training video was prepared to demonstrate to the beta test participants the new visual and audible signals associated with the two different warning modes incorporated into the new IVRs. The performance requirements of the redesigned IVRs were discussed. The requirements of the redesign were: 1- Provide warning in presence of interfering K-band signals, 2- Minimize false alerts, 3- Minimize intermittent signals through obstructions. Cobra laboratory and field testing started for the redesigned IVRs. At the PMC meeting on July 14, it was agreed that a joint IDOT-Raytheon acceptance test would be performed during the course of the new IVR beta test. The design, fabrication, and installation method of the entire TTA was reviewed and evaluated at Cobra's facility, in an attempt to further improve performance of the system as a whole. In particular, changes to the transmitter mounting methods were reviewed to reduce signal fade problems in the immediate vicinity of the crossing. Increased receiver "hang time" was implemented to reduce short duration signal "drop-outs" as a vehicle passed by obstructions and heavy foliage.

### **August 1998**

In order to solve the nulling problem that occurred under the trackside transmitters, the transmitter at Beckwith was inverted. Transmitters were adjusted to eliminate dead or null spots in the vicinity of the crossing. New IVRs were designed to give a Caution message when the IVR was experiencing more than one signal. The IVR settings were modified in efforts to provide one of the following: (1) No alert if the railroad transmitter was not transmitting, whether or not a K-Band radar gun was operating, (2) a "Warning Train" alert when the railroad transmitter was operating, with no (or relatively weak) K-Band radar gun operating, or (3) a "Caution" alert if the receiver could not clearly discriminate that the railroad transmitter was operating in the presence of a relatively strong K-Band radar gun signal. Even with IVR design changes, there were certain situations where the IVR provided no alert.

## **5.2. Improvements Made Before the Beta Tests**

Before the start of the beta tests, several improvements were made to the IVR and the TTA:

Receivers: The allowable pulse count was increased and the “Caution” feature was added. A five-second hang time was incorporated into the software to sustain an alert through intermittent signal blocking. Intermittent signal blocking resulted in a loss of the signal when obstructions (such as tree foliage) periodically blocked the line of sight between the transmitter and receiver. The IVR listened for 5 seconds for the correct signal before triggering the appropriate warning message.

Transmitters: The transmitter at Beckwith was inverted and reoriented to improve close-in coverage and increase range on Lehigh. The directional coverage at Shermer and Greenwood was optimized.

The contracting team beta testing was performed to determine:

- 1- Range of coverage on direct approaches to the crossings
- 2- Continuity of warning on direct approaches to the crossings
- 3- Continuity of coverage when stopped immediately in the vicinity of the crossing
- 4- Continuity of coverage when stopped and a train was passing through the crossing
- 5- Location and causes where coverage was lacking
- 6- Ability of the beta IVR to provide the correct warning in the presence of K-band radar
- 7- Continuity of coverage near large vehicles.

A revised failure report form was prepared to differentiate between false alerts and missed alerts.

### **September 1998**

The system was turned on for the beta test on September 8<sup>th</sup>. Cobra and Raytheon Systems adjusted the transmitters as described in the previous section and tested for coverage at all sites. On September 17<sup>th</sup> and 18<sup>th</sup>, beta testing by the contracting team and IDOT was performed. Eight vehicles were utilized in these tests. The result of these tests determined if 300 new IVRs would be ordered to support the pilot study in the new “Beta” configuration.

Master Brew Beverages and Underwriters Laboratories vehicles also participated in the beta testing. Test results showed significant improvement over results seen in previous tests, and on many approaches, showed that the system could be expected to provide reliable results. At the same time, tests uncovered some specific trouble spots that were addressed to the maximum extent possible prior to the next two-day test period in early October.

### **5.3. Preliminary Evaluation and Analysis of the First Beta Tests**

Tests were conducted at each of the five crossings in the study area (Beckwith Road, Chestnut Street, Shermer Road, Dundee Road and Greenwood Avenue) under four different test cases. These test cases were, Case 1: Deployment mode, no radar gun present, Case 2: Continuous-on mode, no radar gun present, Case 3: Deployment mode, with radar-gun present, Case 4: Continuous-on mode with radar-gun present. According to the plan developed for this comprehensive testing, three runs were to be performed for all direct approaches under each test case. The following sections describe the test results and issues related to each railroad crossing.

#### **BECKWITH CROSSING**

The system functioned properly during the limited runs that were made on this round of beta testing. There was one dropout recorded northbound on Lehigh Avenue but there was insufficient data to evaluate the system performance at the Beckwith Road crossing.

#### **CHESTNUT CROSSING**

Dropouts at the Chestnut crossing occurred in every direction during the first round of testing. On eastbound Chestnut Street, dropouts were recorded while waiting at the traffic signal in the construction area that formerly was the Glenview Naval Air Base. Dropouts on northbound Lehigh Avenue were recorded where line-of-sight obstructions (trees and shrubs) existed between the IVR and trackside transmitter. Dropouts on westbound Chestnut were recorded in close proximity to the tracks when the test vehicle was moving slowly.

#### **SHERMER CROSSING**

The first round of beta tests indicated that signal detection range on Shermer was around 800 feet northbound and slightly less in the southbound direction. Moreover, on northbound

movements close to the tracks, the IVR message shifted from “Warning Train” to “Caution” without a radar gun present.

### **DUNDEE CROSSING**

Signal dropouts were recorded on eastbound and westbound approaches. Westbound dropouts occurred when the test vehicle was very close to the crossing (near or at the stop bar). Eastbound dropouts occurred in the 800-1200 foot range.

### **GREENWOOD CROSSING**

Northbound Chestnut Street and northbound Park Avenue had signal dropout problems. Eastbound Greenwood Avenue appeared to have a signal range less than 800 feet. In all three approaches, the radar gun was able to overpower the transmitter signal when the test vehicle was very close to the radar gun. Westbound Greenwood experienced a shift in the message from “Warning Train” to “Caution” without the presence of a radar gun. This change in the message was observed at very low speeds near the beginning of railroad markings on the pavement.

## **5.4. Preliminary Evaluation and Analysis of the Second Beta Tests**

The second period of comprehensive field-testing was conducted on October 8-9. Similar to the first beta tests, four different test cases were utilized. These test cases were, Case 1: Deployment mode, no radar gun present, Case 2: Continuous-on mode, no radar gun present, Case 3: Deployment mode, with radar-gun present, Case 4: Continuous-on mode with radar-gun present. According to the plan developed for this comprehensive testing, three runs were to be performed for all direct approaches under each test case. The following sections describe the test results and issues related to each railroad crossing.

### **BECKWITH CROSSING**

Eastbound and westbound approaches to the Beckwith crossing functioned properly. Signal dropouts on northbound Lehigh Avenue were recorded mostly at speeds below 25 mph.

### **CHESTNUT CROSSING**

The problems that were observed in the first beta tests were corrected in the second beta tests. Since some modifications to the transmitter were performed, the first and second round of tests

could not be combined. However, the second round of beta tests provided an adequate number of test runs for each approach except for test case 3. One dropout was recorded in the second round of beta tests on westbound Chestnut. This dropout occurred very close to the tracks.

### **SHERMER CROSSING**

On northbound movements close to the tracks, the IVR message switched from “Warning Train” to “Caution” 10 times out of the 13 runs with no radar gun team present. Northbrook police vehicles were also observed in the vicinity of the crossing. The signal detection range on southbound Shermer was observed to be less than 800 feet for 10% of the runs and the detection range on Walters Street was less than 800 feet for a majority of the runs.

### **DUNDEE CROSSING**

One team recorded an early signal cut-off problem when the IVR signal stopped before the Metra gates and flashers quit operating. This problem was observed on eastbound and westbound Dundee Road. Moreover, signal nulling very close to the tracks (near or at the stop bar) occurred westbound when the radar gun team was present.

### **GREENWOOD CROSSING**

The problems that were recorded during the first round of beta tests at the Greenwood crossing were also recorded in the second round of tests. In summary, northbound Chestnut Avenue experienced signal dropouts. However, most of the dropouts reported occurred at the Greenwood and Chestnut intersection when the test car was moving northbound. The eastbound Greenwood approach exhibited a signal detection range of less than 800 feet. The canopy of trees across Greenwood Avenue was blocking the line of sight to the transmitter. Westbound Greenwood experienced a shift in the message from “Warning Train” to “Caution” without radar gun presence.

## **5.5. Combined Results of the First and Second Beta Tests**

### **BECKWITH CROSSING**

Based on the system improvements made prior to the second round of beta tests, eastbound and westbound approaches to the Beckwith Road crossing functioned properly. Signal dropouts on northbound Lehigh were recorded mostly at speeds less than 25 mph. These dropouts took

place in the 400-800 foot range from the railroad crossing. The speed limit on Lehigh Avenue is 30 mph.

### **CHESTNUT CROSSING**

Based on the system improvements made prior to the second round of beta tests, all approaches to the Chestnut crossing functioned properly, except for one dropout event. This dropout event occurred in the continuous-on mode and with the presence of a radar gun. The test vehicle was very close to the tracks and a tractor-trailer truck was blocking the line-of-sight of the IVR.

### **SHERMER CROSSING**

The northbound Shermer crossing had a signal detection range of about 800 feet. In a couple of instances, the southbound Shermer crossing had a signal detection range of less than 800 feet. Shermer Road has a horizontal curve around the crossing and as a result, the line of sight to the transmitter is less than 1,200 feet. Another issue about the Shermer crossing was the shift of the message from "Warning Train" to "Caution" without the radar-gun team present. Northbrook police vehicles were observed in the northbound direction very close to the tracks. The signal coverage was also tested on Walters Street. While it was advantageous to receive a warning signal on eastbound Walters and eastbound/westbound Meadow, the critical need was to receive the signal prior to turning on Shermer. The signal coverage on Walters Street was less than 800 feet.

### **DUNDEE CROSSING**

Dropouts were recorded both eastbound and westbound in the first round of tests. However, there were no dropouts recorded in the westbound direction and only one dropout eastbound in the second round of tests. These dropouts were reported to occur at close proximity to the crossing. A team experienced the one dropout event on eastbound Dundee within 400 feet of the crossing while waiting behind a postal truck. In addition, the radar gun on westbound Dundee was able to overpower and cause nulling of the IVR. This occurred when the test vehicle was very close to the tracks and the radar gun was pointed toward the test vehicle.

### **GREENWOOD CROSSING**

On northbound Chestnut Street, dropouts were recorded. Three out of the five dropouts occurred very close to the tracks while the test vehicle was moving northbound. Eastbound

Greenwood Avenue exhibited a signal detection range of less than 800 feet. The canopy of trees across Greenwood Avenue was blocking the line of sight to the transmitter. This may have been the reason for the short detection range. Moreover, on westbound Greenwood Avenue, the message shifted from “Warning Train” to “Caution” without radar gun presence when the test vehicle was moving at very low speeds just prior to the railroad warning pavement markings. It was observed that when the test vehicle was very close to the radar gun and the gun was pointed towards the test vehicle continuously, the message on the IVR disappeared.

### **October 1998**

The beta test of new IVR software, using 25 units installed in vehicles belonging to Master Brew Beverages and Underwriter Laboratories, was concluded. Based on the results of the two joint testing sessions, it was agreed that the pilot study should proceed subject to improved reception and system performance at certain specific locations. Transmitters at all five sites were turned off at the conclusion of the beta test. Testing revealed that on several approaches – Beckwith & Lehigh, Lehigh & Chestnut, and on Dundee Road – the system could be expected to provide reliable results. At the same time, tests uncovered some specific trouble spots at the remaining two sites (Greenwood Avenue and Shermer Road) that needed to be corrected before the pilot study could proceed.

### **November 1998**

After PMC review and approval of the results of the re-engineered receiver beta test, IDOT announced an intent to direct the order for manufacture of the new pilot study IVRs, subject to final modifications and successful system testing at several sites.

Most missed alerts during beta tests were caused by line-of-sight obstruction. Testing also revealed a number of specific problem areas at two sites (Shermer and Greenwood) that would need to be addressed before the pilot study could progress. An additional issue of a potential dead coverage area near the stop bar on Lehigh Avenue at Beckwith was discovered by the contractor team, which bore further examination. These problem areas were studied in detail during November and several mitigation measures were taken (for example, the transmitter was raised and reoriented slightly at Shermer, and transmitter enclosure shielding was modified at all three sites). Performance improved in all cases. An additional problem with a transmitter test setting at Greenwood – which resulted in the “Warning Train” signal ‘hanging on’ after the gates and flashers ceased operation was identified and corrected.

Final modifications were made to three transmitter sites – Beckwith, Shermer, and Greenwood – to improve coverage performance of the transmitters. Cobra and IDOT teams conducted limited testing at several sites on November 6 to verify correct performance. The system performed acceptably at all sites.

It was agreed that system performance would be monitored throughout the pre-pilot study period, and during the pilot study itself. If the number of false or missed alerts increased at any site beyond the expected values, further adjustments were to be made at that site as required to keep the performance of the system at acceptable levels.

### **December 1998**

The trackside equipment was adjusted to improve performance. Issues remained open after completion of the comprehensive beta tests and supplemental tests. There were some concerns about the message shifting between “Warning Train” and “Caution”. The beta IVR software logic caused the message shifts. The existing hardware constraints limited the ability to fully resolve ambiguity between a K-band radar gun signal and correct trackside transmitter signals. Beta software was optimized to eliminate the missed alerts when strong K-Band signals interfered with the IVR’s ability to provide a proper “Warning Train” message. Raising the strength threshold setting would decrease the tendency to shift messages. However, it would also result in increased missed alerts. On the other hand, lowering the strength threshold would increase the shifting phenomenon. It was recommended that the current software be optimized and the participants trained that the shift between the warning train message and caution message was normal and to be expected.

On December 18, IDOT issued a letter authorizing purchase of 330 new IVRs for the pilot study, and an order was placed.

### **January 1999**

Two versions of the software were ordered, an 8-pulse version which was considered more resistant to radar gun interference and a 6-pulse version, which demonstrated less susceptibility to false alerts. An equal number of 8-pulse (165) and 6-pulse (165) receivers were ordered.

## **February 1999**

Revisions to the training video script and accompanying training material were agreed to. All training items were produced (video, in-vehicle information cards, project executive summary along with other public outreach materials).

## **March 1999**

The details of system acceptance tests were determined. The system acceptance test aimed to demonstrate acceptable system performance versus the baselines established during comprehensive tests at each site. The system performance during the acceptance test needed to be equal to or better than performance during the previous comprehensive tests. The objectives of the system acceptance tests were as follows:

- 1- Demonstrate transmission of the correct signal when gates and flashers were operable during a train event.
- 2- demonstrate acceptable IVR alert in presence of transmitted signal:
  - a) When the vehicle was within the “minimum” 800-foot required coverage area
  - b) When the vehicle was oriented in a general direction of travel toward the crossing
  - c) With the K-band radar gun operating in the vicinity

The acceptance test was a verification/acceptance of the final versions of the new IVRs within the bounds of the acceptable baseline established during comprehensive tests at each site. A single test team and two vehicles were utilized at each site to consistently measure system performance. The contracting team used RF measurement equipment to diagnose anomalies at the time of occurrence. They performed single test runs on each approach.

## **April 1999**

Production of the 330 new IVRs for the pilot study was completed and delivery made to Cobra to begin lab testing. One hundred (100) copies of the revised video were delivered along with 1,000 copies of the revised project executive summary. A revised public outreach briefing presentation was delivered. The contractor submitted draft system acceptance test procedures.

## **May 1999**

The contracting team performed environmental, laboratory and field tests for the new IVRs. The system acceptance test procedures were finalized. Under the system acceptance test plan, two IVR-equipped vehicles were to be used. Necessary support equipment was provided to each

vehicle and a total test staff of 10 people was made available. The acceptance tests consisted of three tests:

- 1- Stationary tests where the transmitters were in normal deployment mode and the vehicles were stopped at or near the stop bar. The purpose of this test was to demonstrate the transmission of a correct signal during a train event and verify no signal blockage by a passing train.
  
- 2- Normal run tests where transmitters were in normal deployment mode and test vehicles were moving through each approach during a train event with a radar gun operating. The purpose of this test was to demonstrate required coverage (800-1,200 feet), no missed alerts due to presence of a radar gun, and no signal blockage due to the passage of a train.
  
- 3- Special run tests where transmitters were in the continuous-on mode and test vehicles were moving through each approach with a radar gun operating. The purpose of this test was to verify earlier results and/or investigate questionable results from other tests.

The personnel resources to perform the system acceptance tests included:

- In-Vehicle Staff of four individuals per vehicle
  - ◆ Coordinator/Communicator/Observer – IDOT
  - ◆ Driver
  - ◆ Recorder
  - ◆ RF Engineer (Cobra)
- Spotter (not in test vehicles) to identify and communicate status of oncoming trains
- Radar Gun Operator (not in test vehicles)

Trackside transmitters were turned on at two sites for contractor field testing.

Due to USDOT interest in the Pilot Study, representatives from IDOT, Raytheon and UIUC participated in a workshop that included several Highway Rail Intersection (HRI) projects in the United States.

**June 1999**

The acceptance tests were conducted at all five sites on June 10-11. The results were all satisfactory except as noted:

- Greenwood Eastbound- Foliage blockage limited range to significantly less than 800 feet.
- Dundee Westbound- a possible dead zone was identified in the right hand lane during a stop bar test, at a position 20-25 feet before the stopbar and 50-55 feet ahead of the transmitter location.
- Beckwith (Lehigh Northbound)- Range was significantly less than 800 feet and warning dropouts/IVR recycling occurred after the initial alert was received.

In order to solve the above problems, some modifications were performed at the sites as noted:

- Greenwood- The lower TTA was placed on an extension arm, eight feet closer to the roadway (and beneath the canopy of trees) to provide a more direct path for eastbound and westbound Greenwood traffic.
- Dundee- Inverted the TTA and pulled screen off the bottom to improve close-in power levels. A second transmitter was installed to provide coverage for the westbound Dundee right lane.
- Beckwith- Moved the TTA towards Beckwith to cover the stopbar and dead zones. Installed a second transmitter on an extension arm to cover primarily northbound Lehigh.

On June 30, another set of system acceptance tests was performed and all three sites passed the test. A variance was granted at Greenwood Avenue to allow for a slight deficiency in range (less than 800 feet) caused by peak seasonal tree foliage. The range improved when there was less foliage.

500 in-vehicle information cards were delivered.

## **July 1999**

On July 9, IDOT sent the contracting team a letter signifying satisfactory completion of acceptance testing at all five sites.

In late July, more than 30 new IVRs were installed in Underwriters Laboratories vehicles and Master Brew Beverage vehicles.

### **August 1999**

At the end of August, approximately 60 percent of the new IVRs were installed. IDOT conducted training on new IVRs with several participants.

### **September 1999**

At the end of September, more than 80 percent of the new IVRs were installed. IDOT continued its training of pilot study participants.

Cobra studied sources of significant false alerts experienced by Master Brew. One of the IVRs was replaced. Even with the installation of new IVRs, it was reported at some locations that the presence of a K-band source still activated the IVRs.

### **October 1999**

Based upon false alert information gathered during IDOT's training sessions, a decision was made to leave all fire department and police department vehicles (except Glenview) in the visual-only mode for the entire pilot study deployment. Cobra performed an investigation of the locations where drivers reported false alerts. The K-band radar test equipment and the digital oscilloscope showed the presence of multiple K-band sources in the Chicago downtown area, Navy Pier and Wacker Drive. In addition, the IVR activated in the presence of door openers and proximity alarm devices. The false alert reports indicated repeatable false alerts at several locations within and outside of the study area.

A few more IVRs were installed and IDOT continued its training effort with participants. Cobra replaced two Master Brew Beverages IVRs due to continuing reports of false alerts.

### **November 1999**

The installation of the IVRs was nearly completed and IDOT completed participant training.

### **December 1999**

Raytheon started deinstalling rogue (old version) IVRs before the pilot study commenced.

Some difficulties were encountered by the contracting team in the de-installation of old IVRs/installation of new IVRs. IDOT completed the training of the participating drivers. The installation of new IVRs was completed.

IDOT and Raytheon provided an interview and on-site demonstration of the pilot study system to a representative from the Volpe National Transportation System Center as part of the USDOT cross-cutting study of high priority HRI projects.

### **January 2000**

Pre-deployment operations started on January 17. Due to changing participant vehicle travel patterns, the total number of IVRs installed was approximately 270. This was less than the original goal of 300 vehicles. On January 26, IDOT deployed three vehicles and each vehicle experienced repeatable false and missed alerts at the Dundee and Shermer sites. The contracting team began a thorough investigation of the problems at both sites.

The contracting team continued its IVR records reconciliation matching the participant vehicle fleet distribution list.

### **February 2000**

Cobra examined the nature of the repeatable false alerts experienced at certain locations. On February 9, false alert source signal measurements were conducted independently by the contractor team at two sites on Waukegan Road (Dominick's at Dempster and Walgreens at Beckwith in Morton Grove), and on February 10 with IDOT, where receiver false alert performance was tested at two additional sites (Jewel-Osco on Roselle (Schaumburg) and the Euclid-Elmhurst intersection (Mount Prospect)). The door openers at these businesses provided a strong source for the lower band (24.11 GHz) carrier frequency. Also, the cell towers observed near Jewel-Osco on Roselle Road may have provided the source signal for the upper band (24.19 GHz). The two signals required to activate the IVRs did not need to come from one source. Therefore, there was no easy remedy for alleviating this type of false alert. In the future, digital signal coding schemes could be used, where IVRs would recognize only a trackside transmitters' coded signal. This would require a major system redesign and modification to all trackside transmitters and IVRs.

Repeatable missed alerts experienced by IDOT at the Dundee and Shermer sites were investigated by the contracting team. The loss of alerts at the Shermer site when a vehicle was near the stopbar position in the left lane facing to the east, was caused by signal strength so strong that it was saturating the IVR (exceeding the upper end of its dynamic response range). As a result, the IVR could not accurately detect the signal. This problem was confirmed during the continuous-on testing on Wednesday, February 9, and was corrected by adding material which absorbed some of the signal strength in the lower region of the transmitter signal lobe. This reduced the signal strength at the stopbar area to where the strongest signal was within the dynamic response range of the IVR, allowing successful performance, while not significantly affecting the long range detectability of the signal between 800 and 1,200 feet. Following this corrective action, the system performance was satisfactory at Shermer, and the system was returned to the normal deployment mode.

It was determined that the loss of alerts at the Dundee site, when a vehicle was in the left lane near the stopbar facing to the east, was due to the fact that the two transmitters had drifted approximately 3.5 MHz from each other in transmitted frequency (due to temperature change). In this situation, the transmitted signal created more “pulses” than the maximum allowed for by the IVR to correctly detect the signal and provide the proper alert. This problem was confirmed during continuous-on testing on Wednesday, February 9, and was corrected by replacing the lower transmitter with a transmitter that was tuned to the same frequency as the higher transmitter. Following the transmitter replacement, the system performance was satisfactory at Dundee, and the system was returned to the normal deployment mode.

### **March 2000**

IDOT and the PMC instructed the contracting team to conduct on-site bi-weekly system monitoring for the Deployment Phase. The contracting team was required to fix any problems and deliver a report at each month’s PMC meeting.

The nine-month pilot study Deployment Phase was officially launched on March 10 and IDOT fielded several media inquiries and conducted some site demonstrations.

The contracting team conducted a visual inspection at the Skokie/Church intersection that was subjected to repeatable false alerts. It was speculated that a combination of automatic door openers and an antenna tower caused these false alerts, which significantly increased the number of Pace bus false alert reports.

A policy was formulated to respond to false alert “hot spot” occurrences. If a particular vehicle experienced a single false alert of five minutes or greater duration or more than one false alert in the same day, the contracting team was required to communicate with the participant to gather more information and analyze possible corrective measures.

### **April 2000**

A new set of 1,000 updated executive summaries was produced. The new executive summary contained a revised project schedule and list of participants.

A missed alert was reported at Dundee Road. The contracting team conducted extensive IVR drive tests and could not repeat this missed alert. The contracting team suspected that a line-of-sight signal blockage may have caused this missed alert. Several additional IVRs were installed to bring the total of 276.

The contracting team was notified by Pace that some IVRs in their buses were malfunctioning. It was found that water damage caused the IVR malfunctions and inoperable IVRs were replaced by the contracting team.

Raytheon officials visited Walgreens’ corporate headquarters to learn more information on the Walgreens automatic door opening systems that may have contributed to false alerts near their stores.

Cobra initiated an engineering investigation of false alert sources for 10 “hot spot” locations.

### **May 2000**

One final IVR was installed bringing the total to 277.

On May 16, IDOT conducted field testing and experienced missed alerts at the Chestnut and Greenwood sites.

### **Chestnut**

On northbound Lehigh, when approaching the Chestnut/Lehigh intersection, the warning was lost in the right turn lane (to go east on Chestnut). The system recycled and continued through the end of the train event.

**Shermer**

On eastbound Walters, the system activated, nulled, recycled and then went dead.

**Greenwood**

On northbound Park, the IVR activated at less than 800 feet. The warning nulled when the vehicle approached Greenwood. At the stop sign, the system remained dead. After the train passed and gates/flashers ceased operating, the IVR reactivated.

On northbound Chestnut, when the vehicle got to the Chestnut/Greenwood intersection, the signal was lost with the train passing through the crossing. The system reactivated after the train completely went through the crossing but before the gates went up.

Cobra officials conducted initial drive tests on May 17 and could not duplicate IDOT missed alerts.

The contracting team further investigated potential causes of false alerts and found that the major automatic door opening systems transmit at a frequency range that was within the same range as the lower frequency setting of the IVR.

On May 18, power was lost at the Greenwood site due a thunderstorm. The uninterruptible power supply continued to power the transmitter for several hours, but power was permanently lost on the morning of Saturday, May 19 and not restored until Monday, May 21. No missed alerts were reported during that timeframe (either by fax or by phone to the Cobra hotline). The possible explanation for this could be a lesser number of participant vehicle movements during the weekend or participant failure to report missed alerts.

On behalf of the pilot study, UIUC representatives presented a paper entitled "Lessons Learned and Achievements in the Development of an In-Vehicle Railroad Warning System" at the ITS America 2000 meeting in Boston.

## **June 2000**

Cobra Electronics completed modality changes for most participants. Cobra conducted further research on the causes of the false alerts. It was found that door opening sensors combined with another RF source probably triggered the IVRs.

Cobra Electronics performed instrumented performance tests at the Chestnut and Greenwood sites to investigate the missed alerts experienced by IDOT on May 16. The transmitters at both sites demonstrated proper operation during train events. The only missed alert that could be duplicated was northbound Lehigh approaching Chestnut. The alert was received at the proper distance but dropped out 600-800 feet from the crossing and restarted at approximately 300 feet from the crossing. Based upon contracting team observations, a conclusion was reached that foliage on Metra property (along the east side of Lehigh) was causing the problem. The line-of-sight signal on northbound Lehigh was blocked for a time interval greater than the 5-second receiver lag time.

IDOT officials made pilot study presentations at the ITS Midwest 2000 Annual Meeting (June 7-8) held at UIUC and the 2000 Midwest Highway/Rail Safety Conference (June 27-29) in Cleveland, Ohio.

## **July 2000**

Concurrence was received from IDOT and Metra to conduct foliage trimming to correct range performance along northbound Lehigh at the Chestnut site in Glenview.

On July 18, IDOT personnel experienced false alerts at the Greenwood site in Deerfield. The problem was confirmed on July 20 during drive tests by IDOT with the Raytheon Program Manager. Cobra Electronics and MTG investigated the problem, and on July 25, Cobra Electronics replaced transmitter and power supply components in the trackside power supply assembly. The problem was probably caused by a short circuit in the transmitter power supply and/or transmitter, causing the transmitter to occasionally remain "on" after a train event. In subsequent drive tests in late July, IDOT personnel experienced a potential recurrence of the original problem. The power supply was changed because of damaged relays. The lower transmitter at Greenwood was also changed to an east/west orientation.

It was agreed at the combined TOC/PMC meeting on July 20 that Cobra would conduct future site monitoring tests on or about the first and third Tuesdays of each month for the remainder of the pilot study. It was agreed that the test on the first Tuesday of the month would be conducted in the morning during peak train activity with the system in the normal deployment mode. The test on the third Tuesday of the month would be conducted in the afternoon with the system placed in the continuous on mode to test transmitter frequency and field of coverage. This second test would be preceded by a morning operational drive test by IDOT with the system in the normal deployment mode, whereby any unusual system behavior would be identified to Cobra prior to their afternoon testing.

A malfunctioning receiver at Pace was repaired.

The IVR modalities were not changed by the contracting team in approximately 50 vehicles. The contracting team attempted to re-schedule appointments with the participants. For unsuccessful efforts, IDOT performed the remaining modality changes.

### **August 2000**

During a system test on August 1, Cobra checked range performance for the system along Park Avenue and found that the maximum IVR range was less the required minimum of 800 feet, confirming IDOT's previous findings.

Concurrence was received from IDOT and Metra to conduct foliage trimming to correct range performance along northbound Lehigh at the Chestnut site in Glenview. Metra personnel trimmed the bushes and trees along the northbound Lehigh approach at Chestnut to correct the signal dropouts and recycling.

At the August 24, 2000 PMC meeting, IDOT reported a problem at the Greenwood/Chestnut crossing. The IDOT IVR recycled 5 or 6 seconds after a train occurrence. On August 25, IDOT, MTG and Cobra representatives met at the Greenwood/Chestnut site to investigate the problem. They concluded that the AC voltage remained on 4 to 5 seconds after the warning system turned off. Metra suspected a bad relay to be the cause of the problem.

IDOT sent a letter to the pilot study participants offering to transfer IVRs to different vehicles to maximize the total number of movements over the five grade crossings. Raytheon agreed to assume the responsibility for installation and transfer of IVRs for the remainder of the pilot

study. This work was previously performed by Cobra. However, Cobra would continue to repair all bad IVRs.

The signal range on northbound Shermer approaching the crossing was significantly less than 800 feet (approximately 500-600 feet). IDOT and the PMC agreed to keep the transmitter configuration constant due to concerns that adjustments would not improve system performance.

### **September 2000**

Concurrence was received from IDOT and Metra to conduct further foliage trimming to correct range performance along northbound Lehigh at the Chestnut site in Glenview. Initially, the foliage was cut back to approximately 500 feet. While performance improved, it did not meet contract specifications. When all of the foliage was removed, the system performance was acceptable. IDOT conducted tests on September 12 and reported that the system worked properly on all direct approaches (eastbound Chestnut, westbound Chestnut, northbound Lehigh, and southbound Lehigh) with one exception. There was one momentary signal dropout on northbound Lehigh. However, the previous problem with inadequate range and numerous signal dropouts on northbound Lehigh had been corrected.

IDOT completed the modality change for the IVRs to the combination audible/visual mode.

IDOT gave Raytheon a list of IVRs to be installed or transferred. Raytheon agreed to perform this work with Raytheon personnel rather than have the work done by Cobra.

### **October 2000**

IDOT completed the modality change for the final phase of testing. A transmitter problem was discovered at the Chestnut site in Glenview. A relay was stuck on the "on" position. MTG replaced the relay and the problem was resolved the same day. Raytheon installed seven IVRs at Alltown Bus Company. Cobra transferred IVRs between 12 Federal Express vehicles to accommodate route changes for these vehicles. Cobra also continued to replace malfunctioning IVRs in participant vehicles.

## **November 2000**

The IVR removal schedule was finalized. Cobra began IVR removal during the week of November 20. IDOT sent a letter to all participants stating that the pilot study would end on December 10 and transmitters would be shut off at all five sites on December 11. Cobra completed the repair and replacement of malfunctioning IVRs.

During deployment mode testing, IDOT officials identified a problem at the Chestnut site in Glenview. On the northbound Lehigh approach, the IVR warning ceased while the primary warning apparatus at the crossing was activated. Cobra investigated this problem and could not duplicate the system anomaly.

## **December 2000**

The contracting team continued the removal of IVRs.

The transmitters were shut off at all five sites on December 11 and all TTAs were removed by the end of December.

## **6. OTHER ISSUES**

### **6.1. Multiple Agency Approval Coordination**

One of the complexities that was encountered during the pre-deployment phase of this study was the involvement of multiple agencies. The railroad grade crossings that were part of this pilot study were located in four communities. This required that all jurisdictions endorse the project. In addition, the railroad crossings and adjacent right-of-way are Metra property. Therefore, a right-of-entry agreement had to be executed between the contractor and Metra to allow for installation of transmitters and controllers on Metra property. Furthermore, Metra was required to submit the project plans to the ICC for approval. In summary, multi-agency coordination required time, effort, and approval from various agencies.

## **6.2. Multiple Participant Training and IVR Installation Coordination**

With 38 participating organizations, the Pilot Study encountered a number of challenges coordinating the installation of IVRs in the many vehicles involved in the study. Also, challenges were encountered in coordinating driver training among the many participant drivers and their supervisors. Both activities were impacted by the location and operating schedules of the 38 participants. The IDOT training included a video presentation on the operation of the advisory warning system, distribution of base line driver surveys, and an explanation of the information card that was placed in each of the vehicles. IDOT officials also needed to be available to answer driver's questions. The IVR redesign complicated this activity because old IVRs needed to be removed and new IVRs installed. Also, drivers were required to be retrained because a significant time had passed since the original installation and training. The retraining provided the drivers an explanation on the operation of the redesigned system.

After the new IVRs were found to be working properly in the comprehensive tests and acceptance tests, the older version IVRs were removed and new IVRs installed in participants' vehicles. This IVR removal/installation and driver training was conducted during the period of September 1999-December 1999. As part of this process, a new training video, in-vehicle information card and executive summary were produced for the pilot study. The new training video and information card aimed to educate the drivers on the revised system operation (new power up sequence) and the two different warning messages (caution and warning train). The new executive summary provided a list of the project participants and a revised project schedule.

Prior to this second round of IVR installations and driver training, it was recognized that some vehicles could have been sold/transferred during the two years since the original IVR installation took place. Also, there were shifts in the driver population. For these reasons, all former drivers were retrained on the system operation.

Furthermore, in a few situations, participating organizations could not locate the whereabouts of transferred/sold vehicles with the original version IVR. Finally, some of the vehicle records compiled by the contracting team did not match the information provided by the participants. In December 1999, the contracting team worked with all of the participants to complete IVR installation verification reports.

Overall, a closely coordinated approach was necessary between the contractor responsible for installing the IVRs and driver training performed by IDOT. This coordination was assured by frequent (daily) voice and data communication.

## **7. CONCLUSIONS AND RECOMMENDATIONS**

The performance history of the Pilot Study showed that overall the system did not meet study expectations even though replacing the original IVRs were helpful to some degree. The off-the-shelf technology that was used in this pilot study was not able to provide adequate system reliability. The concept of an on-board warning system has potential to work if a more reliable technology is used to activate the warning system. There were other challenges that were not directly related to system performance, but had to be overcome. The complexities of multi-agency coordination required time, effort, and approval from various agencies. Coordinating the installation of IVRs among many vehicles, coordinating driver training and retraining among several hundred participant drivers, and keeping 38 participating organizations interested in the study were significant challenges. There were many challenges and significant lessons were learned in this Pilot Study that would be very helpful in future implementation of ITS technologies.