U.S. Department
of Transportation
**Federal Railroad
Administration**

VEHICLE PROXIMITY ALERT SYSTEM: PROTOTYPE 1

Office of Research and
Development
Washington D.C. 20590

**Association of American Railroads
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LETTER REPORT

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PREFACE

As part of Task Order 114, AAR is to provide letter reports following the testing of each prototype VPAS system. These reports are solely for the purpose of summarizing the testing with a brief discussion of the results. No analysis or conclusions on the results of the testing are included in these reports. A full analysis of each system and conclusions based on the results of this analysis will be included in the final report for Task Order 114.

DISCLAIMER

1.0 INTRODUCTION

As part of FRA Task Order 114, the Association of American Railroads (AAR) Transportation Technology Center (TTC), Pueblo, Colorado, completed testing of Vehicle Proximity Alert System (VPAS) system 1. VPAS systems are designed to give priority vehicle operators (emergency, police, school buses, hazmat) advanced warning of the approach and/or presence of a train. These are stand alone systems that do not rely on the activation of conventional highway-rail grade crossing warning/protection devices.

2.0 SYSTEM OVERVIEW

System 1 is a three point system that uses a radio frequency (RF) design developed by Smart Stops, Inc. The three points consist of a locomotive transceiver, a transceiver located at the crossing, and a receiver located in the vehicle.

The communication medium for the particular system tested were RF signals transmitted at 151.6 MHz using dual tone multiple frequency (DTMF) codes for system communication. The system is designed to transmit from the locomotive at all times. Once the locomotive is in the vicinity of a crossing equipped with a transceiver, the crossing transceiver decodes the DTMF signal from the locomotive. If the appropriate code is received at the crossing, the crossing transceiver transmits a signal back to the locomotive and any other vehicle equipped with a decoding receiver. The signal received by the locomotive assures the locomotive engineer that the transceiver at the crossing is functioning. The signal received by the vehicle alerts the driver of an approaching train.

3.0 PROCEDURES

VPAS testing was divided into the following phases:

- Phase I - System installation, calibration, and check-out
- Phase II - System performance and repeatability
- Phase III - Maximum system performance limits
- Phase IV - System response to adverse conditions

3.1 PHASE I

Phase I testing consisted of installation, system calibration, and initial system check-out. Installation, which took less than two hours, was performed by representatives from Smart Stops, Inc. under the supervision of TTC personnel on January 26, 1995. The entire system was delivered ready to install. TTC supplied 110 volts AC on the locomotive and at the crossing and 12 volts DC to the receiver in the vehicle.

The system was then calibrated by placing the locomotive 2000 track feet from the crossing. Smarts Stops representatives tuned the locomotive transmit signal to the minimum power level necessary for the crossing transceiver to begin receiving the locomotive signal. The crossing system was then tuned to the same power level to provide a 2000 foot transmission radius from the crossing to both the locomotive and the vehicle.

After the installation and calibration was completed, a check-out was conducted to validate performance of the VPAS system as well as the instrumentation and data collection. While the vehicle remained stationary 500 feet from and perpendicular to the crossing, the equipped locomotive made several passes of varying speeds through the test zone. For each pass, the VPAS system was activated 1750 track feet from the crossing, and deactivated 1750 track feet past the crossing by means of automatic location detector (ALD) sensors. The check-out was completed with confirmation that each point of the VPAS system and data collection equipment was functioning as desired.

3.2 PHASE II

The objective in Phase II was to test system performance and repeatability in a simulated revenue service environment on a sustained basis. Testing involved repeated actuation of all points by a passing train traveling at 40 mph. For the entire duration of Phase II, the vehicle remained stationary at 500 feet perpendicular to the simulated crossing. Preliminary results of Phase II testing for VPAS system 1 are summarized in the following table:

Table 1. VPAS Phase II Testing

Date	Train Direction	Laps	Failures	Mean Warning Time (sec)	System Operation Time (hrs)
2/03	CCW	56	0	33.3	4.75
2/06	CW	38	0	29.9	3.25
2/07	CW	51	0	31.4	4.25
2/08	CCW	63	0	30.7	5.00
2/09	CCW	52	0	32.9	4.00
2/10	CW	17	0	32.3	3.00
2/12	CCW	86	0	31.4	8.70
2/13	CCW	19	0	31.6	2.50
2/14	CW	119	10	28.7	9.25
		501	10	31.36	44.7

Test zone boundaries were established to provide 33 seconds from entry of the locomotive into the test zone to the middle of the crossing. Warning time for each pass was calculated from the time the vehicle received a signal to the instant the locomotive passed the mid-point of the crossing. System 1 provided a consistent warning time for the vehicle, which frequently received a signal less than one second after the locomotive entered the test zone.

In total, 501 train passes were made during Phase II, 276 counterclockwise and 225 clockwise. System 1 performance was consistent, independent of train direction. No failures were recorded before February 14, 1995; however, it was noted that prior to the beginning of testing on several days, the receiver in the vehicle did not respond until the vehicle's heater had been operating for several minutes. As a precaution, no train passes were made during Phase II until the vehicle receiver was fully operational; the cause of system failure was not known at the time.

It is hypothesized that the 10 failures, which occurred consecutively between 5:45 and 6:23 a.m. on February 14, were caused by cold temperatures. When testing began on February 14, the ambient temperature was approximately 30 degrees Fahrenheit. By the time the first failure was recorded at 5:45 a.m., the ambient temperature had dropped to approximately 13 degrees Fahrenheit.

The data from these failures shows that the vehicle receiver's performance progressively diminished until it no longer received signals from the crossing. At approximately 6:15 a.m., when the heater inside the vehicle was turned on and the internal vehicle temperature began to rise, subsequent data showed an improvement in the vehicle receiver's performance. System 1 susceptibility to cold temperatures was further examined as part of Phase IV testing.

3.3 PHASE III

The objective of Phase III testing was to determine the maximum performance limits of the VPAS system. To determine system design limits, testing was conducted with either the locomotive or the vehicle stationary under good conditions.

3.3.1 RTT Testing

A portion of Phase III testing was performed on the Railroad Test Track (RTT) with a simulated crossing located at post R-14 (Figure 1). Locomotive transmission was initiated approximately 6,000 feet from the crossing. The system was calibrated by Smart Stops personnel during Phase I to a locomotive-to-crossing range and a crossing-to-vehicle range of approximately 2,000 feet each. An initial test for system performance limits revealed that the crossing was still receiving the locomotive transmission as far away as 12,000 feet (16,000 track feet), the maximum attainable distance the locomotive could achieve on the RTT from the crossing. The return signal, from the crossing back to the locomotive, had a maximum limit of approximately 7,000 feet.

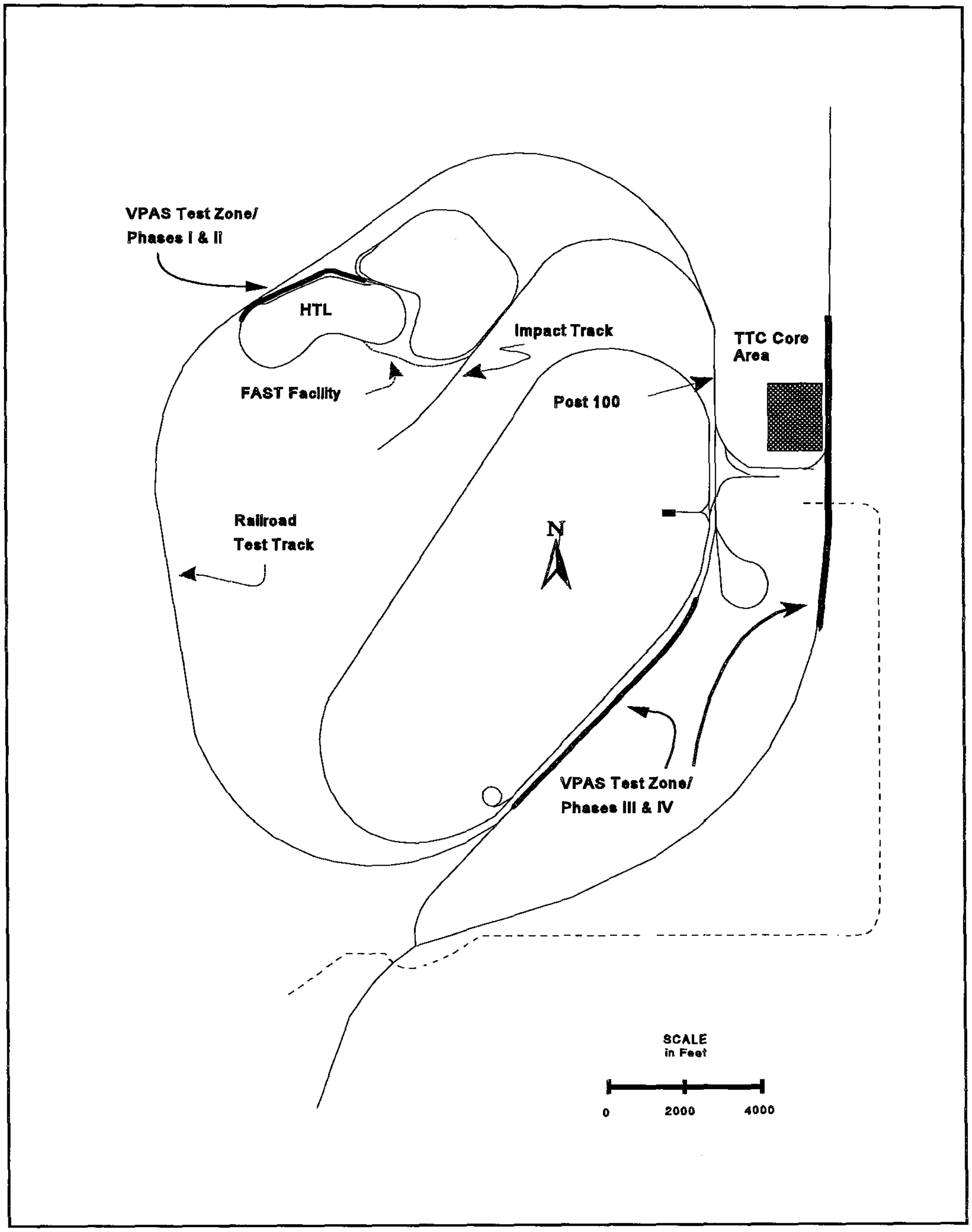

Figure 1. TTC Site Map/VPAS Test Zones

The following table summarizes the performance limits of varying locomotive speeds with the vehicle stationary perpendicular to the crossing. Data indicates that speed has no apparent effect on the performance of this system. Signal characteristics were similar for each pass, regardless of speed.

Table 2. Performance Limits of Varying Locomotive Speeds - Vehicle Stationary Perpendicular to the Crossing

Run No.	Loco Speed (mph)	Vehicle Distance from Crossing (feet)	Comments
01	10	1000	Intermittent signal @ loco receive first 1800' of test zone. Spectrum analyzer @ crossing
02	30	1000	No loco receive first 1500' of test zone Spectrum analyzer @ crossing
03	60	1000	Intermittent @ loco receive first 1300' of test zone Spectrum analyzer @ crossing
04	10	1000	Intermittent signal @ loco receive first 1000' of test zone. Spectrum analyzer @ vehicle
05	30	1000	Intermittent signal @ loco receive first 1300' of test zone. Spectrum analyzer @ vehicle
06	60	1000	Intermittent signal @ loco receive first 4000' of test zone. Intermittent @ crossing receive, crossing transmit, vehicle receive first 1000' of test zone Spectrum analyzer @ vehicle
07	10	2000	No signal @ loco receive first 1300' of test zone. Spectrum analyzer @ vehicle
08	30	2000	Intermittent @ loco receive first 2000'; intermittent to crossing. No receive @ vehicle for first 3300'; intermittent through remainder of test zone.

Table 2. Performance Limits of Varying Locomotive Speeds - Vehicle Stationary Perpendicular to the Crossing (Continued)

Run No.	Loco Speed (mph)	Vehicle Distance from Crossing (feet)	Comments
09	60	2000	Intermittent @ loco receive first 1800' Intermittent @ vehicle receive for last 3500' of test zone
10	10	3000	Intermittent @ loco receive first 1300' Excessive intermittent signal @ vehicle receive throughout entire test zone.
11	30	3000	Intermittent @ loco receive first 1300' Excessive intermittent signal @ vehicle receive throughout entire test zone.
12	60	3000	Intermittent @ loco receive first 1700' No receive at vehicle until loco passed crossing.
13	10	4000	Intermittent @ loco receive first 1300' Excessive intermittent signal @ vehicle receive throughout entire test zone.
14	30	4000	No receive @ vehicle
15	60	4000	No receive @ vehicle
16	10	1500	Intermittent @ loco receive first 1300'
17	30	1500	Intermittent @ loco receive first 2600'
18	60	1500	Intermittent @ loco receive first 1700'
19	10	1250	Intermittent @ loco receive first 1300'
20	30	1250	Intermittent @ loco receive first 1700'
21	60	1250	Intermittent @ loco receive first 3500'

3.3.2 Impact Track Testing

A second segment of Phase III testing was performed on the Impact Track (Figure 1). This particular track has a paved road crossing, essential for mobile vehicle testing, that intersects perpendicular to the track. Markers were set on the road every tenth of a mile from the crossing for one mile. For this portion of testing, the locomotive remained stationary at varying distances from the crossing while the vehicle approached the crossing at varying speeds.

Table 3 summarizes the test results for this segment of Phase III testing:

Table 3. Impact Track Testing Results - Paved Road Crossing

Run No.	Vehicle Speed (mph)	Locomotive Distance from Crossing (feet)	Comments
39	30	1750	Good transmit and receive at all points
40	50	1750	Good transmit and receive at all points
41	30	900	Good transmit and receive at all points
42	50	900	Good transmit and receive at all points
43	30	50	Good transmit and receive at all points
44	50	50	Good transmit and receive at all points

Signal transmission from the locomotive to the crossing was initiated when the vehicle was at speed one mile from the crossing, and maintained throughout this segment of testing.

During the stationary vehicle tests, maximum range from the crossing to the vehicle was determined to be approximately 2000 feet. However, during the mobile vehicle segment of Phase III testing, the vehicle receive signal was immediate when the vehicle was at one mile (5280'), the same point at which the locomotive transmission had been initiated. This increase in range between a stationary and mobile vehicle cannot be explained by the data collected.

3.3.3 Post 100 Testing

The previous runs were performed as the vehicle traveled downhill towards the crossing with the vehicle in its direct line-of-sight. Conversely, the vehicle was examined traveling uphill towards Post 100 (Figure 1) with the crossing beyond the approaching vehicle's line-of-sight. There is no indication of interference caused by differences in elevation or surrounding terrain. Table 4 summarizes the results of the vehicle traveling in the opposite direction.

TABLE 4. Post 100 Testing Results - Vehicle Traveling Uphill; Crossing Out of Line-of-Sight

Run No.	Vehicle Speed (mph)	Locomotive Distance from Crossing (feet)	Comments
45	30	100	Good transmit and receive at all points
46	50	100	Good transmit and receive at all points
47	30	1750	Good transmit and receive at all points
48	50	1750	Good transmit and receive at all points

3.4 PHASE IV

The objective of Phase IV testing was to measure system response to specific adverse conditions expected to influence system performance. VPAS system 1 was exposed to such adverse conditions as temperature, radio frequency interference (RFI), antenna position and obstacles.

3.4.1 Temperature Effects

During Phase II testing, the vehicle receiver had a series of passes categorized as system failures. As stated earlier in this report, the apparent cause for the failures was attributed to temperature fluctuations within the vehicle. As the temperature dropped to a certain level, the vehicle receiver began to fail; conversely, as the temperature within the vehicle began to rise, the vehicle receiver's performance improved.

In order to further examine the system's vulnerability to temperature, part of Phase IV testing included monitoring internal vehicle temperature and associated system responses to changes. Temperature measurements within the vehicle were obtained using a hand-held pyrometer, which measures ambient as well as surface temperatures.

Before testing began on February 15, 1995, the temperature within the cab registered 26 degrees Fahrenheit. The system was allowed to run while the vehicle's heater was on, but the receiver worked intermittently and did not start receiving steadily until the temperature within the vehicle reached approximately 44 degrees Fahrenheit. Vehicle temperature was then reduced by opening the windows and turning the heater off. The receiver again began working intermittently but failed completely when the temperature dropped to approximately 24 degrees Fahrenheit. Once again, the receiver fully recovered when the vehicle's temperature reached approximately 40 degrees Fahrenheit.

3.4.2 Radio Frequency Interference

The next segment of Phase IV testing was conducted on the RTT through the same test zone previously described, with the vehicle stationary at 1,000 feet. Efforts were made to cause system interference by introducing RFI, which was created using a hand-held transceiver FM radio programmed to the same transmission frequency (151.7 MHz) and a nearby frequency (148 MHz). The locomotive speed for all test runs was 30 mph.

For each pass, the hand-held radio was keyed from 500 feet past station R-10 and remained keyed until R-15, approximately 4,000 feet before the crossing and 1,000 feet past the crossing. Table 5 outlines each of the test runs made:

Table 5. RFI Test Run Results

Run No.	Test Description	Result
25	Radio was keyed inside cab of locomotive at 148 MHz.	Intermittent @ loco receive for first 2,640 feet.
26	No data	N/A
27	Radio keyed @ crossing at 148 MHz near crossing antenna	Minor intermittent @ loco receive, crossing receive, crossing transmit, and vehicle receive.
28	Radio keyed @ crossing at 151.7 MHz near crossing antenna	Severe intermittent @ loco receive, crossing receive, crossing transmit, and vehicle receive until 2,000 feet from crossing.
29	Radio keyed @ crossing at 151.7 MHz directly next to crossing antenna	No signal @ loco receive, crossing receive, crossing transmit, and vehicle receive while radio was keyed.
30	Radio keyed @ crossing at 148 MHz directly next to crossing antenna	No signal @ loco receive, crossing receive, crossing transmit, and vehicle receive while radio was keyed.
31	Radio keyed @ 148 MHz near vehicle antenna	Minor intermittent @ loco receive and vehicle receive while radio was keyed.
32	Radio keyed @ 151.7 MHz near vehicle antenna	Minor intermittent @ loco receive, no signal at vehicle receive while radio was keyed.

3.4.3 Antenna Position

The next sequence of phase IV testing, as outlined below in Table 6, involved moving various antennas to different locations to examine the effects of antenna position.

Table 6. Effects of Antenna Position on System Interference

Run No.	Test Description	Result
33	Moved loco antenna from top of locomotive to inside the loco cab. Crossing antenna normal; vehicle antenna normal.	Minor intermittent @ loco receive.
34	Placed loco antenna inside the generator housing. Crossing antenna normal; vehicle antenna normal	Minor intermittent @ loco receive; minor intermittent @ vehicle receive.
35	Placed loco antenna inside the generator housing; crossing antenna at ground level behind signal bungalow. Vehicle antenna normal.	Severe intermittent @ loco receive first 2,000 feet.
36	Placed loco antenna inside the generator housing; crossing antenna placed inside signal bungalow; vehicle antenna normal	No loco receive beyond 1,000 feet on either side of the crossing; no crossing receive or transmit first 700 feet; no vehicle receive.
37	Loco antenna normal; crossing antenna normal; vehicle antenna inside bed of pickup truck.	Vehicle receive intermittent first 2,600 feet.
38	Loco antenna normal; crossing antenna normal; vehicle antenna inside cab.	Major intermittent @ vehicle receive between 2,000 and 3,000 feet from crossing.

3.4.4 Obstacles and Additional RFI Testing

The final segment of Phase IV testing was performed in and around the TTC "core" area, shown in Figure 2. The purpose of these test runs was to (1) perform additional RFI testing using the TTC radio transmission tower, and (2) to examine the effects of obstacles, namely buildings, on the system. Based on the potential susceptibility of this VPAS system to RFI, further testing was performed. This was accomplished by positioning each antenna such that the TTC's radio transmission tower (transmitting on six different channels between 170 MHz and 173 MHz) was between the locomotive and the crossing antenna, which was positioned approximately 550 feet from the locomotive and approximately 475 feet from the radio tower (Figure 2).

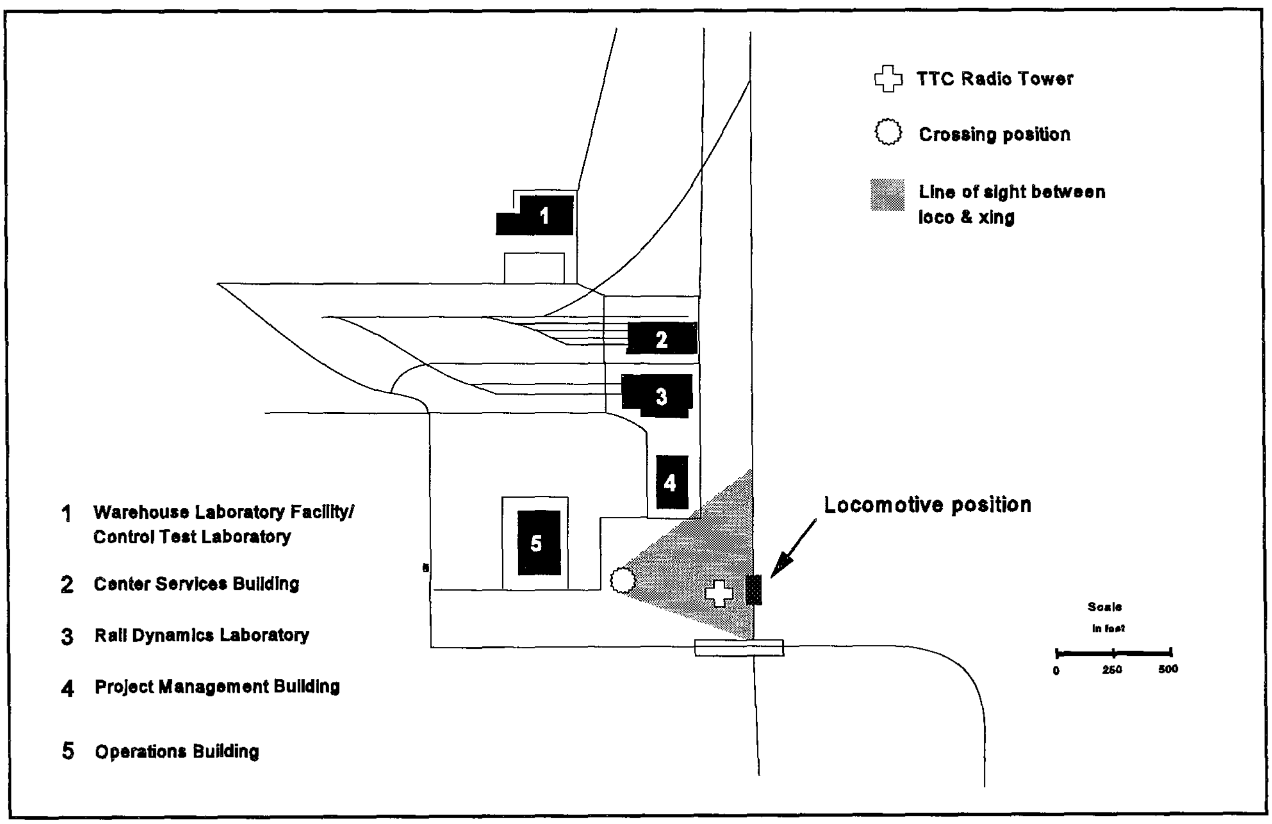

Figure 2. TTC Core Area/Phase IV Orientation

TTC's Operations Control Center assisted during runs 49-51 by transmitting at 170.750 MHz, with both the locomotive and vehicle stationary, for approximately 30 seconds during test operation.

Run 52 was performed with the locomotive stationary as shown in Figure 3 with the vehicle mobile around the TTC core area. The map in Figure 3 shows the route followed by the vehicle. Markers were manually entered as the data was being collected on-board the vehicle. Marker number 8 of the figure shows the location where the vehicle momentarily lost the signal being transmitted; Table 7 summarizes these results.

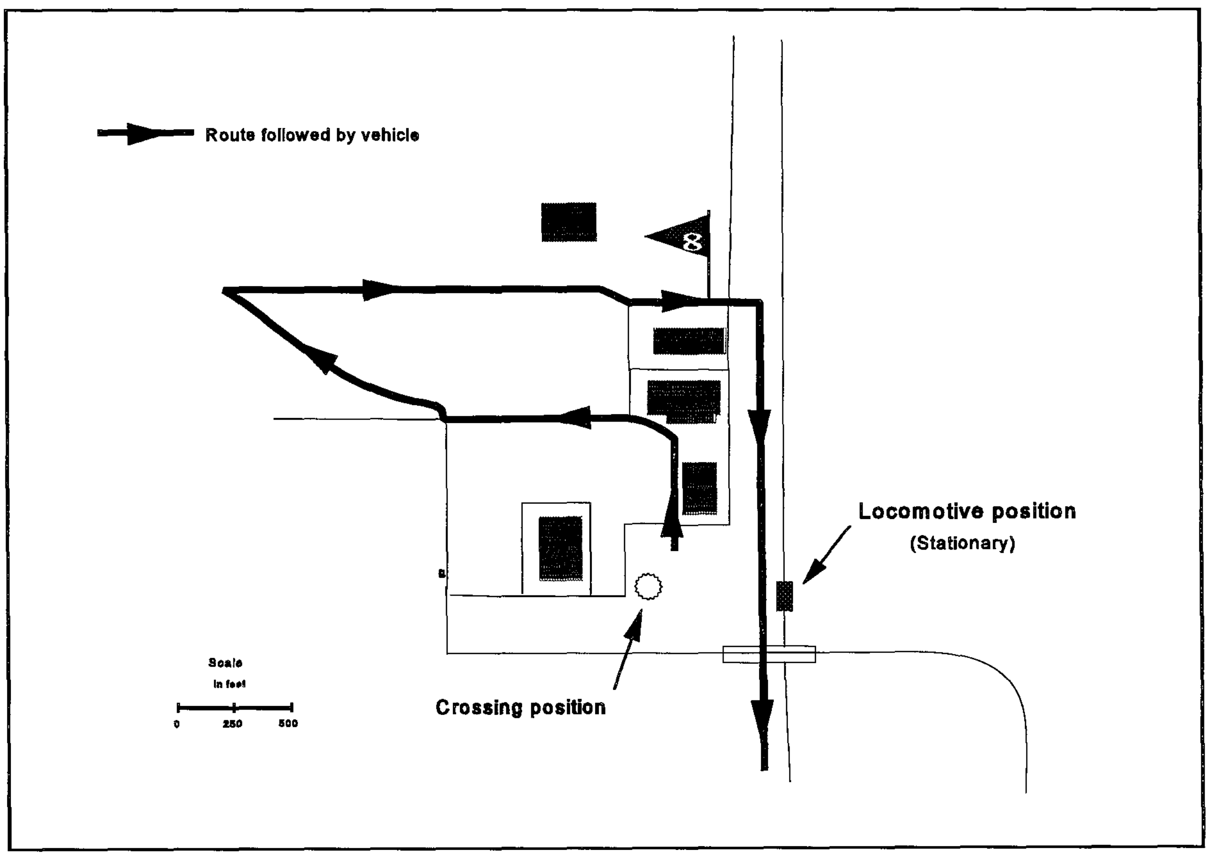

Figure 3. TTC Core Area / Vehicle Route

Table 7. TTC "Core" Area RFI Testing

Run No.	Test Description	Result
49	Locomotive stationary, vehicle at crossing, TTC radio tower transmitting @ 170.75 MHz	Good transmit and receive at all points
50	Repeat run 49	Good transmit and receive at all points
51	Repeat run 49 - moved vehicle 560 feet north of the crossing	Good transmit and receive at all points
52	Locomotive stationary, vehicle mobile around core area.	Momentary loss of receive at marker location #8 (see Figure 3).

In runs 53 through 60, the vehicle remained stationary at various locations with the locomotive mobile and approaching from either the north or south at 30 mph. In run 61, however, the locomotive remained stationary while the vehicle was mobile around the core area. The test configuration for run 61 is illustrated in Figure 4; results are summarized in Table 8.

Table 8. TTC "Core Area" — Obstacle Interference Testing

Run No.	Test Description	Result
53	Locomotive approaching from the north @ 30 mph, vehicle stationary 560 feet north of the crossing.	Minor intermittent signal at vehicle receiver.
54	Locomotive approaching from the south @ 30 mph, vehicle stationary 560 feet north of the crossing.	Minor intermittent signal at vehicle receiver.
55	Repeat run 53 - vehicle stationary between CSB & RDL.	Minor intermittent signal at vehicle receiver.
56	Repeat run 54 - vehicle stationary between CSB & RDL.	Minor intermittent signal at vehicle receiver.
57	Moved crossing between CSB & RDL (see Figure 4). Locomotive approaching from the north @ 30 mph, vehicle next to crossing	Minor intermittent signal at vehicle receiver.
58	Repeat run 57 - locomotive approaching from the south @ 30 mph.	Minor intermittent signal at vehicle receiver.
59	Repeat run 57 - vehicle stationary north of the CSB, locomotive approaching from the north @ 30 mph.	Minor intermittent signal at vehicle receiver.
60	Repeat run 59 - locomotive approaching from the south @ 30 mph.	Minor intermittent signal at vehicle receiver.
61	Locomotive stationary (see Figure 4), vehicle mobile around core area.	Momentary loss of receive at marker locations #8 though # 14 (see Figure 4).

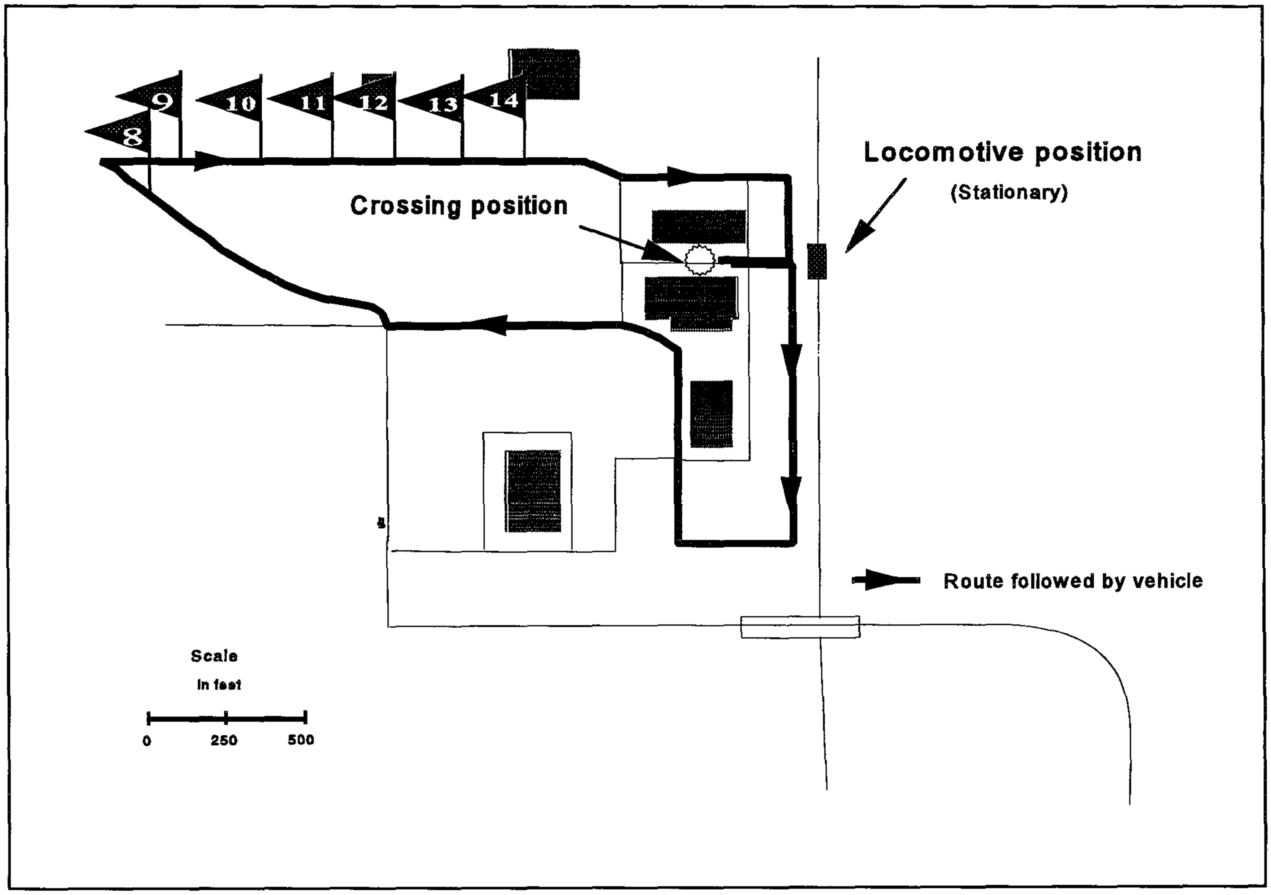

Figure 4. Vehicle Route, Xing Between CSB & RDL