Software Tool for Community Noise Surveys

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***Abstract* — Community noise surveys, such as those carried out during the process of acoustical zoning of open space, sometimes require analyses which cannot be made using standard sound level meters. This can be overcome by implementing a dedicated research tool for noise measurement and analysis. This paper describes software designed as an integral part of such a tool. Its functions are listed and the use is demonstrated on some practical examples.**

***Keywords* — community noise, equivalent sound level, noise measurement.**

I. Introduction

COMMUNITY noise measurement is regulated in detail by international and corresponding national standards [1], [2]. There is a wide range of sound level meters on the market designed for such measurements, differing by the precision and complexity. The capabilities of the most complex of them exceed by far the requirements of noise level measurement, being provided with various software supports. These sophisticated models of sound level meters also allow sound insulation, reverberation time and sound intensity (two channel models) measurements.

However, apart from the highly sophisticated sound level meters nowadays, community noise surveys sometimes require analyses beyond the capabilities of standard noise measurement devices. This is the case, for example, with the analyses of time related characteristics of noise, important for the acoustical zoning of communities. Such analyses are usually carried out at selected micro locations across the settlement, including more than basic statistical data determination in 15-minute time intervals, during day and night periods. The experience in that field has introduced the need for a more flexible research tool, by which the noise analyses could be carried out in various non-standard ways.

Starting with such a need, a special research tool has been designed, allowing the determination and analysis of various parameters derived from noise recordings. The tool consists of several hardware components and two software applications. Hardware pieces of equipment include: measuring microphone, calibrator and portable digital audio recorder. Using this equipment allows calibrated recording of noise signal in any environment and at any time of day, including all-day (or even longer) continuous recordings.

The off-line analyses of recorded signals are done using two software applications. Basic application is specially designed and all the measuring procedures over the noise signals are carried out in it. The preparation of raw signals can be done using any commercial sound editing application. This includes extracting the parts of the signal of interest, and even mixing them into a new signal if needed (for example to insert a certain number of recorded sounds of airplane flyovers, passing cars or any other noise source into a recorded 15-minute noise interval).

This paper describes in more detail a dedicated software application, which is the central part of designed research tool. It is used for off-line analysis and measurement of recorded noise signals. The paper also presents its use on two practical examples.

II. Concept and Organisation of the Software

Computer software, written in *Matlab*, is designed as an application specialized for off-line measurement and analysis of sound level (primarily of community noise). Analyzed input signals are WAV audio files. The results are presented in graphical user interface of the program and also saved in *Excel* sheets. Both recorded noise signal and calibration signal (sine wave of a predefined sound level) are needed for calculating the absolute sound level. Calibration signal should be recorded under the same circumstances as the noise signal, i.e. using an equal gain level. Therefore, two WAV files of recordings are used as the input data of the program – one containing calibration signal and the other containing the signal of noise. Preparation of both WAV files of the recordings can be done in any standard audio editing software. After importing signals and the numerical value of absolute calibration level the analysis can be run within the program.

The basic result in the analysis is the time change of absolute sound level of the noise signal (in dBlin or dBA), using one of standard time weighting – “fast” (125 ms) or “slow” (1 s). The values of noise exposure levels over 1 s and 8 h intervals are also displayed within the program window, calculated by formula [3]:

$$L_e = L_{eq} + 10 \cdot \log_{10} \frac{T}{T_n}, \qquad (1)$$

where L_{eq} is measured equivalent sound pressure level, T is measuring time, and T_n is reference time interval of 1 s ($L_{e(1s)}$) or 8 h ($L_{e(8h)}$). Other parameters calculated over the

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whole signal duration include equivalent sound level, minimum and maximum values and the parameters of cumulative statistical distribution of sound level (percentile levels) – L_1, L_{10}, L_{50}, L_{90} and L_{99} (where the number denotes percentage of time in which the sound level exceeds the value of parameter). All parameters can be calculated in octave and one-third octave frequency bands. However, octave and one-third octave analyses take a longer processing time, which can be problematic in case of very long recorded signals. Usual processing of 2 GB WAV file with the sampling frequency of 48.000 Hz takes about several minutes on a standard PC. In case of a narrow bands analysis this duration is multiplied with the number of octaves and/or 1/3 octaves. Still, 24 h recordings can be wide band analyzed in an acceptable amount of time, which makes the program suitable for community noise analyses and measurements. After the calculation process, all main results are shown in program window, numerically and graphically.

Initial purpose of the software was to be used in community noise research. Hence, its second part is dedicated to the wider analysis of recorded audio signals. It uses the results of the first part of the program as the input data, and allows a more detailed analysis of the recorded signal of noise. That includes the calculation of equivalent sound level in standard successive 15-minute time windows [1], or the windows length and shift of which are specified by the user. Finally, user is allowed to select any interval on the graph representing sound level time change in order to calculate the equivalent sound level in a chosen period of time. The results of these analyses are stored in a separate *Excel* file.

III. Graphical User Interface

Fig. 1. shows graphical user interface of the application. Apart from the menu bar at the top, the window is divided into four sections. Their more detailed descriptions and functions are given below.

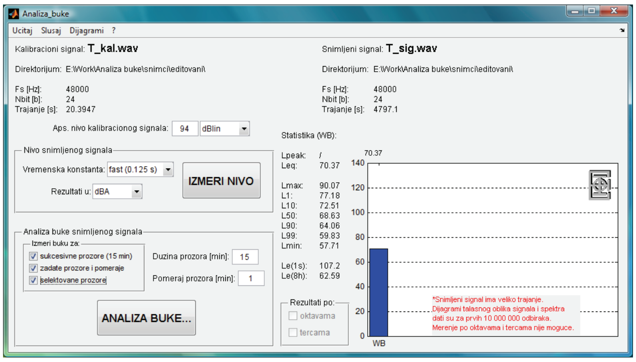

Fig. 1. Main window of the program.

A. Menu Bar

There are three pull-down menus in the menu bar of the program, with the following structure:

1) *Ucitaj* [Load]

- *Kalibracioni signal...* [Calibration signal...] – opens the window for loading the calibration signal
- *Snimljeni signal...* [Recorded signal...] – opens the window for loading the noise signal to be analyzed

2) *Slusaj* [Hear]

- *Kalibracioni signal* [Calibration signal] – plays the first 5 seconds of the calibration signal
- *Snimljeni signal* [Recorded signal] – plays the first 5 seconds of the recorded noise signal

3) *Dijagrami* [Plots]

- *Kalibracioni signal – talasni oblik* [Calibration signal – waveform] – shows the plot of the calibration signal amplitude as a time function
- *Kalibracioni signal – spektar* [Calibration signal – spectrum] – shows the plot of the noise signal spectrum
- *Snimljeni signal – talasni oblik* [Recorded signal – waveform] – shows the plot of the noise signal amplitude as a time function
- *Snimljeni signal – spektar* [Recorded signal – spectrum] – shows the plot of the noise signal spectrum
- *Promena nivoa* [Sound level change] – shows the plot of the noise signal sound level time change
- *Izmereni spektar* [Measured spectrum] – shows the plot of the noise signal octave and third-octave spectra.

B. Section 1: Calibration and Noise Signals

This section is located in the upper part of the program window, below the pull-down menus. It contains basic information about the calibration and noise signal WAV files (the file name, directory, sampling rate, bit resolution and duration; Fig. 2. shows only the left part of the section, containing the information about the calibration signal) and the edit field for typing the absolute sound level of the calibration signal (*Aps. nivo kalibracionog signala*). The value can optionally be expressed in dBA, which can be useful when a standard sound level meter (or any other device capable of measuring A-weighted sound pressure level) is available to the user instead of a calibrator. Calibration is then achieved by simultaneously recording and measuring the sound level of any sound signal. This signal is then loaded in the program as a calibration signal and the measured value of equivalent sound level is typed in as its absolute sound level.

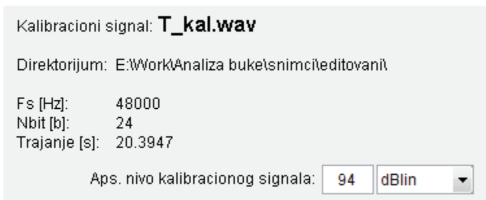

Fig. 2. Section 1: part of the main window containing data about calibration signal.

C. Section 2: Measurement of Recorded Signal

Section 2 (Fig. 3) is located in the left part of the window, below section 1 and contains options for the measurement of the recorded signal sound level: time weighting (*Vremenska konstanta*; "fast" – 125 ms or "slow" – 1 s) and the selection of measurement unit (*Rezultati u*; dBlin or dBA). Clicking the button *IZMERI NIVO* starts the calculation process.

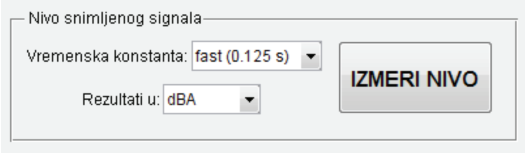

Fig. 3. Section 2: part of the main window for measurement of recorded signal.

The final results of this part of the program are an *Excel* file which stores basic information about the recorded signal (file name and directory, sampling rate, bit resolution and signal duration), the equivalent, maximum and minimum sound level, L-parameters of cumulative statistical distribution and the time change of sound level (in a selected measurement unit and with a selected time weighting applied).

D. Section 3: Analysis of Recorded Signal

In this section user is allowed to define the duration (*Duzina prozora*) and shift (*Pomeraj prozora*) of the time windows in which equivalent sound level will be calculated (*zadate prozore i pomeraje*) or to use predefined, standard successive 15-minute windows (*sukcesivne prozore (15 min)*). Another option left to the user is to mark the time interval on the plot of sound level change in which the calculation of the equivalent sound level is to be performed. This section of application window is show in Fig. 4. Calculation process is launched by clicking the button *ANALIZA BUKE...*, which opens the window for importing the *Excel* file containing the sound level time change obtained as a result of the calculations in section 2. This allows the hardware-demanding and time-consuming process of sound level time change calculation using input WAV file to be carried out only once. Further calculations in terms of noise analyses can be conducted quickly many times, using, for example, different time windows.

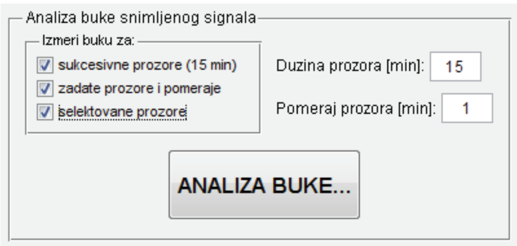

Fig. 4. Section 3: part of the main window for measurement of signal level.

All the results are saved in a new *Excel* file, among which are (depending on the selected options for the time windows):

- all the parameters from the imported Excel file, except for the sampling rate and bit resolution of the original recorded signal
- the values of equivalent sound pressure level in successive 15-minute time windows
- the values of equivalent sound pressure level in time windows of specified length and for a specified time shift
- the values of equivalent sound pressure level in selected time intervals

E. Section 4: Representation of Results

Measurement results are represented in the lower right part of the program window which contains both numerical values of the parameters (maximum sample amplitude, equivalent sound level, maximum sound level, L-parameters, minimum sound level, signal duration and noise exposure levels over 1 s and 8 h) and the bar-graph of equivalent sound level of the wideband signal (*WB*). Equivalent sound level in octave (blue colour in Fig. 5) and third-octave bands (green colour) can also be shown by checking the boxes *oktavama* and *tercama*, respectively. More detailed results are stored in corresponding *Excel* files and the plots are drawn through pull-down menu *Dijagrami*.

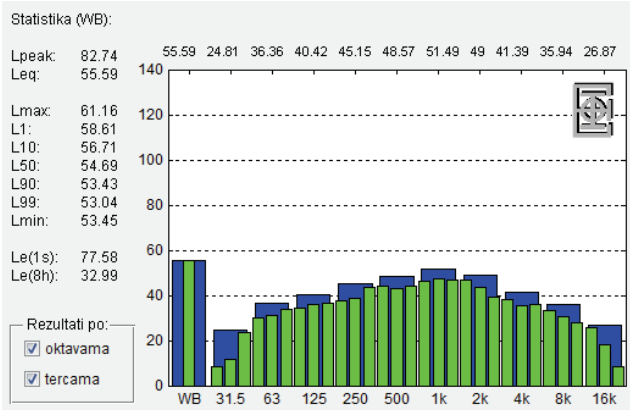

Fig. 5. Section 4: part of the main window containing the results.

IV. Two Examples of Noise Analysis Using the Software Tool

The two examples of noise measurement and analysis using described software are given below. They should demonstrate its flexibility and practical value.

A. 24-hour Measurement of Traffic Noise

The first example illustrates the application of the tool for the analysis of traffic noise in a street. It is prescribed by standards that traffic noise should be measured 24 hours continuously [1]. The described research tool is capable of recording and processing 24 hours long noise signals. Figs. 6-7 show the change of noise level during 24 hours. The signal has been recorded on the facade of a building located in a residential acoustic zone in Belgrade. The facade is facing the street (in the case of Fig. 6) and the courtyard (Fig. 7). A line in black colour represents the change of sound level obtained by "fast" time weighting and red line represents values in successive 15-minute intervals.

The curve representing the change of sound level shows considerably larger dynamics in the case of the street facade than the courtyard. Oscillations of equivalent sound levels in successive 15-minute windows are up to about 5 dB, but are less pronounced in the courtyard. Both curves of 15-minute time weighting decay during night (about 15 dB in the street and 7 dB in the courtyard). A slight maximum is noticeable between 13 and 16h.

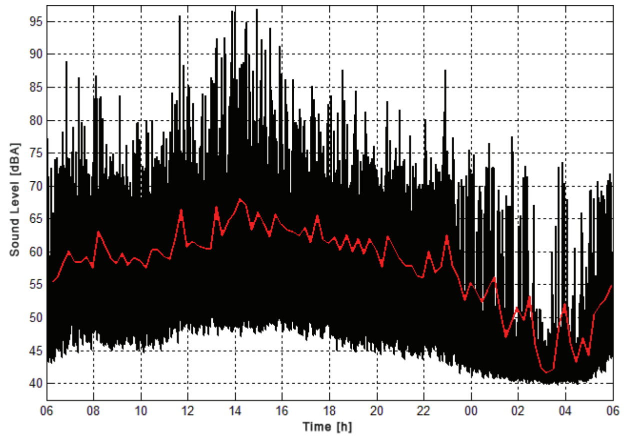

Fig. 6. Noise level change on the facade of a building in residential acoustic zone facing the street.

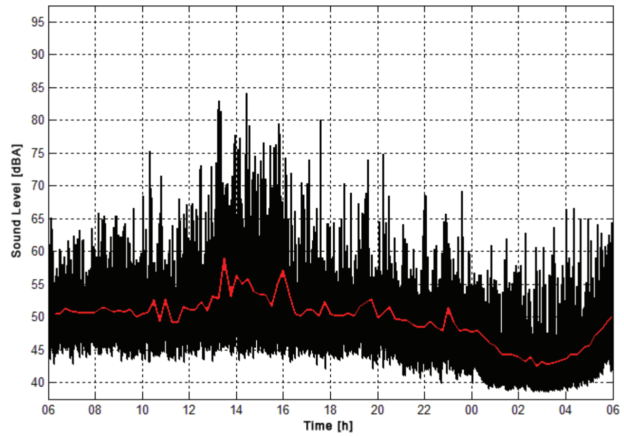

Fig. 7. Noise level change on the facade of a building in residential acoustic zone facing the courtyard.

Table 1 lists the calculated parameters (24h, day and night) for both cases – equivalent, maximum and minimum sound level and L-parameters. Daytime is considered to last from 6 a.m. to 10 p.m. All the parameters are calculated using "fast" time weighing. Equivalent 24-hour sound level in the street is 60.8 dB, which is about 10 dB higher measured value than on the other side of the building. The equivalent daytime sound level is 62.2 dB in the street (52.1 dB in the courtyard) while during the night it drops to 54.4 dB (46.7 dB). The values of parameters L_1 and L_{10} are about 12 dB higher in the street, except for L_{10} during night-time, when the difference is only about 3 dB. Other L-parameters show a smaller difference.

B. Impact of individual car passes on equivalent noise level in a quiet street

Noise level in the streets with a low vehicle flow is proportionally low. However, in such circumstances sporadic car passes may significantly influence equivalent noise level. This is especially the case during night, when the background noise level and the number of passing cars are minimal. Therefore, some insight into noise level variations as a consequence of car passes is useful for community noise analyses. It can be achieved by in situ measurements, but, for general statements, the simulation of such a scenario would be quicker and less demanding.

TABLE 1: VALUES OF NOISE PARAMETERS ON THE FACADES FACING THE STREET AND COURTYARD.

	street			*courtyard*		
	24h	**day**	**night**	**24h**	**day**	**night**
L_{eq}	60.82	62.24	54.36	50.90	52.07	46.74
L_{max}	96.81	96.81	87.55	84.13	84.13	69.10
L_1	70.56	71.61	67.26	58.96	60.57	53.58
L_{10}	62.78	64.23	52.24	52.06	52.72	49.48
L_{50}	50.43	52.92	43.89	48.05	49.07	44.01
L_{90}	42.11	47.73	40.64	41.83	45.97	39.78
L_{99}	40.12	45.31	39.69	39.03	43.55	38.36
L_{min}	39.80	43.02	39.80	38.54	40.57	38.54

This is demonstrated in Fig. 8. The upper part of the picture shows the background noise signal recorded in a small street during the period with no passing cars. The recording of a single car pass was also recorded at the same location. The lower part of the picture shows the same signal of background noise but with the signal of passing car inserted. By inserting more signals of passing cars, their influence on overall noise level can be estimated.

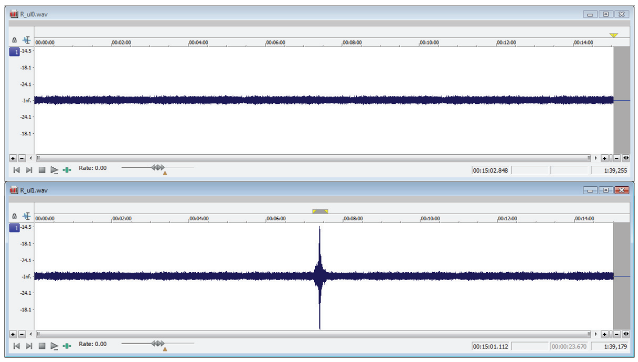

Fig. 8. The signal of car passing in a small street inserted in 15-minute signal of background noise.

Using standard audio editing application the recorded signal of a passing car has been inserted in the 15 minutes long background noise signal recorded in two streets, 1 to 20 times with no overlapping between them. Then the increase of noise level as a function of the number of car passes is calculated by using designed software. Fig. 9 shows the calculated equivalent noise level, L_{10} and L_1 for both streets.

The first street is in the city centre, while the second belongs to the residential acoustic zone. Consequently, the background noise in the first one is about 13 dB higher. This causes the curve of equivalent sound level to rise faster in the case of the second street, since a short noisy sound of the passing car reaches nearly the same level in both cases, as both streets are narrow and of canyon type. It is also noticeable that the difference between L_1 and L_{eq} is fairly constant in the case of more than three car passes, and equals about 13 dB. This matches the night-time value of L_1 in the street given in Table 1.

Because of the impulsive nature of a single car pass (in comparison to a 15-minute time window), L_{10} is lower than the equivalent sound level for small numbers of passing cars. It can be found in literature [4] that L_{10} linearly depends on L_{eq}, and is about 3 dB higher, but this holds only for more sustainable traffic noise. When there are only few car passes in an otherwise quiet street, L_1 is a much more appropriate parameter. It is also reasonable to consider adding a 5 dB adjustment to the equivalent sound level measured in a quiet street (especially during night) if a small number of car passes occurred, as in the case of conventional impulsive noise sources [5].

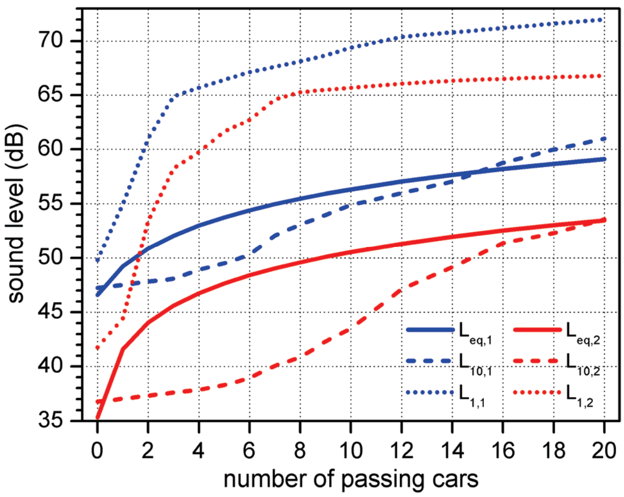

Fig. 9. Calculated parameters of noise level in two streets as a function of the number of passing cars.

V. Conclusion

The computer software presented in this paper, being an integral part of the research tool designed for complex analyses of community noise, at the first level meets the usual requirements of noise measurement. Additionally, it provides the user with higher flexibility and a more detailed insight into the characteristics of a recorded signal than standard sound level meters. The program is intended to be used in forthcoming surveys of community noise, suggesting its further modifications and improvements depending on the future needs. That also presents its advantage over the standard devices when used as a research tool – making modifications in a relatively easy way according to user demands.

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