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Reverse Alarms on Vehicles: Which One is Better?

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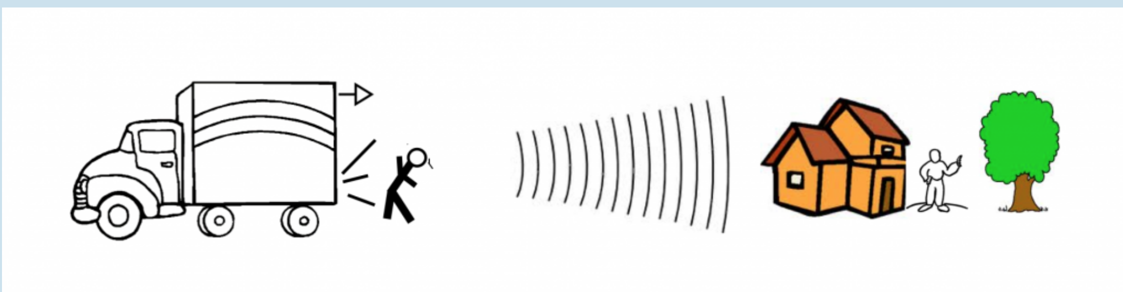

Introduction

Reverse (or back up) alarms are mandatory on most heavy vehicles. Such alarms must be well designed and properly installed to be effective (clearly audible and elicit sufficient reaction from workers or pedestrians near reversing vehicles), without being excessively loud to the point of creating noise annoyance in the community.

In practice, many interacting factors may affect the performance of reverse alarms, including but not limited to the acoustical properties of the alarm, the mounting of the alarm on the vehicle, the masking characteristics of the surrounding noise, the hearing profile of the workers and the use of hearing protection devices (HPDs). This article summarizes the findings of research projects carried out jointly by the University of Ottawa and the Institut de recherche Robert-Sauvé en santé et sécurité du travail in Montreal over the past ten years[1-3] which compared the performance of a conventional **tonal alarm** and the newer **broadband alarm.**

Tonal alarm:

Canadian Academy of Audiology · TONAL

Broadband alarm:

Canadian Academy of Audiology · BROADBAND

Acoustical Factors

The technical characteristics of reverse alarms are governed by standard SAE J994[4], which requires that the dominant signal frequencies be in the 700-2800 Hz range. The tonal alarm contains one dominant pure-tone component (about 1250 Hz for the model used in our studies) and several harmonics. In contrast, the broadband alarm covers a wide frequency span, mostly in the 700-3000 Hz range, without sharp peaks or valleys (Figure 1).

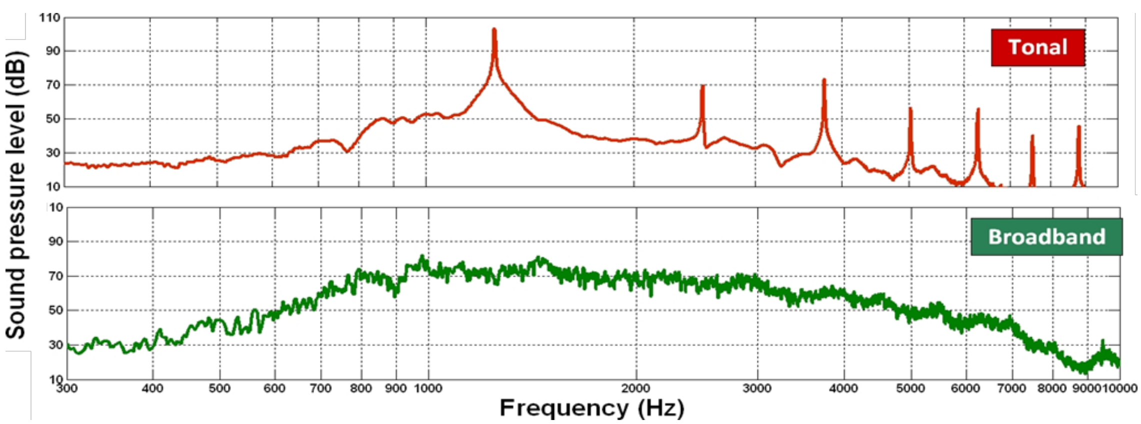

Figure 1. Spectra of the two reverse alarms.1

While both alarms meet the SAE J994 criteria, their spectral characteristics have important implications for sound propagation patterns[1,2]. Figure 2 (left) shows the layout used for reverse alarm sound level measurements behind vehicles along 7 trajectories[2]. Ideally, if a worker was moving along these trajectories, the alarm level should be as uniform as possible along trajectories 6 and 7 and smoothly decreasing with distance for trajectories 1 to 5. Figure 2 (right) shows an example of measurements made along trajectory 6 with both alarms. Large spatial variations in sound level within a short distance are noted with the tonal alarm, due to the interaction of the direct sound with the ground reflections (constructive and destructive interference). For example, moving by only 0.5 m along trajectory 6 is shown to produce variations as much as 15 dB. Because the broadband alarm covers a wide spectral span, frequency-specific constructive and destructive interferences cancel themselves out to produce a much smoother, uniform pattern.

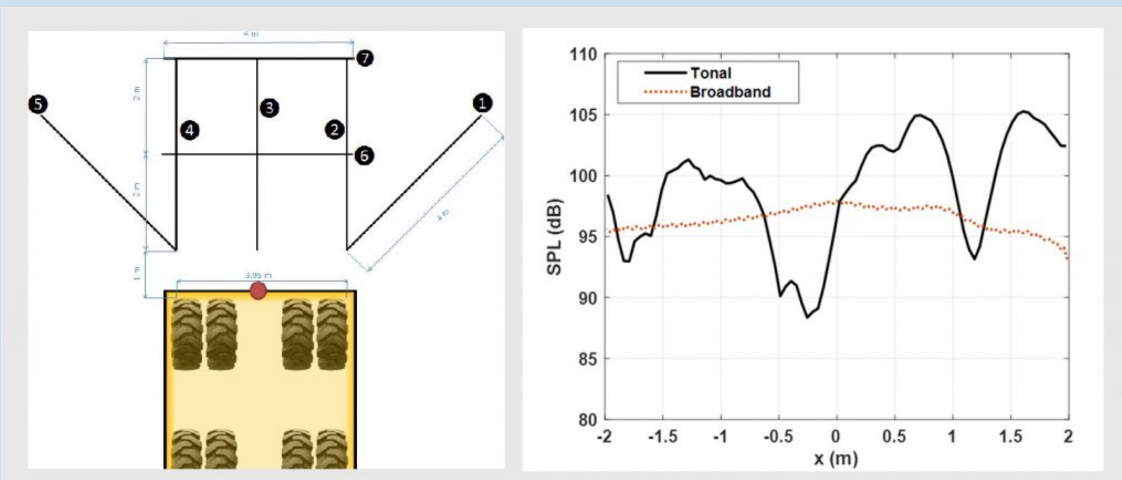

Figure 2. Sound propagation of reverse alarms behind a vehicle2. Left: measurement trajectories. Right: sound level distribution 2 meters on either side of the midline along trajectory 6 for the tonal (black line) and broadband (dotted line) alarms. The red dot represents the position of the alarm unit.

Generally, the broadband alarm produces a sound field behind the vehicle typical of a smooth geometrical decrease of sound with distance.[1,2] As such, if a vehicle is backing up towards a worker, the sound will gradually increase, as expected. With the tonal alarm, an approaching vehicle may sometimes lead to a decrease in sound level (e.g., if a worker is positioned in a sound valley), creating a false impression that the vehicle is moving away.[1,2]Moreover, the deep sound valleys produced by the tonal alarm are such that, compared to the broadband alarm, louder sound levels must be generated to ensure it is perceived in noise at all positions in the danger zone behind the vehicle.

Psychoacoustical Factors

Irrespective of sound propagation issues, the acoustical properties of the alarms largely influence their efficacy in promoting good auditory situational awareness about mobile reversing equipment. The lowest sound level at which reverse alarms can be detected in noise for individuals with normal hearing occurs at signal-to-noise ratios (SNRs) between about ?13 to ?25 dB.[2,3,5,6] Typically, the tonal alarm has slightly lower detection thresholds than the broadband alarm (by about 2–4 dB), and wearing passive HPDs also slightly lowers detection thresholds (by about 1–2 dB).

In practice, reverse alarms need to be adjusted at a level well above detection thresholds to elicit an immediate reaction. The so-called reaction threshold occurs at SNRs of about 0 dB or slightly less for normal hearing individuals not wearing HPDs, in conformity with the alarm adjustment specifications found in ISO 9533.[7] Passive HPDs significantly increase reaction thresholds in noise by about 8 dB for the tonal alarm and 5 dB for the broadband alarm, so that SNRs over the minimum recommended value in ISO 9533 may be needed.[6]Increases in reaction thresholds are also seen when using level-dependent HPDs (i.e., devices designed to produce a change in attenuation as a function of the noise level), but high-volume settings may somewhat reduce this detrimental effect in some devices[3]. Generally, reaction to the broadband alarm is less affected by the use of HPDs than the tonal alarm.

Another important parameter is the ability of workers to quickly localize the source of danger. The broadband alarm is easier to localize than the tonal alarm[1,2,3,5] and yields far less front-back confusions, which could mislead workers into searching for a vehicle in the opposite direction. Finally, HPDs significantly affect sound localization. In most cases, earmuff-type HPDs have a more detrimental effect on sound localization than earplug-type

HPDs, whether passive or level dependent and double hearing protection (earmuff plus earplugs) makes it virtually impossible to localize reverse alarms in space, even when the alarms are audible.

Final Remarks

Overall, results indicate that the broadband alarm possesses better properties than the tonal alarm to warn workers and passersby of a reversing vehicle. It produces more uniform acoustic propagation patterns behind the vehicle, has slightly lower reaction thresholds, and provides better sound localization accuracy than the conventional tonal alarm. However, it is relatively new and important questions remain about its recognisability as an alarm signal.

Finally, it should be noted that reverse alarms should never be considered fail-safe devices and always be used in conjunction with other risk mitigation measures.[8] The best method to reduce the risks of accidents is to plan the work area to eliminate the need for reversing maneuvers. Otherwise, the reversing area needs to be well organized with clear traffic routes for pedestrians and vehicles, and the distance travelled while reversing minimized.[8] It is also important to ensure that the driver has good all-around visibility, by use of mirrors, cameras, Lidars, and other technologies where necessary.

References

1. Vaillancourt V, Nélisse H, Laroche C, Giguère C, Boutin J, Laferrière P. Safety of Workers Behind Heavy Vehicles: Assessment of Three Types of Reverse Alarm. Studies and Research Projects / Report R-833 / IRSST, Montreal, Quebec; 2014. Available at: http://www.irsst.qc.ca/media/documents/PubIRSST/R-833.pdf
2. Nélisse H, Laroche C, Giguère C, Vaillancourt V, Boutin J. Performance acoustique des alarmes de recul tonales et large-bandes en milieu ouvert en vue d'une utilisation optimale). Rapports scientifiques / Rapport R-977 / IRSST, Montréal, Québec; 2017. Available at : http://www.irsst.qc.ca/media/documents/PubIRSST/R-977.pdf
3. Vaillancourt V, Laroche C, Giguère C, Nélisse H. Effet du port de protecteurs auditifs et

de casques de sécurité sur la perception et la localisation auditive des alarmes de recul. Rapports scientifiques / Rapport R-1067 / IRSST, Montréal, Québec; 2018. Available at : https://www.irsst.qc.ca/media/documents/PubIRSST/R-1067.pdf

4. SAE J994. Alarm – Backup – Electric Laboratory Performance Testing. Society of Automotive Engineering; 2009.
5. Vaillancourt V, Nélisse H, Laroche C, et al. Comparison of sound propagation and perception of three types of backup alarms with regards to worker safety. Noise Health 2013;15(67):420–36.
6. Laroche C, Giguère C, Vaillancourt V, et al. Detection and reaction thresholds for reverse alarms in noise with and without passive hearing protection. Internat J Audiol 2010;57:S51-S60
7. ISO 9533. Earth-moving machinery - Machine-mounted forward and reverse audible alarm – Sound test method. International Standards Organization; 2010.
8. Health and Safety Authority. Workplace Transport Safety Reversing Vehicles – Information Sheet. Ireland; 2009.