Improving The Performance of a Clearance Restricted, Low-mount Antenna Installed Between Two Tracks At a Multi-Track AEI Reader Installation

A Case Study

Executive Summary

At multi-track AEI Reader installations in general, the antennas installed between the tracks consistently do not read tags on certain vehicle types. AEI antennas mounted between tracks must adhere to strict height and distance restrictions, which is the primary contributing factor in performance degradation. At one of the test sites maintained by Southern Technologies Corp (STC), experiments were performed to determine whether better performance could be achieved by relocating the low-mount antennas, while still adhering to the clearance restrictions. After some experimentation, it was determined that moving the antenna from its initial location of 49 inches from the nearest rail to a distance of 73 inches significantly improved the performance of the antenna on a specific vehicle type and offered some improvement across all vehicle types.

Introduction

It is common for AEI Readers installed at multi-track locations to experience performance issues from the antennas located between the tracks. The clearance restrictions which dictate how close to the rails and how high these antennas can be installed drive this problem. It is also common at these AEI Reader locations for specific railcar types to prove especially problematic. One of the test sites maintained by STC is a double-track site where the standalone AEI Readers have consistently shown poor performance from the low-mount antennas when recording the coal hopper unit trains that frequently cross the site. These trains are typically made up of two to four locomotives and 100+ coal hopper vehicles. In many cases, the low-mount antennas <u>read only the locomotive tags</u> on these trains. The two low-mount antennas installed permanently at this location are located roughly mid-way between the two tracks. Each of these antennas is configured to read AEI tags from traffic on one of the tracks.

Because the coal hopper unit trains represent a worst-case scenario, for the purpose of this test, the performance of the antenna being studied was measured chiefly in terms of how well it acquired tags from these trains. The primary metric in the experiments performed was the count of the tags read from the coal hopper vehicles in these consists.

The secondary metric used to evaluate antenna performance relates to the number of times each tag is read as it passes through the antenna's “field of view.” This tag-read-count is typically referred to as the number of handshakes recorded for a given tag. For each tag detected by the AEI reader, a handshake value is recorded. The averages of these handshake values, recorded across each train, were used as the secondary metric for this study.

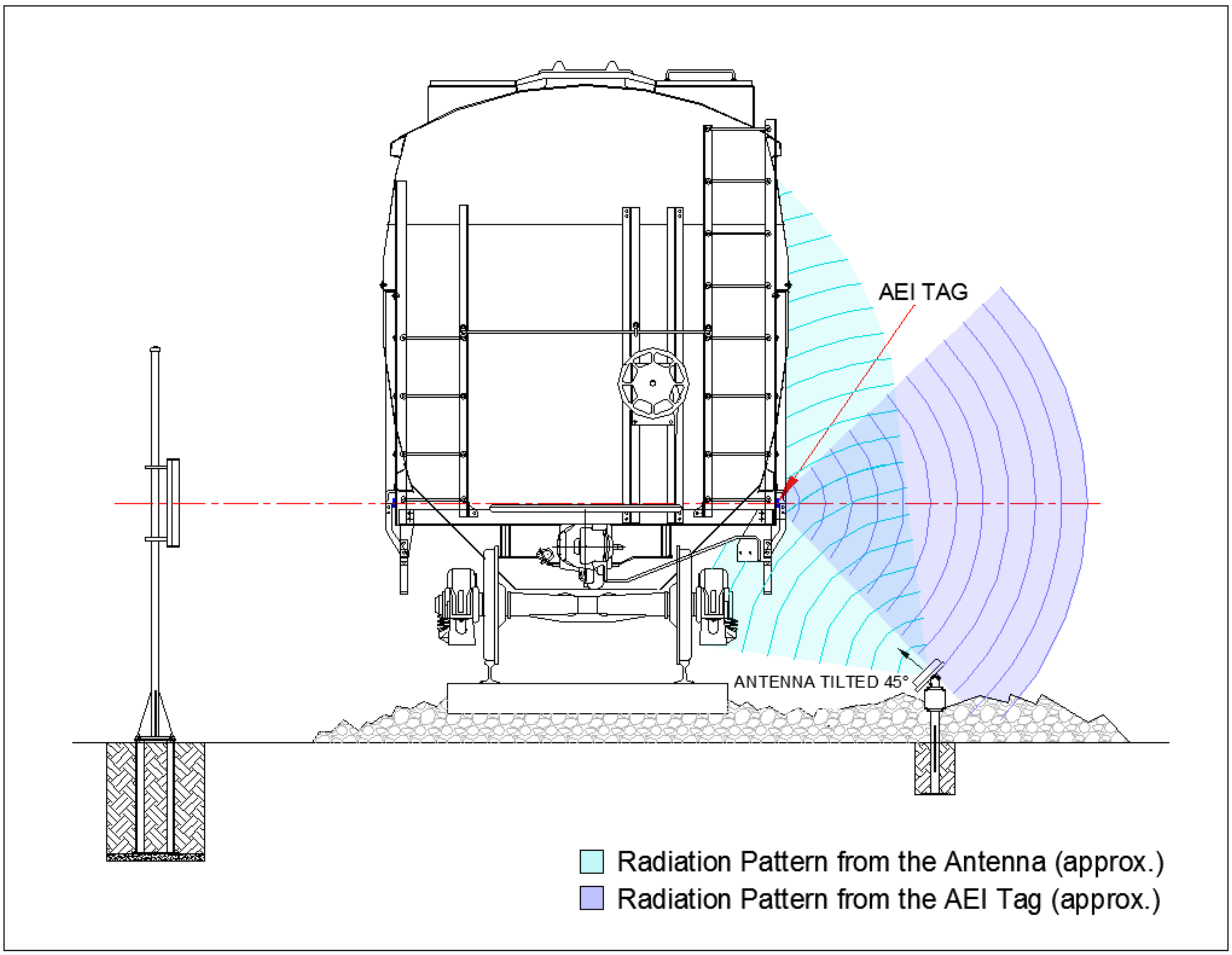
Testing began with the antenna under test located in the same relative location to the rail, and at the same relative height, as the baseline antenna. We first incrementally raised the antenna, leaving the distance from the rail unchanged. We then dropped the antenna down to its original height and incrementally moved it away from the rail. Data from passing trains was recorded at each of the heights and distances. Ultimately, the test data reflected significant improvement in performance as the test antenna was moved to a distance of 73 inches from the near rail. At this distance, the AEI system read better than 95% of tags on the coal hopper unit trains. This distance also showed a consistent improvement in the average handshake values recorded for each train. These improvements held both at the original baseline height as well as with the test antenna at the height of one inch below the top of the rail.

Problem Statement

At multi-track railroad locations, the close proximity of adjacent tracks lead to clearance restrictions that prevent the installation of AEI antennas in the ideal location – ten to fifteen feet from the near rail and 4 feet above the top of the rail, with the antenna polarized horizontally. Clearance restrictions specify maximum vertical height allowed and minimum linear distance to the nearest rail in the space between two adjacent railroad tracks. For certain types of rail vehicles, the height restriction on the antenna between the tracks prevents the low-mount antenna from capturing a readable signal transmitted by the AEI tags. This constraint results in missing tags in consist data.

A passive AEI tag has an internal antenna that receives and radiates an RF signal. A tag, illuminated with RF energy from the reader antenna, becomes energized and radiates an RF signal modulated with preprogrammed tag data. The signal radiated by the tag's antenna propagates in a direction perpendicular to the ground plane to which the tag is mounted (the side of the rail car), and it spreads as it does so. *The height at which tags are installed on some railcar types results in the tag's radiation pattern overshooting the antennas which are installed per railroad height restrictions.*

The image below presents a highly simplified illustration of this issue.



Antenna and Tag Radiation Patterns (A simplified depiction)

The Test Environment

Testing was conducted at a double-track site with the following features.

- Distance between track centers: approximately 13.5 feet.
- Distance between the two inner rails: 99 inches, measured between the outside edge of the crown of each rail.
- Antenna Type: Sinclair Model SP470-SF47P75SNF, Panel directive, 6.5 dBd, 75° Horizontal beamwidth, 900-920 MHz (commonly used for this purpose)
- Original antenna installation location: approximately midway between the two tracks (43” to 49” from near rail)
- Train speeds: nominally 25 to 45 mph. Trains sometimes stop at this location.
- Tag Reader: Transcore MPRX – configured to multiplex its RF transceiver on two antennas.

The Process

During this process, two antennas of the Sinclair model SP470 were used. Initially, these were installed at a distance 49 inches from the nearest rail, on opposite sides of the same track. This configuration gave us two low-mount antennas, directed at the same traffic, one on each side of the track. These antennas were connected to a Transcsore MPRX tag reader, which in turn was connected to an STC Model 2600 AEI Reader. The center of the front face of the antennas aligned to 3.5 inches above the top of the rail. The antennas were tilted back 45 degrees off of vertical. During the testing process, one of the antennas was kept in its original location and was used as a control to establish a baseline of antenna performance. The other antenna was repositioned, first in height, and subsequently in distance from the rail.

<u>Adjusting The Height</u>

After setting up the antennas in their initial locations, as described above, we first confirmed that they read approximately the same number of tags from each of the passing trains and had comparative average handshake counts across consists. Subsequently, we raised one antenna a total of 18 inches, in six-inch increments, to a maximum height of 21.5 inches above the top of the rail. When the antenna was raised to 9.5 inches and then 15.5 inches above the top of the rail, successive performance improvements were seen. Both the ability to read the tags on the coal hopper vehicles and the average handshakes counts per train improved. Although at no point did the re-positioned antenna read 100% of the coal hopper vehicle tags on any consist.

However, when the antenna was positioned 21.5 inches above the top of the rail, the average handshakes recorded per train dropped across all trains and, on trains other than the coal hopper consists, the control antenna consistently read more tags. We believe that this was due to the reduced effective beamwidth of the RF signal transmitted by the test antenna in the plane in which the AEI tags are located. The image below illustrates this phenomenon.

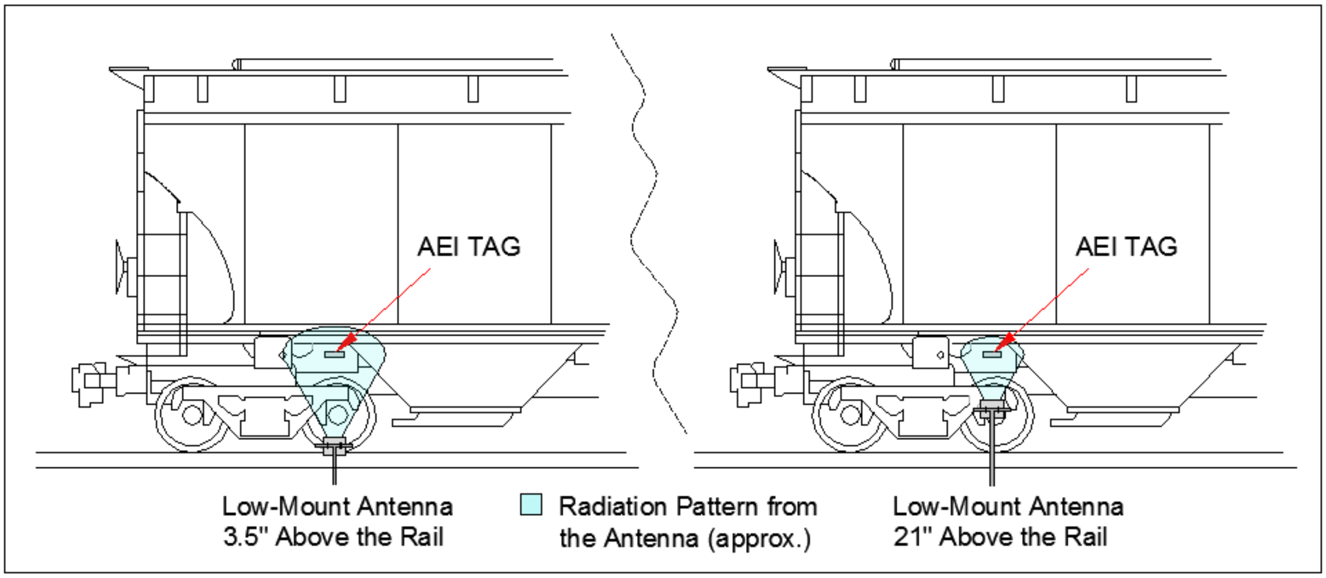


Illustration of reduced effective RF beamwidth with antenna at 21 inches above the top of the rail

Increasing the Distance

After performing experiments with the height of the antenna, as described above, we dropped the test antenna back down to its original height of 3.5 inches above the top of the rail and then moved it away from the rail. The first position to which it was moved was 61 inches from the near rail and the second was 73 inches away, representing a change of one foot with each move. Successive performance improvements were seen at each of these locations. Both the performance on the coal hopper unit trains and the average handshakes across each consist improved. With the antenna at 73 inches from the near rail there were many coal hopper consists on which the antenna read 100% of the coal hopper vehicle tags.

Reducing The Height

As it turned out, the 73-inch distance from the near rail would have put the antenna within a few inches of the end of the ties of the adjacent track. Anticipating that additional height restrictions could apply with the antenna so close to the other track, we elected to test the performance of the antenna with its height reduced to one inch below the top of the rail. We maintained the antenna distance at 73 inches from the rail. Dropping the antenna to this height resulted in no measurable degradation of the performance of the antenna.

Conclusions

Moving the antenna away from the track, to a distance of 73 inches from the near rail, produced substantial improvements in the performance of the low-mount antenna. At this distance, the antenna performed as well at the height of 1 inch below the top of the rail as it did when at 3.5 inches above the top of the rail.

Merely increasing the height of the antenna, while maintaining the original distance of 41 inches from the near rail, did result in some performance improvement – up to a point. As we elevated the antenna, diminishing returns set in resulting in performance degradation as the antenna was raised to a height of 21.5 inches. At no point did an increased height produce improvements as significant as those that resulted when the antenna was moved away from the rail.

Glossary

AEI – Automatic Equipment Identification is an electronic recognition system in use in the North American railroad industry, consisting of passive tags mounted on each side of rolling stock and active trackside readers. AEI uses RF technology to identify railroad equipment while en route.

Consist – A railroad industry term that generally refers to the vehicles that make up a train.

Ground Plane - A conducting surface large in comparison to the wavelength, which serves as a reflecting surface for radio waves.

Handshakes – A term that refers to the number of times a railcar mounted AEI tag gets read as it passes through the field of view of an AEI antenna. Handshake values can be used as a rough gauge of the health of an AEI Reader system as they provide a rough measure of the ability of the RF subsystem to acquire AEI tag data from passing trains.

Low-Mount Antenna – Refers to the antennas installed between tracks at a multi-track railroad site. These antennas must meet strict maximum height requirements and generally are installed at a much lower height than that of standard AEI antennas.