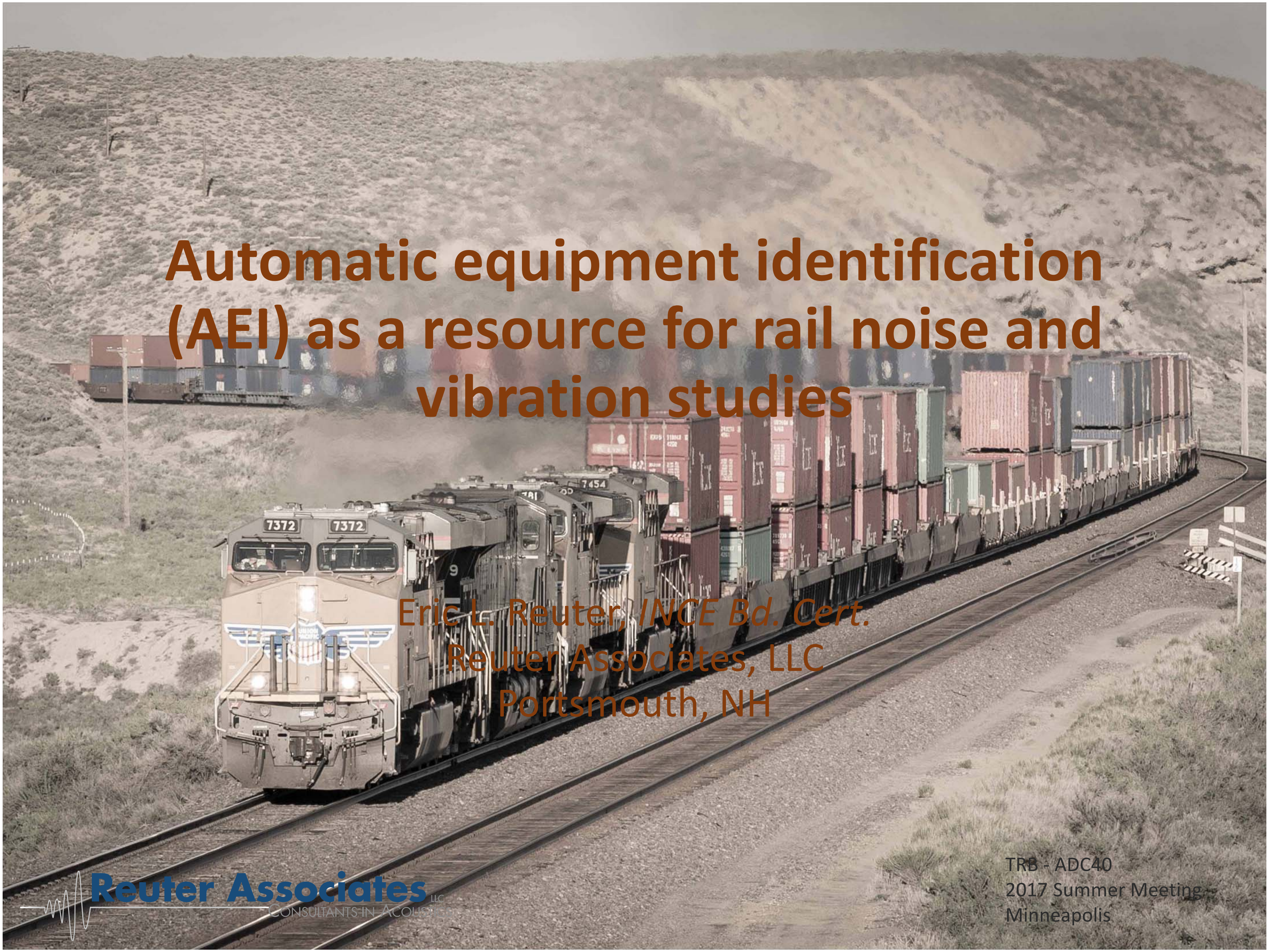

Automatic equipment identification (AEI) as a resource for rail noise and vibration studies

Eric L. Reuter, *INCE Bd. Cert.*
Reuter Associates, LLC
Portsmouth, NH

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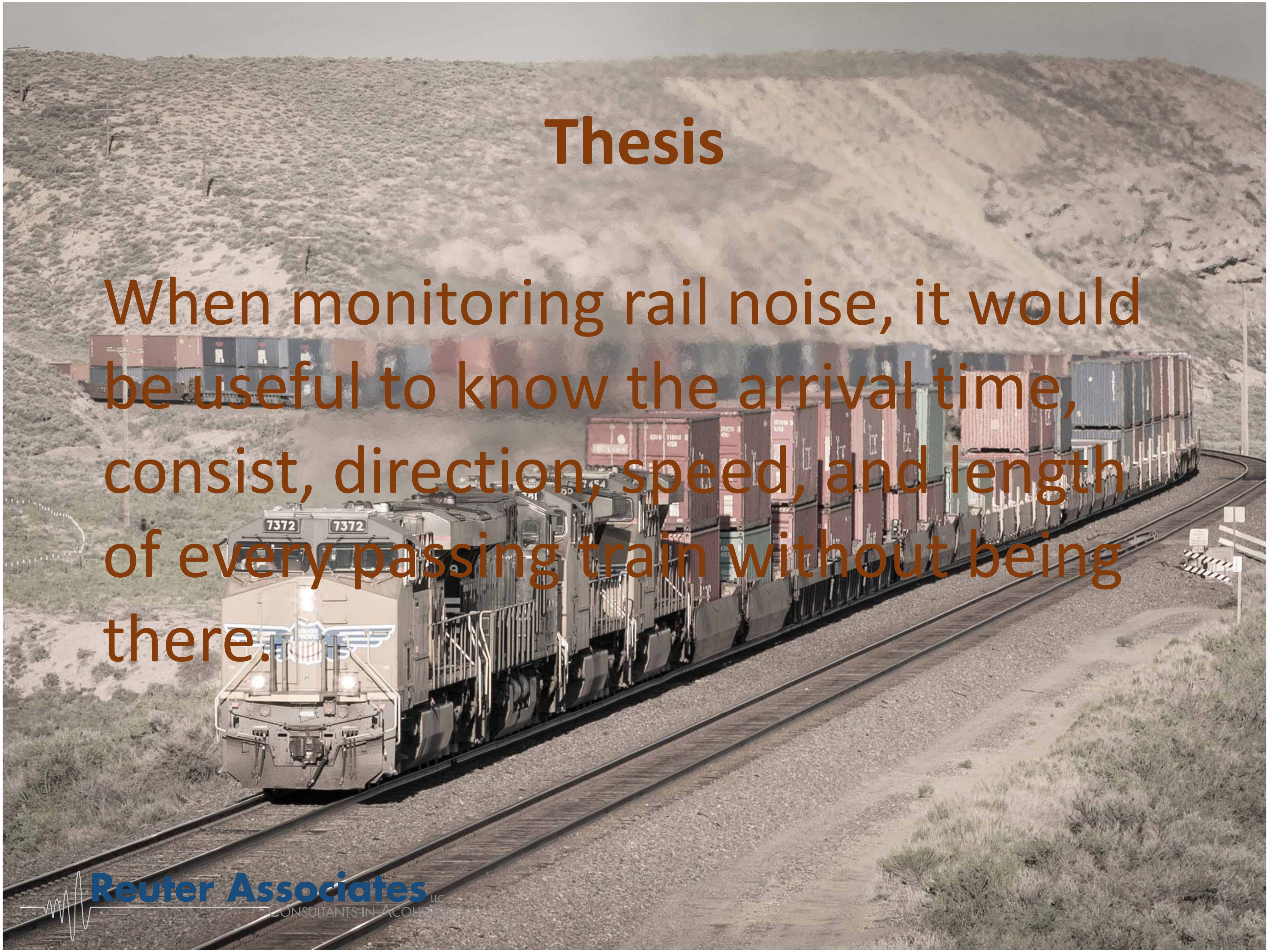
TRB - ADC40
2017 Summer Meeting --
Minneapolis

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.



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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

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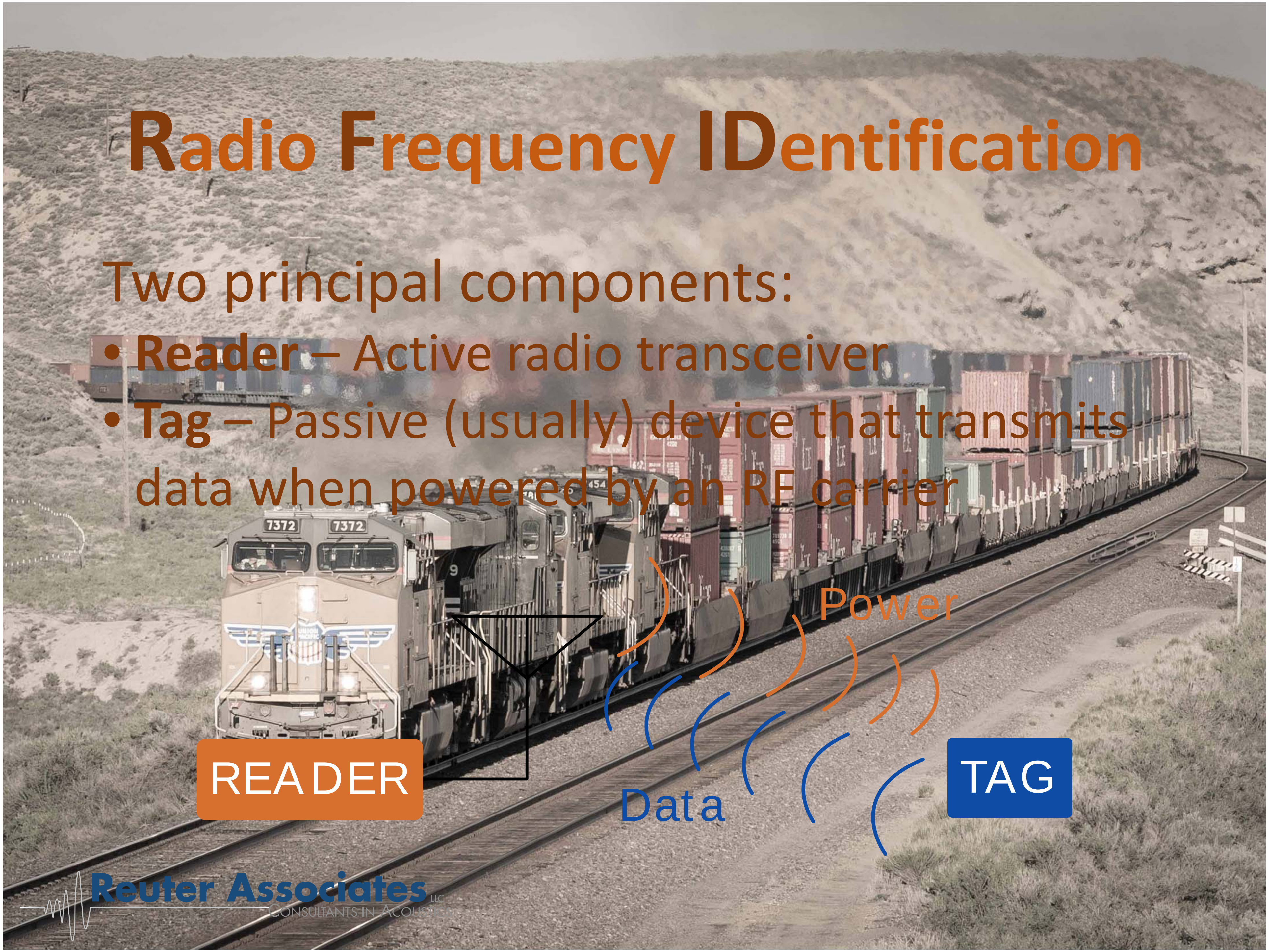
Radio Frequency IDentification

Two principal components:

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



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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

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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.

AEI Performance

ERP Calculatation

ERP = transmitter power + antenna gain

Example:

2 W transmitter power into

9 dBi antenna (dB re: isotropic)

ERP = 2 W * $10^{0.9}$ = <u>15.9 W</u>

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)

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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.

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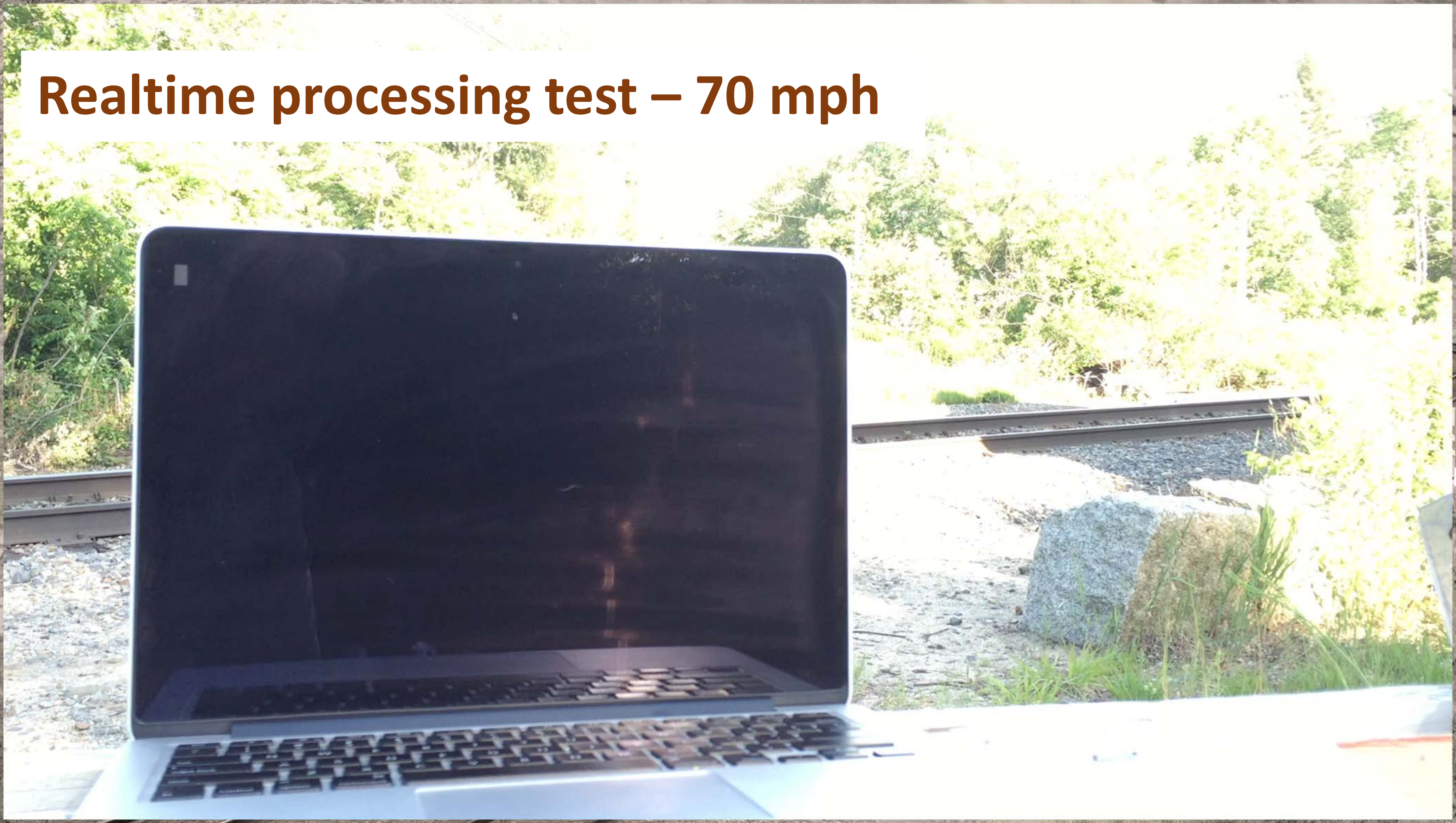
Experimental Setup

Realtime processing test – 70 mph



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Experimental Setup

Triggering

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

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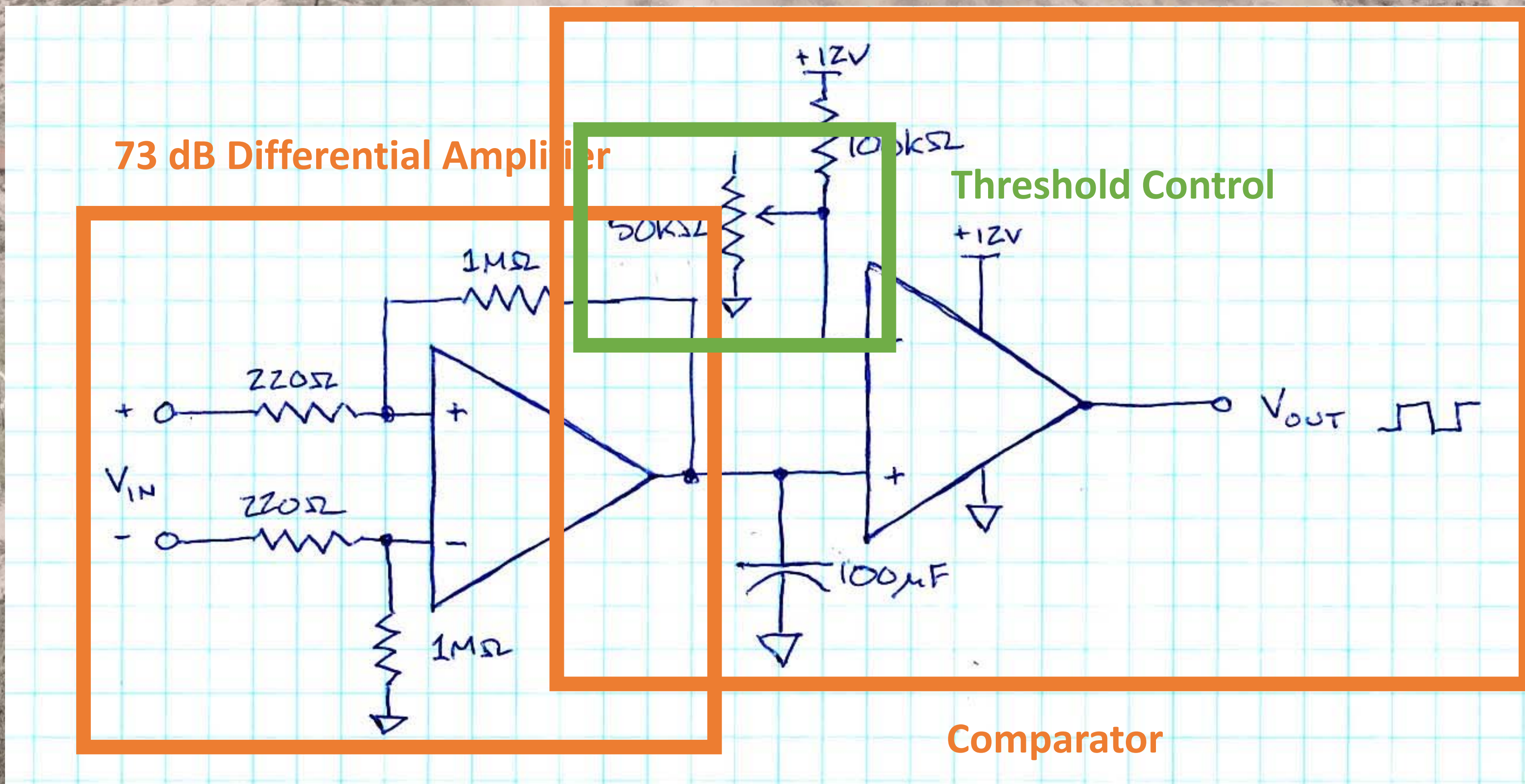
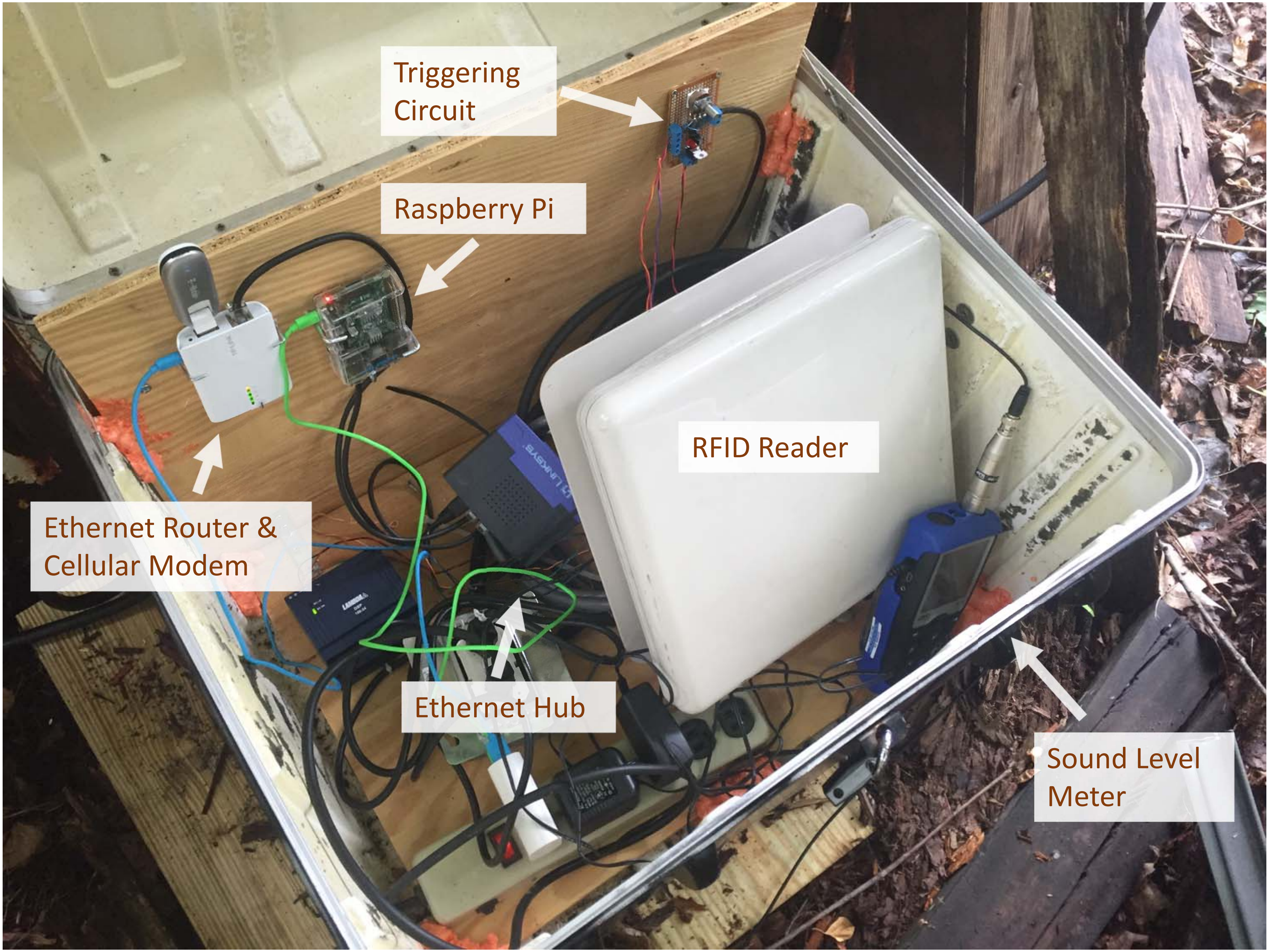
Experimental Setup

Triggering Circuit




Triggering Circuit
Raspberry Pi
RFID Reader
Ethernet Router & Cellular Modem
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=0x9E44F94421AED01B90000000002E8738, first=2016-08-18T23:04:21.631
event.tag.arrive tag_id=0x9F7C28C51B8CCF1F90000000002E8738, first=2016-08-18T23:04:23.245
event.tag.arrive tag_id=0x9F6710C2110AD2139000000002E8738, first=2016-08-18T23:04:24.993
event.tag.arrive tag_id=0x9F73F5929B4CD2179000000002E8738, first=2016-08-18T23:04:26.704
event.tag.arrive tag_id=0x9E286B2FACD4C817900000000000000330, first=2016-08-18T23:04:28.461
event.tag.arrive tag_id=0x9E286B2FAE34C817900000000000000330, first=2016-08-18T23:04:30.165
event.tag.arrive tag_id=0x9F6710C21104D21F90000000002E8738, first=2016-08-18T23:04:31.938
event.tag.arrive tag_id=0x9F73F5929DC0D2139000000002E8738, first=2016-08-18T23:04:33.752
event.tag.arrive tag_id=0x9F73F5929B1AD2179000000002E8738, first=2016-08-18T23:04:35.666
event.tag.arrive tag_id=0x9E286B2FAD5EC81F900000000000000330, first=2016-08-18T23:04:37.485
event.tag.arrive tag_id=0x9B73F59270C2D21B90000000002E8738, first=2016-08-18T23:04:39.419
event.tag.arrive tag_id=0x9F6710C21156D21B90000000002E8738, first=2016-08-18T23:04:41.367
event.tag.arrive tag_id=0x37218902FD31800B0000000000000338, first=2016-08-18T23:04:43.106
```

tag_id=0x37218902FD31800B0000000000000338

32 digits (hex) = 128 bits

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Data : Decoded

10011 EQUIP GRP = $\boxed{\text{RAILCAR}}$
11 TAG TYPE = $\boxed{\text{RAIL}}$
0111101011001101110 INITIAL 251502
01010000100110110011 CAR # $\boxed{330163}$
1 RIGHT SIDE
000 011010010 210 dM = $\boxed{\text{69 FT}}$
00011 $\boxed{\text{\# AXLES}}$
00
11 CHECKSUM & FRAME MRKR
64 1
001 BEARING TYPE = $\boxed{\text{ROLLER}}$
0000 PLATFORM = $\boxed{\text{NOT ARTICULATED}}$
00000000000000000000000 SPARE
94-96 000
000000000
101110100001
110011
10
00
RESERVED

12 M
20 T
26 Z
24 X

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Data : Formatted

```
event.tag.arrive tag_id=0x2AEA4C8004F6B413D0F00144002E8730, first=2016-08-18T23:04:20.334
event.tag.arrive tag_id=0x9E44F94421AED01B90000000002E8738, first=2016-08-18T23:04:21.631
event.tag.arrive tag_id=0x9F7C28C51B8CCF1F90000000002E8738, first=2016-08-18T23:04:23.245
event.tag.arrive tag_id=0x9F6710C2110A421B90000000002E8738, first=2016-08-18T23:04:24.993
event.tag.arrive tag_id=0x9F73F5929B4CD21790000000002E8738, first=2016-08-18T23:04:26.704
event.tag.arrive tag_id=0x9E286B2FACD4C8179000000000000330, first=2016-08-18T23:04:28.461
event.tag.arrive tag_id=0x9E286B2FAE3468179000000000000330, first=2016-08-18T23:04:30.165
event.tag.arrive tag_id=0x9F6710C21104D21F90000000002E8738, first=2016-08-18T23:04:31.938
event.tag.arrive tag_id=0x9F73F5929DC0D21390000000002E8738, first=2016-08-18T23:04:33.752
event.tag.arrive tag_id=0x9F73F5929B1AD21790000000002E8738, first=2016-08-18T23:04:35.666
event.tag.arrive tag_id=0x9E286B2FAD5E481F9000000000000330, first=2016-08-18T23:04:37.485
event.tag.arrive tag_id=0x9B73F59270C2D21B90000000002E8738, first=2016-08-18T23:04:39.419
event.tag.arrive tag_id=0x9F6710C21156D21B90000000002E8738, first=2016-08-18T23:04:41.367
event.tag.arrive tag_id=0x137688992FD3140000000000000331, first=2016-08-18T23:04:43.106
```

```
Train 51 2016-08-18 23:04:20.334000

1   LOC MEC  317    R 59.0 ft 4 axles 23:04:20.334
2   CAR DOWX 67691  R 68.2 ft 4 axles 23:04:21.631
3   CAR TTZX 83683  L 67.9 ft 4 axles 23:04:23.245
4   CAR SRIX 33858  R 68.9 ft 4 axles 23:04:24.993
5   CAR TILX 304851 L 68.9 ft 4 axles 23:04:26.704
6   CAR CBTX 781109 L 65.6 ft 4 axles 23:04:28.461
7   CAR CBTX 781197 L 65.6 ft 4 axles 23:04:30.165
8   CAR SRIX 33857  L 68.9 ft 4 axles 23:04:31.938
9   CAR TILX 305008 L 68.9 ft 4 axles 23:04:33.752
10  CAR TILX 304838 R 68.9 ft 4 axles 23:04:35.666
11  CAR CBTX 781143 R 65.6 ft 4 axles 23:04:37.485
12  CAR TILX 302128 R 68.9 ft 4 axles 23:04:39.419
13  CAR SRIX 33877  R 68.9 ft 4 axles 23:04:41.367
14  EOT PARX 48972

Total Length = 874.1 ft
Total Time = 22.772 s
Speed = 26.2 mph
```

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CONSULTANTS IN ACOUSTICS

Data : Formatted

```
2016-09-17 16:32:57 AMTK 22    WB 1+6    564 ft  28 axles 43 mph
2016-09-17 18:31:48 AMTK 139   EB 2+5    550 ft  28 axles 47 mph
2016-09-17 20:42:30 AMTK 140   WB 1+6    550 ft  28 axles 44 mph
2016-09-17 20:59:58 CSXT 5107  EB 3+102 6085 ft 426 axles 23 mph
2016-09-17 21:28:17 AMTK 22    EB 1+6    564 ft  28 axles 49 mph
2016-09-17 22:17:20 MEC  611   WB 3+101 5751 ft 420 axles 21 mph CSXE 44973
2016-09-18 00:43:03 AMTK 140   EB 1+6    550 ft  28 axles 46 mph
2016-09-18 07:06:47 CSXT 3285  WB 4+110 8361 ft 510 axles  8 mph CSXE 58355
2016-09-18 09:35:16 AMTK 22    WB 1+6    564 ft  28 axles 52 mph
2016-09-18 10:56:02 AMTK 821   EB 1+6    550 ft  28 axles 49 mph
2016-09-18 13:16:31 AMTK 22    EB 1+6    564 ft  28 axles 47 mph
2016-09-18 14:24:41 AMTK 90220 WB 2+5    550 ft  28 axles 37 mph
2016-09-18 16:25:02 AMTK 22    WB 1+6    564 ft  28 axles 44 mph
2016-09-18 16:43:53 CSXT 931   EB 2+95  5986 ft 392 axles 26 mph CSXE 48521
2016-09-18 18:28:11 AMTK 139   EB 2+5    550 ft  28 axles 46 mph
2016-09-18 20:43:20 AMTK 821   WB 1+6    550 ft  28 axles 43 mph
2016-09-18 21:28:20 AMTK 22    EB 1+6    564 ft  28 axles 49 mph
2016-09-19 00:42:38 AMTK 821   EB 1+6    550 ft  28 axles 45 mph
2016-09-19 02:57:14 MEC  614   EB 4+61  2994 ft 268 axles 26 mph
2016-09-19 06:10:14 CSXT 3068  WB 2+69  5633 ft 328 axles 20 mph WRE  97812
2016-09-19 06:31:42 AMTK 22    WB 1+6    564 ft  28 axles 51 mph
2016-09-19 09:14:08 AMTK 821   WB 1+5    465 ft  24 axles 47 mph
2016-09-19 10:42:24 AMTK 22    EB 1+6    564 ft  28 axles 48 mph
2016-09-19 13:00:19 AMTK 821   EB 1+5    465 ft  24 axles 51 mph
2016-09-19 14:06:43 AMTK 90220 WB 2+5    550 ft  28 axles 48 mph
2016-09-19 15:03:57 MEC  610   EB 2+54  3386 ft 228 axles 26 mph
```

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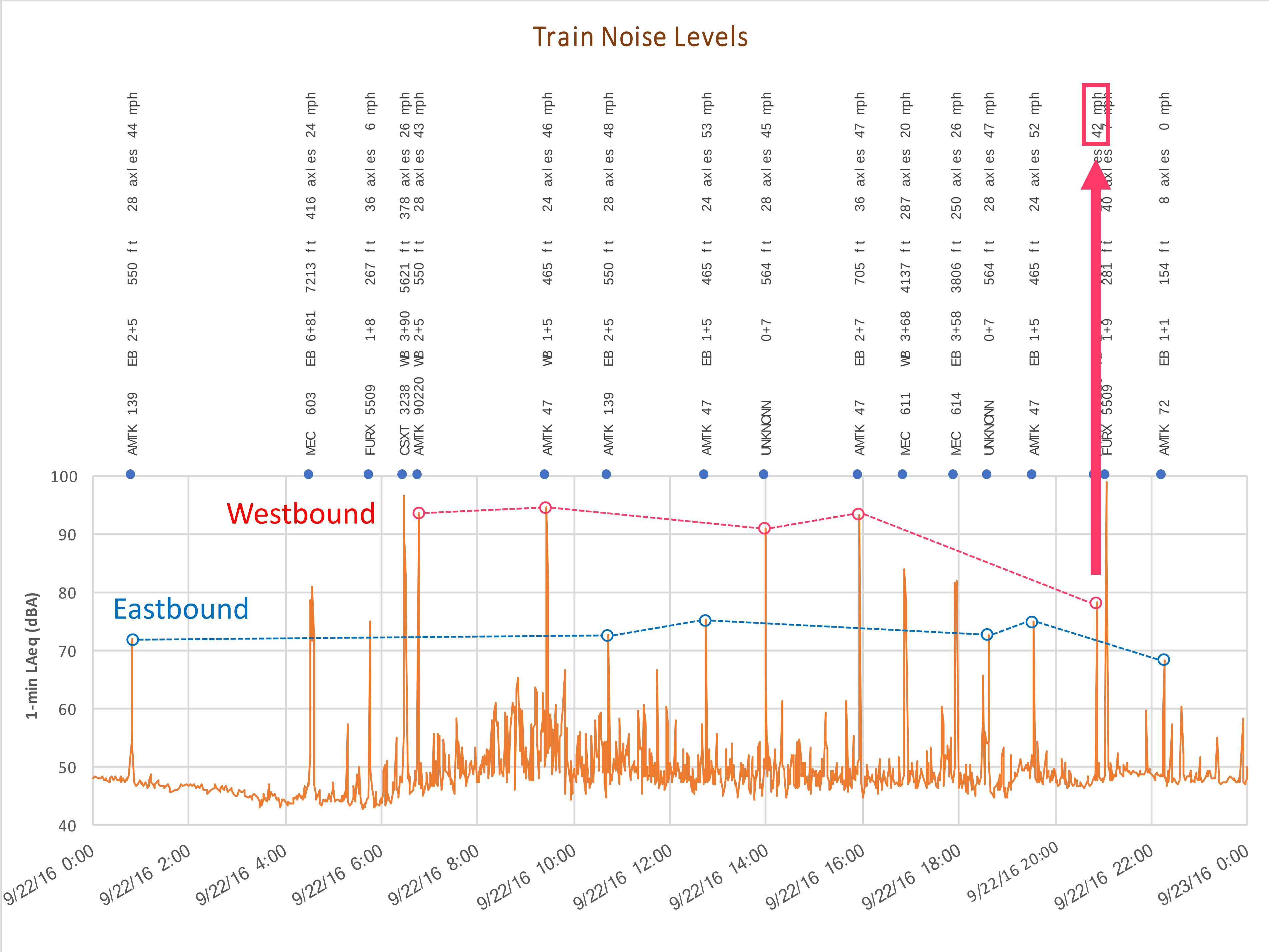
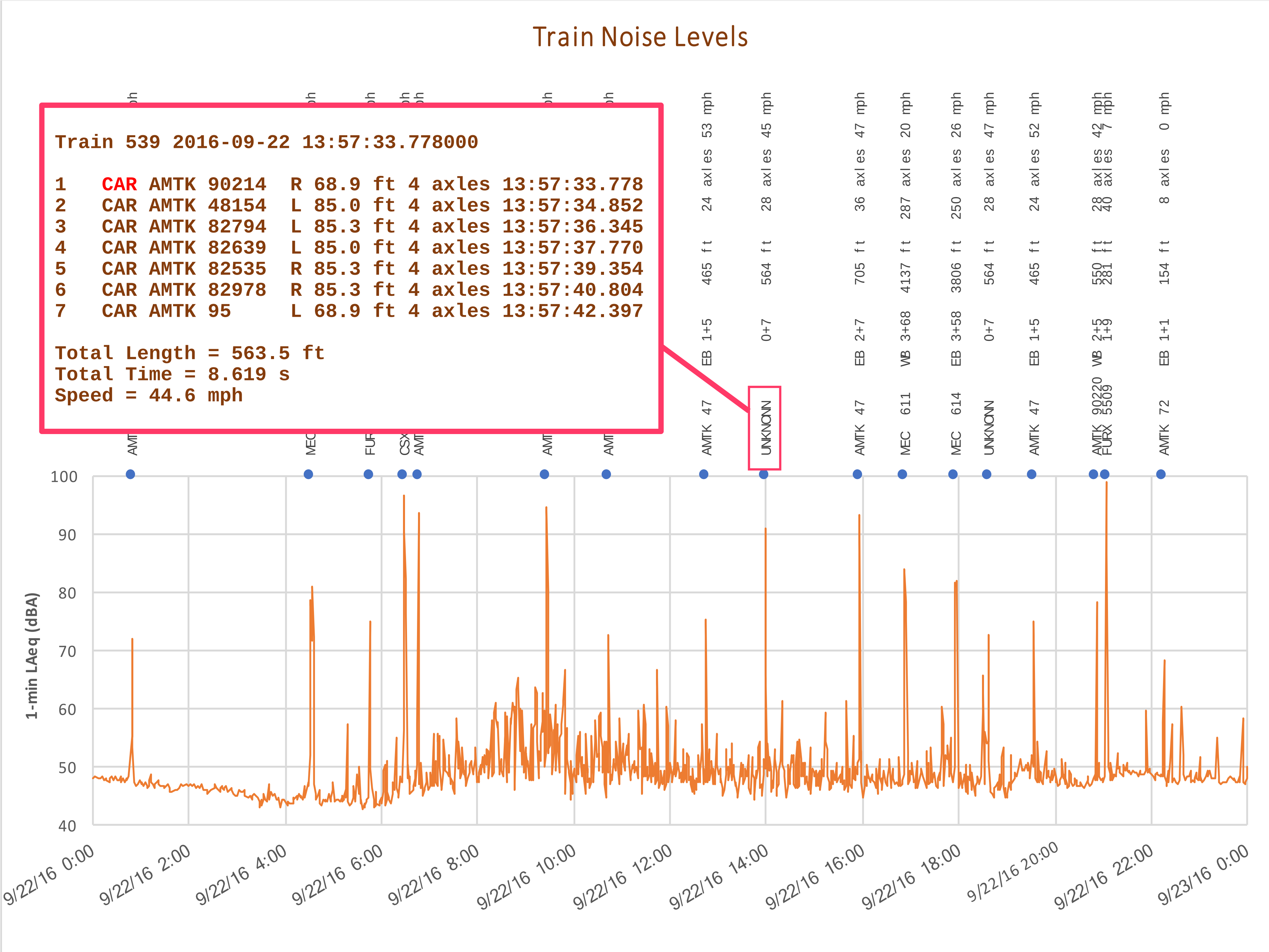
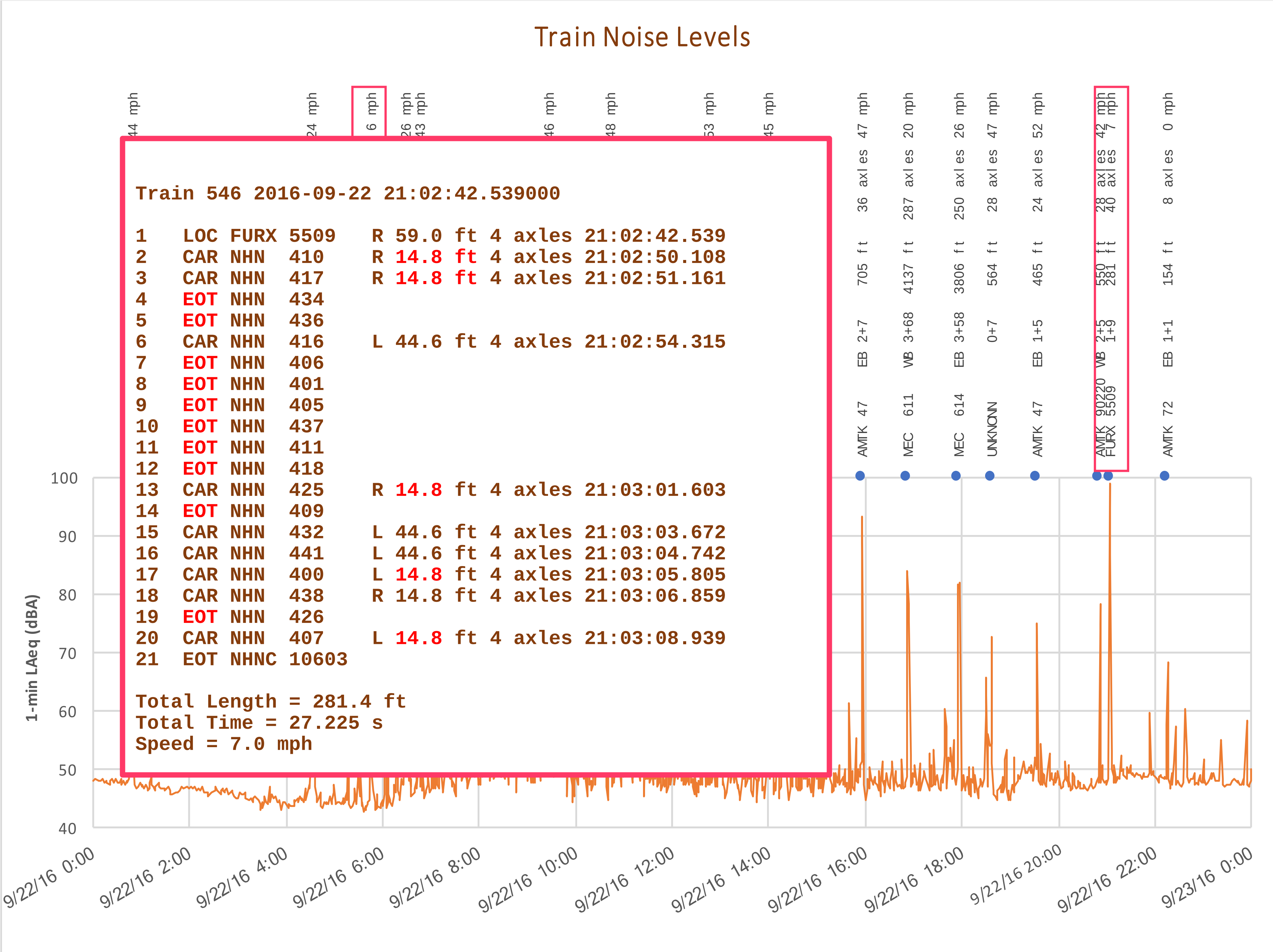
CONSULTANTS IN ACOUSTICS



Train Noise Levels
Westbound
Eastbound
1-min LAeq (dBA)
100
90
80
70
60
50
40
9/22/16 0:00
9/22/16 2:00
9/22/16 4:00
9/22/16 6:00
9/22/16 8:00
9/22/16 10:00
9/22/16 12:00
9/22/16 14:00
9/22/16 16:00
9/22/16 18:00
9/22/16 20:00
9/22/16 22:00
9/23/16 0:00
AMTK 139 EB 2+5 550 ft 28 axles 44 mph
MEC 603 EB 6+81 7213 ft 416 axles 24 mph
FURX 5509 1+8 267 ft 36 axles 6 mph
CSXT 3238 WB 3+90 5621 ft 378 axles 26 mph
AMTK 90220 WB 2+5 550 ft 28 axles 43 mph
AMTK 47 WB 1+5 465 ft 24 axles 46 mph
AMTK 139 EB 2+5 550 ft 28 axles 48 mph
AMTK 47 EB 1+5 465 ft 24 axles 53 mph
UNKNOWN 0+7 564 ft 28 axles 45 mph
AMTK 47 EB 2+7 705 ft 36 axles 47 mph
MEC 611 WB 3+68 4137 ft 287 axles 20 mph
MEC 614 EB 3+58 3806 ft 250 axles 26 mph
UNKNOWN 0+7 564 ft 28 axles 47 mph
AMTK 47 EB 1+5 465 ft 24 axles 52 mph
42 mph
FURX 5509 1+9 281 ft 40 axles
AMTK 72 EB 1+1 154 ft 8 axles 0 mph



Train Noise Levels
Train 539 2016-09-22 13:57:33.778000
1 CAR AMTK 90214 R 68.9 ft 4 axles 13:57:33.778
2 CAR AMTK 48154 L 85.0 ft 4 axles 13:57:34.852
3 CAR AMTK 82794 L 85.3 ft 4 axles 13:57:36.345
4 CAR AMTK 82639 L 85.0 ft 4 axles 13:57:37.770
5 CAR AMTK 82535 R 85.3 ft 4 axles 13:57:39.354
6 CAR AMTK 82978 R 85.3 ft 4 axles 13:57:40.804
7 CAR AMTK 95 L 68.9 ft 4 axles 13:57:42.397
Total Length = 563.5 ft
Total Time = 8.619 s
Speed = 44.6 mph
AMTK 47 EB 1+5 465 ft 24 axles 53 mph
UNKNOWN 0+7 564 ft 28 axles 45 mph
AMTK 47 EB 2+7 705 ft 36 axles 47 mph
MEC 611 WB 3+68 4137 ft 287 axles 20 mph
MEC 614 EB 3+58 3806 ft 250 axles 26 mph
UNKNOWN 0+7 564 ft 28 axles 47 mph
AMTK 47 EB 1+5 465 ft 24 axles 52 mph
AMTK 90220 WB 2+5 550 ft 28 axles 42 mph
FURX 5509 1+9 281 ft 40 axles 7 mph
AMTK 72 EB 1+1 154 ft 8 axles 0 mph
1-min LAeq (dBA)
100
90
80
70
60
50
40
9/22/16 0:00
9/22/16 2:00
9/22/16 4:00
9/22/16 6:00
9/22/16 8:00
9/22/16 10:00
9/22/16 12:00
9/22/16 14:00
9/22/16 16:00
9/22/16 18:00
9/22/16 20:00
9/22/16 22:00
9/23/16 0:00


Train Noise Levels
44 mph
24 mph
6 mph
26 mph
43 mph
46 mph
48 mph
53 mph
45 mph
AMTK 47 EB 2+7 705 ft 36 axles 47 mph
MEC 611 WB 3+68 4137 ft 287 axles 20 mph
MEC 614 EB 3+58 3806 ft 250 axles 26 mph
UNKNOWN 0+7 564 ft 28 axles 47 mph
AMTK 47 EB 1+5 465 ft 24 axles 52 mph
AMTK 90220 WB 2+5 550 ft 28 axles 42 mph
FURX 5509 1+9 281 ft 40 axles 7 mph
AMTK 72 EB 1+1 154 ft 8 axles 0 mph
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
1-min LAeq (dBA)
100
90
80
70
60
50
40
9/22/16 0:00
9/22/16 2:00
9/22/16 4:00
9/22/16 6:00
9/22/16 8:00
9/22/16 10:00
9/22/16 12:00
9/22/16 14:00
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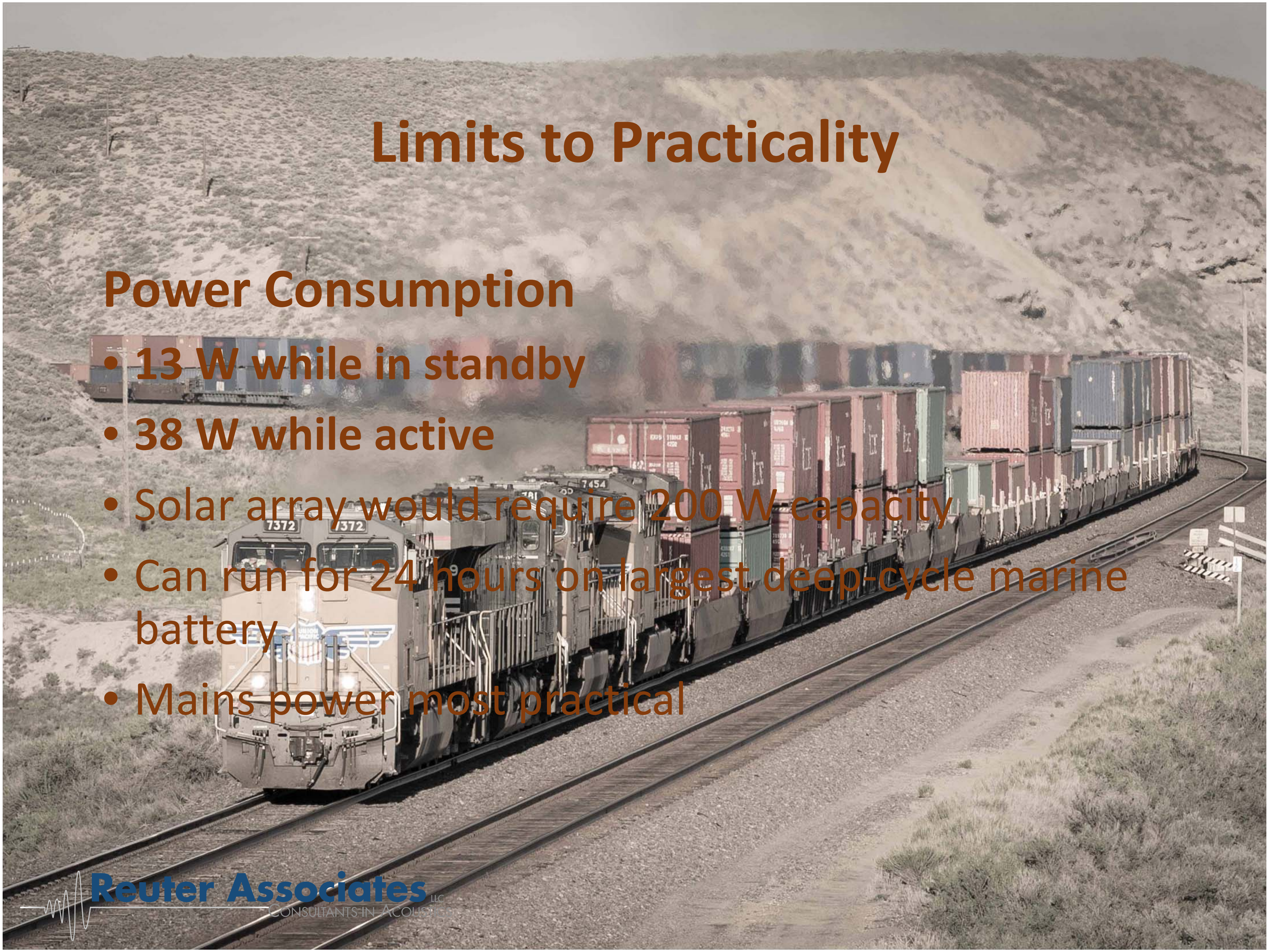
9/22/16 18:00
9/22/16 20:00
9/22/16 22:00
9/23/16 0:00



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

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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"

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Limits to Practicality

Railroads don't like private readers

- Security concerns
- ClipperData Fiasco ->
- Make sure you're not on railroad property!

Trains

Login or Register | Customer Service

Home / News / News Wire / FCC fines clandestine train tracking company

14

FCC fines clandestine train tracking company

Federal communications agency says company had incorrect licensing to install special readers along railroad rights-of-way

By Justin Franz | September 27, 2016

RELATED TOPICS: CLASS 1 FREIGHT RAILROADS | COMMODITIES | SECURITY | CRIME

WASHINGTON D.C. — A New York-based data-company must pay a $195,000 fine a year after it was caught setting up unauthorized freight car trackers near rights-of-way across the country.

What's in a picture? In this one, a brown-painted automatic equipment identification, or AEI, reader barely pokes out of a slope along a Conrail right-of-way in New Jersey. A company that installed this reader received a $195,000 fine from the Federal Communications Commissions for having incorrect licensing for tracking freight trains near rights-of-way.

On Aug. 29, the enforcement bureau of the Federal Communications Commission announced it had entered into an agreement with ClipperData LLC for violating federal communications law because it was installing and operating automatic equipment identification, or AEI, readers without acquiring the correct license.

In September 2015, *Trains* News Wire first reported that the Association of American Railroads' Railway Alert

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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.