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Transportation

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PTC Test Bed Upgrades to Provide ACSES Testing Support Capabilities at Transportation Technology Center

Office of Research
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13. ABSTRACT (Maximum 200 words) FRA Task Order 314 upgraded the Positive Train Control (PTC) Test Bed at the Transportation Technology Center to support testing of PTC systems, components, and related equipment associated with the Advanced Civil Speed Enforcement System (ACSES) in a revenue service environment. Transportation Technology Center, Inc. (TTCI) purchased and installed the necessary components, which included a combination of wayside, onboard, and back office server equipment. A final test of the ACSES II system, which accurately represented ACSES installation in revenue service, was successful and the objective of the task order was accomplished. In the future, FRA's Task Order 331 will allow for additional transponders to be placed within the PTC Test Bed and programmed for different track speeds, Positive Train Stops, and Permanent Speed Restrictions. Also, within TO 331, TTCI will be able to adjust and reprogram the ACSES equipment to reflect changes to desired testing scenarios and track layout.				
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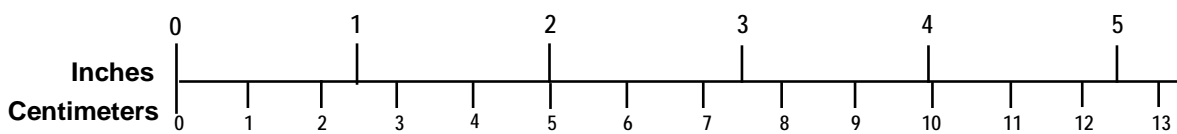
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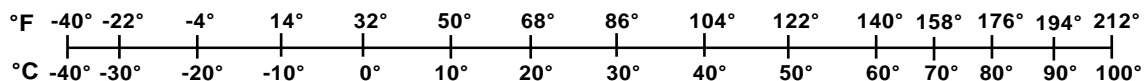
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Executive Summary

The Rail Safety Improvement Act of 2008 (RSIA) requires implementation of interoperable Positive Train Control (PTC) systems on certain rail lines identified therein. The scope of PTC implementation covers more than half of the national railroad network and will require significant capital expenditure by railroads subject to the statutory mandate.

To assist the U.S. railroad industry in implementing the prescribed PTC capabilities, the Federal Railroad Administration (FRA) and Transportation Technology Center, Inc. (TTCI) have been investing in a PTC Test Bed at the Transportation Technology Center (TTC) in Pueblo, CO. The test bed was initially developed and subsequently upgraded to provide a resource facility for testing PTC-related systems, equipment, and technologies in an environment free of certain constraints associated with revenue service test activities.

As developed, TTC's PTC Test Bed provides a facility that may be used to support development of PTC systems, to conduct performance evaluations of PTC system segments, and to perform interoperability and compliance testing. As examples, PTC system development could include proof of concept demonstrations, system development testing, and simulations and on-track (field) testing. Prior to this task order, capabilities were focused on supporting Interoperable Train Control (ITC) (e.g., Interoperable Electronic Train Management System (I-ETMS®)* based activities).

In 2012, FRA used Task Order 314 to task TTCI with upgrading the PTC Test Bed by installing an Advanced Civil Speed Enforcement System (ACSES) II system (using 220-MHz communications) to support testing of PTC systems, components, and related equipment in an environment representative of its installation in revenue service. ACSES is a vital overlay PTC technology that uses a combination of on-track, wayside, locomotive, and back office server components to enforce civil speeds and positive train stop (PTS), temporary speed restriction (TSR), and other PTC enforcement functions.

Under this task order, TTCI upgraded the PTC Test Bed's infrastructure and test support capabilities to include ACSES II testing activities. The scope included providing the key ACSES functionalities of office, locomotive, and wayside (interlocking). The Office function is provided through the use of an emulator for the Safety Server. Other functions are provided through the use of actual ACSES equipment from current ACSES equipment providers. The scope also included the engineering required to design the installation of equipment at TTC and to provide installation documentation for all system components.

In order to accurately represent the operation of ACSES in revenue service, TTCI used engineering services and components from Siemens Rail Automation Carborne Systems (formerly PHW, Inc.), Convergent Communications Incorporated (CCI), and Ansaldo STS. Back office software includes a Safety TSR Server (STS) Emulator to provide TSR data and a Field Simulator to provide Interlocking Status (IS) information. Wayside equipment includes a 900-MHz and a 220-MHz ACSES communications infrastructure and a series of passive transponders

* Note that when I-ETMS is used in this document, it refers collectively to the I-ETMS® PTC system and the ETMS® PTC system, both of which are registered trademarks of Wabtec Corporation.

to transmit track information. Two locomotives at the TTC are equipped with 9-aspect cab signaling and vital onboard ACSES equipment. The PTC Test Bed incorporates two interlockings, each with a simulated wayside interface unit (WIU), one Permanent Speed Restriction (PSR) location, and a track database within the STS Emulator to implement TSR data. Line speeds are dictated by five train types ranging from freight to high speed passenger operations. An independent Automatic Train Control (ATC) cab signal system uses seven aspects of the 9-aspect signal system.

TTCI purchased and installed the necessary components that included a combination of in-track, wayside, onboard, and back office equipment. A TTCI ACSES-equipped locomotive successfully enforced PTSs, PSRs, and TSRs around the PTC Test Bed, meeting the requirements of the task order.

A follow-on FRA task order will allow for additional transponders to be placed within the PTC Test Bed and programmed for different track speeds, PTSs, and PSRs. Also, within the follow-on task order, TTCI will have the ability to adjust and reprogram the ACSES equipment to reflect changes to desired testing scenarios and track layouts.

1. Introduction

1.1 Background

The Rail Safety Improvement Act of 2008 (RSIA), as passed by the U.S. Congress and signed by the President, requires the implementation of interoperable PTC systems on specified rail lines identified therein and on any additional lines identified by the U.S. Secretary of Transportation. Interoperability means the ability of a controlling locomotive to communicate with and respond to any railroad's PTC system, including uninterrupted movements over railroads property boundaries. The scope of PTC implementation required by law is unprecedented, covering more than roughly half of the national railroad network and will require significant capital expenditure by railroads subject to the statutory mandate. PTC is a very important element of train control and once fully deployed, is expected to have a significant impact on the safety and efficiency of railroad operations in the decades to come.

To assist the U.S. railroad industry with its implementation of PTC, FRA and TTCI have been investing in a PTC Test Bed at TTC in Pueblo, CO. The PTC Test Bed was initially developed and subsequently upgraded to provide a resource for testing PTC-related systems, equipment, and technologies in an environment free of the challenges associated with revenue service test activities.

Testing a PTC system on revenue service routes can present significant challenges, such as:

- Scheduling test activities around revenue service traffic;
- Obeying all operating rules or obtain waivers (frequently a lengthy process);
- Dealing with difficulties associated with conducting stress testing (i.e., degraded equipment or high capacity performance testing);
- Experiencing operational challenges with obtaining repeatable results; and
- Modifying or recalibrating vital equipment, potentially requiring lengthy verification and validation processes before retest is possible.

Among other uses, the PTC Test Bed provides a controlled environment that can be used to support development of PTC systems, to conduct performance evaluations of PTC system segments, and to perform interoperability and compliance testing. As examples, PTC system development could include proof of concept demonstrations, system development testing, and simulations and on-track (field) testing. Other examples of potential PTC Test Bed uses, as well as past and current uses, include the following:

- Preliminary field trials and debugging of PTC systems
- Development and testing of improved PTC braking algorithms
- Evaluation of the impact of communications system performance and loading on PTC system performance
- Development and testing of PTC positive end of train determination systems
- Development and testing of PTC train location systems

- Over-the-air testing of PTC-related communications devices and capabilities
- Demonstration of the operation of potential PTC highway-rail grade crossing protection systems
- Certification/acceptance testing of PTC systems or components
- Interoperability/interchange testing of multiple PTC systems

Modifications to the PTC Test Bed enabled it to support more generalized PTC testing, such as for interoperability, functionality verification, and performance and stress characterization.

1.2 PTC Test Bed Development Summary

1.2.1 Early History

In 1997 and 1998, the PTC Test Bed was created when Harmon track signal circuits were installed in the Railroad Test Track (RTT) to provide the 9-aspect cab signaling needed to support subsequent National Railroad Passenger Corporation (Amtrak) testing. Twelve 6,000-foot track signal blocks were created by installing insulated joints and alternating current impedance bonds between adjacent signal blocks. Harmon Electrified ElectroCode 4+ track signal electronics were installed in 12 instrument cases located around the RTT at the junction of each pair of adjacent blocks. This equipment provided rail integrity monitoring and track occupancy indications for each signal block, as well as 9-aspect cab signaling information to support Amtrak testing. By 2005, TTCI had implemented several radio systems at the test bed to support PTC, including ATCS “Spec 200” radios, Wi-Fi, GPS-based vehicle tracking, etc.

By 2009, TTCI had begun testing the V-PTC system and had made the following additions to the test bed:

- PTC communications (wayside, locomotives, and base station) using Meteorcomm 900-MHz radios
- RailComm computer-aided dispatch (CAD) system
- Lockheed Martin Vital PTC (V-PTC) back office server (BOS)
- PTC test local area network (LAN) segregated from the TTCI business LAN
- Wayside equipment bungalow located near RTT Switch 602B
- Special test equipment for creating and controlling PTC test conditions
- PTC subsystem simulators and emulators

Also, in 2009, TTCI expanded test bed capabilities by adding a 4,000-foot siding to enable the testing of PTC-controlled meet and pass movements. Installation of the siding included:

- 4,000 feet of siding track with a centerline offset 20 feet from the RTT’s centerline;
- Remotely monitored and controlled powered switches at each end of the siding and at each end of the RTT and Transit Test Track (TTT) crossover; and
- Dwarf signal lights at each switch used as switch point indicator lights.

1.2.2 Task Order 256 Upgrades to Support Communication Testing

In September 2010, upgrade activities associated with FRA Task Order 256 began. These activities included tasks to upgrade the TTC PTC Test Bed to provide an operationally representative PTC system test environment that would support developmental field testing of the PTC 220-MHz radio spectrum currently being acquired by the railway industry and for other PTC-related tests. TTCI purchased and installed the required equipment and verified correct functional operation. The test bed was configured to accept PTC communications equipment when it became available.

All of the upgrades under this task order were implemented to provide an ITC-compliant PTC environment representative of freight PTC operations so that the PTC 220-MHz radio spectrum currently under development would have a test facility capable of supporting field testing. The communication system included base station, locomotive, and wayside PTC 220-MHz radios, as well as a required wayside messaging server at each wayside location. A PTC communications infrastructure typically includes additional equipment at each wayside location to support cellular and Wi-Fi communication links. None of the required cellular or Wi-Fi communication equipment was provided as part of this task order. However, all the other test bed equipment was installed and was ready to interface with the communications equipment when it became available.

Under FRA Task Order 256, the PTC Test Bed was upgraded so that additional PTC testing configurations could be supported. The following features were added:

- Wabtec's Train Management Dispatch System (TMDS™) CAD system
- Wabtec's I-ETMS BOS
- Two locomotives equipped with Wabtec I-ETMS onboard systems
- Six 12,000-foot (~2¼-mile) signal blocks with 4-aspect block signaling that is PTC-capable
- General Electric's (GE) WIUs for signal block ITC-compliant communications
- Ansaldo STS Microlok II WIUs for switch ITC-compliant communications

These modifications greatly enhanced the test bed's capabilities to support ITC-compliant field testing of PTC system communications, especially the capabilities needed to support field development testing of the Meteorcomm PTC 220-MHz radio.

FRA Task Order 270 activities started in April 2011. These activities included tasks to upgrade the PTC Test Bed to provide an operationally representative PTC test environment that would support more generalized testing than that associated with PTC communications testing. The expanded capabilities included those needed to support interoperability, functionality verification, and performance-stress characterization of I-ETMS and related PTC equipment. The major tasks performed were as follows:

- Expanded the number of PTC-controlled signal blocks on the RTT from 6 to 12, taking advantage of the 12 broken rail detection blocks currently in place. Retained the capability to reconfigure to the previous six signal block configuration.

- Increased the number of PTC switch control points on the RTT by two by converting manual switches on the RTT to remotely monitored and controlled electrically powered switches (SW 301 and SW 304). Included control point WIUs at switch locations. Left two switches unchanged (SW 501 and SW 303), thereby providing a combination of different switch types (electric lock, powered switches, and manual throw switches). Moved SW 303 to a new location. Configured the switches and associated equipment to support PTC testing and evaluation.
- Upgraded the speed protection capability (from 120 to 160 mph) and improved the reliability and performance of the two problematic grade crossing systems at Post 85 and Post 100 by replacing them with wheel sensor-based systems from Tiefenbach.
- Procured software needed to support design, development, and documentation of the test bed upgrade equipment and also support test and evaluation activities. Specifically procured licenses for the primary software and related tool boxes for AutoCad and MatLab to support test bed documentation and data analysis.

To perform these tasks, TTCI installed the required equipment and performed an initial evaluation of the enhanced test bed's PTC testing capabilities in a manner that ensured the upgrades provided railroads and suppliers with a dedicated PTC test environment free of the limitations normally associated with testing under revenue service conditions.

1.3 Organization of the Report

This report is organized into four major sections. Section 1 is the introduction, which includes the background and history of the PTC Test Bed. Section 2 describes the upgrades that were made for PTC-variant ACSES testing and discusses the project's objectives, scope, and overall approach. Section 3 describes the upgrades in more detail. Section 4 provides a short summary of the related tasks.

2. Task Order 314 Activities

2.1 Objective

The objective of this project was to upgrade the PTC Test Bed to support testing of PTC systems, components, and related equipment in an environment that accurately represents ACSES applications in revenue service. The project includes testing ACSES equipment and interoperability of I-ETMS overlaid on ACSES, as will be implemented in certain portions of the Northeast Corridor (NEC). The ultimate goal of the project is to provide railroads and suppliers with a dedicated PTC test environment that has an ACSES representative closed track test environment free of the limitations normally associated with testing on revenue service routes.

2.2 Scope

The project focused on enhancing the existing capabilities of the PTC Test Bed to enable it to support ACSES-related testing. The scope included providing the key ACSES functionalities of office, locomotive, and wayside (interlocking). The office function was to be provided through the use of an emulator for the safety server. Other functions were to be provided through the use of actual ACSES equipment from current ACSES equipment providers. The scope also included the engineering required to design the installation of equipment at TTC and to provide installation documentation for all system components.

2.3 Overall Approach

The major tasks performed were as follows:

- Provide engineering to design ACSES equipment installations and to document installed equipment configurations.
- Procure and install the equipment required to provide:
 - ACSES office functionality. The office function is based on using an ACSES safety server emulator.
 - ACSES locomotive capabilities. Provide for equipping two locomotives with complete ACSES onboard equipment sets using upgraded ACSES II 220-MHz radios for communications.
 - ACSES wayside capabilities at selected Railroad Test Track (RTT) control point interlocking locations. Ensure ACSES wayside locations use communications configurations for including upgraded ACSES II 220-MHz radios.
 - ACSES on-track transponders, including providing for development of the transponder database and for programming transponders for operational usage.
- Modify existing RTT 4-aspect signal system software to be configurable for either 4-aspect freight signaling or 9-aspect cab signaling for passenger operations on the RTT.
- Conduct an on-track demonstration of fully functional ACSES capabilities.

3. ACSES System Overview

This section provides a high-level description of the architecture and functions of the ACSES system, and it is from an Alstom document titled “ACSES II – System Generic Description” (April 2009, Rev 00.00.02). It is not a system specification design document.

System Description

ACSES on the Northeast Corridor (NEC) supplements the ATC cab signal system by providing additional train control functions and thus creating an enhanced overall system required by FRA for this vitally important rail corridor. The primary functions of ACSES as applied to the NEC include enforcement of civil/track speeds for fixed locations such as curves, bridges, etc., as well as temporary speed restrictions. These are speed enforcement functions that are beyond the scope of the ATC cab signal subsystem. ACSES also enforces Positive Train Stops at interlocking home signals.

The NEC ATC cab signal systems do not provide protection for:

- Civil/Track speeds: line speeds and PSRs for curves, bridges, track conditions, etc.
- Temporary speed restrictions to protect roadway workers, bad tracks, bridge strike, etc.
- Enforcement of an absolute stop (0 speed) at home signals displaying a stop signal.

The ACSES system, as applied to the NEC, is a permanent (civil or track) speed limit, temporary speed limit, and home signal positive stop enforcement system. The onboard system uses data obtained from transponders via a data radio network to enforce permanent and temporary speed limits. It acts on data received intermittently from transponder and radio, and it is a profile-based system where the onboard system calculates a speed profile for both warning and enforcement. If the warning profile is exceeded, the engineer is given an audible alert to reduce the train speed. If the brake profile is exceeded, the onboard system initiates a request for application of the train brakes—to be released when the train speed is back under the maximum speed envelope.

The ACSES system utilizes passive (fixed) transponders at wayside locations, a Ground Network communications system (Safety TSR Server), Wayside Communications Controllers (WCC), Network Servers and Encoders, Base Communications Packages (BCP) along the right of way (ROW), Mobile Communications Packages (MCP) onboard, an ACSES onboard subsystem, and an onboard transponder reader. The data radio system (WCC, BCP, and MCP) is used to route interlocking data (route data, civil speed limits, etc.) and temporary speed limit data (start of speed restriction, length of speed restriction, speed limit, etc.) to the onboard ACSES system.

The ACSES wayside transponders are installed in ACSES territories at home signals, distant signals, and at other signal, block point, or cut section locations to communicate with the onboard ACSES subsystem. The transponders provide data to the onboard system, allowing it to determine its location and direction along the track. The transponders also provide civil (track) speed restriction data for the territory ahead, thereby ensuring that speeds are kept safe for the various types of restrictions not caused by train occupancy (bridges, curves, etc.). ACSES works on a distance-to-target principle and the transponder data includes targeting distances (distance from the transponder to the data validity point); therefore, transponders do not need to be installed at the point at which the system uses the data (i.e. the transponders are not installed at the speed change limit but in advance of it).

The ACSES system consists of two main areas of operation: interlocking areas and Automatic Block (between interlocking) areas. Within these two areas, the ACSES system provides civil speed and temporary speed and positive stop enforcement (at interlocking areas only). In addition, if the ATC cab signal system is inoperative or cut-out, ACSES enforces a maximum cap speed of 79 mph. The ACSES system works in conjunction with the ATC/cab signal systems used on the NEC. The ATC cab signal system continues to ensure “Safe Train Separation” and “Signal Speed Enforcement” while the ACSES system essentially acts as an addition to the ATC cab signal system to provide other functions. The two systems are functionally independent. Only the operating status (cut-in and operating or cut-out) and data used for the PTS enforcement (e.g., the ACSES request for an ATC cab signal enforcement of a PTS) is shared between the two systems.

ACSES is being applied to Amtrak trains but also to commuter operator vehicles (MNR, CDOT, MBTA) and freight operators (P&W, CSX).

Main Functions of ACSES on the NEC

ACSES on the NEC is a vital overlay system that performs the following main functions:

1. Enforcement of civil/track speeds for five different train types (PSR) operating at different speeds.
2. Enforcement of passenger and freight temporary speed restrictions through data radio network and by use of temporary transponders (TSR).
3. Enforcement of a Positive Train Stop (PTS) (i.e., enforcement of an absolute Stop at Home Signals displaying a Stop Signal).
4. Override of the PTS by radio if the interlocking signal status allows the train to go (PTSO).
5. Enforcement of a civil speed received by radio based on switch alignment at interlockings. This speed corresponds to the diverging or crossover civil speed. (Interlocking PSR)
6. Route Dependent speed enforcement based on exit track selection. (Route Dependent PSR)

7. Utilizing the communications network to upload the ACSES specific Maintenance Messages to Amtrak NEC Network Servers. (ACSES Maintenance Message)

4. TO 314 Major Task Summaries

4.1 Engineering Design and Documentation

TTCI performed engineering designs and provided documentation for installation of ACSES II equipment items. The ACSES II installation on the PTC Test Bed is comprised of the track layout (including wayside components), locomotive equipment, and Safety Server Emulator (SSE) (functional BOS). To support TTCI's efforts, engineering support and services were provided by CCI and Siemens Rail Automation Camborne Systems (formerly PHW, Inc).

CCI provided engineering support services for developing and implementing the 900-MHz and 220-MHz communications infrastructure to support ACSES testing at TTC. Also, CCI's PTC software solutions were embedded into onboard communications, wayside hardware, and the SSE.

Siemens provides engineering products and services in support of both onboard ACSES equipment and SSE software as used in several applications on the NEC. At TTC, a track database of the RTT, Safety TSR Server, 9-aspect cab signaling, and ACSES onboard system were provided to support the ACSES installation on the PTC Test Bed.

4.2 On-Track Transponder Layout

ACSES equipment was installed on TTC's RTT. The RTT has a total of 14 field-programmable on-track transponder pairs purchased from Ansaldo STS. Figure 1 shows an installed pair of transponders.



Figure 1. Transponder Pair

The transponders are installed at fixed locations dictated by linking distances between transponder pairs. These distances are measured from the chainage (or milepost) around the RTT. Since ACSES works on a distance-to-target principle, every successful transponder reading

is a verification of the distance traveled by the locomotive. If an incorrect or unsuccessful transponder reading occurs, a maintenance message is sent noting the location. Figure 2 shows the locations of each transponder pair.

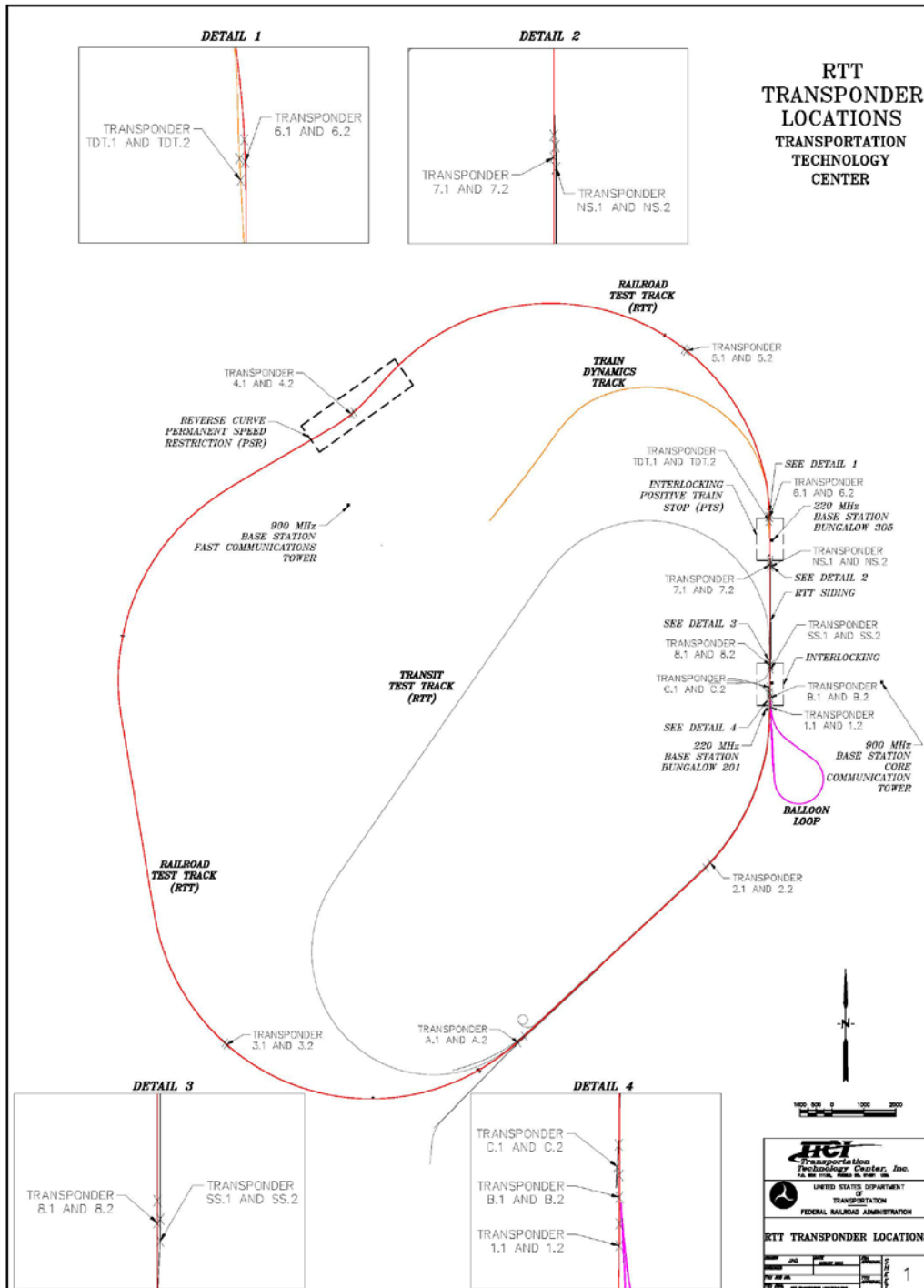


Figure 2. RTT Transponder Locations

Eight of the 14 pairs are located on the RTT mainline, and the remaining transponders are located at RTT entry and exit points. These entry and exit point transponders inform a locomotive that it is either entering or leaving ACSES territory. In non-ACSES territory, the system does not enforce civil speed restrictions, but instead operates in a restricted state, limiting the allowable line speed.

An ACSES-equipped locomotive will enter the PTC Test Bed traveling over a transponder pair, indicating the train has entered ACSES territory. When radiated by radio frequency (RF) energy from a locomotive's transponder scanner, an on-track transponder is powered by the 27.115-MHz RF transmission from a locomotive's scanner, and the on-track transponder transmits information at 4.5 MHz back to the scanner, including the linking distance to the next transponder pair, track grade, chainage, line speed, encoder, and channel information for sending temporary speed restriction requests (TSRR) and interlocking status requests (ISR) to wayside interface units (WIU). A locomotive entering ACSES territory will be triggered to transmit TSRRs. Additionally, a locomotive approaching an interlocking will travel over a distance signal (DS) transponder pair, alerting the onboard ACSES system to request both ISRs and TSRRs. As a locomotive travels through the interlocking, the transponder pair before and after the interlocking inform the locomotive it has entered and departed the interlocking and that it is clear to run, on the basis of allowable operating conditions.

As Figure 2 shows, a PTS is enforced at both ends of each interlocking depending on the locomotive's direction of travel, and a PSR is positioned at the reverse curve between mileposts R47 and R61. The two interlockings are located between transponder pairs 1 and 8 and 6 and 7 with a Limit of Movement Authority (LMA) incorporated for movements in both the clockwise and counterclockwise directions. An LMA is required when the distance between consecutive interlocking home signals is less than the braking distance required to stop a train. The WIU message associated with an LMA will provide PTS information for the second interlocking. The WIU monitoring the interlockings are simulated using the Field Simulator discussed in Section 4.4.

Figure 2 also shows the base station locations. The two 220-MHz base stations are located within Bungalows 201 and 305 and are configured to transmit and receive at 219.275 MHz using GE TD220-MHz radios and a CCI-provided Communication Network Adapter (CNA) 2004 to communicate ACSES messages. The two 900-MHz base stations are located at the Facility for Accelerated Service Testing (FAST) Communications Tower and at the CORE Communication Tower. The base stations are equipped with EF Johnson Viking VX 900-MHz LTR Repeater radios and a CCI provided CNA 2004 transmitting on Advanced Train Control System (ATCS) channel 3 at 935.9875 MHz. The ATCS base stations will receive ACSES-equipped locomotive transmissions at 896.9875 MHz.

The ATC cab signal system works independently of, but in conjunction with, the ACSES system. The ACSES system operates as an overlay to the ATC cab signal system, which is a 9-aspect signal system and assures safe train separation and signal speed enforcement, providing continuous data with an in-cab indication to the locomotive engineer. TTC utilizes seven of the nine aspects, as shown in Table 1. The allowable speeds of Approach Limited and Approach Medium are determined by train type.

Table 1. Cab Rate Table

CAB Rate Table		
	Designator	Pulse Rate
Clear (150 MPH)	C150	180/180
Clear (125 MPH)	C125	180/-
Cab Speed (80 MPH)	CS80	120/120
Cab Speed (60 MPH)	CS60	270/-
Approach Limited	AL	120/-
Approach Medium	AM	75/75
Approach	A	75/-

4.3 Onboard Equipment

Amtrak 9-aspect cab signaling and vital onboard ACSES equipment provided by Siemens was installed on the DOT 004 and 2001 located at TTC to provide real time information to enforce track speeds, TSRs, and PTSs. The equipment includes the onboard computer (OBC), axle generator, aspect display unit, transponder scanner, track receivers (as seen in Figure 3), Sinclair mobile omni 220-MHz and ultrahigh frequency (UHF) 900-MHz shark fin radio antennas, CNA 2028, GE TD220-MHz, and JEM 900-MHz radios.



Figure 3. Transponder Scanner and Track Receiver

The combination of train type, onboard, and transponder information allows the OBC to create a warning and braking profile. Passing the warning profile causes an audible alarm to give the engineer time to slow the locomotive to within allowable speeds. If the engineer does not reduce speed before the braking profile is passed, ACSES enforces with penalty braking.

ACSES utilizes five different train types for line speed restrictions and braking characteristics. Table 2 shows the train types defined for the PTC Test Bed.

Table 2. ACSES Train Types

ACSES Train Types			
Type	Description	Line Speed on RTT	PSR on RTT
A	High speed trainset with tilting	125 MPH	75 MPH
B	High speed trainset without tilting	125 MPH	75 MPH
C	Commuter rail	110 MPH	75 MPH
D	Locomotive with mail/express	90 MPH	75 MPH
E	Freight operations	50 MPH	45 MPH

4.4 Back Office Server

The BOS is responsible for all TSR data in the ACSES system at TTC. TTCI will add function to the server to monitor the IS through the use of CCI's Field Simulator. The components of the BOS are CCI's Office Communication Manager (OCM), Siemens' STS Emulator, and CCI's Field Simulator. TTCI installed two virtual machines on a Dell PowerEdge R420 with Windows Server 2008 for the STS Emulator and Field Simulator.

The STS Emulator is responsible for storing all TSR data to respond to a locomotive's TSRR. The emulator contains the track database describing the key characteristics of the RTT including chainage, milepost, grade, direction, and railroad line number. An operator submits the chainage or milepost and speed restriction for each location and stores it within the emulator.

The Field Simulator is a modeling program used to create IS messages in the PTC Test Bed. The program models distances, switches, LMAs, signals, and WIUs around the RTT. An IS is created through the simulated WIU monitoring the switch positions within the program. Once the back office receives an ISR, the Field Simulator responds with the corresponding IS.

All communication traffic is controlled by the OCM, which routes messages received from the locomotive to the appropriate program. Messages from the programs are returned to the requesting locomotive. An ISR will be directed to the Field Simulator and a TSRR will be sent to the STS Emulator. The resulting IS and TSR are directed back to the proper locomotive.

4.5 Communications

The addition of a 900-MHz radio communications infrastructure upgraded ACSES I to an ACSES II system. Radio communications allow for the BOS components to create TSRs to

protect roadway workers and identify a number of other temporary situations where reduced speed increases safety. In addition, the BOS provides a more efficient braking curve approaching an interlocking by receiving switch information or IS from a WIU. Recent upgrades to the ACSES II system incorporate the transition to 220-MHz radio communications.

Due to a number of passenger railroads beginning the transition from ACSES II 900 MHz to ACSES II 220 MHz, the PTC Test Bed was designed to have a 220-MHz communications infrastructure. The BOS software is designed to be compatible for both frequency spectrums and allows the PTC Test Bed to support the transition from 900-MHz to 220-MHz communications.

A 220-MHz and 900-MHz communication infrastructure was created to allow the successful routing of ACSES messages from the locomotive to the BOS. Figure 4 shows the system overview for the 220-MHz system, and Figure 5 shows the system overview for the 900-MHz system.

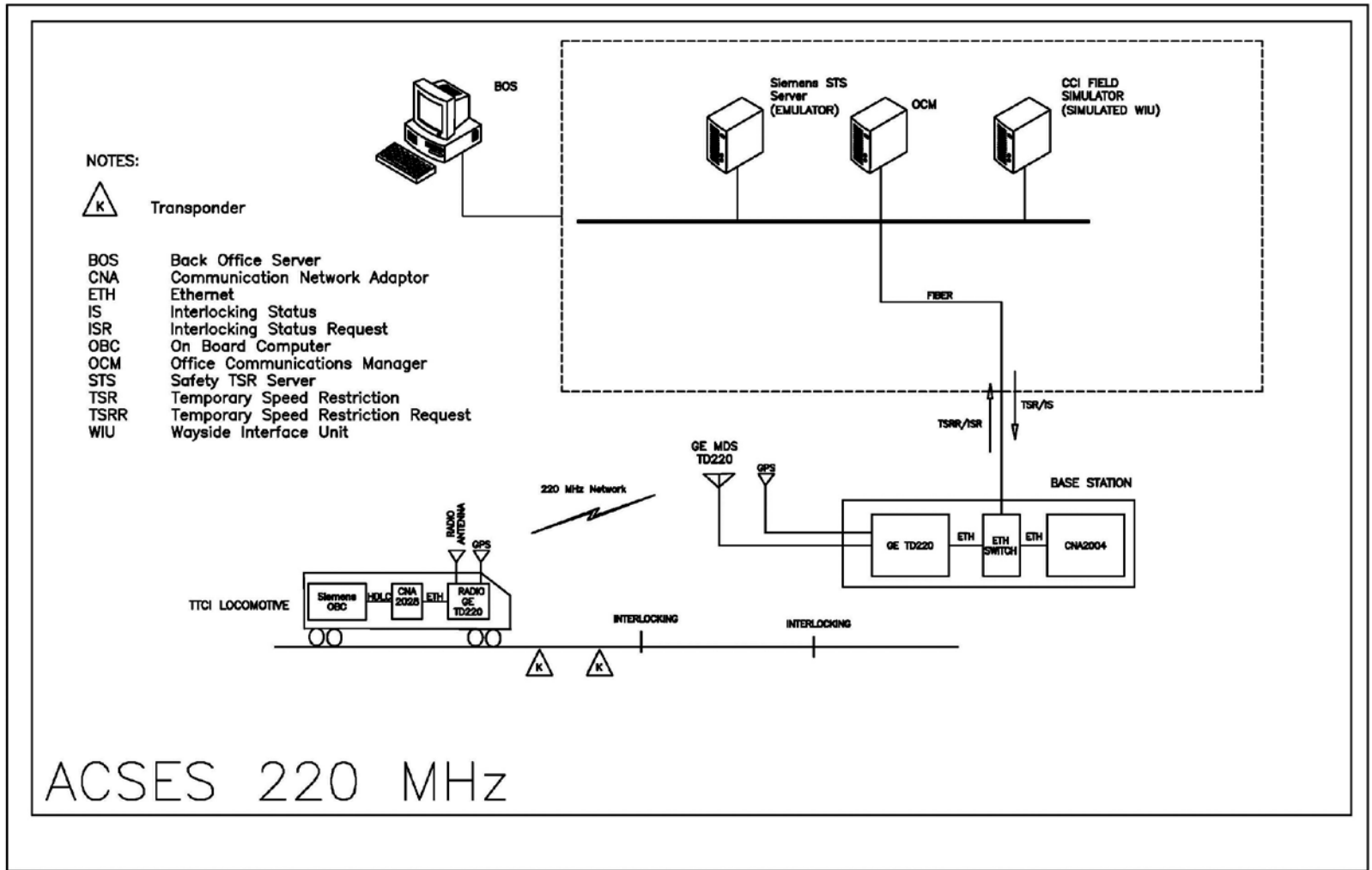


Figure 4. TTCI 220-MHz Communications

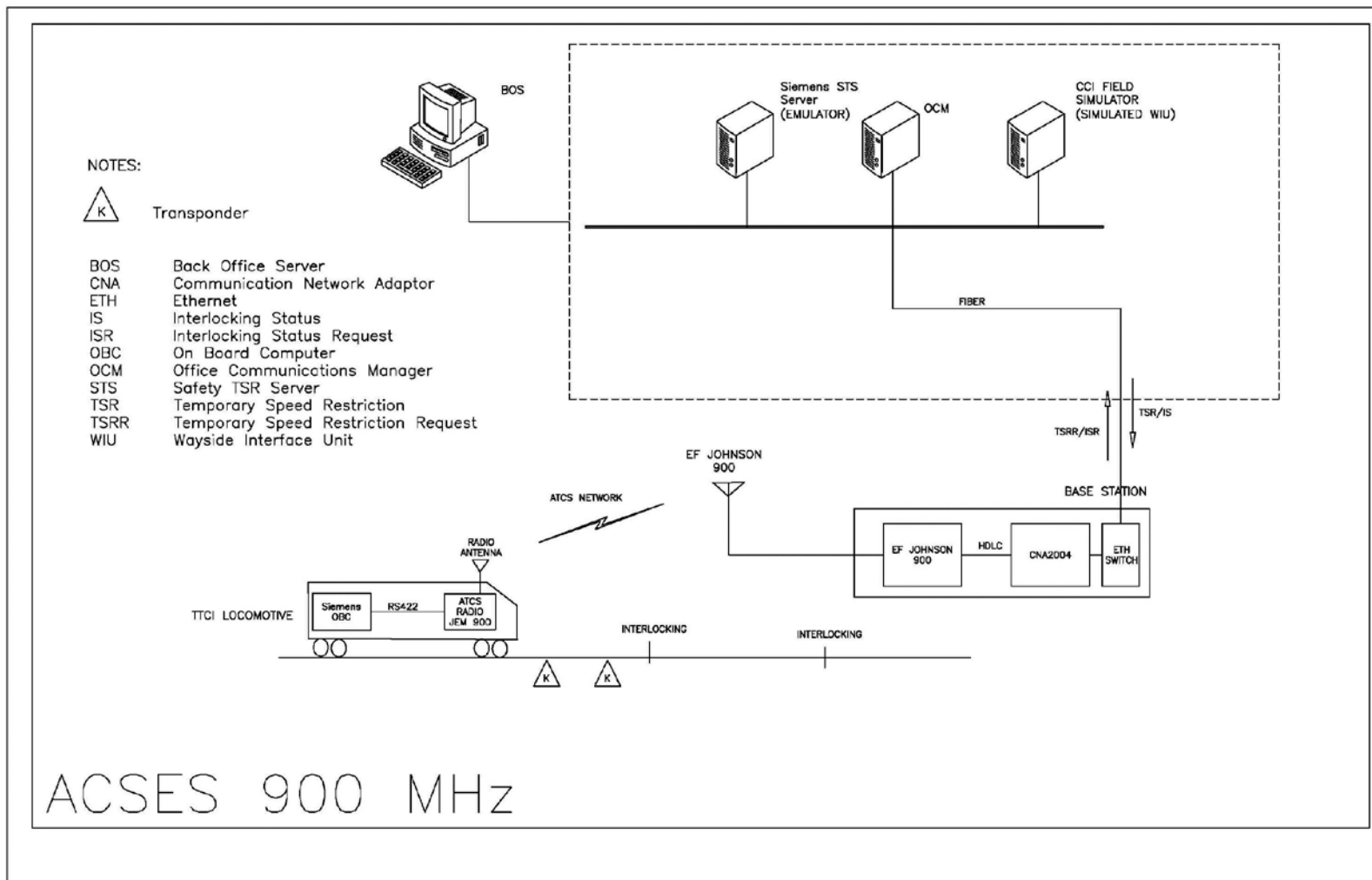


Figure 5. TTCI 900-MHz Communications

During the 220-MHz installation, TTCI performed radio coverage testing around the RTT. The base GE TD220-MHz radio was configured to transmit a message every second, while the mobile GE TD220-MHz radio was configured to transmit every 6 seconds. Figure 6 shows the coverage test results of the mobile radio transmissions, which includes position information while traveling around the RTT. Every successful mobile transmission received at the base station is seen as a red marker. The two yellow markers indicate the two base station locations.

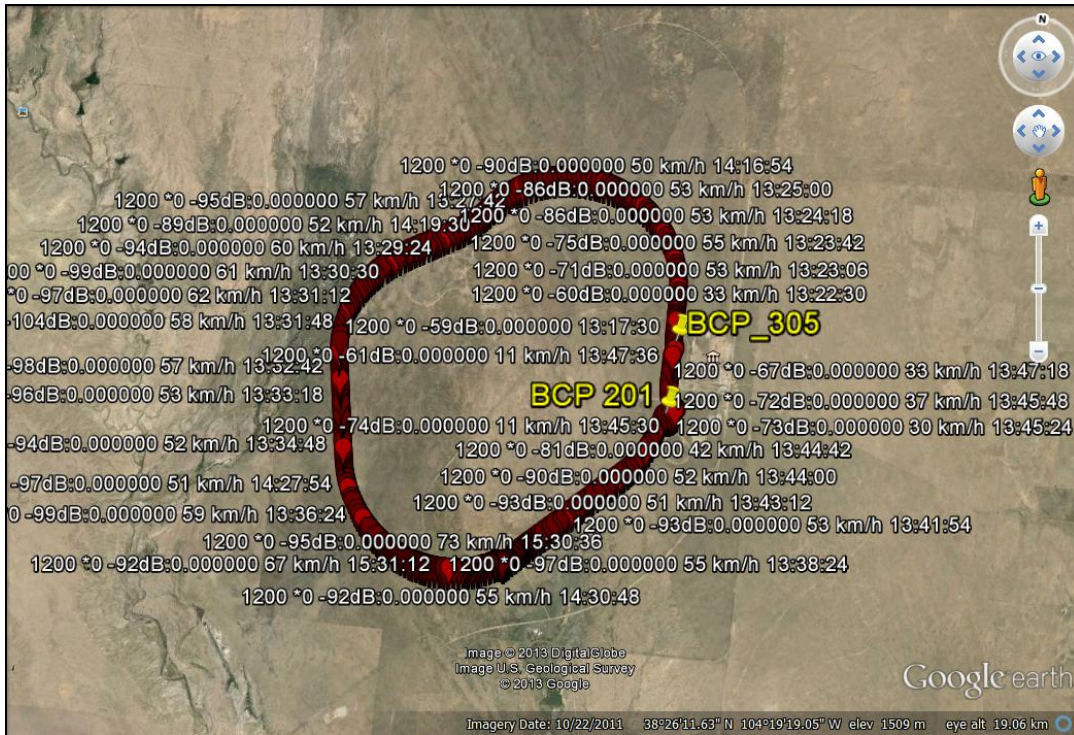


Figure 6. 220-MHz Radio Coverage

A locomotive traveling over a transponder pair will receive radio channel information to request TSRRs and/or ISRs. The radio transmission will broadcast in either the 220-MHz or 900-MHz spectrum, depending on the testing that needs to be completed. The TSRR and/or ISR will be processed through the base station's CNA and sent to the BOS via fiber optics in TTCI's network. In the BOS, the OCM will route the corresponding TSRR to the STS Emulator and the ISR to the Field Simulator. Both the STS Emulator and Field Simulator are installed on virtual machines within the BOS. The returning TSR and IS are sent back through the OCM and into the CNA where the base station transmits the message back to the requesting ACSES locomotive's OBC.

4.6 Testing

A combination of system and component level testing was utilized to verify proper installation on the PTC Test Bed.

ACSES and ATC departure tests were performed on the current onboard equipment. The ACSES departure test runs through seven steps requiring the operator to acknowledge only alerts and recover the locomotive's braking system when necessary:

- Step 1: Train Type Check – Operator must acknowledge alert for correct train type
- Step 2: Train Type Acceptance
- Step 3: Antenna Check
- Step 4: Magnet Valve and Alarm Check – Operator must acknowledge alert
- Step 5: Permanent Suppression Check – Operator must recover the brake system and acknowledge alert
- Step 6: Positive Train Stop Check – Operator must acknowledge alert
- Step 7: Radio Check

The ATC departure test simulated the nine aspects used in cab signaling through the locomotive's track receivers (Figure 3). The test progressed through all of the aspects beginning with the most restrictive speed to the least restrictive speed. The test was completed once each aspect was simulated from the least restrictive speed to the most restrictive speed. Each downgrade in speed required the operator to acknowledge the lower speed or the locomotive applied a penalty brake. Further testing was performed by placing the ACSES-equipped locomotive on the RTT. The seven cab signaling aspects utilized by TTCI (Table 1) were cycled through one aspect every minute. Each aspect was received by the locomotive and viewed on the onboard ACSES display unit.

Wayside and back office equipment was tested by successfully routing TSRR and ISR messages triggered by transponder sets around the RTT through the base stations into the BOS. The ACSES-equipped locomotive accepted the resulting TSR and IS messages, enforcing PTSs and TSRs when required. The reverse curve PSR (Figure 2) was enforced per ACSES train type (Table 2) generated by transponder pairs.

5. Conclusion

Task Order 314 upgraded the PTC Test Bed at TTC to support testing of PTC systems, components, and related equipment associated with ACSES II in a revenue service environment. TTCI purchased and installed the necessary components, which included a combination of wayside, onboard, and BOS equipment. A TTCI ACSES-equipped locomotive was successfully operated around the PTC Test Bed enforcing PTSs, PSRs, and TSRs and effectively meeting the requirements of the task order.

In the future, Task Order 331 will allow for additional transponders to be placed within the PTC Test Bed and programmed for different track speeds, PTSs, and PSRs. Also, within this new task order, TTCI will have the capability to adjust and reprogram the ACSES equipment to reflect changes to desired testing scenarios and track layout.

Abbreviations and Acronyms

ACSES	Advanced Civil Speed Enforcement System
Amtrak	National Railroad Passenger Corporation
ATC	Automatic Train Control
ATCS	Advanced Train Control System
BCP	Base Communications Packages
BOS	back office server
CAD	computer-aided dispatch
CCI	Convergent Communications Incorporated
CNA	Communication Network Adapter
CP	control point
DS	distance signal
FAST	Facility for Accelerated Service Testing
FRA	Federal Railroad Administration
GE	General Electric
I-ETMS®	Interoperable Electronic Train Management System
IS	interlocking status
ISR	interlocking status request
ITC	Interoperable Train Control
LAN	local area network
LMA	Limit of Movement Authority
MCP	Mobile Communications Package
MHz	megahertz
NEC	Northeast corridor
OBC	onboard computer
OCM	Office Communication Manager
PSR	Permanent Speed Restriction
PTC	Positive Train Control
PTS	Positive Train Stop
PTSO	Positive Train Stop Override
RF	radio frequency
RTC	Rail Traffic Controller
RTT	Railroad Test Track
SSE	Safety Server Emulator
STS	Safety TSR Server
TMDS™	Train Management Dispatch System
TSR	Temporary Speed Restriction
TSRR	Temporary Speed Restriction Request
TTC	Transportation Technology Center (the site)

TTCI	Transportation Technology Center, Inc. (the company)
TTT	Transit Test Track
UHF	ultrahigh frequency
V-PTC	Vital Positive Train Control
WCC	Wayside Communication Controllers
WIU	wayside interface unit