NOISE EXPOSURE OF BROADCAST PRODUCTION PERSONNEL

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ABSTRACT

This paper presents a study to investigate the noise exposure of radio and tv broadcast production personnel, and to evaluate the efficiency of the protective devices in use. A total of 182 noise exposure measurements were made in concerts, sports and other live events. Additionally, 48 measurements were made using microphone in real ear (MIRE) method to measure the effect of the intercom system on the employees' noise exposure.

Cameramen were, in average, exposed to the highest ambient noise levels, and their average noise exposure level was 86 dB. The average noise exposure levels of technical and stage managers and light and sound engineers were 82 and 81 dB. The highest noise exposure levels were typically measured in concert, but exposure to high noise levels was also recorded in sports events.

The range of equivalent sound pressure levels (L_{Aeq}) measured over the event duration inside the communication earpiece was from 62 to 101 dB. Levels exceeding 85 dB were recorded inside both earmuffs and earphones. The calculated average attenuation of exposure to external noise was 2 dB for headphones and 11 dB for earmuffs. While the protective effect of earmuffs is substantially better than that of earphones, neither system provides sufficient protection in all cases.

1. INTRODUCTION

Technical staff and the production teams of the broadcasting companies are exposed to high noise levels in concerts, sports events and other live productions. They communicate using intercom systems wearing a headset that are typically either headphones or modified earmuffs. For acceptable intelligibility, signal to noise ratio of 5 to 15 dB is required, and the communication volume level is user adjustable. Therefore, the communication signal is a potential source of additional sound exposure even when noise protection is used. It is known that headphones provide insufficient attenuation of ambient noise, and even though earmuffs are more effective, the communication signal partially negates the greater attenuation achieved.

Employees have become increasingly concerned about the occupational noise exposure for several reasons. They believe that sound levels today are higher in events—sports, for example—that were not classified as "noisy" earlier. Common interest in noise exposure of the musicians and audiences has also raised awareness on the issue [1],[2]. The exposure time of the production crew is longer than that of the audience or the performers, as it usually includes rehearsals, sound checks and the actual performance. Additionally, studies on intercom system sound levels and noise exposure in broadcast production work has not been reported, even though this type of noise exposure has been studied in other cases [3],[4],[5].

Thus, the main objectives of this study were to evaluate the sound exposure caused by the ambient noise in productions sites, the effect of communication sound on total noise exposure, and the efficiency and need for development of the protective devices used by the personnel in programme production. The directive 2003/10/EC sets new requirements for occupational noise exposure measurements and practices and methods to meet these requirements were tested [6].

2. MATERIALS AND METHODS

2.1. Productions and occupations

Total of 182 noise exposure measurements and 48 recordings with the MIRE technique defined in [7] were made in 22 productions.

The productions were classified in three catergories (number of events/noise exposure measurements):

- concerts, including rock, pop and classical (6/56)
- sports events, including ice hockey, volley-, hand- and basketball (12/97)
- other studio, gala and live productions (4/29)

Occupational groups studied were (number of noise exposure measurements):

- cameramen (119)
- technical managers and stage managers (15)
- directors, directors of photography, lightning supervisors, production assistants (13)
- sound engineers and mixers (15)
- others including performers, audience and crew members (20)

Forty-three (43) of the MIRE measurement subjects were cameramen, 3 stage managers, 1 lightning supervisor and 1 sports commentator.

2.2. Methods

2.2.1. Noise exposure measurements

The A-weighted noise exposure levels ($L_{EP,d}$) were measured with noise dosimeters Noise Badge 705 or LD 706 (Larson & Davis, USA). The microphone was located on middle of the left or right shoulder of the subject. The measurement was made according to the Finnish national standard SFS 4578, which corresponds to ISO 1999:1990 [8]. The measurement period in different productions varied from 2 h 30 minutes to 10 hours. The A-weighted equivalent sound pressure levels were normalized to a nominal eight-our working day noise exposure levels using the formula

$$L_{EP,d} = L_{Aeq,T} + 10\,\lg_{10}(\frac{T}{T_0}) \quad (1)$$

where T is the duration of exposure and T_0 is the reference duration of 8 h (480 minutes).

2.2.2. MIRE measurements

Noise exposure inside the earpiece of the communication headset was measured with two different digital audio tape (DAT) based recording equipment.

Recording system described in [9] is a two-channel system with miniature microphone capsules (Sennheiser KE4-211-2), self-constructed microphone preamplifier and a walkman-type recorder (Sony TCD-D8). The equipment fits a waist bag and it does not limit subject's work or movements. One microphone was placed at the entrance of the ear canal. The microphone cord was secured with adhesive tape under the cushion of the earpiece (Figure 1). The other microphone was placed on the subject's shoulder as in noise exposure measurements to

Figure 1: The miniature microphone was positioned at the entrance of an open ear canal for MIRE-recordings.

record the exterior noise. Recorder was used in Long Play (LP) mode, which enabled recording time of 4 hours and changing tapes was therefore necessary only during the longest events. Use of LP-mode limits the frequency response to 20-14,500 Hz. The accuracy of the measurement setup is better than 2 dB [10].

Second equipment for the MIRE recondings was a wireless microphone system. It consists of commercial transmitter-receiver system (Sennheiser SK50/EK3401) used in the broadcasting companies. The microphone (Sennheiser miniature microphone MKE2-4) was placed at the entrance of the ear canal as above. The signal from the receiver was recorded with a DAT recorder (TEAC DA P1 or Technics SV-260-A). When the wireless equipment was used, only the signal inside the earpiece was recorded and the external noise was measured with noise dose meters as described in section 2.2.1. Thus, the two channels on DAT-recorder were used for two separate measurements.

The wireless transmitter-receiver system is not designed for acoustical measurements. The frequency response and level linearity of the device was tested and its accuracy proved to be acceptable for this study. Noise and music samples and reference sound sources were used for testing. Error in unweighted sound pressure level was less than 1 dB in comparison with a signal analyzer, and no level linearity distortion was found.

For analysis the recording were copied from DAT to PC digitally—no additional DA or AD conversions were made. Spectrum analysis and averaging was made using Spectralab software and the post processing of the spectra with Excel. Ear canal frequency response ($\Delta L_{df,f}$, see figure 2) was applied to convert noise levels inside the earpiece ($L_{ear,exp,f}$) to diffuse-field related sound pressure levels (dfr-L_f):

$$\text{dfr-}L_f = L_{ear,exp,f} - \Delta L_{df,f} \tag{2}$$

A-weighted equivalent sound pressure level was calculated:

$$\text{dfr-}L_{Aeq} = 10 \lg \sum_f 10^{(\text{dfr-}L_f + A_f)/10} \ \text{dB} \tag{3}$$

and the calculated equivalent sound pressure levels were normalized to daily noise exposure levels ($L_{EP,d}$, see section 2.2.1).

Diffuse-field related values were used instead of free-field related values because, according to our experience they match better with the results of noise exposure measurements in made in same events.

Noise exposure measurements were made for the full duration of the event, including rehearsals and other preparations and MIRE recordings when the subjects were wearing communication headset. Recording durations ranged from 1 hour to 6 hours and 40 minutes. When the duration of the measurement and the recording was not equal, the exposure level due to the ambient noise was separately calculated for the overlapping period.

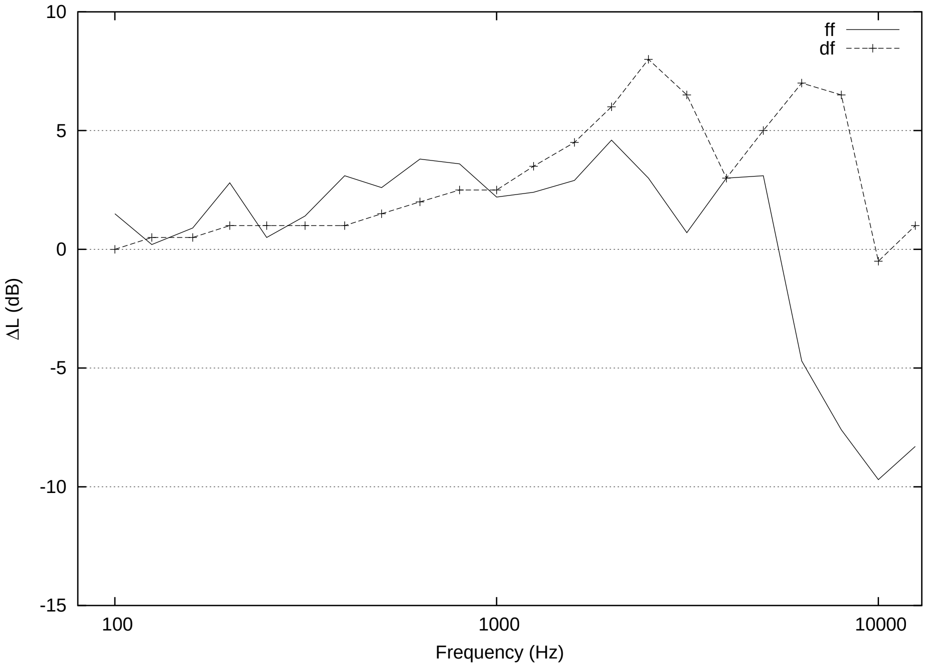

Figure 2: Free-field (ff) and diffuse-field (df) related frequency responses for conversion of sound pressure level measured at the entrance of ear canal. Numerical values in third-octave bands given in [7].

3. RESULTS

3.1. Noise exposure from event noise

Daily sound exposure levels ($L_{EP,d}$) ranged from 65 to 99 dB, and the overall average was 85 dB. The highest exposure level, 99 dB, was found among cameramen. The techinical staff had the lowest risk of having a noise dose exceeding 85 dB (Table 1). The highest noise exposure levels, 88 dB in average, were measured in concerts. Noise exposure in sports events was nearly as high, the average being 3 dB lower (Table 2)

3.2. Noise exposure from communication sound

The overall average of equivalent sound pressure levels (L_{Aeq}) inside communication headset was 81 dB (n=48), ranging from 62 to 101 dB. The corresponding sound level outside the communication device was, in average

Table 1: Measured sound exposure levels ($L_{EP,d}$) arranged according to occupation.

occupation	avg [dB]	s.d. [dB]	range [dB]	n
cameraman	86	6	65–99	119
technical or stage manager	82	6	65–87	15
light	81	8	66–94	13
sound	81	9	68–94	15
other	85	4	76–91	20

Table 2: Measured noise exposure levels ($L_{EP,d}$) arranged according to production type.

production	avg [dB]	s.d. [dB]	range [dB]	n
concert	88	7	58–99	56
sports event	85	4	69–93	97
other	77	7	69–86	29

Table 3: Headset type and daily personal sound exposure level from ambient noise and communication sound.

headset	$L_{EP,d,MIRE}$ [dB]	range [dB]	$L_{EP,d,ext}$ [dB]	n
earmuff	73	53–92	85	29
headphone	81	64–96	83	19
total	76	53–96	84	48

87 dB, ranging from 69 to 105 dB. Daily sound exposure levels ($L_{EP,d}$) calculated from this data are presented in table 3 where MIRE-results are diffuse field related values as defined in section 2.2.2.

The average effective attenuation of ambient noise exposure was 2 dB for headphones, and 11 dB for earmuffs. (Table 4). Calculated daily sound exposure level of 9 subjects exceeded 85 dB. The subject was using a headphone type communication headset in 7 of these cases.

4. DISCUSSION

High noise levels are present in various types of broadcast productions. Cameramen are the occupational group with the highest sound exposure levels, both in average and individually. Single cases with high exposure levels were present in all occupations, but the averages were less or equal to 85 dB in all other groups. The highest sound exposure levels were measured in concerts, but the sports events' contribution to sound exposure was higher than expected, and in some cases as high as in concerts.

Table 4: Sound exposure level and headset type in different productions. (hp=headphone, em=earmuff)

production	headset	$L_{EP,d,MIRE}$ [dB]	$L_{EP,d,ext}$ [dB]	$L_{Aeq,ext}$ [dB]	n
concert	hp	76	83	87	5
	em	76	89	95	11
sports	hp	84	86	90	10
	em	75	85	89	12
other	hp	78	75	80	4
	em	65	75	83	6

It was found that headphones as well as earmuffs provide *some* protection against ambient noise. The communication sound, however, reduces the achieved effective attenuation. In case of headphones the effective attenuation is negligible, and for earmuffs it was 11 dB in average. The communication sound volume level is user adjustable, and to assess the effect of the communication sound, an estimation of the users preferred volume settings was necessary. The estimation was made by comparing the actually measured sound pressure level inside earmuffs to a calculated sound pressure level. Calculation was based on the measured ambient noise level and spectrum and the known characteristics of the earmuffs [11]. In average, the difference of measured and calculated sound levels was 6 dB (1,5–10 dB), i.e. the user typically did set the communication volume to exceed the attenuated external sound by 6 dB.

Actually, the range of measured ear canal sound pressure levels was very wide, and the calculation above is a simplification of a complex situation. Other factors also have an effect on the ear canal sound level—the choice of headsets according to the production type is based on subjective conventions and expectations of an individual, the characteristics of event sounds have an effect on the insertion loss achieved with the headset, and also on the user's intercom volume setting. For example, the measured noise exposure level for headphone and earmuff users in concerts was equal, but earmuffs had been used in conditions where the external sound level was 8 dB higher. In sports events all subjects were exposed to equal external sound levels and both headset types were used equally often, but the sound exposure level of earmuff users was remarkably lower. This was interpreted indicate that concerts are expected to be noisy, and earmuffs are chosen, unless one knows that he or she is not going to work in the high noise areas. On the other hand, in sports events the exposure to event sound is similar for all, but they are not commonly considered as a noisy event, and headphones are used instead of earmuffs.

According to the present suggestions the ambient noise level in audience areas may be up to 100 dB [12]. On the stage, where cameramen are working, noise level is usually 3–9 dB higher. This worst case scenario regarding the noise exposure and the estimated 6 dB signal to noise ratio set by user together set the pre-conditions for the instructions on hearing protector selection. Single hearing protectors will not provide an adequate protection when the additional exposure from communication signal is taken into account, but a combination of communication earplugs and effective earmuffs will. It is therefore suggested that in productions where noise levels are moderate, the user would use his or her primary hearing protector alone, and in the productions where high noise exposure is expected, combined protection will be used. This hearing protector policy is being tested in YLE, and the initial user feedback has been positive. Further development of the communication system is also recommended. For example, higher quality of communication signal should reduce need for excessive sound levels.

The MIRE technique as defined in [7] proved to be suitable for field measurement of noise exposure of communication headset users. Measurements can be made with the microphone positioned at the entrance of the ear canal i.e. inserting the microphone in ear canal is not necessary, which is essential for field measurements when the subject is not stationary. It has been shown that in regard of measurement accuracy and repeatability the ear canal entrance is not ideal measurement position [13]. Nevertheless, the results acquired using the standard frequency responses are comparable with the results of conventional sound exposure measurements. Beside the data for sound exposure analysis the recordings provide the possibility of aural monitoring of earmuff leaks, for example.

The method is also versatile—it can be applied using widely available microphones and recording devices, but special equipment, such as the wireless transmitter-receivers, may be used as well when available. It also seems to be applicable for the measurement of the actual attenuation of conventional earmuffs at workplaces. This kind of measurements are expected to be necessary in near future due to the forthcoming requirement that hearing protectors will be taken into account when determining the worker's effective noise exposure [6].

Other measurement methods for communication systems will, however, be necessary. For example, measurement of the effective attenuation of the suggested combination of communication earplug and earmuff is not easy to do safely in field conditions with the MIRE technique as-is. A possible approach for such special needs may be the method described in [3] where the electrical input signal of the headset is measured and the ear canal sound pressure level is calculated.

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