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New York State Department of Transportation

Centerline Audible Roadway Delineators (CARDs)
NYS Route 77 & NYS Route 441

NOISE ANALYSIS REPORT

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INTRODUCTION

The New York State Department of Transportation (NYSDOT) now considers Centerline Audible Roadway Delineators (CARDs) along eligible roads across New York State. The CARDs, also called centerline rumble strips, located along the pavement markings dividing opposite-direction travel lanes, are a low-cost measure designed to reduce dangerous head-on and opposite-direction sideswipe crashes. Federal Highway Administration (FHWA) officials have stated that safety is a top priority, and centerline rumble strips are among the most important and cost-effective safety devices available today to prevent cross-over crashes on our roadways. However, there are concerns regarding the noise associated with the installation of these centerline rumble strips. The purpose of this noise study is to investigate the external to the vehicle noise of the CARDs on two-lane rural and suburban highways by identifying the characteristics of the sound generated when the tire of a motor vehicle passes over (or overrides) the CARDs, and to quantify the sound level increase between the CARDs overrides and a standard vehicle pass-by.

NOISE THEORY

Three characteristics of noise have been identified as being important to analyzing the subjective community response to noise:

- Intensity
- Frequency
- The time-varying characteristics of the noise.

Intensity is a measure of the magnitude or energy of the sound, and is directly related to pressure level. The human ear is capable of sensing a wide range of pressure levels. Pressure levels are expressed in terms of a logarithmic scale with units called decibels (dB). Generally, as the intensity of a noise increases, it is judged to be more annoying.

Frequency is a measure of the tonal qualities of sound. The spectrum of frequencies provides the identity of a sound. People are most sensitive to sounds in the middle to high frequencies, therefore higher frequencies tend to cause more annoyance. This sensitivity led to the use of the A-weighted sound level, which provides a single number measure that weighs different frequencies of the frequency spectrum in a manner similar to the sensitivity of the human ear. Thus, the A-weighted sound level in decibels (dB(A)) provides a simple measure of intensity and frequency that correlates well with the human response to environmental noise.

Environmental noise is rarely constant with time. If noise is intermittent, irregular, or rhythmic rather than steady, it is quite often denoted as being less tolerable. It is necessary to use a method of measure that will account for this time-varying nature of sound when studying environmental noise. The equivalent sound pressure level (L_{eq}) is defined as the continuous steady sound level that would have the same total A-weighted sound energy as the real fluctuating sound measured over the same period of time. These three characteristics combine to form a single descriptor (L_{eq} in dB(A)) that helps to evaluate human response to noise, and has also been chosen for use in this study. Table 1 provides examples of common outdoor and indoor noises and their corresponding noise levels in decibels.

Table 1: Common Outdoor And Indoor Noise Levels[1]		
Common Outdoor Noise Levels	**Noise Level Decibels**	**Common Indoor Noise Levels**
	110	Rock Band
Jet Fly Over at 1,000 feet	100	Inside Subway Train (N.Y.)
Gas Lawn Mower at 3 feet		
Diesel Truck at 50 feet	90	Food Blender at 3 feet
Noisy Urban Daytime	80	Garbage Disposal at 3 feet/ Shouting at 3 feet
Gas Lawn Mower at 100 feet	70	Vacuum Cleaner at 3 feet
Commercial Area		Normal Speech at 3 feet
	60	
		Large Business Office
Quiet Urban Daytime	50	Dishwasher Next Room
Quiet Urban Nighttime	40	Small Theater, Large Conference Room (Background)
Quiet Suburban Nighttime		Library
	30	
Quiet Rural Nighttime		Bedroom at Night, Concert Hall (Background)
	20	
		Broadcast & Recording Studio
	10	Threshold of Hearing
	0	

1. Adapted from *Guide on Evaluation and Attenuation of Traffic Noise* AASHTO-1974

Research indicates that noise level changes of up to 3 dB(A) are barely perceptible, while a change of 5 dB(A) is considered noticeable by most people. A 10 dB(A) increase is usually perceived as a doubling of loudness, and similarly, when a sound level is reduced by 10 dB(A) this is perceived as one-half the loudness.

NYSDOT NOISE POLICY

In response to the issues associated with highway traffic noise, the Federal Highway Administration (FHWA) developed a highway noise regulation as required by the Federal-Aid Highway Act of 1970 (Public Law 91-605, 84 Stat. 1713). The noise regulation, “Procedures for Abatement of Highway Traffic Noise and Construction Noise” (23 CFR 772), requires highway agencies, such as the NYSDOT, to investigate traffic noise impacts in areas adjacent to all Federal or Federal-aid highway projects authorized under Title 23, and consider abatement if the agency identifies impacts. The noise regulation also requires highway agencies to maintain written statewide noise policies. Noise policies specify how each highway agency will implement the noise regulation, and must be approved by FHWA.

It is NYSDOT policy to address traffic noise concerns resulting from transportation projects by complying with FHWA regulations for Federal-aid projects and by also applying the policy and procedures to State-funded projects. In accordance with 23 CFR 772.7(b), the Environmental Manual Section (Section 4.4.18) constitutes NYSDOT noise policy.

Section 772.5 of the noise regulation establishes three types of projects. All projects will fall into one of these types:

Type I Project.

(1) The construction of a highway on new location; or,

(2) The physical alteration of an existing highway where there is either:

(i) Substantial Horizontal Alteration. A project that halves the distance between the traffic noise source and the closest receptor between the existing condition to the future build condition; or,

(ii) Substantial Vertical Alteration. A project that removes shielding, thereby exposing the line-of-sight between the receptor and the traffic noise source. This is done by either altering the vertical alignment of the highway or by altering the topography between the highway traffic noise source and the receptor; or,

(3) The addition of a through-traffic lane(s). This includes the addition of a through traffic lane that functions as a High Occupancy Vehicle (HOV) lane, High-Occupancy Toll (HOT) lane, bus lane, or truck climbing lane; or,

(4) The addition of an auxiliary lane (see definition in Chapter 2 of NYSDOT Highway Design Manual), except for when the auxiliary lane is a turn lane; or,

(5) The addition or relocation of interchange lanes or ramps added to a quadrant to complete an existing partial interchange; or,

(6) Restriping existing pavement for the purpose of adding a through-traffic lane or an auxiliary lane; or,

(7) The addition of a new or substantial alteration of a weigh station, rest stop, ride share lot or toll plaza.

If a project is determined to be a Type I project per Section 772.5, then the entire project area as defined in the environmental document is a Type I noise project.

Type II Project. A project for noise abatement on an existing highway. Note that the development and implementation of Type II projects shall not be considered without separate additional funding by the Legislature for this specific purpose.

Type II noise abatement measures shall be approved only for projects that were approved before November 28, 1995 or are proposed along land where substantial construction predated the existence of any highway. The granting of a building permit must have occurred prior to right-of-way acquisition for the original highway. Further, noise abatement measures shall not be approved at locations where such measures were previously determined not to be reasonable and feasible for a Type I project. It is the responsibility of the respective NYSDOT Regional Offices to be certain that appropriate local officials in their jurisdiction are aware of these requirements.

Type III Project. A highway project that does not meet the classifications of a Type I or Type II project. Hypothetical projects may include the construction of bicycle or pedestrian facilities or the resurfacing of existing highway pavement. Type III projects do not require a noise analysis or consideration of noise abatement measures under 23CFR 772.

Noise abatement criteria (NAC) developed by the Federal Highway Administration (FHWA), define limits for determining impacts due to traffic noise levels in areas based on defined land use. These are summarized in Table 2. Federal regulations (23 CFR 772) define traffic noise impacts as "occurring when the predicted traffic noise levels approach or exceed the NAC, or when the predicted future loudest hour levels are substantially higher than the existing levels." In practice the NYSDOT definition of this regulation quantifies "approach" as within 1 dB(A), and "substantially higher" as 6 dB(A) or greater. Therefore, an impact is considered to occur if the predicted future noise level is one decibel lower, equals or exceeds the NAC, or is 6 dB(A) or more above the existing noise level. If an impact is identified, abatement measures for reducing or eliminating the impact must be considered.

TABLE 2 FHWA NOISE ABATEMENT CRITERIA (NAC)		
Activity Category	**L_{eq}(h)**	**Activity Description**
A	57 (Exterior)	Lands on which serenity and quiet are of extraordinary significance and serve and important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B	67 (Exterior)	Residential
C	67 (Exterior)	Active sport areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section 4(f) sites, schools, television studios, trails, and trail crossings.
D	52 (Interior)	Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios.
E	72 (Exterior)	Hotels, motels, offices, restaurants/bars and other developed lands, properties or activities not included in A-D or F.
F	---	Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical), and warehousing.
G	---	Undeveloped lands that are not permitted

Reference: NYSDOT TEM 4.4.18.5.2.1 Table 1

The installation of CARDs does not meet the classifications of a Type I or Type II project. Instead, CARDs could be categorized as a Type III project, which does not require a noise analysis or consideration of noise abatement measures under 23 CFR 772. However, NYSDOT policy does allow for discretionary consideration of noise measurement and impact analysis on Type III projects that do not require analysis under 23 CFR 772. Normally these special considerations would follow the methodology outlined in NYSDOT's the Environmental Manual but the CARDs will not follow the noise measurement and impact analysis of typical highway projects. The CARDs overrides are considered a single event occurrence, which are evaluated using one-second measurements ($L_{eq(1\text{-second})}$), unlike highway traffic that is evaluated over a longer continuous one-hour measurement period of time ($L_{eq(1\text{-hour})}$). The CARDs study will not determine impacts as defined by NYSDOT noise policy, instead it will identify the characteristics of the sound generated when a motor vehicle overrides the CARDs, and quantify the sound level increase between a CARDs-override and a standard vehicle pass-by.

SITE SELECTION / SITE CONDITIONS

The CARDs have been installed state-wide in various NYSDOT Regions. For this study, two (2) separate locations within NYSDOT Region 4 have been chosen as typical analysis sites. Bergmann Associates established contact with property owners before conducting noise study measurements at the identified locations to gain access and set up measurement apparatus. The first site (NYS77) is in Wyoming County along NYS Route 77, which is considered a rural principal arterial functional classification. The measurements were taken at the Salon 77 property located approximately 2500 feet south of Cohocton Road in Pembroke NY. This site was selected along a straight alignment and relatively flat (less than 1% grade) portion of the highway (with no horizontal curve or significant vertical grade change) within a passing zone in both northbound and southbound travel directions. The second site (NYS441) is in Monroe County along NYS Route 441, which is considered an urban principal arterial functional classification. The measurements were taken at the Penfield Fire Co. Station #3 property located approximately 1000 feet east of Harris Road in Penfield NY. This site was selected along a portion of the highway that contained both a horizontal curve and a significant vertical grade change (greater than 1%) within a no-passing zone that transitioned into a passing zone for the eastbound travel direction. The two samples with different alignment and grade types provide a testing sample of varying geometric roadway conditions that can be evaluated for potential noise impacts. Location figures and photographs of the CARDs for the NYS Route 77 and the NYS Route 441 sites are provided below.

Figure 1 – NYS Route 77 Location Map

Figure 2 – NYS Route 441 Location Map

Figure 3 – NYS Route 77 (Looking South)

Figure 4 – NYS Route 441 (Looking West)

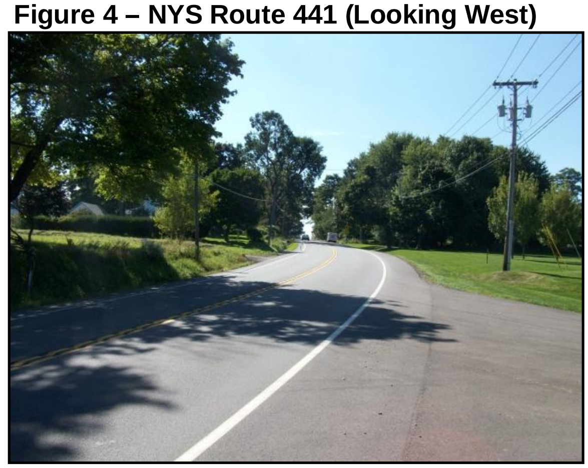
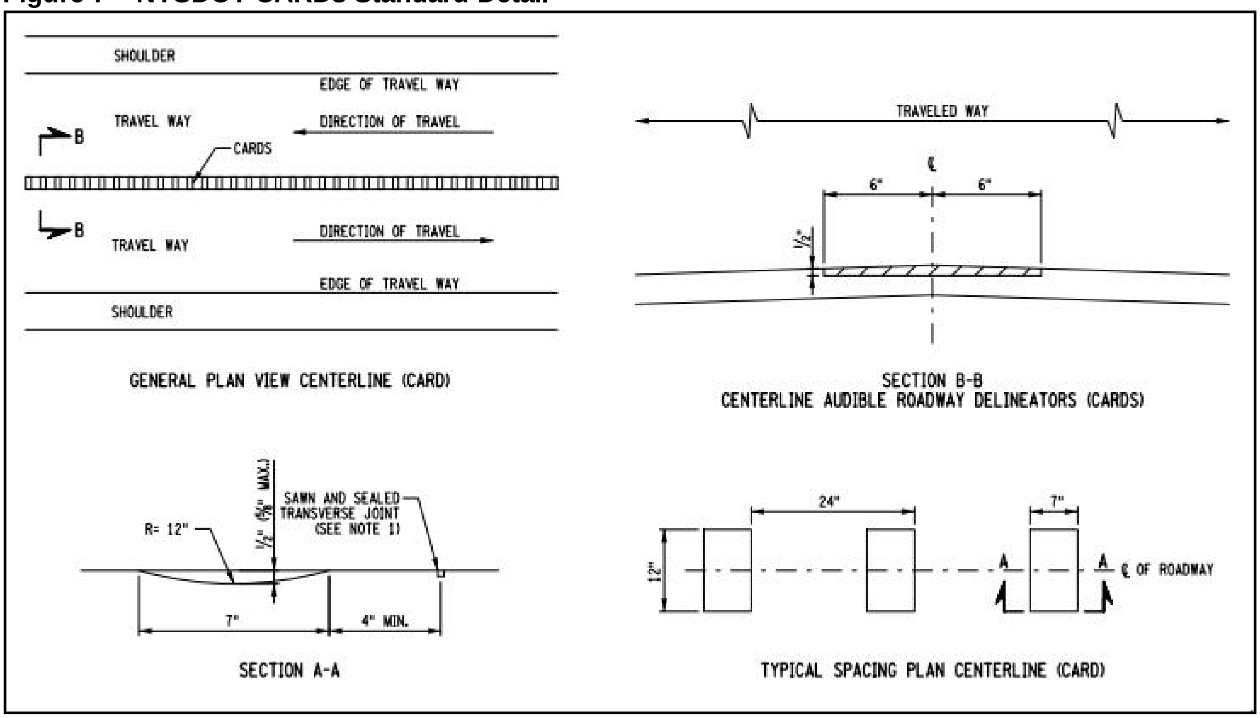


Figure 5 – NYS Route 77 CARDs

Figure 6 – NYS Route 441 CARDs

The CARDs dimensions and configuration are based on the NYSDOT 649-01 Standard Sheet, as shown below in Figure 7. Actual field measurements at the analysis sites were within the NYSDOT CARDs specification.

Figure 7 – NYSDOT CARDs Standard Detail



NOISE LEVEL MEASUREMENTS

Noise measurements were taken as part of a twofold investigative process that included: 1) identifying the characteristics of the sound generated when a motor vehicle overrides the CARDs; and 2) to provide a basis for quantifying the sound level increase between the CARDs override and a vehicle pass-by that does not override the CARDs. On-site field measurements were performed at the analysis locations (NYS77 and NYS441) on September 19, 2013; and follow-up measurements were taken at the NYS Route 441 site on September 27, 2013. Noise measurement equipment included a Larson Davis 824 integrating noise level meter, meeting ANSI Standard S1.4-1983 for Type I noise meters. In addition, the Larson Davis 824 meter records 1/3 Octave Band (audio spectrum from 12.5Hz to 20kHz) measurements. Controlled pass-bys using a 2013 Ford Fusion (automobile vehicle class) were performed during the September 19th measurements. A 2006 Toyota Sienna (automobile vehicle class) was used to perform controlled pass-bys during the September 27th measurements. During the pass-bys, the vehicles were driven at 50 mph at the NYS77 site, and at the posted speed limit of 45 mph at the NYS441 site. The controlled single-vehicle pass-bys included: a base run (or *"Staying-In-Lane")* going in both travel directions; and a *"CARDs-Override"* going in both travel directions. During each pass-by, the time was recorded, and the distance (ranging from 50 to 100 feet) from the noise meter microphone to the centerline of the roadway was recorded. After completing on-site controlled measurements at each individual site, the noise meter was programmed to collect one-second interval measurements (dB(A)), and 1/3 Octave Band) for a 24-hour period.

Follow-up noise measurements were taken at the NYS441 site on November 20, 2013, using a Metrosonics db-308 integrating noise level meter that meets ANSI Standard S1.4-1983 for Type II noise meters, to collect additional information regarding traffic noise level drop-off rates. Specifically, the noise meter microphone was positioned 50 feet, 100 feet, 250 feet, and 500 feet from the roadway centerline to record noise levels for single-vehicle *"Staying-In-Lane"* pass-bys and *"CARDs-Override"* pass-bys.

NOISE ANALYSIS AND RESULTS

<u>1/3 Octave Band and CARDs-Override Review:</u> The frequency pattern of the *"CARDs-Override"* was identified upon review of the recorded data from the controlled measurement testing period. Results indicate that the *"CARDs-Overide"* by an automobile vehicle class has both a portion of its frequency pattern (in the 63 Hz to 250 Hz range), and an overall A-weighted decibel level (70 dB(A) at 50 feet) that are similar to a typical motorcycle pass-by. In simple terms, there are tonal qualities (i.e. the rumbling sound) that make overriding the CARDs similar to the muffler of a motorcycle, and the maximum sound level experienced by a receptor approximately 50 feet from a roadway is the same from a typical motorcycle pass-by and a *"CARDs-Override"*. Figure 8, below, shows a graphical comparison of noise levels generated by different vehicle classes, and the similarity of a portion of the frequency pattern and the A-weighted decibel level of the motorcycle and CARDs-Override.

The identified frequency pattern of the *"CARDs-Override"* was also used as a filter for the one-second data collected over the 24-hour period to determine the overall number of CARDs overrides at each analysis site. Results indicate that during the 24-hour measurement period (September 19th at 6:00 PM to September 20th at 6:00 PM) a total of 23 *"CARDs-Override"* events occurred at site NYS77, and a total of 68 *"CARDs-Override"* events occurred at site NYS441. The most frequent *"CARDs-Override"* hours (6:00 AM to 9:00 AM) at the NYS441 site were revisited on September 27, 2013, to verify that the number of *"CARDs-Overrides"* determined from the 24-hour measurement data was identified correctly. Figure 9 shows the recorded *"CARDs-Override"* events for the 6:00 AM to 9:00 AM time period on September 20, 2013, and the observed number of *"CARDs-Override"* events for the 6:00 AM to 9:00 AM time period on September 27, 2013. The recorded data and the observed data over this 3-hour period both show 24 *"CARDs-Override"* events.

Figure 8 – NYS Route 441 Controlled Test - Frequency and dB(A) Level Comparison

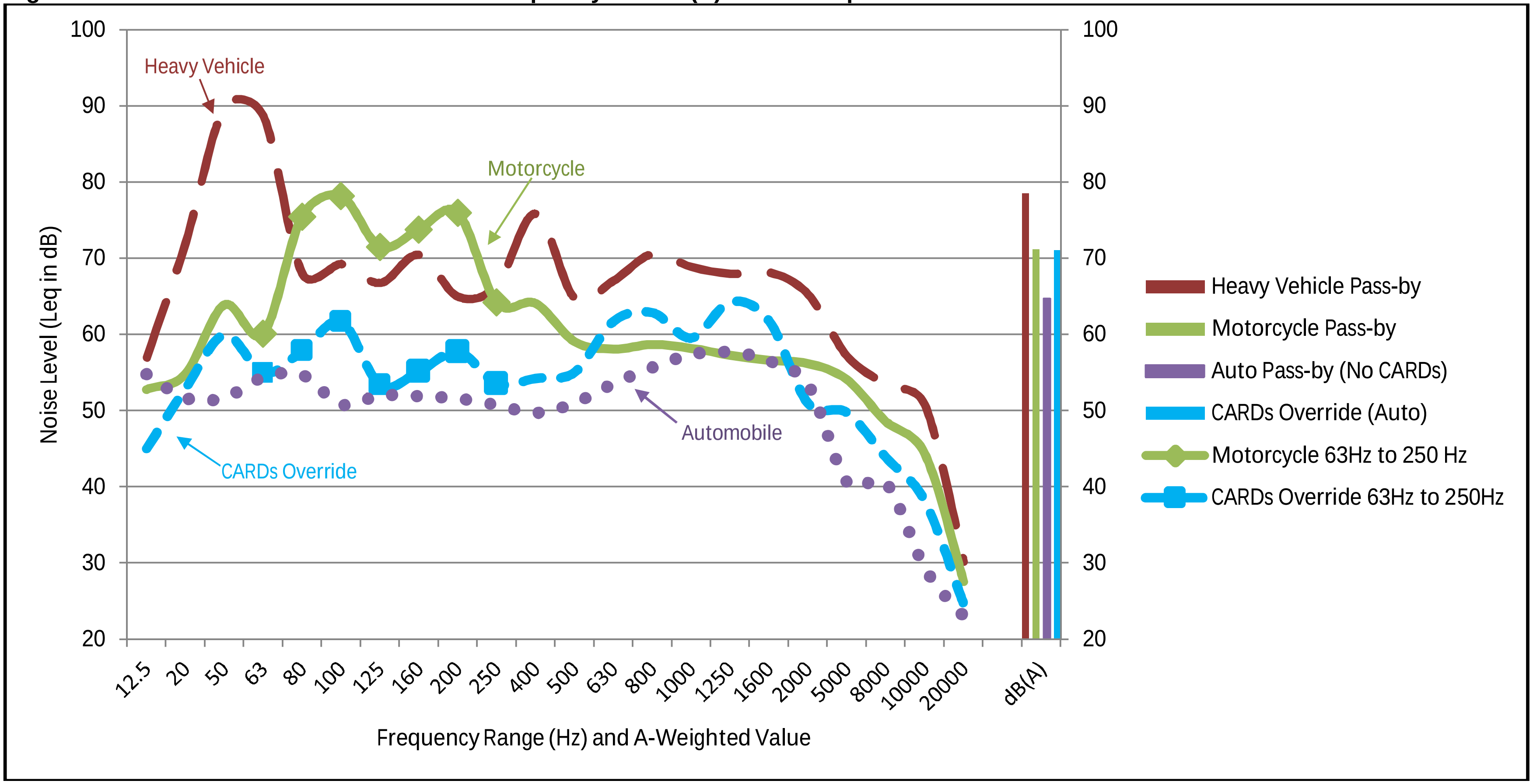
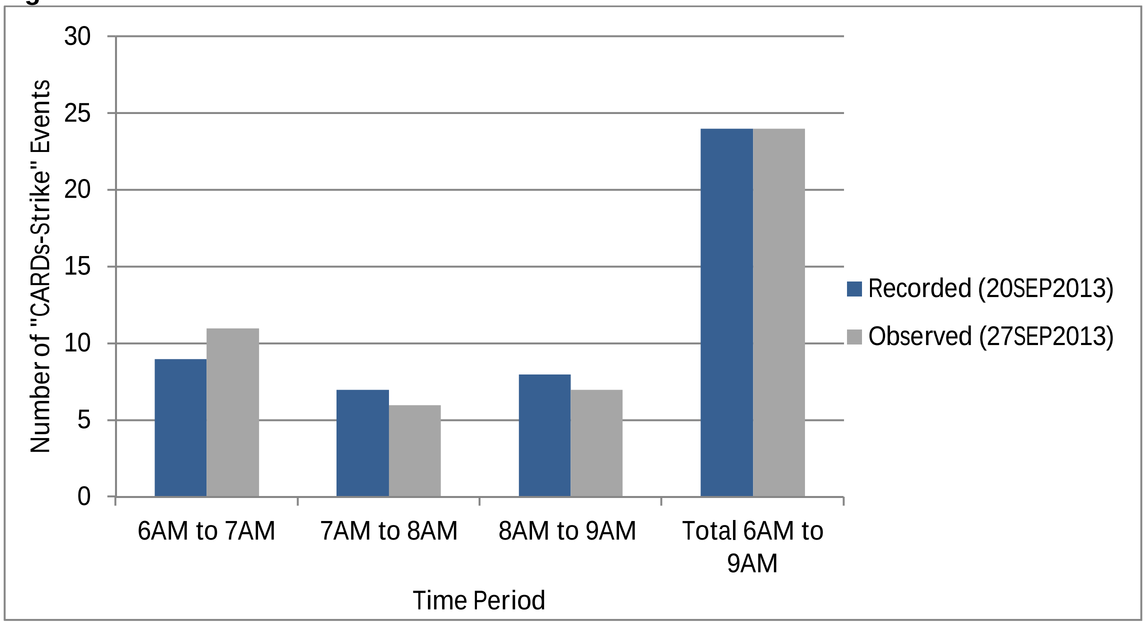


Figure 9 – Recorded Versus Observed "CARDs-Override" Events at Site NYS Route 441



The recorded data also indicates that *"CARDs-Overrides"* during the nighttime / early morning period (10:00 PM to 6:00 AM) are a small portion of the total number of overrides over a 24-hour period. For the NYS77 site there were 4 out of the 23 overrides between 10:00 PM and 6:00 AM, and for the NYS441 site there were 3 out of the 68 overrides between 10:00 PM and 6:00 AM.

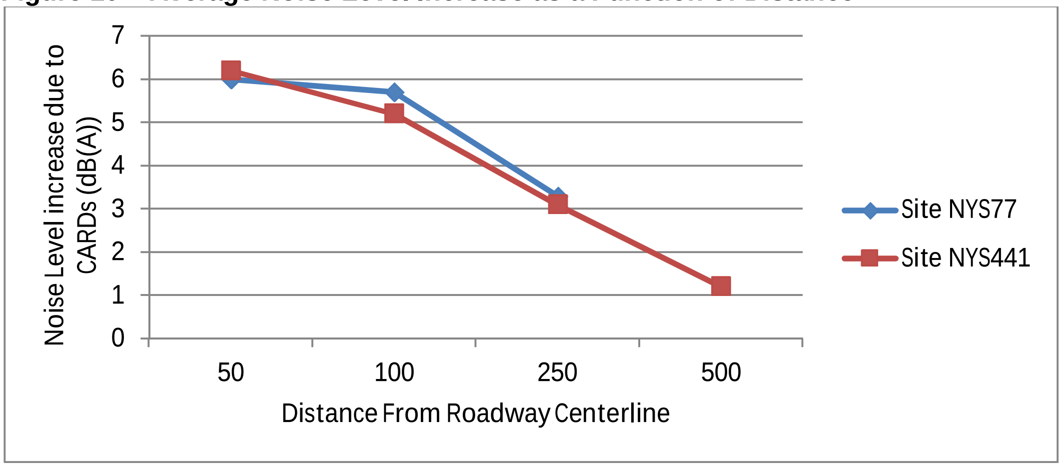
One-Second Leq Measurements and Sound Level Drop-Off Rates: Equivalent (L_{eq}) noise levels were measured at one-second intervals at varying distances ranging from 50 feet to 500 feet between the noise meter microphone and the roadway centerline. The maximum one-second recorded values were averaged at each site for the given distances for both the *"Stay-In-Lane"* pass-by and the *"CARDs-Override"* pass-by. Table 3 shows the average one-second L_{eq} sound levels for the *"Stay-In-Lane"* case and the *"CARDs-Override"* case for all of the automobile class vehicles used during the controlled testing periods at distances between 50 feet and 500 feet from the roadway centerline.

TABLE 3
SUMMARY OF MAXIMUM ONE-SECOND L_{eq} MEASURED NOISE LEVELS

Noise Measurement Site	Offset Distance from Noise Meter to Centerline of Roadway	Vehicle Pass-By Condition: Base Run (*"Stay-In-Lane"*) Average Noise Level (dB(A))	Vehicle Pass-By Condition: *"CARDs-Override"* Average Noise Level (dB(A))	Average Noise Level Increase (dB(A))
NYS77	50 ft	69.2	75.2	6.0
NYS77	100 ft	61.8	67.5	5.7
NYS77	250 ft	54.9	58.2	3.3
NYS441	50 ft	66.9	73.1	6.2
NYS441	100 ft	58.1	63.3	5.2
NYS441	250 ft	51.6	54.7	3.1
NYS441	500 ft	44.6	45.8	1.2

By subtracting the average *"Stay-In-Lane"* pass-by from the average *"CARDs-Override" pass-by*, the average increase in sound level is quantified. The comparison of the pass-bys and the observation that the difference in sound level diminishes with distance are further presented in graphical form on Figure 10. These sound level drop-off values rates are in line with expected drop-off rates for point noise sources, which are generally 6 to 8 dB(A) within site conditions found at the analysis sites.

Figure 10 – Average Noise Level Increase as a Function of Distance



Hourly L_{eq} Effects: The greatest number of *"CARDs-Overrides"* within a single recorded hour period totaled nine events, and these were identified between 6:00 AM and 7:00 AM at the NYS441 site. This would indicate that nine single event cases occurred where the traffic pass-by sound levels increased during a one-second interval by an average 6 dB(A) due to a *"CARDs-Override"* at a distance of 50 feet between the noise meter microphone and the roadway centerline. However, in terms of a one-hour measurement period, the nine *"CARDs-Override"* events at a distance of 50 feet between the noise meter microphone and the roadway centerline results in a 0.15 dB(A) increase in traffic pass-by sound level. According to the observed data, it would actually take approximately 135 *"CARDs-Override"* events within a one hour period to realize a 1 dB(A) increase in the traffic pass-by sound level at a distance of 50 feet between the noise meter microphone and the roadway centerline.

CONCLUSION

Sound sources are uniquely identified by their frequency (also known as pitch or tone). The frequency pattern of a *"CARDs-Override"* was identified as a result of the controlled test of vehicle pass-bys on the CARDs. It was determined that the tonal "rumble" sound is similar to a motorcycle pass-by. The NYS77 test site consisted of a roadway segment with a straight alignment that is relatively flat (less than 1% vertical grade), however, the NYS441 test site is considered a worst case (or highest potential *"CARDs-Override"*) location because this section of roadway has a horizontal curve and a substantial vertical grade change (greater than 1%). The total number of *"CARDs-Overrides"* over a 24-hour period was identified during this study at the two test sites. Results of a sample 24-hrour period included 23 *"CARDs-Overrides"* at site NYS77, and a 68 *"CARDs-Overrides"* at site NYS441.

In regards to quantifying a sound level increase due to the installation of CARDs, it has been determined that a single automobile *"CARDs-Override"* pass-by produces a short duration (less than 5 seconds) sound level increase of approximately 6 dB(A) at a distance of 50 feet from the roadway centerline, when compared to a standard pass-by (i.e. when an automobile does not override the CARDs). To put this noise level increase into perspective, a similar increase of 6 dB(A) occurs at a point 50 feet from the roadway centerline when two separate pairs of automobiles (4 total automobiles) concurrently pass in opposite directions within a given roadway section. By moving further away from the roadway, the additional sound of a *"CARDs-Override"* diminishes. There is only a 1 dB(A) increase over a standard pass-by at a point 500 feet from the roadway centerline, instead of a 6 dB(A) increase experienced at 50 feet. Separate noise studies of audible roadway delineators performed by both the Kansas Department of Transportation (KSDOT 2009) and the Delaware Department of Transportation (DelDOT 2012) show similar results that the additional sound level due to a vehicle tire hitting audible roadway delineators above a standard pass-by will diminish with distance.

This study did not evaluate the effect of a heavy vehicle *"CARDs-Override"*. However, research by the Delaware Department of Transportation (DelDOT 2012) concluded that a heavy truck classification generates more noise during a standard pass-by than an automobile vehicle classification, therefore, the contribution of the heavy truck itself to the overall pass-by noise level is relatively large, which ultimately makes the contribution from the tires overriding the audible roadway delineators less noticeable.

Since the *"CARDs-Override"* events are considered a single (short-term) event occurrence, this evaluation utilized one-second measurements to quantify sound level changes. However, under NYSDOT policy, highway traffic noise is evaluated over a longer continuous one-hour measurement period of time. In terms of a one-hour period this study has shown that the $L_{eq(1\text{-}hour)}$ remains essentially unchanged along a roadway that is even considered a worst-case scenario of potential *"CARDs-Override"* events.

REFERENCES

Delaware Department of Transportation (DelDOT). (2012). SR 24 Longitudinal Edge Line Rumble Strip Noise Study, September 2012.

Kansas Department of Transportation (KSDOT). (2010). Promoting Centerline Rumble Strips to Increase Rural, Two-Lane Highway Safety, Final Report, Sponsored by the Kansas Department of Transportation, Topeka, Kansas, December 2010.