Acoustic Rail-Break Detection Demonstration at MTA New York City Transit

DETAILS

7 pages | | PAPERBACK
ISBN 978-0-309-43686-1 | DOI 10.17226/23260

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February 2006

TRANSIT COOPERATIVE RESEARCH PROGRAM
Sponsored by the Federal Transit Administration

Subject Areas: VI Public Transit, VII Rail

Responsible Senior Program Officer: Christopher W. Jenks

Research Results Digest 76

ACOUSTIC RAIL-BREAK DETECTION DEMONSTRATION AT MTA NEW YORK CITY TRANSIT

This digest summarizes the results of TCRP Project D-7/Task 10, "Acoustic Rail-Break Detection Demonstration at MTA New York City Transit." The digest was prepared by the Transportation Technology Center, Inc. (TTCI) of Pueblo, Colorado. Richard P. Reiff served as principal author.

INTRODUCTION

This digest provides the results of a demonstration of an acoustic-based rail-break detection system in a transit application. Although no rail breaks occurred during the demonstration, lessons were learned on the potential deployment of this technology.

SUMMARY

As part of a multiyear, multitask project, the Transit Cooperative Research Program (TCRP) funded a program to install and monitor the performance of an acoustic-based system designed to detect broken rails on a revenue service rail transit system.

A prototype acoustic-based, rail-break detection system was installed over a 2,200-ft section of track on the "A" line of the MTA New York City Transit (NYCT). The detection system was in place for about 11 months. During the monitoring period, no broken rails occurred; therefore, the prototype's reliability in detecting such an event could not be verified.

Individual transmitter/receiver pairs did, on occasion, drop out for periods of 30 sec to over 30 min, which would be considered a false detection if the system were in actual use. While this scenario is considered as a false detection, some issues with the installation may have contributed to these occurrences, such as:

- Frequency ranges that were not optimized for the rail section used,
- Higher than anticipated quantity of thermite welds within the test section,
- Doubling of transmitter/receiver pairs on a single rail, and
- Temperature compensation of receivers located in the signal room, but not on the track.

Additional development of transducers and possible polling time adjustment is needed for this concept to be used in the transit environment. In addition to the issues stated above, the acoustic system must be able to send a signal through mechanical rail joints. The development of an acoustic bond to allow continued detection when a mechanical rail joint is installed within the length of track being monitored is needed.

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rails are utilized, when rail is cracked but not fully separated, or where alternative electrical paths are present, may not always be properly and reliably detected using conventional track circuits. In addition, the use of track circuits where electric traction is used for train propulsion adds additional complexity (i.e., insulated joints and impedance bands) to the detection system.

BACKGROUND

A program to demonstrate an acoustic-based rail-break detection system in the transit environment was conducted under funding by the TCRP. This demonstration program was conducted to (a) install and monitor the performance of an acoustic-based rail-break system on a revenue service transit system and (b) record system output and interpretation.

Conventional track circuits are not 100% effective in detecting broken rails, and they often require the use of insulated mechanical rail joints that require additional track maintenance effort. Broken rails occurring over a tie plate, within limits of special track work, within areas where guard rails are utilized, when rail is cracked but not fully separated, or where alternative electrical paths are present, may not always be properly and reliably detected using conventional track circuits. In addition, the use of track circuits where electric traction is used for train propulsion adds additional complexity to the detection system.

Transportation Technology Center, Inc., a subsidiary of the Association of American Railroads, has investigated a number of technologies for broken rail detection in the freight railroad environment. These technologies include systems using longitudinal strain gages, bonded fiber optics, and acoustics to detect broken rails. As part of the TCRP, research results aimed at addressing freight railroad issues are being investigated for implementation into the transit environment. Based on implementation limitations and the current state of technology development investigated to date, the acoustic-based rail-break system appears to offer the easiest transition from the freight to the transit environment. Key advantages of this system include its immunity to track circuit and electrical return or ground issues and its independence from requiring insulated mechanical rail joints.

Major issues limiting systemwide application of this acoustic-based rail-break detection technology include blockage of the detection signal by conventional mechanical rail joints (including rail plugs), potential interference from adjacent sources of vibration, and its inability to transmit signals through certain types of special track work.

Objectives

The primary objective of this demonstration was to determine the effectiveness and reliability of an acoustic-based rail-break detection system in detecting broken rails in the transit environment.

Additional objectives included the following:

- Comparison with reliability and effectiveness of a conventional track circuit on the basis of the rail-break detection system,
- Identification of areas where the acoustic system may demonstrate need for additional development in order to be viable in the transit environment, and
- Preparation of preliminary implementation guidelines for use of acoustic systems in the transit environment.

GENERAL APPROACH

With cooperation from Alstom and Railsonics, a prototype acoustic-based rail-break detection system—similar to one used by Spoornet of South Africa and demonstrated at the Facility for Accelerated Service Testing (FAST), Transportation Technology Center (TTC), Pueblo, Colorado—was obtained and installed in an active mainline track on the "A" line of the NYCT.[1] This system uses a remotely located transmitter and a receiver. The transmitter can be located up to 1 mile from the receiver. The transmitter sends a coded acoustic signal into the rail at prescribed intervals, adjustable from 15 sec to over 3 min. The receiver "looks" for the coded message. If the proper coded message is not received in a prescribed time window, a rail defect or fault is assumed to have happened, and a stop signal is generated. A general schematic of the concept is shown in Figure 1. For purposes at the NYCT demonstration site, only the system's output was monitored; that is, train operations were not governed by the system's

[1]The Transportation Research Board of the National Academies and the FTA do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

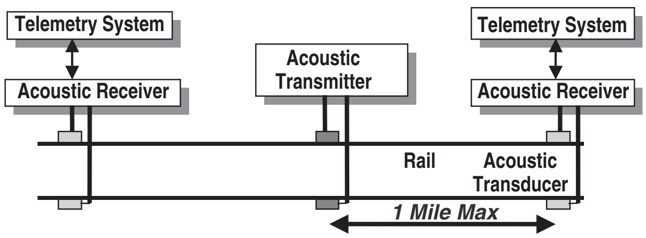

Figure 1 Schematic of the acoustic-based broken rail detection concept.

output. Primary safety and broken rail detection remained with the existing track circuit system.

The system as traditionally configured transmits a signal every 3 min. A rail break occurring between signal transmissions will not be detected until the next signal transmission, thus a delay was encountered between a rail-break occurrence and detection. A more frequent transmission and signal capture rate (30 sec) was developed for the system used for the NYCT demonstration.

SITE LAYOUT

The prototype acoustic system was installed over a section of track identified by NYCT as the "B" Division, 8th Ave "A" line, southbound express track number A3. Approximately 2,200 ft of continuously welded rail (CWR) was assigned for this demonstration segment. Figure 2 shows the map of the test area.

The transmitter equipment was located between tracks about mid platform at the 190th Street station, while the receiver equipment was located inside the existing signal building just south of the 200th Street station platform. The 2,200-ft length of track was the longest section of CWR available in this area and had experienced several broken rails in the past. The extreme ends of this section were equipped with insulated mechanical rail joints. Only one rail was used for the demonstration because the other rail had several additional insulated mechanical rail joints.

A normal installation would have one transmitter and receiver per each rail. The NYCT signal system uses a ground rail (which is CWR) and a signal rail, broken into shorter blocks with insulated mechanical rail joints. The major issue with broken rail detection at this site was on the ground rail, not the shorter blocks of the signal rail. To assess transmitter reliability, four transmitters and two receivers were installed, operating at different paired signal codes, which allowed simulation of a more typical layout. This simulated two transmitters at one end of the 2,200-ft rail section, each on a different coded signal sequence, with one receiver for a pair of transmitters. The four receivers were designated as DL, UL, DR, and UR.

The receiving station monitors acoustic signals as detected by the receiving transducer. For this test, a 30-sec detection window was established at the receiving station. Provided a correct acoustic pattern is received within the 30-sec window, the 2,200 ft of rail between the transmitter and receiver was declared "intact," and no broken rail signal was generated. Should an adequate or correct signal not be received within the 30-sec window, a broken rail indication will be generated.

Any indication of a broken rail was recorded and then sent to a phone for automated notification to

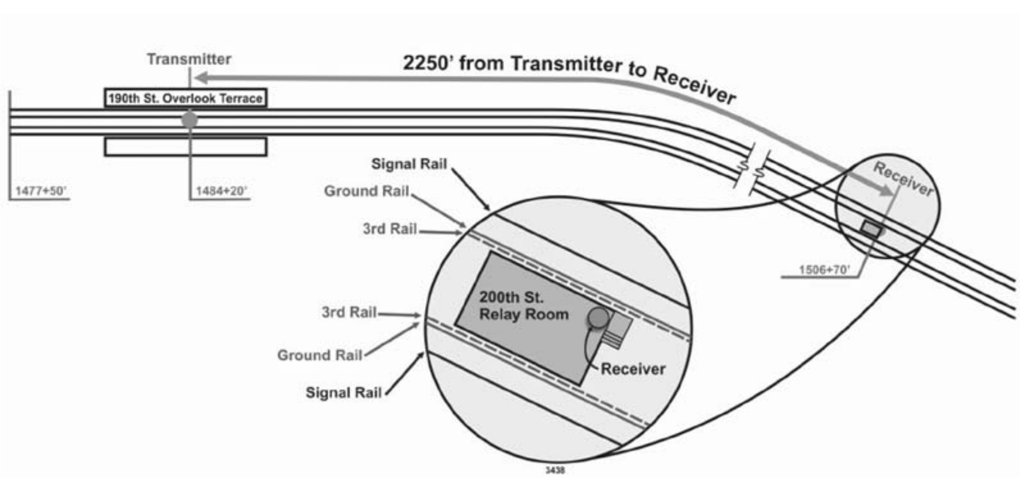

Figure 2 Schematic of test demonstration site.

Figure 3 View looking northward of transmitter location midway along 190th Street station. Cables can be seen between the case and rail. The transmitter case is located between pillars, center between tracks.

NYCT operations in the form of a prerecorded broken rail indication announcement.

ACOUSTIC-BASED RAIL-BREAK DETECTION SYSTEM DESCRIPTION

The acoustic-based rail-break detection system includes a number of components. Photos of the NYCT installation are included to clarify system layout and component locations.

Site Layout:
Transmitter location—190th Street station (Figures 3 and 4)
Receiver location—in tunnel, south of 200th Street station

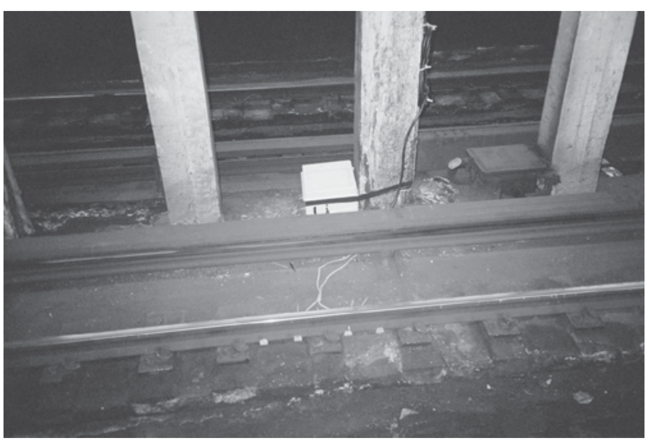

Figure 4 View of the transmitter case, which was subsequently mounted to one of the center pillars.

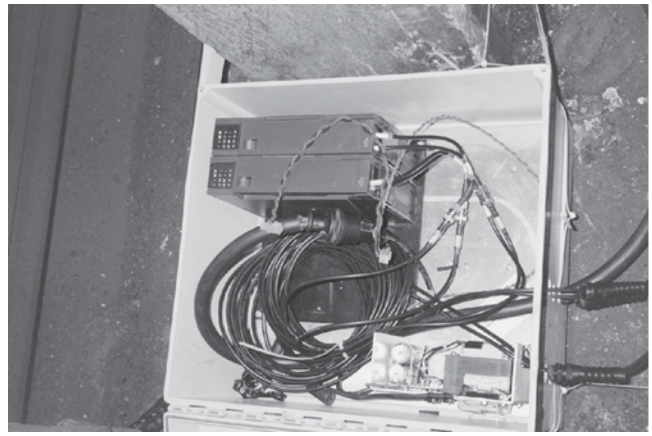

Figure 5 Inside view of transmitter case showing signal-generating equipment and power supplies and battery.

Transmitter
Signal-generating equipment (Figure 5)
Rail-mounted transducers (Figure 6)

Receiver
Rail mounted transducer (Figure 7—of installation at TTC)

Receiver location and bungalow
Exterior and interior of site (Figures 8 and 9)

TEST SCHEDULE

During October 2003, a detailed walking inspection of the entire test zone from the transmitter to the receiver was undertaken. Locations for the transmitter and receiver were selected and power supplies

Figure 6 View of transmitter site showing four transducers. Normal installation would be equipped with only one transducer per rail.

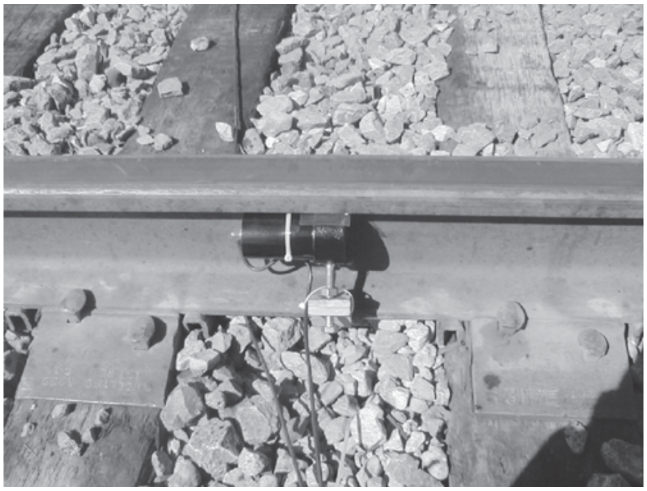

Figure 7 Typical single receiver transducer installation.

Figure 8 View of receiver location. Access to relay Room is through fenced doorway.

Figure 9 View of interior of relay room for receiver station and data transmission line.

for the 12-vdc charging system at the transmitter were identified.

Shortly after the October 2003 inspection, a rail detector car inspection was made by NYCT. This inspection identified some defects in the rail within this 2,200-ft test zone. Rail was immediately cut out and temporary rails bolted in place. These bolted sections would have prevented the acoustic signal from passing; thus, the system installation was delayed until February 2004. At that time, several bolted mechanical rail joints remained. However, the installation of acoustic transmitter and receiver equipment was completed.

Although the bolted rail joints prevented the acoustic signal from being received, by installing the system and letting it operate, any equipment related failures would be detected. Final rail repairs were completed after June 2004 and, in July 2004, the acoustic system was calibrated and monitoring of the integrity of the 2,200-ft test zone commenced. Monitoring continued until May 2005, during which time no broken rails occurred.

EVENTS

A scientific data logging system was used to monitor the status of each of the four receiver outputs. (These were designated as DL, UL, DR, and UR). The data logging system monitored all parameters every 5 sec and recorded data whenever a change in state of one of the outputs was detected. Thus, if no change in receiver status was noted (i.e., the receiver was indicating that it had received a transmitter signal within the last 30 sec), then no data was recorded. The following information, as the sample below shows, was recorded at every change in receiver status event:

- Year
- Time—hours-minutes
- Time—seconds
- Receiver status (–3 indicates a good signal, 0 indicates receiver has not detected a signal from the transmitter in the last 30 sec)
  - DL
  - UL
  - DR
  - UR
- Ambient room temperature Deg C
- Ambient room temperature Deg F
- Receiver system battery voltage

When the system was installed, one of the receiver transducers produced enough noise to prevent the received signal from being detected. A replacement receiver transducer was ordered and installed in March 2004. Once the rail repairs had been completed, the system was checked and adjusted in July 2004. The system was monitored remotely by phone modem with the data downloaded at TTC. Single channel dropouts, as shown by a "0" in one of the columns (DL, UL, DR, or UR) were seen often in the data logs. In almost all cases, a single channel dropout lasted for 2 to 15 min and then recovered. For example, as can be seen in the sample shown below, channel DR dropped at 12:10:10 and did not recover until 12:41:55, for a total dropout period of over 31 min. It also dropped out for shorter periods at other times.

The issue of a single channel dropping out was not resolved during the test. Possible causes were data collision (running all four channels on one rail), train noise, and noise in the receiver from running the gain at maximum. A rail-break indication was not received during the test (a rail-break indication is all four channels staying at zero). The number of single channel dropouts became more frequent as the weather turned colder in the winter period. The temperature in the data shown is from inside the relay room. The temperature in the tunnel is colder because the relay room is heated; thus, the system temperature compensation was not able to adjust for receiver temperatures.

Sample of data from the data logger is shown below.

Year	Day	HH:MM	Seconds	DL	UL	DR	UR	Temp C	Temp F	Batt Volt
2005	38	11:37	35.1	–3	–3	–3	–3	9.39	48.67	13.74
2005	38	11:39	45.1	–3	–3	0	–3	9.43	48.75	13.83
2005	38	11:55	5.1	–3	–3	–3	–3	9.41	48.71	13.83
2005	38	12:00	30.1	–3	–3	0	–3	9.39	48.67	13.83
2005	38	12:02	55.1	–3	–3	–3	–3	9.39	48.67	13.8
2005	38	12:10	10.1	–3	–3	0	–3	9.38	48.65	13.83
2005	38	12:24	10.1	–3	–3	0	0	9.37	48.68	13.82
2005	38	12:26	10.1	–3	–3	0	–3	9.37	48.68	13.82
2005	38	12:41	55.1	–3	–3	–3	–3	9.36	48.61	13.83
2005	38	12:43	55.1	–3	–3	0	–3	9.36	48.66	13.82
2005	38	12:45	55.1	–3	–3	–3	–3	9.36	48.7	13.83
2005	38	12:47	55.1	–3	–3	0	–3	9.36	48.66	13.83
2005	38	13:30	50.1	–3	–3	–3	–3	9.36	48.7	13.8
2005	38	13:32	50.1	–3	–3	0	–3	9.36	48.7	13.83
2005	38	15:55	50.1	–3	–3	–3	–3	9.41	48.8	13.8
2005	38	16:00	15.1	–3	–3	0	–3	9.41	48.8	13.83
2005	38	16:00	40.1	–3	–3	–3	–3	9.41	48.8	13.82

SUMMARY AND RESULTS

No broken rails occurred during the monitoring period; therefore, acoustic system reliability in detecting such an event could not be verified. Individual transmitter/receiver pairs did, on occasion, drop out for periods of 30 sec to more than 30 min, which would be considered a false detection if the system were in actual use. While this is considered as a false detection, some issues with the installation may have contributed to these occurrences, including:

- Non-optimized frequency ranges for the rail section used.

  The system, as currently designed, is optimized for operation on heavier rail. As part of the investigation into the cause of the relatively weak signals, subsequent testing has been performed on smaller rail, such as the type that is used at NYCT. The results of these tests suggest that the optimum frequency to operate the equipment is different than the frequency actually used. Further testing is required to substantiate this theory.
- The quantity of thermite welds within the test section.

  Within the test section, 14 thermite welds existed between the transmitter and receiver sites. Each weld contributes to a finite amount of signal attenuation. This attenuation may be greater when combined with the smaller rail size.
- The doubling of transmitter/receiver pairs on a single rail.

  The system is designed to monitor two separate rails using one transmitter/receiver pair on each rail. Theoretically, combining multiple transmitters on one rail, although not a common practice, should not create any operational issues. In this application, since only one rail was being protected with the system, both transmitters were installed on a single rail to prevent the receiver's data logger from being filled with log entries that would have occurred if only one transmitter/receiver pair had been used. Intermittent operation may have been due to non-optimized settings required for this type of arrangement.
- Temperature compensation of receivers located in the signal room, but not on track.

  Although the track temperature swings within the tunnel are less severe than if the equipment were installed outside, it is known that temperature does play a role in the amount of signal attenuation. The equipment does include temperature measurement capability, but these data are not currently used to compensate for low signal level. Additionally, since the electronics were located in a temperature-controlled room, this compensation would not be effective in this application.

Within the test period, once installed, there was one transducer replaced due to an internal problem; nonetheless, the transmitter station and receiver station operated without failure.

RECOMMENDATIONS

Additional development of transducers and possible polling time adjustment is needed for this concept to be used in the transit environment. The following major issues need to be considered:

- Transducer frequency for the rail section used by rail transit systems should be optimized.
- Compensation for transducer/receiver performance over a wide range of operating temperatures should be automated.
- A more frequent detection cycle should be considered as train headway may be such that the 30-sec detection window is insufficient to complete the monitoring process between trains.
- There should be an ability to send an acoustic signal through mechanical rail joints (acoustic bond should be developed) to allow continued detection when a temporary mechanical rail joint is installed within the length of rail being monitored.