Communication

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Abstract: Environmental pollution by noise is one of the most serious health threats nowadays. The impact of noise on the human body depends not only on the sound level but also on its spectral distribution. Reliable measurements of the environmental noise spectrum are often hampered by the very high price of top quality measuring devices. This paper explores the possibility of using much cheaper audio recorders for frequency analysis. Comparative research were performed in laboratory and field conditions, which showed that, with some limitations, these devices can be useful for the needs of environmental noise frequency analysis. This fact gives an opportunity for reduce the cost of noise analysis experimental work.

Keywords: environmental noise measurement; spectral analysis; sound measurement devices; railway transport

1. Introduction

Environmental noise has a negative impact on human well-being and health, and excessive exposure to it, apart from the obvious effect i.e. hearing loss, causes a number of other diseases and ailments such as: cardiovascular diseases, poorer concentration, increased stress levels, increased sugar and cholesterol levels, decreased immunity, sleep disorders and even mental illnesses [1-19]. For this reason, monitoring environmental pollution by noise is an important issue. The main sources of environmental noise in the human environment are transport and industry [20-30]. The nuisance of a given noise results not only directly from its intensity, but also from the acoustic signal spectrum [31-37]. This is due to the non-linear sensitivity of the human ear to particular sound frequencies. As a rule, the most annoying noise is in higher parts of the acoustic spectrum. To assess the noise level and its spectral distribution, the so-called sonometers, i.e. sound level meters measure the sound pressure level. They allow for immediate control of the noise level and analysis of the frequency spectrum. However, top quality sound level meters are very expensive devices, while cheap ones do not fulfil their purpose due to the use, during their production, of low-class technical components. In particular, spectral analysis of noise, performed by using cheap sonometers is impossible due to the very limited bandwidth of their measurement microphones. An alternative to usage of high-class sonometers may be to apply audio recorders, which are much cheaper but often equipped with high-quality built-in microphones with a wide acoustic band; sometimes they allow for connection of external microphones. Of course, audio recorders do not allow for direct measurement of sound intensity due to their ability to adjust the recording level. This assessment is only possible by

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comparison with a sonometer. However, it seems that they can be used for noise spectrum analysis. This article assesses the suitability of a relatively cheap audio recorder with an external microphone for spectral analysis of environmental noise.

2. Subject and methodology of research

During the conducted research usefulness of a portable audio recorder TASCAM - model DR-40X, for spectral analysis of environmental noise has been assessed. Both microphones built into the device and the external condenser microphone from AKG – model P170 – have been checked. The first-class sound level meter from Bruel & Kjaer – model 2250 Light – has been used as a reference device. Table 1. presents a summary of the main technical parameters of the used equipment.

Table 1. Summary of main technical parameters of used equipment.

Device	Main parameters	
B&K 2250-L 	Dynamic range	120 dB
	Max. sound level	140 dB
	Frequency range	5 Hz – 20 kHz
	Self-noise level	16.6 dB(A)
	Approximate price	9000 EUR
Tascam DR-40X 	Signal to noise ratio	≥ 94 dB
	Frequency range	20 Hz – 40 kHz (+1/–3 dB)
	Total harmonic distortion	≤ 0.01%
	Approximate price	200 EUR
AKG P170 	Frequency range	20 Hz – 20 kHz (+4/–12 dB)
	Self-noise level	19 dB(A)
	Max. sound level	135 dB SPL (for 0.5% THD)
	Signal to noise ratio	75 dB(A)
	Impedance	≤ 200 Ω
	Approximate price	80 EUR

Comparative research was carried out in two stages. First, measurements were made in controlled conditions, i.e. using a known acoustic signal recorded in a room with a high degree of sound attenuation. In the second stage, the results obtained in field conditions when measuring environmental noise emitted by trains running on the railway line were compared. In both cases, differences in the spectrum of the signal recorded by individual devices were analysed in detail.

3. Results

3.1. Results of laboratory experiments

Laboratory research was performed in well soundproofed chamber, whose walls and ceiling were covered with sound absorbing material. Also, the floor was a double-layer one, with layers separated by sound damping material. Thanks to this, good insulation from external sounds was obtained, despite the fact that the room itself only partially meets the requirements for anechoic chambers. The background noise level in the chamber was about 18 dB. An overview of the room during the tests is shown in Figure 1.

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Figure 1. Equipment arranged in an acoustically insulated chamber.

Two types of waveforms were used as test signals, namely white noise and chirp signal i.e. sound with a smoothly changing frequency in the acoustic band area. The sound source was two active Presonus Eris E5 monitors. For the first test signal, the results were subjected to spectral analysis, while in the second case the time waveforms of the relative sound level were compared. The shape of the response, both spectral and time, reflects the image of loudspeaker and chamber resultant frequency characteristics. From the subject analysis point of view this does not matter, because the interesting issue are the differences between individual devices, not the frequency characteristic of a given element. Microphones of recording equipment were placed at the height of the tweeter speaker at a distance of about 130 cm. During registration, individual devices were placed in the same place, on the symmetry axis lying between the loudspeakers (differently that shown in Figure 1). This allowed us to obtain repeatability of registration conditions for all the individual devices.

Comparison of spectral analysis results for signals recorded by individual devices is shown in Figure 2. The source sound during this analysis was a white noise.

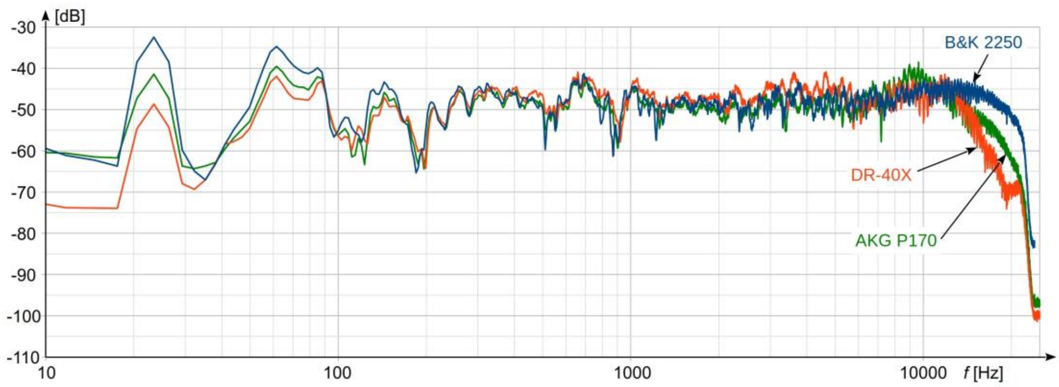

Figure 2. Comparison of spectral analysis results obtained for signals recorded by individual devices.

The comparison of results presented in Figure 2 shows that, in the frequency range from 100 Hz to 10 kHz, the spectrum for all three devices is very similar. Small differences of level do not exceed

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several dB. Slightly lower compliance in the range from 3 to 10 kHz results from the presence of standing waves in the chamber which, in combination with small differences in individual microphone transducer positions in space, gave the effect of some differences in the spectrum shape. Greater deviations between the reference and other devices are present in the areas of very low and very high frequency. They are caused by less linear frequency responses of microphones embedded in TASCAM recorder and AKG microphone in comparison with the reference instrument – with 2250L Bruel & Kjaer meter. However, the AKG microphone clearly has better frequency parameters compared to the built-in TASCAM microphone, which would contradict the parameters of both devices provided by their manufacturers.

The comparison results of sound level changes in time for chirp signal, which is shown in Figure 3. confirm frequency analysis results. Both trials generally confirms the usefulness of cheaper devices for testing environmental noise acoustic spectra. The justification for this conclusion is the lack of local spectrum deviations between devices, which could be misinterpreted in measurements.

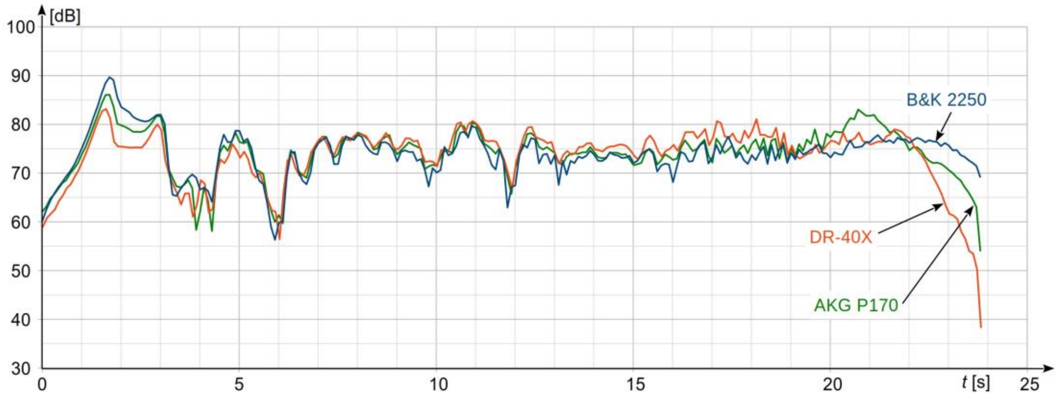

Figure 3. Comparison of time analysis results obtained for chirp signal recorded by individual devices.

3.2. Results of field experiments

In order to confirm the laboratory research results, all three analysed devices were compared in field conditions. For this purpose, environmental noise generated by a passing train was measured. The comparison of the results obtained for two selected electrical multiple units (EMU) are shown in Figure 4 and 5.

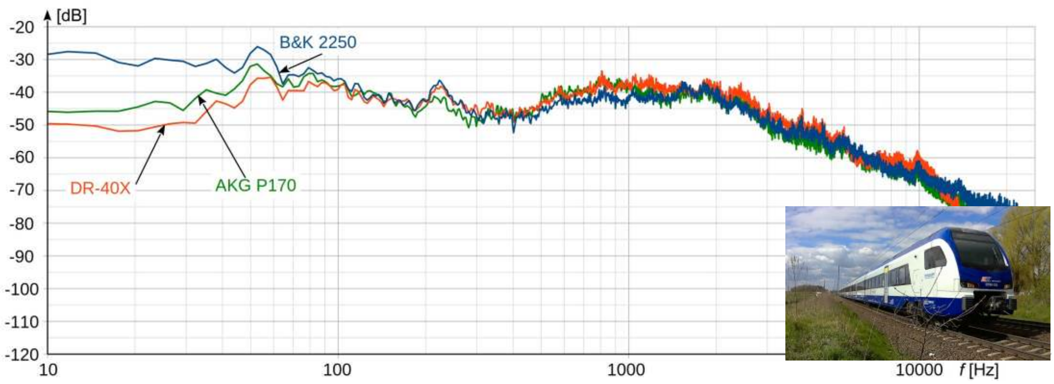

Figure 4. Comparison for noise spectrum generated by EMU ED160.

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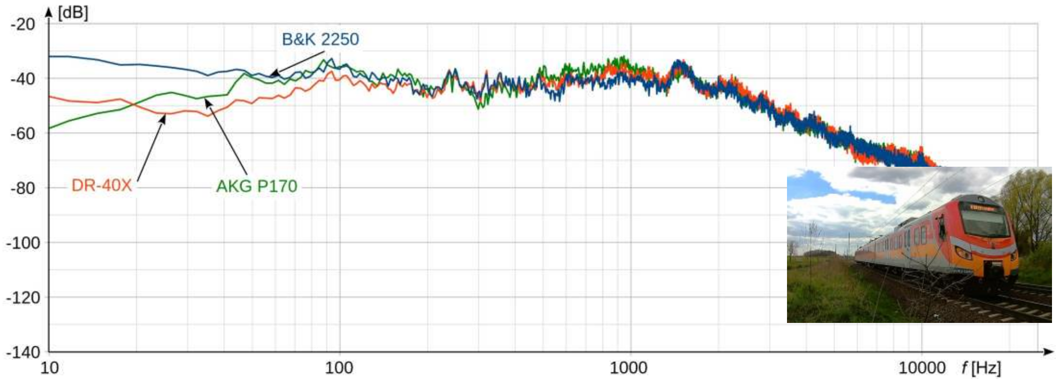

Figure 5. Comparison for noise spectrum generated by EMU EN57.

The results recorded in field conditions confirm the dependencies observed during laboratory measurements. Basically, there is a compatibility of spectra shapes for each device in the frequency range from 100 Hz to 10 kHz. As a result of sound recording in the open area, and thus lack of standing wave effect characteristic for closed rooms, better compatibility of individual spectra for frequencies from 3 to 10 kHz is visible. The most significant differences in comparison to reference device occur for infrasound range. The reason for this feature are frequency characteristics of the microphones, both that built into TASCAM recorder and the external AKG one. Neither of them has good frequency response below 20 Hz, so infrasound, as well as the ability to conduct very low sounds in the 20 – 60 Hz band is slightly limited.

The frequency response of the reference instrument reaches 5 Hz. However, it should be remembered that legal provisions regarding environmental noise measurements do not require infrasound measurements.

4. Discussion and conclusions

The considerations presented in this paper were aimed at checking the usefulness of using cheap audio recorders for environmental noise spectral measurements. Conclusions of the conducted research clearly indicate that such devices may be useful, with certain limitations. If the basic acoustic spectrum is taken into account, i.e. the frequency range from 30 Hz to 15 kHz, the correspondence between results obtained from cheap and reference instruments is very good. Differences are visible only at edges of the acoustic band and in close ultrasound and infrasound areas. Especially in this last part of spectrum, the results obtained from cheap devices are different than those registered by the reference one. However, it should be noted that the difference lies only in the acoustic level and relative level compared to other frequencies of the acoustic band, while the characteristic frequencies which appear in these areas of the spectrum are visible for all the analysed recording devices. Better results could certainly be obtained by microphones with more flat frequency characteristics. Hence further research will be aimed at testing other types of external microphones. Nevertheless, the results shown indicate the possibility of using cheaper sound recording devices for the spectral analysis of environmental noise, which allows for a significant reduction in the costs of experimental work.

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Data Availability Statement: The obtained measurement data is confidential and therefore is not on a publicly accessible server.

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Conflicts of Interest: The authors declare no conflict of interest.

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