Automatic equipment identification (AEI) as a resource for rail noise and vibration studies

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Thesis

When monitoring rail noise, it would be useful to know the arrival time, consist, direction, speed, and length of every passing train without being there.
Automatic Equipment Identification (AEI)

Beginning in 1960s, the US railroad industry sought a way to automatically identify equipment (cars, locomotives, etc.)
Automatic Equipment Identification (AEI)

- KarTrak (1967) used color barcodes
- Poor read rates due to physical damage and dirt accumulation
- Abandoned in 1977
Automatic Equipment Identification (AEI)

- AEI implemented beginning in 1991
- RFID tags affixed to all rail equipment in US by 1994
Radio Frequency IDentification

Two principal components:

- **Reader** – Active radio transceiver
- **Tag** – Passive (usually) device that transmits data when powered by an RF carrier
Types of RFID

Inductive Coupling (coil)
- 125 kHz (LF) & 13.56 Mhz (HF)
- Short range (< 1 m)
- Building access, inventory control, animal ID, ticketing, etc.

Long Range (antenna)
- 433 Mhz, 900 Mhz (UHF) & Microwave
- Range up to 12 m
- Vehicle tracking, inventory control
- Some tags are active
AEI Standards

Air Interface: ISO 10374
• Defines physical interface and communication protocol (900 Mhz ISM Band)
• Tag returns a 128-bit ID when interrogated
• Used by other industries in the past (tolling, intermodal), but mostly obsolete.

Data Format: AAR S-918
• Defines data format of 128-bit ID
• Provides guidance on tag placement
AEI Tag Data

Tag contains these fields:

• Equipment type (car, locomotive, etc.)
• Reporting Mark (owner’s initials)
• Car/Locomotive Number
• Side (left or right)
• Length
• Number of axles
• Bearing type
• Additional equipment-specific parameters
AEI Performance

- Range depends on effective radiated power (ERP) and train speed.
- Maximum performance observed was 20 ft (12 m) for 70 mph (112 km/h) train at 32 W ERP.
ERP Calculation

ERP = transmitter power + antenna gain

Example:
2 W transmitter power into 9 dBi antenna (dB re: isotropic)

$$ERP = 2 \text{ W} \times 10^{0.9} = 15.9 \text{ W}$$
AEI Performance

Conventions for Reader RF Power

• Low-power reader
  • 1 W + 9 dBiC (Circular polarization: -3 dB)
  • ERP = 5 W
  • FCC Part 15 (no license required)
  • Not practical unless on RR property

• High-power reader
  • 2 W + any antenna gain
  • ERP may be as high as 32 W
  • FCC Part 90 (site license required)
Experimental Setup

Sirit ID5100

- Obsolete – eBay purchase
- Supports ISO 10374
- Used with 9 dBi Yagi
- Operating under my amateur radio license
Experimental Setup

Sirit ID5100
- Runs Linux on internal microprocessor
- Communicates via TCP over ethernet
- Provides raw tag data
- Can log tag data internally

Software
- Developed Python to decode and analyze tags
- Can be used for real-time processing or post-processing of log files.
Experimental Setup

Realtime processing test – 70 mph
Experimental Setup

Triggering

- Triggering reduces power consumption, heat, and RF pollution.
- Railroads use wheel flange detectors
- I used ground vibration
- Seismic geophone

1 s @ 70 mph
Experimental Setup

Triggering Circuit

73 dB Differential Amplifier

Threshold Control

Comparator
Experimental Setup

- Ethernet Router & Cellular Modem
- Raspberry Pi
- Triggering Circuit
- RFID Reader
- Ethernet Hub
- Sound Level Meter
Data : Raw

event.tag.arrive tag_id=0x2AEA4C8004F6B413D9F00144002E8730, first=2016-08-18T23:04:20.334
event.tag.arrive tag_id=0x9E44F94421AED01B900000000002E8738, first=2016-08-18T23:04:21.631
event.tag.arrive tag_id=0x9F7C28C51B8CCF1F90000000000E8738, first=2016-08-18T23:04:23.245
event.tag.arrive tag_id=0xF6710C2110AD213900000000002E8738, first=2016-08-18T23:04:24.993
event.tag.arrive tag_id=0x9F73F5329B4CD217900000000002E8738, first=2016-08-18T23:04:26.704
event.tag.arrive tag_id=0x9E86B2FAE34C81790000000000330, first=2016-08-18T23:04:28.461
event.tag.arrive tag_id=0x9E86B2FAE34C81790000000000330, first=2016-08-18T23:04:30.165

32 digits (hex) = 128 bits
### Data: Formatted

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<th>Tag Type</th>
<th>Tag Data</th>
<th>Arrival Time</th>
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</table>

**Total Length:** 874.1 ft

**Total Time:** 22.772 s

**Speed:** 26.2 mph
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<th>Type</th>
<th>Number</th>
<th>Direction</th>
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<td>228</td>
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Train Noise Levels

Westbound

Eastbound
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<tr>
<th>Car</th>
<th>Train</th>
<th>Direction</th>
<th>Length (ft)</th>
<th>Axles</th>
<th>Speed (mph)</th>
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<tbody>
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</table>

Total Length = 563.5 ft
Total Time = 8.619 s
Speed = 44.6 mph
Train Noise Levels

Train 546 2016-09-22 21:02:42.539000

1. LOC FURX 5509 R 59.0 ft 4 axles 21:02:42.539
2. CAR NHN 410 R 14.8 ft 4 axles 21:02:50.108
3. CAR NHN 417 R 14.8 ft 4 axles 21:02:51.161
4. EOT NHN 434
5. EOT NHN 436
6. CAR NHN 416 L 44.6 ft 4 axles 21:02:54.315
7. EOT NHN 406
8. EOT NHN 401
9. EOT NHN 405
10. EOT NHN 437
11. EOT NHN 411
12. EOT NHN 418
13. CAR NHN 425 R 14.8 ft 4 axles 21:03:01.603
14. EOT NHN 409
15. CAR NHN 432 L 44.6 ft 4 axles 21:03:03.672
16. CAR NHN 441 L 44.6 ft 4 axles 21:03:04.742
17. CAR NHN 400 L 14.8 ft 4 axles 21:03:05.805
18. CAR NHN 438 R 14.8 ft 4 axles 21:03:06.859
19. EOT NHN 426
20. CAR NHN 407 L 14.8 ft 4 axles 21:03:08.939
21. EOT NHNC 10603

Total Length = 281.4 ft
Total Time = 27.225 s
Speed = 7.0 mph
Limits to Practicality

Power Consumption

• 13 W while in standby
• 38 W while active
• Solar array would require 200 W capacity
• Can run for 24 hours on largest deep-cycle marine battery
• Mains power most practical
Limits to Practicality

FCC Part 90 License Required

• License is site-specific (Type LN)
• Device must not interfere with other services
• Cost: “a few hundred dollars”
Limits to Practicality

Railroads don’t like private readers
• Security concerns
• ClipperData Fiasco ➔
• Make sure you’re not on railroad property!
Conclusion

Automatic equipment identification has the potential to be a useful tool for correlating train data with noise measurements, provided that:

1. Electrical power is available
2. The project is significant enough to support applying for the required license.
3. Monitoring can be done from private property.