Wayside Horn Sound Radiation and Motorist Audibility Evaluation

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Executive Summary

Wayside horns are a viable alternative to locomotive horns for audible warning at grade crossings. Wayside horns have the advantage of being closer to the motorist. In addition, they have a more focused radiation pattern and produce less community noise exposure.

Previous FRA studies[1,2] have been encouraging but less than totally favorable. Consequently, RCL (Railroad Controls Limited Inc.) increased the warning volume capacity and added low frequency tones, seeking more resemblance to the classical train horn.

The current RCL horn was tested on May 3, 2000 to demonstrate both dBA and one third octave bands at 22.5º angular increments. This data allows more accurate community noise exposure forecasts and motorist audibility evaluations.

The Volpe Center evaluated the wayside horn as an audible device for approaching motorists prior to gate closure. With this perspective, they concluded that the historical horn volumes were insufficient. Consequently, RCL increased horn volume capacity in current systems by 6-10 dB. This change alerts 99% of approaching drivers with only partial anticipation of a train event. The system is just as successful at lower volumes, if the driver is at rest behind the gates.

The wayside horn is usually applied only to gated crossings with constant warning time control. Previous installations have constant warning time control which activate gates 25 seconds prior to train arrival. Gates are fully closed in 5 seconds, forcing the cars to stop. This is 20 seconds before the train arrives. In this situation, the wayside horn is not the primary warning device, but a secondary confirmation of train arrival. Horn audibility requires less volume because the car is at rest and closer to the horn location. The first car and fourth cars are 16' and 61' from the horn , respectively. In this example, the horn is audible to 99% of the population in the fourth car, with a volume of 83 dBA, outside the car. This is 19 dB less than maximum volume, which improves community compatibility.

With stationary cars, a wayside horn reference of 78 dBA at 100' is as good as a more distant train horn with a 96 dBA reference. Although unnecessary, louder wayside horn volumes up to 92 dBA can insure warnings as good as the full range of locomotive horn inventory. The focused radiation pattern minimizes community intrusions, making it a viable alternative to louder locomotive horn warnings.

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[1] *Railroad Horn Systems Research*, U.S. Department of Transportation Federal Railroad Administration, Report No. DOT-VNTSC-FRA-98-2, January 1999

[2] *Field Evaluation of a Wayside Horn at a Highway-Railroad Grade Crossing*, U.S. Department of Transportation Federal Railroad Administration, Report No. DOT-VNTSC-FRA-97-1, June 1998.

Introduction

The Volpe Center authored the first two references. The FRA publication “Railroad Horn Systems Research” is referenced many times. This publication provides current car noise reduction characteristics (insertion loss) and interior noise levels. It also provides a pivotal understanding of horn detection theory, based on driver’s expectation and horn S/N values. The same basic methodology is used to calculate the warning level inside the car and to forecast motorist response. This report in part updates those conclusions based on the most current wayside characteristics. It also seeks to elaborate more on the wayside horn attributes at a gated crossing with constant warning time control.

The Volpe Center examined the audibility of approaching motorists, pointing out that the horn may be the first alerting characteristic of gate activation. The horn sounds at the same time as the gates start to close. Therefore, a driver might hear the warning before they saw the gates in a partially closed position. Their analysis of the horn is based on audible warning alone, without any synergistic contribution from visual observations.

The wayside horn application has only been applied to a crossing with constant warning time control. The electronic crossing circuitry activates gate closure, 25 seconds before the train arrives. The controls sense and account for train speed. Gates close fully 20 seconds before the train arrives.

The Volpe Center worries about motorists who stop at the gates and then drive around them without waiting for the train to pass. They determined that this motorist needs 10 seconds to accomplish that task. In this example, the wayside horn provides an additional verification that the train is coming to encourage re-evaluation.

In fact, this is the primary function of the wayside horn. The gates are always down before the train arrives. This perspective allows a lower horn volume because the drivers are closer, more attentive, with less interior car noise.

Wayside Horn Tests in Fort Worth, TX on May 3, 2000

The current wayside horn design produced 98 dBA (100’), on May 3, 2000 in Fort Worth, TX. The test site was a large parking lot, east of IH35. Highway traffic background noise averaged 65 dBA and 70 dBL. The lot provided 600’ of clear space, except for one single building located 400’, 22.5º counter clockwise, off centerline. The wayside horn was mounted 12’ high on a parking lot light pole. Measurement heights are 4’.

Measurements were made at 100’ and 200’ distances in 22.5º increments, in front of the horn. The horn was then turned 180º for measurements on the back side. The table below presents these sound levels not only in overall, dBA, but also in one third octave frequency bands.

A type one, Quest model 1400 sound level meter provided the microphone input to a Rion Model SA 27 analyzer. The microphone has recent lab certification. A Quest Model QC-20 calibrator also provided field checks. Calibration checks included both 250 Hz and 1000 Hz and amplitudes of both 94 dB and 114 dB.

The horn software sounds two longs, a short and a long. Amplitudes were consistent in level and one or two events provided data at each of the 32 measurements. The data provides current reference amplitudes as well as typical radiation patterns.

Sound Levels, dBA

The current horn levels are 98 dBA at 100’. The level was 90 dBA at 200’. This result is unexpected because it deviates from the expected 6 dB change with distance doubling. It is premature to conclude that the fall off with distance is 8 dBA, with each doubling. Reflective interference unique to some hard surface test sites most likely causes the 2 dB difference. Reflective waves off hard surfaces can interact with sound that propagates directly to the microphone and cause additional reductions because of phase mismatch. This condition is a function of distance, measurement height, and surface reflective characteristics.

It is more likely that sound consistently reduces by the classical 6 dB with each doubling of distance. Later calculations use this assumption.

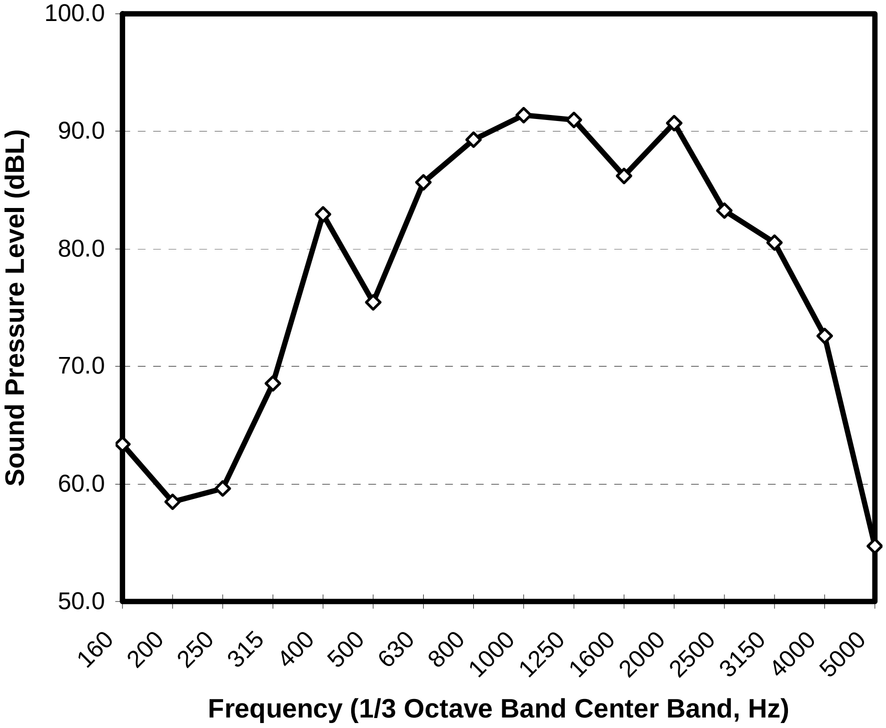
Wayside Horn Sound Levels 5/3/00
Table 1

Orientation	**dBA**	**160 Hz**	**200 Hz**	**250 Hz**	**315 Hz**	**400 Hz**	**500 Hz**	**630 Hz**	**800 Hz**	**1000 Hz**	**1250 Hz**	**1600 Hz**	**2000 Hz**	**2500 Hz**	**3150 Hz**	**4000 Hz**	**5000 Hz**
@**100'**	dBA	dBL	dBL	dBL	dBL	dBL	dBL	dBL	dBL	dBL	dBL	dBL	dBL	dBL	dBL	dBL	dBL
0.0º	98.0	63.4	58.5	59.6	68.6	82.9	75.5	85.7	89.3	91.4	91.0	86.2	90.7	83.3	80.5	72.6	54.7
22.5º	95.6	60.9	56.5	58.0	71.4	79.8	72.6	77.7	88.8	89.2	91.0	81.2	85.3	73.8	72.3	63.8	47.2
45.0º	91.5	62.8	57.7	58.8	69.8	73.8	71.5	76.6	87.9	86.5	83.9	71.2	73.4	70.0	59.7	53.0	45.3
67.5º	85.1	65.9	60.7	58.5	65.7	70.6	68.4	69.6	83.3	77.7	68.4	67.3	71.9	58.6	56.3	50.0	45.4
90.0º	78.7	61.4	56.8	56.7	63.9	71.1	66.4	74.9	74.0	71.4	66.0	63.6	65.5	55.2	52.5	48.5	45.2
112.5º	76.8	63.5	59.1	55.4	60.3	74.1	68.2	70.8	69.2	67.7	68.0	63.4	60.5	54.2	50.3	48.3	45.3
135.0º	76.4	60.9	56.6	55.3	63.2	74.5	67.1	62.3	69.9	68.8	66.8	61.0	61.5	54.6	50.3	47.8	45.3
157.5º	75.7	61.5	58.5	55.6	64.5	72.2	64.6	68.4	70.2	66.7	65.1	62.6	61.2	55.4	50.2	48.3	45.8
180.0º	77.9	64.6	60.3	57.3	61.7	76.1	70.7	67.0	71.9	68.9	67.7	64.4	57.5	54.9	50.2	48.9	45.0
202.5º	75.8	63.3	60.7	57.3	62.3	74.9	69.8	70.8	67.1	65.4	62.1	59.4	58.0	52.6	48.1	47.6	45.9
225.0º	75.7	62.6	58.0	55.1	61.7	74.9	69.3	67.6	69.0	62.8	63.4	61.3	57.7	53.8	49.3	48.7	45.4
247.5º	76.9	61.9	58.9	55.9	61.4	75.1	68.7	70.5	68.2	68.9	64.8	62.9	64.0	54.7	50.4	48.5	46.0
270.0º	79.6	65.9	62.6	56.9	60.4	78.1	71.8	71.6	74.1	68.9	64.7	66.5	61.9	55.0	50.4	48.7	46.4
292.5º	83.0	65.4	60.8	57.4	67.4	80.4	75.3	70.0	77.6	74.2	73.2	69.6	65.3	60.4	51.9	48.8	47.3
315.0º	86.6	65.6	59.0	57.4	69.2	74.7	72.7	74.1	80.4	81.5	81.2	70.4	68.7	69.0	53.6	51.8	52.2
337.5º	93.9	67.1	59.5	60.7	72.2	77.6	72.4	82.5	87.2	87.4	89.5	80.7	81.2	71.3	65.2	62.0	66.0
360.0º	98.0	63.4	58.5	59.6	68.6	82.9	75.5	85.7	89.3	91.4	91.0	86.2	90.7	83.3	80.5	72.6	54.7
200'	**dBA**	**160 Hz**	**200 Hz**	**250 Hz**	**315 Hz**	**400 Hz**	**500 Hz**	**630 Hz**	**800 Hz**	**1000 Hz**	**1250 Hz**	**1600 Hz**	**2000 Hz**	**2500 Hz**	**3150 Hz**	**4000 Hz**	**5000 Hz**
0.0º	89.8	60.3	55.6	55.1	68.5	83.5	83.5	84.1	83.0	79.0	73.3	77.1	80.8	77.1	73.8	66.7	60.0
22.5º	86.8	63.0	60.3	55.5	66.2	85.8	81.0	76.6	79.4	73.4	70.9	74.4	75.4	64.5	60.0	54.6	47.1
45.0º	83.2	70.3	63.1	60.9	66.3	83.0	76.7	77.5	76.3	66.8	64.6	65.6	65.2	64.4	49.6	49.9	45.4
67.5º	79.6	63.0	56.4	56.3	66.2	76.5	75.2	73.2	75.0	63.9	55.9	65.8	64.4	54.7	48.6	47.8	45.8
90.0º	75.0	65.4	63.0	61.0	61.6	74.4	70.4	69.7	66.4	60.4	58.1	58.6	55.5	50.3	47.9	47.1	45.3
112.5º	76.1	60.9	54.5	51.7	61.0	73.7	70.7	74.0	69.5	58.4	59.3	56.6	53.8	50.2	48.8	47.7	45.3
135.0º	73.8	63.4	58.1	53.9	62.6	72.8	70.1	69.8	64.5	56.6	54.3	56.5	53.7	48.8	47.6	47.0	45.6
157.5º	73.0	60.4	55.7	54.0	61.8	72.8	68.4	66.0	62.8	58.6	55.5	60.3	55.3	49.2	47.4	47.1	45.2
180.0º	76.7	59.4	54.2	53.6	63.1	76.4	73.1	70.6	68.2	55.7	58.8	59.2	56.2	50.2	48.3	48.0	45.8
202.5º	76.9	65.9	61.8	58.7	62.1	78.0	71.9	70.7	65.0	56.5	55.5	57.2	54.5	50.3	47.9	47.7	44.4
225.0º	75.0	59.5	56.1	53.3	59.8	75.9	71.0	65.1	63.7	55.0	55.7	58.9	54.7	50.6	47.5	47.6	45.2
247.5º	76.2	62.7	60.1	54.2	63.2	74.9	71.2	72.8	67.5	56.1	58.3	60.9	60.7	52.8	48.9	48.3	45.5
270.0º	75.7	68.2	64.5	63.4	63.5	76.2	70.5	66.0	66.1	61.1	58.7	60.4	58.9	53.1	49.6	48.1	45.9
292.5º	80.5	63.8	58.5	56.6	65.8	78.4	77.6	72.3	73.2	68.8	67.0	65.8	64.2	56.4	51.2	47.7	46.3
315.0º	83.6	64.0	59.4	57.6	65.2	81.2	77.5	77.7	77.3	71.1	70.4	72.1	67.7	62.6	53.2	50.3	45.8
337.5º	87.1	60.7	53.0	56.4	67.7	78.9	76.0	83.8	76.9	72.5	76.0	80.4	78.2	66.3	58.1	57.7	47.4
360.0º	89.8	60.3	55.6	55.1	68.5	83.5	83.5	84.1	83.0	79.0	73.3	77.1	80.8	77.1	73.8	66.7	60.0

Frequency Content

Figure 1 presents the horn frequency content. The chart shows tonal amplitudes in one third octave band frequencies. There are significant differences in this chart from the frequency spectrum found in Figure 11, page 32 in “Railroad Horn Systems Research”. Figure 1 includes a new low frequency tone. In addition, the levels are 10 dB higher and more closely resemble the train horn signature. This makes the frequency spectrum similar, in both frequency content and amplitude to a train horn.

RCL Wayside Horn Frequency Spectrum
on Centerline at 100' Distance
Figure 1



A Union Pacific mainline track was located 1000’ to the west of the test site. Several trains passed during several hours of testing, blowing the horn at grade crossings. The subjective resemblance to the wayside horn is remarkably similar.

Radiation Patterns

The physical characteristics of this warning device limit efficient radiation at frequencies below 500 Hz. Figure 1 infers that radiation is most efficient at frequencies around 1000 Hz. The wavelength of 1000’ is approximately 1’ and has directional tendencies. This is beneficial for limiting side radiation and minimizing community intrusions.

Figure 2 shows the change in levels with orientation at 200’. The shape is symmetric in front of the horn. Site background noise causes the symmetry deviation on the back side. The lower levels were not consistently 10 dB above the highway noise on the site.

RCL Horn Radiation Patterns
Sound Levels (dBA) at 200' Distance
Figure 2

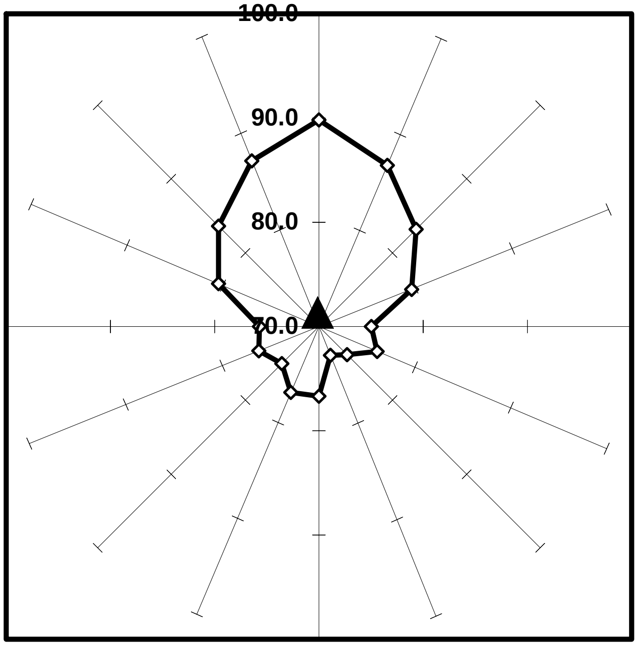


Table 2 lists the change in noise level with centerline orientation. The change is 3 dB, 22.5º either side of centerline. It progressively reduces another ~3 dB with successive 22.5º increment, up to 90° and then is fairly constant in level behind the horn.

Noise Reductions with Changes in Orientation for Horn Centerline
Table 2

Orientation	22.5º	45º	67.5º	90º	112.5º	135º	157.5º	180º	202.5º	225º	247.5º	270º	292.5º	315º	337.5º
Noise Reduction	3 dBA	6.6 dBA	10.2 dBA	14.8 dBA	13.7 dBA	16 dBA	16.8 dBA	13.1 dBA	12.9 dBA	14.8 dBA	13.6 dBA	14.1 dBA	9.3 dBA	6.2 dBA	2.7 dBA

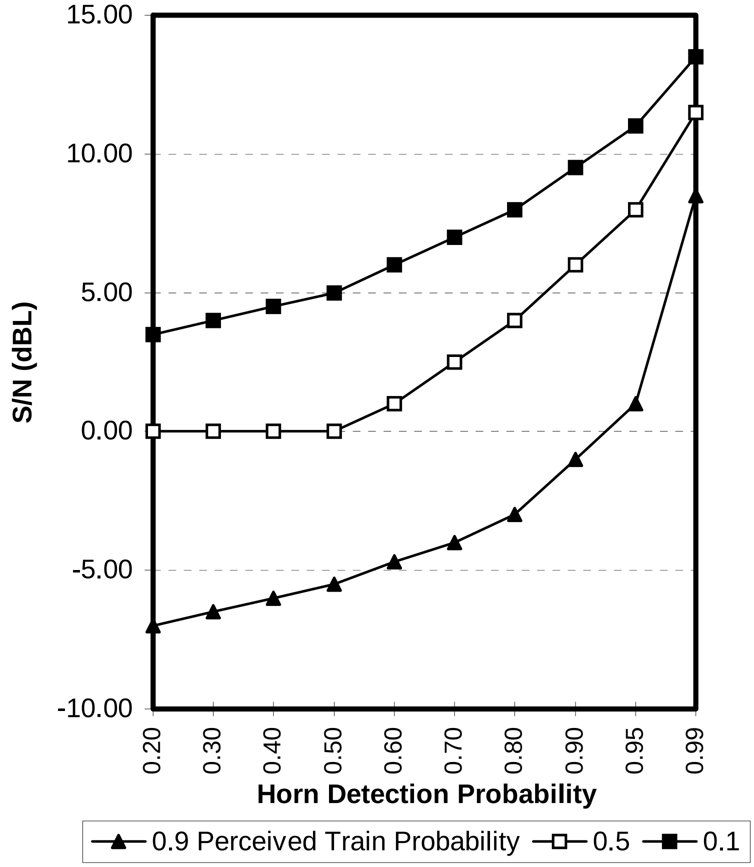
The horn level is substantially quieter on the back side. Levels reduce approximately 15 dB and are more omnidirectional.

Approaching Motorist Warning Detectability

An approaching motorist will hear the warning if there is sufficient amplitude based on car interior noise and the motorist's attention level. The FRA publication, “Railroad Horn Systems Research” presents a methodology for making this determination. The concept of tonal detection as a function of background noise level has been studied for many years. H. Fletcher published the concept of critical bandwidth in 1940.[3] Critical bandwidth recognizes that the human ear acts like a filter to hear a specific tone. Only a limited bandwidth of background noise tends to mask or cover up that tone.

Sanford Fidell made the concept more applicable to wayside horns in his publication, “Effectiveness of Audible Warning Devices on Emergency Vehicles”.[4] He pointed out like Fletcher before, that audibility occurs with sufficient horn signal at only one tone (one 1/3 octave band). Other work in detection theory led to Figure 4 on page 24 of “Railroad Horn System Research”. Figure 3 below is a reproduction.

Horn Detection Probability vs S/N
Figure 3



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[3] H. Fletcher, *Auditory Patterns*, Revs. of Mod. Phys., 12:47-65 (1940).

[4] Potter, R.C., Fidell, S.A., Myles, M.M., and Keast, D.N. *Effectiveness of Audible Warning Devices on Emergency Vehicles*. Report No. DOT-TSC-OST-77-38, August 1977.

Perceived train probability is defined as the motorist's expectation of a train. The motorist's previous driving experience may formulate an expectancy that he will see a train. This is similar, if not the same as the probability that the driver will actively look and listen for a train. The lower curve shows the expected result if the motorist looks and listens for a train, 9 out of 10 times. The results are similar to lab detectability tests when the subject expects a tone. Lab detection subjects routinely identify tones that are lower in level than the background noise. Figure 3 forecasts that this driver would hear the warning half the time if the horn signal inside the car were 5 dB less than the background noise. This is a -5 S/N (signal to noise). He would hear it 95% of the time if the horn signal were only 1 dB above the background noise level.

A preoccupied driver would actively look and listen for the train less often. Even so, they would hear the warning 50% of the time, with a +0 S/N (any one 1/3 octave band), if they only anticipate the train half the time.

Table 3 is a sample calculation of the horn S/N value. It is the same format used in Appendix E of "Railroad Horn Systems Research". The first tabular line item is the horn level from testing on May 3, 2000. Item 2 is the level at 358'. The calculation uses the classical change in distance of 6 dB with each doubling of distance. This distance is suggested as the necessary warning distance for a car traveling 40 mph (Table 12, page 34)[1] for a wayside horn application.

The car insertion loss is a measure of the car shell noise reduction characteristics. The values in item 3 are from Figure C-11 of Appendix C[1] and are an average of seven vehicles tested. Item 4 determines the horn level inside the car by subtracting the car insertion loss from the outside horn level.

The car interior noise is also an average of seven tested vehicles (Figure C-2)[1] . It is a classic shape with higher amplitudes at lower frequencies and a gradual reduction in amplitude with increased frequencies. Vehicle speed for interior noise is 30 mph with no ventilation fan operating.

Example Calculation of Motorist Horn S/N Values
Table 3

1.) Spectrum values from 5/3/00 testing

Freq	Hz 160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
@100'	63 dBL	59	60	69	83	75	86	89	91	91	86	91	83	81	73	55

2.) Calculating the horn level at 358' uses the levels at 100' and adjusts them for distance. This adjustment is 20*log(100/358)=-11 dB Subtracting 11 dBL from item 1.)

Freq	Hz 160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
@440'	52 dBL	48	49	58	72	64	75	78	80	80	75	80	72	70	62	44

3.) Car insertion loss[1]
These values will be subtracted in the next line from item 2.)

Freq	Hz 160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
IL	18 dBL	20	18	18	22	26	29	29	27	30	34	32	34	34	34	35

4.)Horn level inside the car. Item 2)-item 3)

Freq	Hz 160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
interior horn	34 dBL	28	31	40	50	38	46	49	53	50	41	48	38	36	28	9

5.) Average interior car noise

Freq	Hz 160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Interior noise	61 dBL	59	58	56	53	51	47	45	44	42	40	36	34	31	30	26

6.) Horn S/N value inside the car

Freq	Hz 160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
S/N	-26.3	-31.7	-27	-16.8	-3.3	-12.2	-1.1	4.5	9.5	8.0	1.4	11.3	4.5	4.2	-2.2	-17.2

Comparison of the horn interior level with the car noise shows a positive signal to noise in seven consecutive bands from 800 Hz - 3150 Hz. Figure 3 shows that a 11.3 dB signal to noise in the 2000 Hz, one third octave band assures that 99.9% of the drivers hear the warning with only a 50% train expectancy. Even with this conservative assumption that the driver only looks for the train one half the time, 99.9% of motorists should hear the warning.

Stationary Motorist at Gated Crossing Audibility

At a gated crossing with constant warning time control, the wayside horn activates at the same time the gates start to close. Gate closure begins 25 seconds prior to train arrival and takes 5 seconds to close fully. Gates are down 20 seconds prior to train arrival. In this situation, the wayside horn is not the primary warning device, but is a secondary confirmation of train arrival. Horn audibility requires less volume because the car is at rest and closer to the horn location. The first car is 16’ from the horn instead of 358’ away traveling 40 mph. The fourth car in line is 61’ away.

This calculation, in contrast to the last example, begins with the S/N necessary in any one third octave band and works backward to determine the necessary exterior horn levels. Item 1 is the average interior car noise at 30 mph. This includes tire noise which is too high for a stationary car. However, it is used for consistency.

Example Calculation of Necessary Horn Volume for Stationary Motorist
Table 4

1.) From Figure C-2 the average interior noise level is

Freq	Hz 160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
interior	61	59	58	56	53	51	47	45	44	42	40	36	34	31	30	26

7 dB signal to noise requirement
2.) Adding 7 dB to item 1.) for 99% detection rate

Freq	Hz 160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
interior	68	66	65	63	60	58	54	52	51	49	47	43	41	38	37	33

3.) Car insertion loss
These values will be added in the next line to item 2.) to obtain exterior horn level requirements

Freq	Hz 160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
IL	18	20	18	18	22	26	29	29	27	30	34	32	34	34	34	35

4.) Adding 3.) + 2.) determines the exterior horn requirements for the fourth car in line at 61' distance.

Freq	Hz 160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
@61'	86	86	83	81	82	84	83	81	78	79	81	75	75	72	71	68

5.) Horn level needed at 100’, adjusts for distance correction. Adjustment is 20*log(61/100)= -4.3 dB

Freq	Hz 160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
@100'	81	82	78	77	78	79	79	77	74	75	77	71	70	68	67	64

6.) 5/3/00 testing at 100'

Freq	Hz 160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
@100'	63	59	60	69	83	75	86	89	91	91	86	91	83	81	73	55

Wayside volume headroom
7.) Subtracting item 5.) from item 6.)

Freq	Hz 160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Headroom	-18.0	-23.4	-18.7	-8.5	5.0	-3.9	7.2	12.8	17.8	16.3	9.7	19.6	12.8	12.5	6.1	-8.9

Item 2 calculates the necessary horn signal inside the car by adding 7 dB to each of the interior car noise levels. Figure 3 shows that this increase is sufficient to alert 99% of the drivers who listen 9 out of 10 times. Item 4 calculates the necessary horn level outside the car and item 5 calculates the corresponding reference distance at 100’ from the horn. This is compared to the maximum levels tested on 5/3/00. Item 7 shows that the maximum levels are 19.6 dB higher than they need to be for alerting the fourth driver in line.

This is good news to residents immediately at the crossing. At gated crossings with constant warning time control, a volume of 78 dBA @ 100’ (98 dBA -19.6 dBA) is sufficient. This 78 dBA reference level produces 83 dB outside the car because the fourth car is closer at 61’. The lower volume maximizes community compatibility without sacrificing warning effectiveness.

Train Horn Comparisons

With the gates down, the wayside horn is as effective as the more distant train horn. Table 4 demonstrates that 83 dBA outside the car is sufficient warning. This is achieved with a wayside horn reference of 78 dBA at 100’. Table 5 shows the corresponding train distance from the crossing, with the gates fully closed, 20 seconds prior to train arrival. It also shows the train horn level outside the cars for different volume train horns.

Train Horn Levels at Fourth Car : 20 Seconds Before Crossing
Table 5

Train speed	20 mph	22 mph	24 mph	26 mph	28 mph	30 mph
Train Distance to Crossing	587'	645'	704'	763'	821'	880'
96 dBA train horn	81 dBA	80	79	78	78	77
104dBA train horn	89 dBA	88	87	86	86	85
108dBA train horn	93 dBA	92	91	90	90	89
111dBA train horn	96 dBA	95	94	93	93	92
Wayside Horn	82 dBA	82	82	82	82	82

The wayside horn is as good as the FRA required train horn certification (96 dBA @ 100’). Although the lower wayside horn level is sufficient, higher level adjustment can match and exceed the higher train horn inventory.

Wayside Horn Reference Volume (100’)
Necessary to Match Train Horn Volume Levels
20 Seconds Before Crossing
Table 6

Train Horn Level (100’)	Wayside Horn (100’)
96 dBA	77 dBA
104 dBA	85 dBA
108 dBA	89 dBA
111 dBA	92 dBA

Table 6 presents corresponding wayside horn volumes that match the level produced by different volume train horns, 20 seconds before train arrival. The wayside horn achieves the same result at a lower volume because the fourth car is only 61’ away from the horn instead of the 587’ comparative distance from the train horn traveling 20 mph.

Conclusions

Wayside horn applications have had favorable community responses at several installations. The maximum horn levels demonstrated on May 3,2000 are 6-10 dB louder than previous installations. Although unnecessary, this increased volume is available, if desired.

The focused radiation patterns maximize residential compatibility. This system is a good balance between adequate warning of motorists and minimizing community noise levels.