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VIRTUAL BLOCK TRACK CIRCUIT ASSESSMENT

SUMMARY

To research the Virtual Block Track Circuit (VBTC) concept and evaluate the performance of a supplier's prototype, the Federal Railroad Administration (FRA) sponsored Transportation Technology Center, Inc. (MxV Rail) from 2021 through August 2022 to perform a capacity analysis related to potential efficiency improvements that can be achieved by implementing VBTC where Positive Train Control (PTC) is in operation.

The research and testing within this project demonstrated that the expectation of the VBTC system is to be able to reduce train headway and improve line-of-road capacity without modifications to the PTC architecture.

BACKGROUND

With the wide-scale implementation of PTC, the railroad industry is now looking for new methods to reduce train headways and improve line-of-road capacity that leverage the PTC infrastructure. The VBTC concept is one of the options for which the industry has expressed considerable interest.

Virtual block (VB) research is a method that divides a physical track circuit block into multiple VBs without adding wayside devices or insulated joints (IJ) at each VB boundary. Each VB created by this method is intended to perform a similar train control support function as a physical track block with some limitations.

The concept addressed and analyzed one approach that is based on an existing pulsed direct current (DC) VBTC system.

The critical function of the VBTC system is to analyze the transmit (Tx) current sent out from a VBTC transceiver, as illustrated in Figure 1, and to calculate the distance from that device to the closest shunting item (e.g., a moving train). Through this method, the system can create location-based virtual boundaries and detect the location of the closest shunting item.

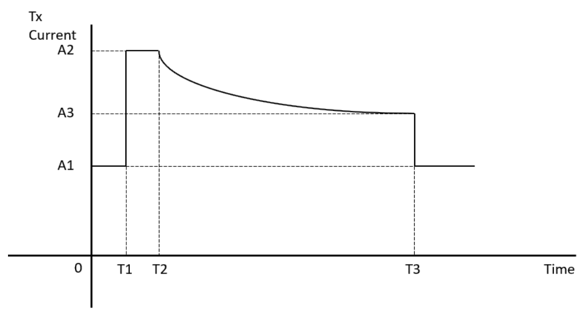

Figure 1. Outbound Side Device Tx Current Flow for a Constant Speed Movement Train

The basic VBTC system can be understood by the simplified model illustrated in Figure 2.

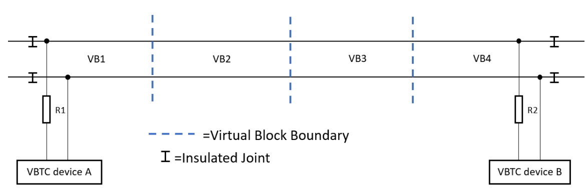

Figure 2. Simplified VBTC System Hardware Model

In this model, the physical block is divided into four equal-length VBs, referred to as VB1, VB2, VB3, and VB4. On each end of the physical block, there is a set of VBTC wayside devices (marked as VBTC device A and VBTC device B) that both function as transceivers that are coordinated by a synchronized time cycle and can measure the Tx current and receive (Rx) current. R1 and R2 represent the total resistance of wayside devices, including track wires, at each VBTC device location.

To verify this concept and evaluate the current existing prototype, a field test was conducted on the Railroad Test Track (RTT) at the Transportation Technology Center (TTC) in Pueblo, CO. The test bed comprised two physical blocks, each of which was 11,880 feet (2.25 miles) long and contained four VBs.

OBJECTIVES

The objectives of this project were:

- Assessing compatibility and determining how the proposed VBTC concept could be integrated with and enhance the existing overlay Interoperable Train Control (ITC) PTC system as well as the Quasi-Moving Block (QMB) concept
- Analyzing the performance of VBTC and estimating the potential capacity benefits when integrated with ITC PTC and QMB
- Acquiring and testing a VBTC prototype for functional and performance demonstration. Evaluating the VBTC prototype's ability to perform properly under varying conditions and scenarios. Recording and analyzing the results.
- Incorporating the observed results from testing of the VBTC prototype into the analysis to validate the potential benefits that this enhancement brings to train control operation and its degree of robustness

METHODS

This project was conducted with the following approaches:

- By developing a high-level VBTC Concept of Operations (ConOps), with analysis of basic VBTC theory, a number of performance-related system characteristics were uncovered and the basic VBTC architecture was proposed.
- The test track and related equipment were prepared, and a test matrix, presented in Table 1 was developed.

Table 1. Test Case Matrix

Test No.	Test Group	Test Case Name
1	Basic performance test	Basis system operation test
2	Basic performance test	System detection accuracy under same VB Scale Factor
3	Basic performance test	System detection accuracy under different VB Scale Factors
4	Basic performance test	Changing speed test
5	Operational scenario test	Single locomotive test
6	Operational scenario test	Pull-apart test
7	Operational scenario test	Double occupancy within single block test
8	Operational scenario test	Changing movement direction within single block
9	Operational scenario test	Broken rail test with multiple scenarios
10	Operational scenario test	Power outage test
11	Operational scenario test	Loss of shunt due to simulated rusty surface test
12	Wet track test	Wet track preparation
13	Wet track test	Constant speed test
14	Wet track test	Broken rail test
15	Wet track test	Ballast condition test

- Research engineers conducted the field test in accordance with the test matrix, recorded and analyzed results, reached conclusions, and generated a field test report.
- The VBTC ConOps document was updated with the field test findings and a capacity analysis was conducted based on the ConOps and field test results.
- Based on those research achievements, MxV Rail generated a report that included the results from the research.

RESULTS

This project included both research and field testing. The following was achieved:

1. The VBTC concept research focused on

high-level system characteristics. A basic VBTC architecture, including the message and onboard architecture, and potential implementation within the current ITC PTC system and future QMB train control system, was proposed. This architecture can satisfy the basic functional requirements for VBTC operation without significant modification of the current ITC PTC system. Some limitations based on the proposed architecture were addressed in this research. A ConOps was generated to document the concept for the industry.

2. Testing performed with a supplier's equipment (one set of which is shown in Figure 3) provided an opportunity for evaluating the feasibility of the VBTC concept and a practical evaluation of the equipment performance.

Figure 3. VBTC Device Used for Field Testing

The field test focused on the performance of the system under basic train movement scenarios, operation related scenarios, and wet track scenarios. Multiple test cases were developed considering a variety of issues that may affect performance of the system under varying operational conditions. The concept, with the devices tested at the TTC, performed essential VBTC functions in most cases and VBTC can therefore be expected to provide a means to reduce train headways and increase network traffic capacity under various common operational test scenarios.

3. A field test report was generated to present the test results and findings.

4. A capacity analysis, focused on the efficiency improvements in an ideal scenario, was conducted. The analysis showed that, under ideal following move scenarios, train headway reduction using the VBTC concept is in the range of 12 to 40 percent, depending on train types, train speeds, and track circuit lengths. The research team generated a report to present research findings about the capacity gain.

CONCLUSIONS

The VBTC has the potential to increase railroad network capacity by reducing train headways.

Based on the results of the field testing, it was determined that the devices evaluated at the TTC could perform essential VBTC functions. However, additional evaluation under a broader range of conditions, both operational and environmental, is recommended to fully evaluate the performance of VBTC.

Additionally, a capacity analysis based on the VBTC concept provided an estimate of the capacity gains VBTC can offer in an ideal following move scenario. Estimated capacity gains are highest for homogeneous freight trains operating at uniform constant speed where there is no need for meets or passes. In this ideal scenario, the capacity increase is in a promising range compared with the current and some potential near-future train control methods.

Multiple factors affect the results, including track circuit length, train types (along with their corresponding real-time braking distance), Maximum Authorized Speed (MAS), safety buffer length for VBTC, and VB sizes. In a rail network scenario, where meets and passes occur, train characteristics are varied, and track speeds are varied, the expected capacity gains would be smaller than presented in the ideal mathematical model.

FUTURE ACTION

Future work on this topic should focus on further field testing and operation rule changes, and analysis of potential limitations that were discovered during this project. Specifically, the VBTC devices should be further characterized with regard to a rapidly changing ballast condition scenario, such as can occur in a heavy rain or other environmental changes. This can affect train operations by temporarily deactivating VB mode for the VBTC device. Tests related to the number of train movements needed to recalibrate the devices to adjust to a given change in the environmental condition are recommended.

By further understanding the response of the system under changing conditions, the availability of the VBTC benefits will be better understood.

If an improved product or prototype becomes available, such as a device with the ability to support more VBs per physical block, or a longer physical block, researchers recommend testing in a controlled environment.

If a means is developed for communication between VBTC devices when the track is shunted, a revision of the ConOps and related further testing is recommended. An industry standard could be developed documenting the requirements for the VBTC system.

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CONTACT

Francesco Bedini
Federal Railroad Administration
Office of Research, Development and Technology
1200 New Jersey Avenue, SE
Washington, DC 20590
(202) 493-0800
francesco.bedini@dot.gov

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Virtual Block Track Circuit, VBTC, Positive Train Control, PTC, Quasi-Moving Block, QMB, virtual block, VB, ConOps, direct current

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