



Evaluation of Sound and Vibration of Directional Rumble Strips for Detering Freeway Wrong-way Entries

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Introduction

Wrong-way driving (WWD) on freeways has been identified as a serious traffic safety problem. The Directional Rumble Strips (DRS) is designed to generate elevated noises and vibrations to warn against WWD and to generate normal noises and vibrations to slow down the traffic for the correct-way direction.

- Objectives:
 - Propose different conceptual designs of DRS based on existing TRS designs.
 - Evaluate and verify the effectiveness of three DRS patterns.
 - Recommend the most efficient DRS for practical implementation.

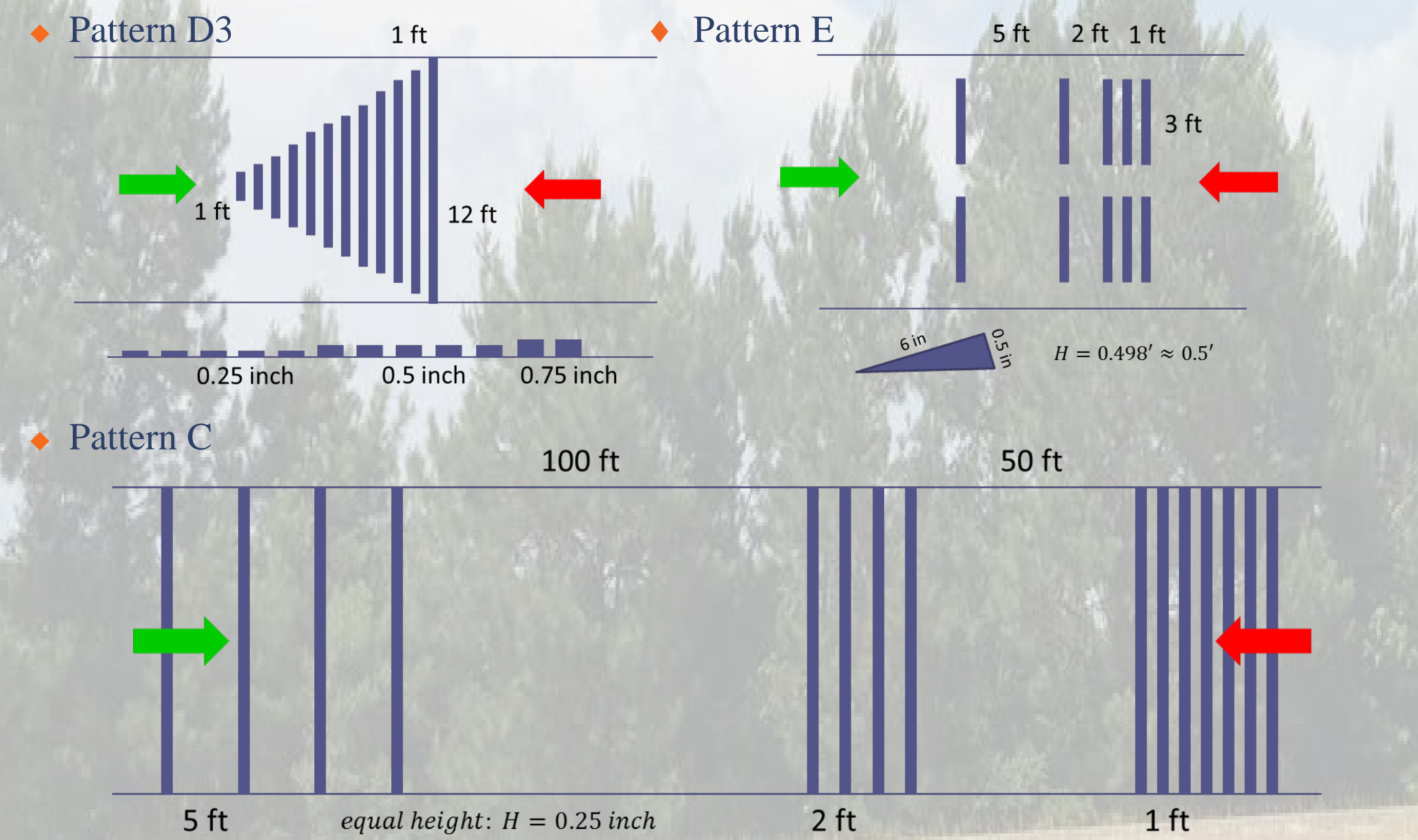
Data Collection

Data Collection

- Full-size passenger car
- Sound meter
 - Sampling rate - 10Hz
- Accelerometer:
 - Sampling rate - 100Hz
- Tested speeds: 10, 15, 20, 25, 35, 45 mph
 - Each speed was tested 5 times for both directions



Methodology



Results: Statistical Results Comparison

Sound (correct way V.S. wrong way)

Pattern	Test	10 mph	15 mph	20 mph	25 mph	35 mph	45 mph
D3	t-test	0.6049	0.5130	0.6291	0.2666	0.1839	0.1174
E	t-test	0.2682	0.1072	0.3895	0.5236	0.4343	0.4116
C	t-test	0.01455	0.00001	0.03724	0.00069	0.085	0.5478

Vibration (correct way V.S. wrong way)

Pattern	Test	10 mph	15 mph	20 mph	25 mph	35 mph	45 mph
D3	t-test	0.08487	0.1272	0.08246	0.1026	0.1971	0.07437
E	t-test	0.1730	0.2787	0.09524	0.5943	0.1764	0.00112
C	t-test	0.00005	0.00003	0.00004	0.00101	0.6523	0.6473

Conclusions and Discussions (scores from focus group)

Factors		Pattern D3			Pattern E			Pattern C		
Speed /mph (Low:10,15; Medium:20,25;High:35,45)		Low	Med	High	Low	Med	High	Low	Med	High
Sound /dBA	Recognizable	3	3	2	2	2	1	1	1	3
	RW-WW Difference	1	1	3	2	2	2	3	3	1
	Max Value	2			3			1		
Vibration /g	Severity	3	2	2	2	3	3	1	1	1
	RW-WW Difference	2	2	2	1	1	3	3	3	1
	Max Value	2			3			1		
Feasibility*5		1			2			3		
Damage to Pavement		2			1			3		
Durability*2		2			1			3		
Costs*2		2			3			1		
OVERALL		45			49			51		

Sound and Vibration Analysis

Pattern D3

Recommended Location for Implementation

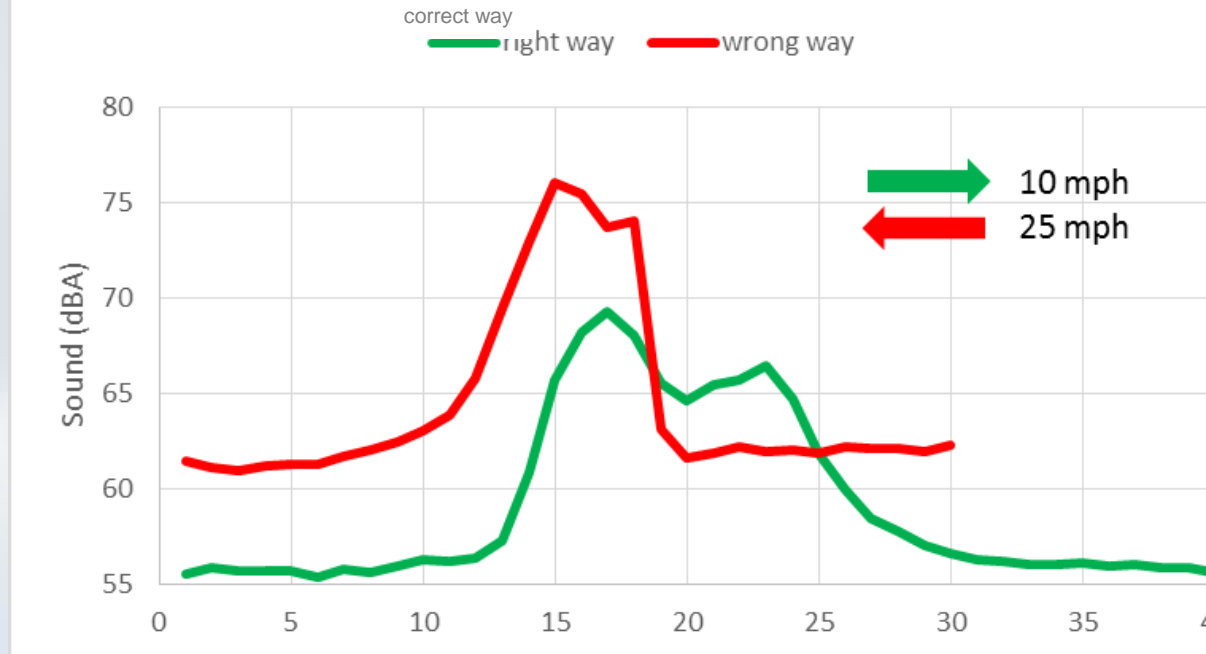
Exit-ramp Terminal

Features

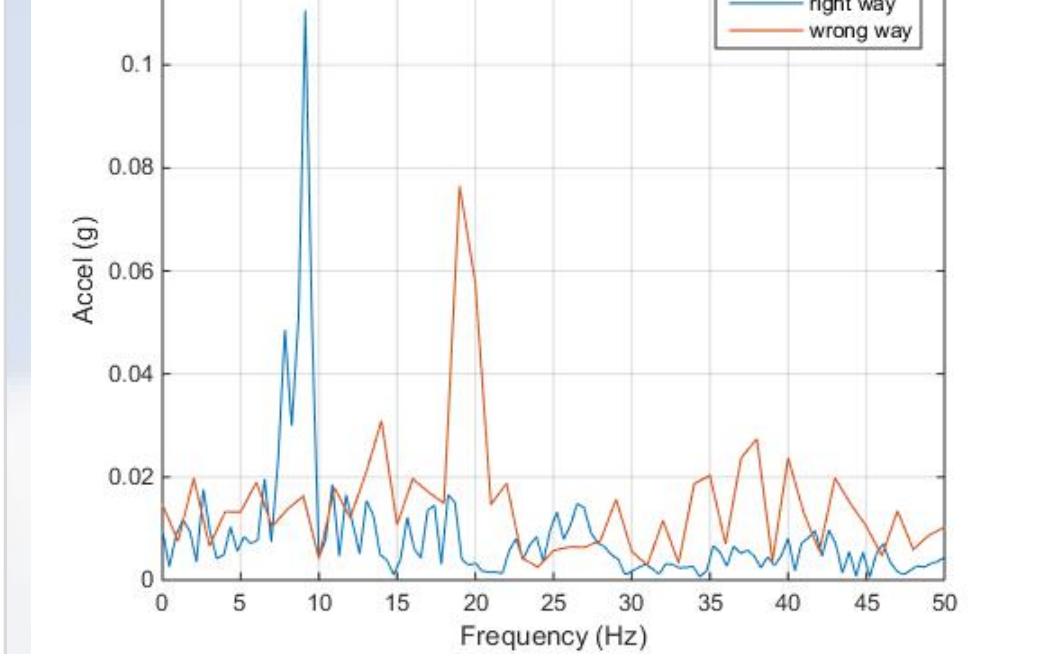
- Visually warn potential wrong-way drivers;
- High visible reflective painting could be applied on the highest strip as the stop bar.



Performance of PatternD3 @ Exit-Ramp Terminal



FFT - Pattern D3



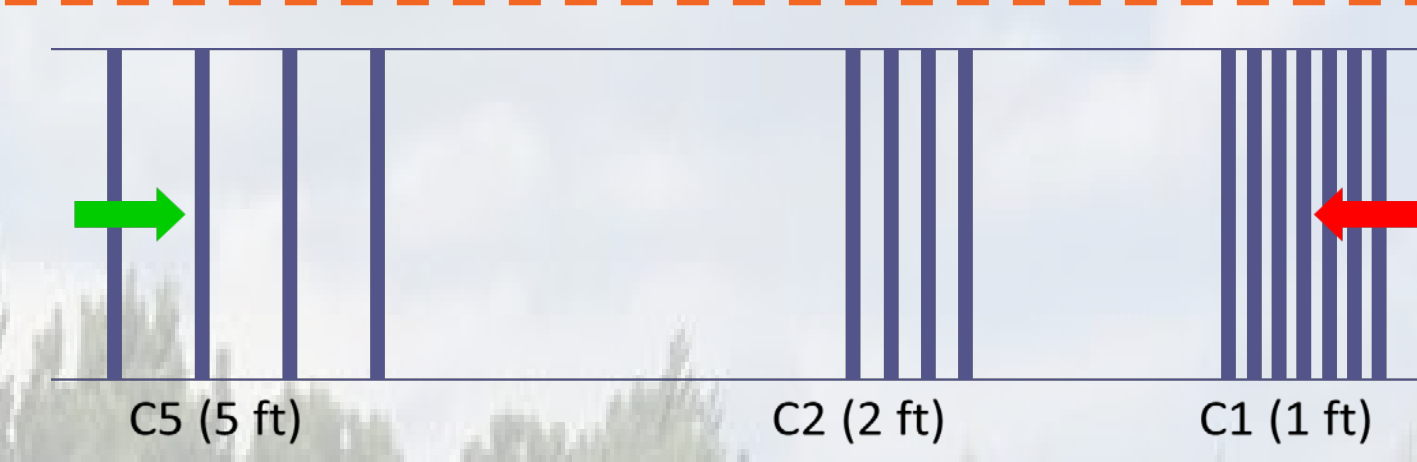
Pattern C

Recommended Location for Implementation

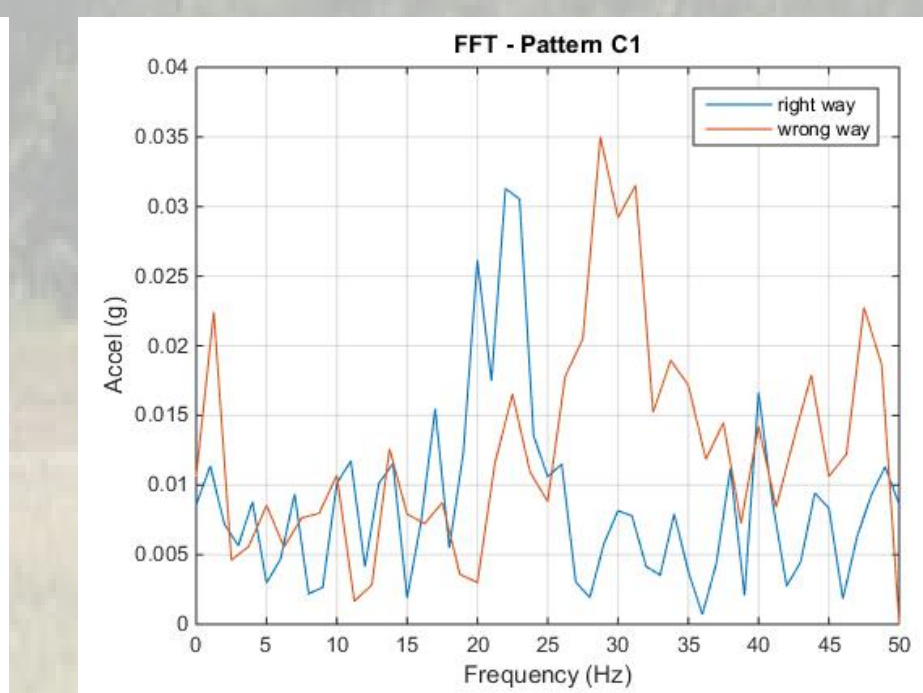
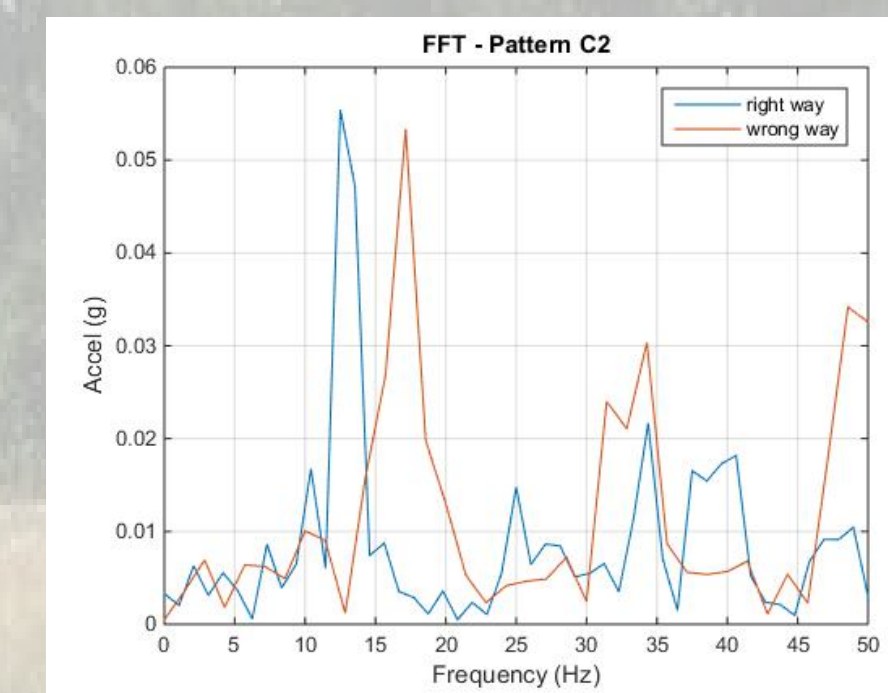
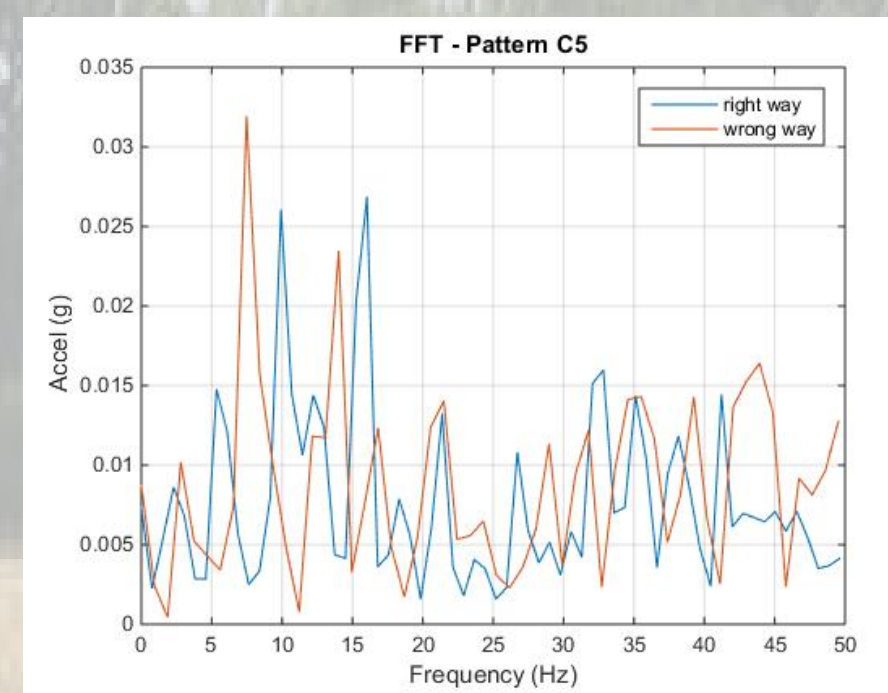
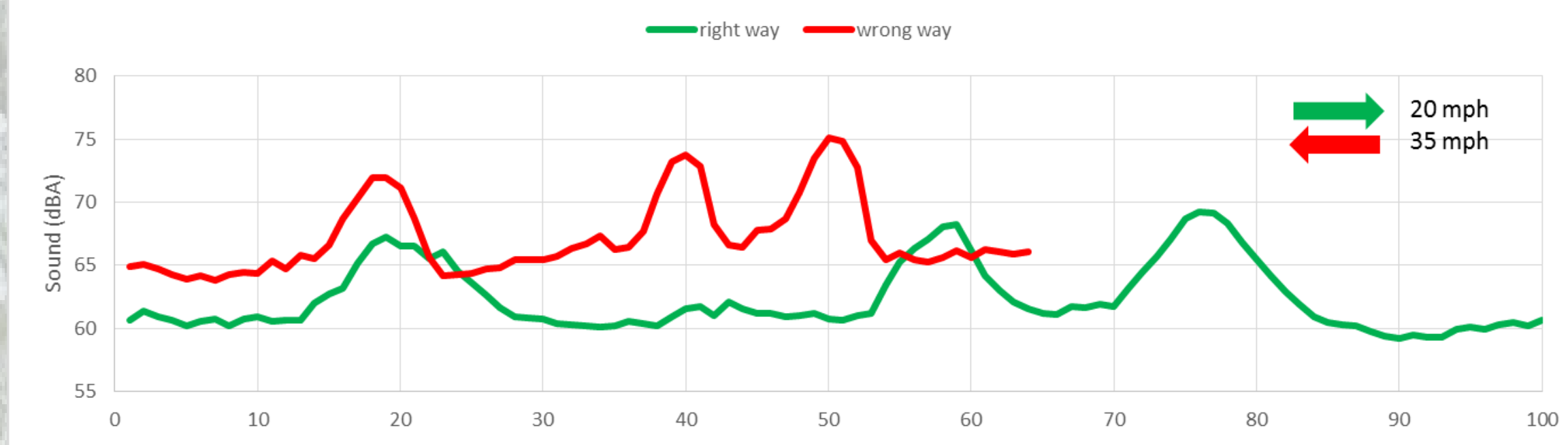
Straight long exit-ramp

Features

- Similar to Transverse Rumble Strips;
- Easy implementation



Performance of PatternC @ straight long Exit-Ramp



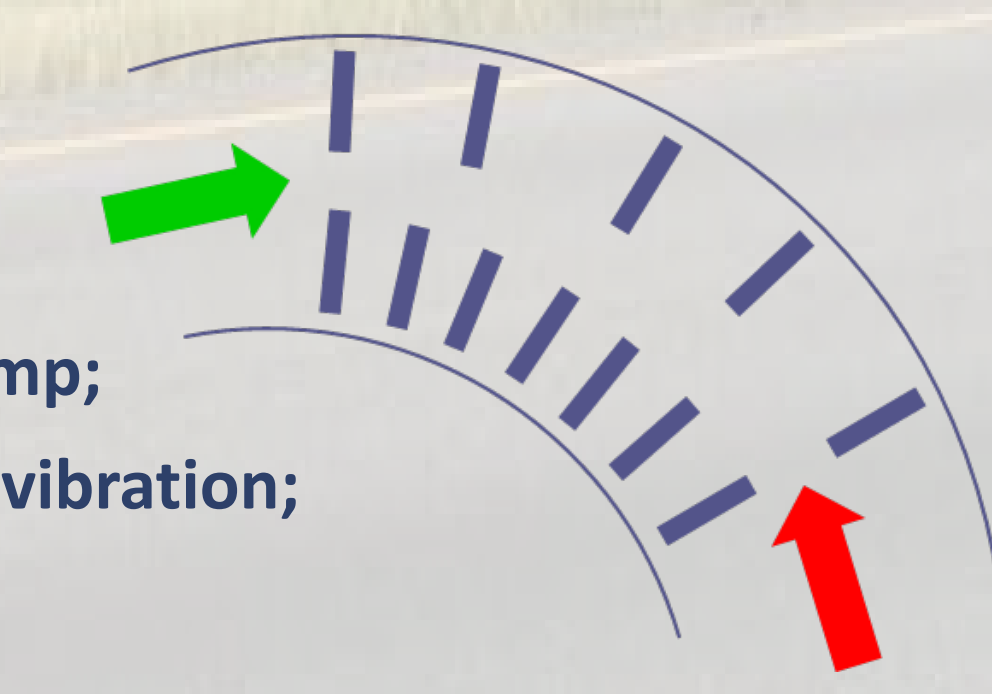
Pattern E (modified)

Recommended Location for Implementation

Exit-ramp Curves

Features

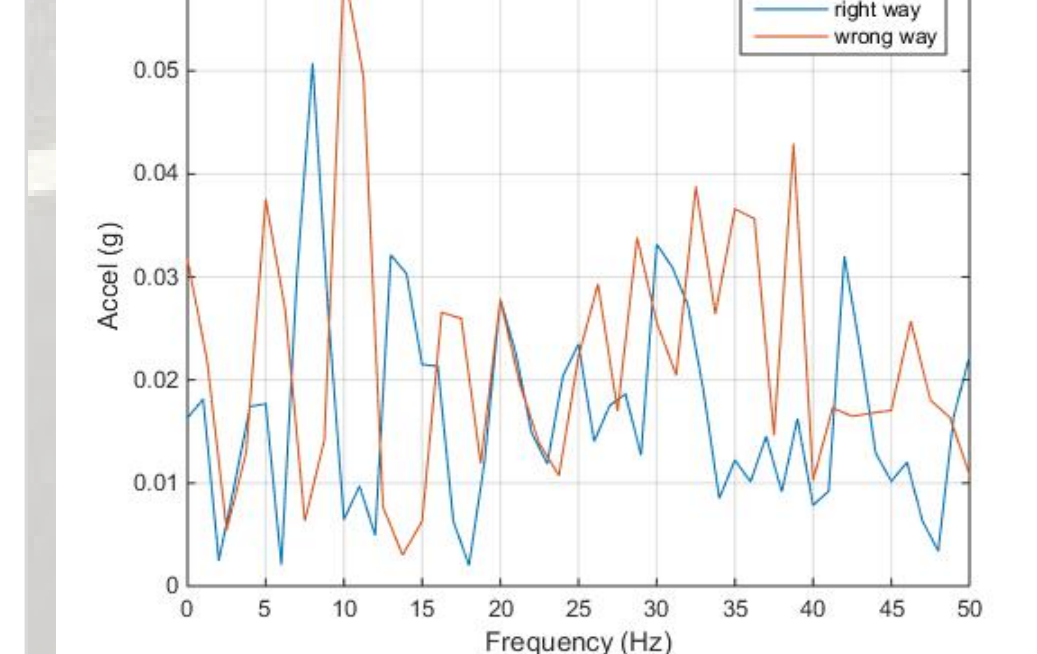
- Unequal numbers of strips on each side of the ramp;
- Wrong-way driver would receive more noise and vibration;
- Visual warning of curves;
- Increase friction of road surface.



Performance of PatternE @ Exit-Ramp Curve



FFT - Pattern E



Results: Economic Comparison

Pattern	Overall Length on the Road (ft)	Cost (\$) per set	Installation Time (min)	Damage to Pavement
D3	23	652.68	30	Slight
E	13	580.00	20	Hard to remove
C	192	648.36	40	Slight

Acknowledgments

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