SELF-ADJUSTING BACKUP ALARMS IN NOISY WORKPLACES

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1 Introduction

Self-adjusting backup alarms are often used to reduce annoyance in residents living near industrial and construction sites with significant traffic from heavy vehicles. These devices automatically adjust, within a certain operational range, the level of the emitted warning signal to exceed that of the surrounding background noise, which is sampled by an integrated sensor. However, apart from the work of McDaniel *et al.*[1] and the test requirements set out in ISO 9533[2], little information is available in the literature and in the form of technical manufacturer's data to explain their functioning and to document their effectiveness in real workplaces. Questions therefore arise as many prevention specialists, local authorities and residents regularly claim that self-adjusting alarms fail to minimize noise annoyance. This paper presents research aimed at describing the inner-workings of self-adjusting backup alarms, more specifically how they adjust their output level based on the surrounding background noise in typical noisy workplace environments. Using microphones, a recorder and a current clamp, the backup alarm level can be estimated, even amidst background noise, when the device is installed on a heavy vehicle operating in typical noisy workplace conditions. Laboratory and field data are presented for two backup alarms, a tonal alarm and a broadband alarm.

2 Methodology

2.1 Laboratory measurements

To understand how a self-adjusting alarm operates, the setup shown in Figure 1(a) was used during laboratory measurements carried out in an anechoic room. Two microphones (one near the alarm and the other a meter away) were used to measure alarm levels, while a loudspeaker placed two meters from the alarm device generated various levels of a white noise and a current clamp fixed to the device's wiring measured its input current. To verify how the alarm levels are set based on noise levels in effect prior to the activation of the device, two time sequences of pulsed background noise were played as depicted in Figure 1(b). In the "Out-of-sync" sequence, the background noise pulses are progressively increased in level but appear only during the "off" (quiet) portions of the alarm, thus allowing the microphones to measure exclusively the sound pressure level of the alarm during the "on" portions since both signals (alarm and background noise) appear at different times. Results obtained with this sequence provide an insight into how alarm levels increase with increasing background noise levels. They also allow defining the relationship between the current flowing through the device and the alarm levels measured acoustically at 1 m, knowledge which will prove useful to obtain equivalent free-field estimates of alarm levels in field trials where continuous background noise sources representing real workplace conditions are encountered. In the "In-sync" sequence, the background noise pulses appear only during the "on" portions of the alarm. Alarm levels should then remain stable (at the minimal value) in this case since the preceding "off" portion was free of noise.

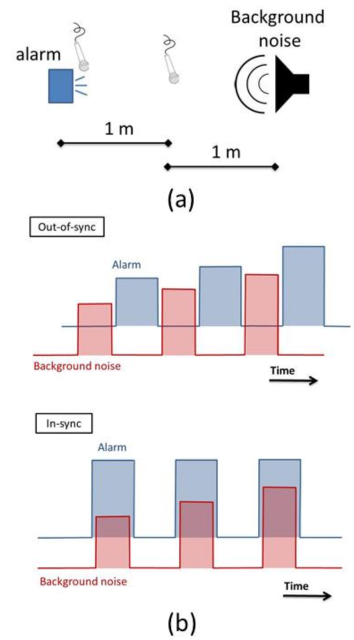

Figure 1: (a) Alarm device, microphones and loudspeaker setup; (b) Time sequences for presenting the background noise amidst the "on" and "off" portions of the alarm.

2.2 Field measurements

During field trials, a microphone placed on top of the alarm device, which was mounted on a heavy vehicle, measured the surrounding sound field. Results at this measurement point served to characterize the background noise levels used by the device to set alarm levels. A second microphone placed directly at the rear of the vehicle (exterior side and centered horizontally) was used to provide more representative readings of sound pressure levels within the danger zone behind the vehicle, levels which could differ significantly from those obtained at the other microphone position. Measurements of current were also performed. Both microphones and the current clip were connected to a recorder and continuous time recordings were performed using a 24 kHz sampling rate. Recordings were thereafter analyzed using an in-house Matlab™ code to extract and plot measured sound pressure levels (SPL) as a function of time, and to obtain estimates of equivalent free-field alarm levels based on readings from the current clip.

3 Results and discussion

3.1 Laboratory data

For both alarms, a linear relationship was found between sound pressure levels (SPL) measured at 1 meter during the “on” portions and measurements of current, results which support the use of current measurements to make free-field estimates of alarm SPLs. Such estimates are shown for the two alarms in Figures 2 and 3, along with the background noise level measured in the “Out-of-sync” sequence. The vertical lines represent alarm SPL estimates during an “on” portion of approximately 400 ms (in red) and background noise levels measured 300 ms prior to each “on” portion (in blue), while the two horizontal lines (in black) define the labeled operating range of the alarm device.

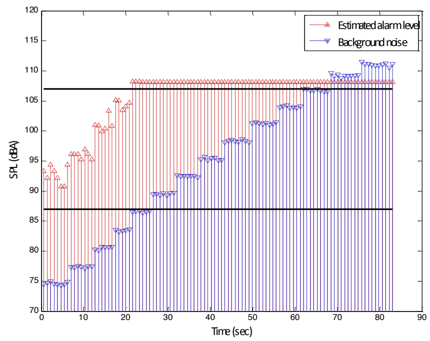

Figure 2: Alarm SPL estimates and background noise SPLs as a function of time for the broadband alarm (“Out-of-sync” sequence).

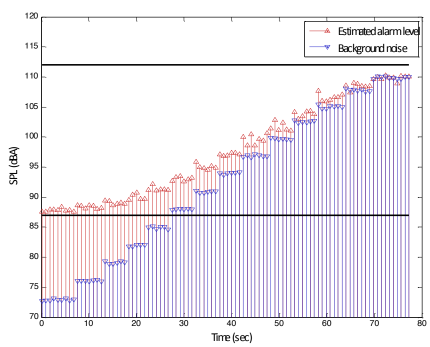

Figure 3: Alarm SPL estimates and background noise SPLs as a function of time for the tonal alarm (“Out-of-sync” sequence).

As can be seen, the levels of the broadband and tonal alarms exceed those of the background noise; however, the resulting signal-to-noise ratio or SNR (alarm level minus background noise level) appears to depend on background noise levels and alarm type. Compared to the tonal alarm, the broadband alarm produces higher SNR values and reaches its maximum output level more rapidly with increasing background noise levels.

For both alarms, current measurements (and associated alarm SPL estimates) remained constant at the lower level of the alarm operating range during the entire “In-sync” sequence, thereby confirming that the two self-adjusting alarms are only sensitive to background noise in the “off” portions of the alarms.

3.2 Field data

SPL estimates and background noise SPLs over a short time period are shown in Figure 4 for a self-adjusting broadband alarm device mounted on a heavy truck. While in this example alarms level are clearly well above the background noise, it should be noted that the resulting SNR fluctuates significantly over a few seconds, even when the background noise appears to be relatively stable. Similar results were obtained with a tonal alarm.

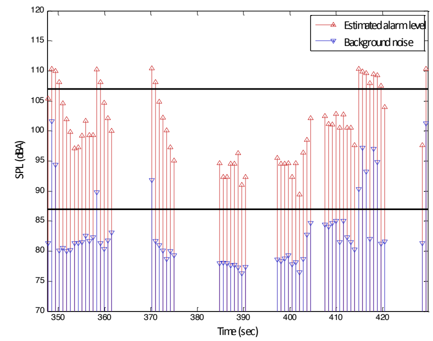

Figure 4: Example of alarm SPL estimates and background noise SPLs as a function of time for a broadband alarm device mounted on a heavy truck under normal operating conditions.

Overall, results of the field trials showed significant SNR variations and alarm levels far exceeding those of the background noise. This suggests that, in the presence of low to moderate background noise, the alarm produces levels well above the minimal SNR specified in [2]. Further data analysis is currently underway to get a better understanding of these sharp fluctuations and high SNR values since both factors may impact worker safety and noise annoyance arising from the alarms, and therefore need to be more thoroughly investigated and addressed.

4 Conclusion

A simple methodology, developed and tested in a laboratory, was used to estimate the levels of self-adjusting backup alarms in the field when mounted on heavy vehicles operating in typical noisy workplace conditions. Preliminary results show that alarm levels can fluctuate significantly even when the background noise is relatively low and stable. This impact of these fluctuations on the safety of workers and pedestrians, as well as the noise annoyance reported by nearby residents, must be further analyzed.

Acknowledgments

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References

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[2] ISO 9533, "Earth-moving machinery--Machine-mounted forward and reverse audible warning alarm--Sound test method", *International Standards Organization*: (2010).