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# ON-BOARD BROKEN RAIL DETECTION (OBRD) RESEARCH AND DEVELOPMENT

## SUMMARY

From October 2019 to May 2022, the Federal Railroad Administration (FRA) sponsored a research and development project, performed by Transportation Technology Center, Inc. (TTCI), to research the feasibility of an Onboard Broken Rail Detection (OBRD) concept at the Transportation Technology Center. The research team collaborated with a rail industry stakeholder technical advisory group (TAG) to research the OBRD system concept. The overall objective of this research project is to validate a usable concept for an OBRD system. Finding an onboard solution is important because it could contribute to the implementation of moving block train control, which could potentially improve railroad capacity to near the theoretical maximum limit. This solution could also reduce the life cycle cost of broken rail and occupancy detection.

The project involved a series of laboratory and field tests performed on a transmission coil designed to induce a current in the rail, the receiver coils, and the shielding of the transmission and receiver coils. These tests helped determine the viability of the proposed concept. In addition, researchers performed a parallel, long-term track impedance, multi-seasonal data collection effort from a 650-foot section of track with the goal of characterizing track impedance variability.

## BACKGROUND

During previous work, researchers developed a concept for a system that uses electromagnetic induction to send and receive alternate current (AC) electrical signals generated on board a locomotive through the track (Figure 1). The induction is done using coils similar to those used for cab signaling mounted on a locomotive. As illustrated in Figure 1, an AC signal is induced by a circuit that comprises the two running rails, the wheels and axles of the train, and a series of passive tuned shunts placed along the track. Each of these shunts allows one frequency band to pass through and be picked up by the receiver coil on the locomotive. The impedance of the length of track through which the signal propagates affects the transmitted and received signals.

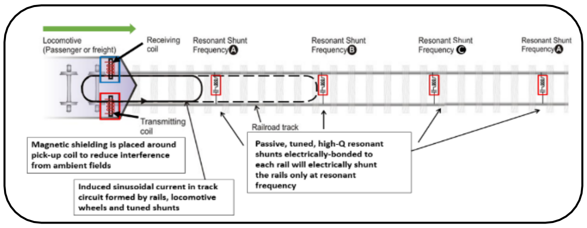

Figure 1. Illustration of OBRD Concept

## OBJECTIVES

The objectives of the OBRD research and development effort are 1) to develop a viable OBRD system, and 2) to detect occupancies and distinguish them from rail breaks. The objective of the parallel track impedance characterization effort was to understand the track as a lossy electrical transmission line under varying environmental conditions to support the OBRD system design and feasibility analysis. The focus of this current phase of the project was on the viability of the system in relation to three fundamental challenges.

## CONCEPT OVERVIEW

The concept illustrated in Figure 1 provides an indication of clear track to the location of the tuned shunt associated with each frequency received. It also detects occupancies and distinguishes them from rail breaks. Given that the concept is based on electromagnetic induction, the fundamental question to be answered by this project is: "Can the concept of using electromagnetic induction to induce a signal in the rail by a locomotive be used to reliably determine clear track ahead at useful distances?"

To answer this question, the three fundamental challenges to overcome were identified as:

1. **Limited mutual inductance between the rail and the induction coils:** To be useful for broken rail detection applications, the current induced by the system on board the locomotive must be strong enough to flow through the length of track and be reliably detected at the locomotive, requiring a strong magnetic field to be generated by the locomotive's transmit coil.
2. **Track impedance variability:** Track impedance, particularly when due to ballast and ties, is heavily influenced by track infrastructure and ambient conditions, both of which significantly affect the system's ability to function reliably under the range of expected conditions.
3. **Strong mutual inductance between the transmit and receive coils:** The magnetic field generated by the transmit coil passes through the receive coil and induces a current in the receive coil that can mask the desired signal picked up from the rail by the receive coil.

## TRACK IMPEDANCE DATA COLLECTION

The accompanying track impedance data collection effort was carried out on the Precision Test Track (PTT) at the Transportation Technology Center (TTC) in Pueblo, CO, over a 650-foot section of track from P64–P59, consisting of 115-pound rail and wood ties spaced approximately 19 inches apart and interspaced by relatively clean ballast. The data, including information on the electrical characteristics of the track and the environment, was collected at a rate of 2 MB per day and stored in a relational database. Due to low moisture conditions prevalent at the TTC, the track had to be artificially wetted to simulate high moisture conditions.

## METHODOLOGY

The project began with a track impedance characterization task that was used, in part, to develop a transmission line model of the track. The optimization and evaluation of the transmit (Tx) and receive (Rx) coils were done concurrently with collection of the track impedance data. The research team first conducted laboratory testing and concluded with dynamic field testing of the Tx and Rx coils. In addition, the team completed the following tasks:

- Research review
- Track impedance characterization
- Evaluation of transmission and receiver coils through laboratory and field testing
- Model development
- Migration plan development

In this stage of field testing, broadband (wire) shunts, rather than tuned shunts, were used to avoid creating undesired reactive effects upon rail impedance that could color the data being collected.

## RESULTS

The track impedance, weather and track sensor measurements were collected over 9 months and analyzed. The temperature of the ballast/rail and moisture content of the ballast were observed to have the most significant effect on the characteristic impedances of the track.

The field testing culminated in the dynamic testing of the system over 12,000- and 6,000-foot sections of test track. Researchers selected two test configurations: one with the Rx coil on the same locomotive (Configuration A) over 12,000 feet, and one with the Rx coil at the far end of the test block (Configuration B) over 6,000 feet. The locomotive with the Tx and Rx coils had no motive power and was coupled to a pusher locomotive with care taken to avoid dynamic braking and reduce the effect of external electrical noise that could potentially affect the performance of the Tx and Rx coils.

The induced signal propagated through the entire 12,000-foot test block and was observed to vary proportionally based on the locomotive distance from the shunt (Figure 2). A rail break with an insulated joint (IJ) was simulated at the halfway point (T33.5). The rail break was applied for 30 seconds and then removed (IJ shunted) for 30 seconds, repeatedly. The effect of the changing rail break state can be seen in Figure 2 when the locomotive was between T27 and T33.5 (until the locomotive passed the rail break location). In Configuration A, the Rx coil detection capability was masked by the electromagnetic coupling with the Tx coil. However, in Configuration B, a clear indication of broken rail was observed, indicating that the concept is viable once the crosstalk issue is addressed.

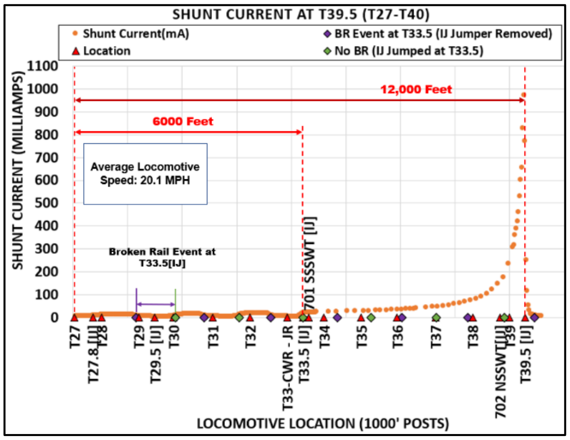

**Figure 2. Shunt Current at End of Test Block vs. Location of Locomotive with Tx and Rx Coils on Same Locomotive**

Several models were developed to help understand and evaluate system characteristics. The standard transmission line model was used to estimate the input and characteristic track impedances at different frequencies. These models were enhanced by weather condition parameters (i.e., temperature and moisture) that were shown to influence the track impedance. A system transfer function was developed for future use in quantifying the OBRD system behavior and propagation characteristics due to varying track impedance.

## CONCLUSIONS

The authors conducted research on a concept for an OBRD system. This research was accompanied by long-term data collection of track electrical parameters for use in track impedance modeling. The research effort led to the following major outcomes:

- Significant progress made in 1) inducing a usable signal in the track and 2) reliably propagating the signal over a range of over 2 miles. Test results indicate that the range could likely be increased to over 3 miles.
- Crosstalk between the Tx and Rx coils was reduced using passive shielding; however, the crosstalk still masked the desired signal detected by the Rx coil. Consequently, more work is required in crosstalk mitigation and signal detection.
- The track impedance characterization effort collected several million data points of resistance, inductance, capacitance, and conductance for alternating open- and closed-circuit conditions along with weather and sensor data for a 650-foot rail section. This data was used 1) to develop track-impedance-based signal propagation models, and 2) to better understand the relationships between the varying system parameters.

## FUTURE ACTION

This project focused on determining the viability of the concept to induce, propagate, and detect a usable signal onboard the train. Future work will focus on improving the detection and range capabilities of the overall system, adding tuned shunts to the test setups, carrying out track impedance characterization over a longer section of track, and developing a breadboard and prototype of the system.

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