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Signals and Communication Working Group

Audio Frequency Track Circuit Inspection and Maintenance

Abstract: This standard offers requirements necessary to ensure the safety and reliability of audio frequency track circuit systems.

Keywords: AF track circuit, audio frequency track circuit, bond, HF track circuit, impedance bond, shunt, shunting device, signal, track circuit

Summary: This standard provides audio frequency track circuit tests that verify train detection (shunting), and continued proper operation. These tests include recording the measured values for comparison over time to reveal trends in transmit and receive signal levels, which can help predict possible equipment and/or track deterioration. This standard also provides track circuit inspection requirements.

Foreword

The American Public Transportation Association is a standards development organization in North America. The process of developing standards is managed by the APTA Standards Program's Standards Development Oversight Council (SDOC). These activities are carried out through several standards policy and planning committees that have been established to address specific transportation modes, safety and security requirements, interoperability, and other topics.

APTA used a consensus-based process to develop this document and its continued maintenance, which is detailed in the manual for the APTA Standards Program. This document was drafted in accordance with the approval criteria and editorial policy as described. Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

This document was prepared by the Signals and Communication Working Group as directed by the Rail Standards Policy and Planning Committee.

This document represents a common viewpoint of those parties concerned with its provisions, namely transit operating/planning agencies, manufacturers, consultants, engineers and general interest groups. APTA standards are mandatory to the extent incorporated by an applicable statute or regulation. In some cases, federal and/or state regulations govern portions of a transit agency's operations. In cases where there is a conflict or contradiction between an applicable law or regulation and this document, consult with a legal adviser to determine which document takes precedence.

This document supersedes APTA RT-SC-S-009-03, Rev. 1, which has been revised. Below is a summary of changes from the previous document version:

- This document has been updated using the latest document template for the APTA Standards Program (e.g. new sections include a summary, foreword, summary of changes, etc.). This document was revised with new language describing inspection and maintenance of audio frequency track circuits
- The acronym RTS has been replaced with rail transit system and/or rail transit agency throughout the document in addition to minor grammatical corrections.
- Section 1.1 General - Entire section was updated with new language
- Section 1. 2 Test prerequisites - Section 1.2.1 Unshunted tests, Entire section was updated with new language
- Section 1. 2. 3 Unintended or spurious signal test - Entire section was updated with new language
- Section 1. 2. 4 Cab signal levels - Entire section was updated with new language
- Section 2.2 Test Equipment - Cab signal rail current measuring device* and micro-ohmmeter* were added it was also noted that any tools marked with an asterisk (*) should be calibrated in accordance with OEM and/or rail transit agency requirements
- Definitions - Hard shunt, insulated joint, shunt sensitivity, soft shunt and system designer definitions where added. Automatic train control (ATC), automatic train operation (ATO) , automatic train protection (ATP), automatic train supervision (ATS), safety critical, self-revealing failure, service, revenue, turning unit, and vehicle definitions where removed.

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Introduction

This introduction is not part of APTA RT-SC-S-009-03, "Audio Frequency Track Circuit Inspection and Maintenance."

APTA recommends the use of this document by:

- individuals or organizations that operate rail transit agencies;
- individuals or organizations that contract with others for the operation of rail transit agencies; and
- individuals or organizations that influence how rail transit agencies are operated (including but not limited to consultants, designers and contractors).

Scope and purpose

This standard provides minimum requirements to test, inspect, maintain and manage:

1. Analog audio frequency track circuits
2. Digital audio frequency track circuits
3. Training criteria for maintenance and operation
4. Evaluation of adequate maintenance staff requirements for corrective and preventative maintenance

Note on alternate practices

Individual rail transit agencies may modify the practices in this standard to accommodate their specific equipment and mode of operation. APTA recognizes that some rail transit agencies may have unique operating environments that make strict compliance with every provision of this standard impossible. As a result, certain rail transit agencies may need to implement the standards and practices herein in ways that are more or less restrictive than this document prescribes. A rail transit agency may develop alternates to APTA standards so long as the alternates are based on a safe operating history and are described and documented in the system's safety program plan (or another document that is referenced in the system safety program plan).

Documentation of alternate practices shall:

- identify the specific APTA rail transit safety standard requirements that cannot be met;
- state why each of these requirements cannot be met;
- describe the alternate methods used; and
- describe and substantiate how the alternate methods do not compromise safety and provide a level of safety equivalent to the practices in the APTA safety standard (operating histories or hazard analysis findings may be used to substantiate this claim).

Audio Frequency Track Circuit Inspection and Maintenance

1. AF track circuits tests

1.1 General

The following tests are required for all audio frequency track circuits, both analog and digital. When track circuits are initially commissioned, have been modified and after corrective maintenance, they shall be adjusted, verified and recorded in accordance with the system designer's and manufacturer's recommendations. All data recommended to be recorded by the system designer and manufacturer shall be evaluated. At a minimum, the track circuit transmit signal level and the track circuit receive signal level (shunted and unshunted) shall be measured and recorded to establish a baseline for evaluation and comparison to subsequent measurements. These tests are not recommended for use with audio frequency overlay train detection systems.

Independent of commissioning and post-corrective maintenance tests, each track circuit shall have the tests and inspections in this document completed at a minimum of once every 12 months or at the frequency recommended by the system designer and manufacturer. Specified test intervals should be provided in written documentation or included in the system designer's and manufacturer's manuals.

The rail transit agency's audio frequency track circuit preventative maintenance and inspection procedure shall at a minimum include each of the following activities:

1. Inspect the track circuit for an accumulation of debris. Remove and bag debris.
2. Inspect wayside drains for blockage or ineffective drainage.
3. Inspect the track circuit for damage caused by standing water, water leaks or retention.
4. Inspect the track circuit for any condition that may interfere with the operation of the equipment.
5. Inspect impedance bond and loop layout cables, wiring, power bonding, and hardware for defective insulation, rust, corrosion, missing components, damage, and loose or broken connections.
6. Inspect audio frequency track circuit cable, where visible, for insulation degradation and damage.
7. Inspect track circuit insulated joints, gauge plates and switch rods for bridging, broken or deteriorated insulation, metal shavings, and loose or missing hardware.
8. Inspect the track circuit room and/or enclosure equipment (e.g., junction boxes) for damage; cracks; breaks; defective latches, locks, hinges or covers; and loose, deteriorated or damaged conduit connections and hardware. Holes and unused entrances not used for ventilation shall be sealed.
9. Inspect cable conduit material for damage, cracks, breaks, loose conduit connections, and missing or loose components and hardware.
10. Ensure that covers, doors and locks are in place and secured.

1.2 Test prerequisites

CAUTION: When a track circuit has to be taken out of service, adequate measures shall be taken to safeguard train operations.

Prior to conducting the following tests:

- Measure and verify that the power supplies and power sources are within specified voltage tolerances.
- Verify that the shunting device(s) and associated resistors are approved for this use (i.e., shunting on an electrified railroad).
- Verify that shunt resistor values are as specified by the system designer and manufacturer. Values shall be periodically measured with a calibrated instrument (e.g., micro-ohmmeter) to ensure that they measure within tolerance.
- Verify that the shunt straps are in good condition, including cables, electrical connections and sharpness of rail connection points.

1.2.1 Unshunted tests

Each track circuit shall be tested to determine if component deterioration or track condition changes (e.g., ballast, bonding, connections, insulated joint deterioration) have caused signal level changes. This is best done by measuring the track circuit's unshunted signal levels.

In concert with the other tests described in this document, the track circuit unshunted transmitter and receiver signal levels shall be measured, recorded and compared with the baseline values established when the track circuit was last adjusted. This data can then be analyzed for trends and used to predict future problems. At a minimum, measure the track circuit transmitter and receiver signal levels and compare the readings with the baseline values.

The data shall be within the system designer's and manufacturer's recommended range or within 15% of the established baseline value. Otherwise, immediate steps shall be taken to determine the cause and make the necessary repairs.

The track circuit shall be retested within three months after any adjustment has been made, resuming the required interval thereafter.

1.2.2 Shunt sensitivity verification

Every track circuit shall be tested to verify that it is functioning properly by detecting a shunt at the design-specified shunting value, or soft shunt. Typically, the soft shunt value is between 0.06 and 0.5 ohms and is application-specific. The track circuit to be tested is first verified to be indicating clear or unoccupied when not soft shunted.

To verify that the track circuit detects the shunt, the soft shunt is first placed across the transmitter track connections, and the track circuit is verified to be occupied. The shunted receive level should be recorded for trend analysis. The soft shunt is then connected across the rails at the midpoint of the track circuit, and again the track circuit is verified as occupied. The shunted receive level should be recorded for trend analysis. The soft shunt is then connected across the rails at the receiver location, and the track circuit is verified as occupied. The shunted receive level should be recorded for trend analysis.

If during any of these tests the track circuit fails to occupy with a soft shunt, fails to indicate unoccupied without a soft shunt, or intermittently indicates unoccupied and occupied (i.e., bobs) with or without a soft shunt, then the track circuit is in a failure condition. The track circuit shall not be returned to service until the

cause of the failure is understood and corrected, and the track circuit meets all test and inspection requirements. In no case is it acceptable to increase transmit power and/or receive gain as a resolution to a failed audio frequency track circuit without fully understanding and resolving the cause of the failure. Only by determining the cause of the problem is it possible to determine if an increase in power and/or gain is appropriate and safe.

The signal levels recorded during the shunt sensitivity verification should be compared against the previous readings for trend analysis based on test intervals. If the receiver signal level is at any time more than 15% different from the baseline value, immediate steps shall be taken to determine the cause and make the necessary repairs.

If the double hard shunt test in Section 1.2.3 is performed at the same time as the shunt sensitivity verification described above, the midpoint soft shunt test can be omitted. However, if the midpoint soft shunt test is omitted, then historical data will not be available for comparison because it is not appropriate to compare the double hard shunt data with soft shunt data, as double hard shunt receiver voltage will be much lower.

The track circuit shall be retested within three months after any adjustment has been made, resuming the required interval thereafter.

1.2.3 Unintended or spurious signal test

By isolating an audio frequency track circuit's own transmitter, the purpose of this test is to verify that there are no sneak paths or unintended signals entering the receiver. The test will measure and analyze the signal at the receiver when its own transmit signal is double hard shunted as described below. Alternate methods may be used as specified by the system designer and manufacturer.

The double hard shunt test requires that a minimum of two hard shunts be placed centered on the midpoint of the track circuit approximately 75 ft apart. For track circuits 225 ft or less in length, the hard shunts should be placed at approximately the one-third and two-thirds points. This configuration effectively eliminates signals from the transmitter propagating down the running rails to the receiver.

If, with the double hard shunt, receiver levels are measured above the system designer's and manufacturer's recommended levels (specified levels should be provided in written documentation or included in the system designer's manuals), then operational protection shall be immediately provided until the unintended signal is eliminated, reduced to an acceptable level or verified to not affect the track circuit's ability to detect trains. The source or cause of the unintended signal can usually be found by turning off same-carrier transmitters, one at a time, until the unintended signal drops.

1.2.4 Cab signal levels

The cab signal transmit entering end rail currents or associated voltages shall be measured in accordance with the system designer's and manufacturer's recommendations. The measurements shall be recorded when initially installed and whenever readjusted to provide baseline values. Signal levels measured at subsequent tests should be compared with the baseline values. This data can then be analyzed for trends and used to predict future problems. If the difference between the baseline and subsequent readings is outside the ranges specified by the system designer and manufacturer, immediate steps shall be taken to investigate and repair.

2. Training, equipment and safety

2.1 Training

The rail transit agency and/or its maintenance contractors shall develop and execute training programs on a regular basis that provide employees with the knowledge and skills necessary to maintain the audio frequency

track circuits that are operating on the authority and to safely and effectively perform the tasks outlined in this standard. Training shall be consistent with the system designer's and manufacturer's manuals and recommendations.

2.2 Test equipment

The following tools are required for inspecting and maintaining audio frequency track circuits. All test equipment should be compliant with manufacturer recommendations:

- multimeter*
- oscilloscope*
- frequency counter*
- cab signal rail current measuring device*
- micro-ohmmeter*
- rail transit agency–approved shunting devices
- rail transit agency–approved portable radio
- standard tools carried by maintenance personnel
- additional tools as required by the test procedures, system designer and/or rail transit agency

NOTE: Tools marked with an asterisk (*) should be calibrated in accordance with instrument OEM and/or rail transit agency requirements.

2.3 Materials

The materials required for inspecting, testing and maintaining audio frequency track circuits shall be as required by the system designer, manufacturer, test procedures and/or rail transit agency.

2.4 Personal protective equipment

Personal protective equipment, as required by the rail transit agency, shall be worn at all times during inspection and maintenance.

2.5 Safety

It is recommended that the rail transit agency have a System Safety Program Plan. APTA will work with the rail transit agency to develop an SSPP and will provide scheduled audit reviews at the request of the rail transit agency as part of a Rail Safety Audit Program.

Rail transit agency safety rules, procedures and practices shall be followed at all times.

Definitions

audio frequency track circuit: A device that may use audio frequency carriers to transmit a vital signal to the train and that uses audio frequency carriers to vitally detect the presence of a train within the limits of the track circuit.

baseline measurements: Measurements taken when a track circuit is commissioned or readjusted after repair or modification.

fail-safe: A design philosophy applied to safety-critical systems such that the result of hardware failure or the effect of software error shall either prohibit the system from assuming or maintaining an unsafe state, or shall cause the system to assume a state known to be safe.

hard shunt: Used to short-circuit current between the transmitter and receiver of a track circuit. Typically, a hard shunt is a shunt strap with no shunt resistor.

hazard: Any real or potential condition that can cause injury, death, damage, or loss of equipment or property.

impedance bond: A device of low resistance and low impedance to all frequencies to which it is not tuned, used with jointless audio frequency track circuits to couple inductively and confine the signaling energy to its own track circuit and equalize the return propulsion current between rails without impeding its flow.

insulated joint: A joint in which electrical insulation is provided between adjoining rails.

shunt: A device installed from one running rail to the other.

shunt sensitivity: The highest resistance value of a soft shunt that will cause a given audio frequency track circuit to occupy when placed at a specific point in the track circuit.

soft shunt: Used to limit the current flow between transmitter and receiver by using a resistor that represents the worst-case shunting value of a train consist axle shunt. The soft shunt is used to adjust and verify audio frequency track circuits such that they just indicate occupancy when the soft shunt is placed anywhere within an audio frequency track circuit.

system designer: The party responsible for and qualified to design, assemble, install and commission an audio frequency track circuit system, integrating equipment to function as required by the end user and in accordance with the equipment constraints. Depending on the situation, the system designer may be a third party or the manufacturer of the audio frequency track circuit equipment.

system safety: The application of engineering and management principles, criteria and techniques to optimize all aspects of safety within the constraints of operational effectiveness, time and cost throughout all phases of the system life cycle.

system safety program: The combined tasks and activities of system safety management and system safety engineering that enhance operational effectiveness by satisfying the SSPP and all safety requirements in a timely, cost-effective manner throughout the system life cycle.

train: A consist of one or more basic operating units.

vital function: A function in a safety-critical system that is required to be implemented in a fail-safe manner.

Abbreviations and acronyms

AF audio frequency
FRA Federal Railroad Administration
HF high frequency
OEM original equipment manufacturer
SSPP System Safety Program Plan

Document history

Document Version	Working Group Vote	Public Comment/ Technical Oversight	Rail CEO Approval	Policy & Planning Approval	Publish Date
First published	June 10, 2003	—	—	Sept. 28, 2003	Jan. 28, 2004
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Appendix A (informative): Recommended additional support requirements

Manufacturers, system designers and/or operators should meet regularly as necessary to define the rules, conditions and constraints relevant to functional safety, which needs to be observed in the operation and maintenance of the track circuit equipment.

General topics that should be considered:

- identification of maintenance- and operation-related assumptions used in failure mode and effects analyses
- precautions in testing
- rules and methods for maintenance and fault-finding
- periodic maintenance requirements and frequency
- operational safety monitoring

It is recommended as part of contracts that system designers and manufacturers be required to meet with operators and discuss issues of safety and reliability related to operation, test and maintenance of AF track circuits. This should include documentation and estimated staffing requirements. This could be included in the training program.

It is recommended that manufacturers issue Safety Notifications similar to the FRA requirements for any safety-related issues with similar equipment operating at any authority where that equipment may be installed.

It is recommended that system designers and manufacturers review all generations of published material for audio frequency track circuit operation and identify test and adjustment differences between generations of equipment and where possible minimize differences, consolidate maintenance practices and ensure uniformity in maintenance procedures.

It is recommended that system designers, manufacturers and operators discuss what tests normally recommended by the manufacturers can be eliminated, added or reduced as a result of the tests in this document being performed.