Limiting the levels of outdoor music clubs sound reinforcement systems at Zrće, Croatia

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Summary
Sound reinforcement systems in music clubs have become the synonym for sound sources that produce excessive noise levels, both in indoor and outdoor facilities. Typical sound insulation measures, such as the box-in-a-box design, cannot be applied for music clubs located outdoors. The only means of sound level control are the frequency equalization of loudspeakers, their proper positioning in space and the overall sound level limitation. Noise barriers can be placed as well, but their efficiency is usually very limited due to the high positioning of loudspeakers. In this paper, the problem of excessive noise levels in the famous bay of Zrće in Croatia will be presented, where five large music clubs attract several thousand visitors each day during summer season. Many complaints have been made by residents of nearby towns and villages over the last couple of years. Noise levels of more than 70 dBA were measured in those settlements during the day, but also in night time. Simulations of sound propagation from the sound reinforcement systems to the nearest settlements will be presented, along with measured noise levels. The proposed and implemented solution for successful coexistence of music clubs and settlements will be discussed.

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1. Introduction

In recent years, certain destinations in the coastal part of Croatia strive to profile themselves as top-grade destinations oriented on clubbing and music festivals which would attract first and foremost the young population. By definition, such events are accompanied with elevated noise levels generated by electroacoustical systems designated for music reproduction. Some of these events take place in old industrial facilities, even abandoned mines on remote locations and as such do not represent a disturbance for residents and local population. Unfortunately, a much more common situation is that the clubs and party locations are located close to or even within densely populated areas. In this case, the noise levels generated by the activities on these locations can become the source of disturbance for local population, but also for tourists who do not necessarily want to participate in these activities, but look for other ways of spending their time.

The Zrće Beach on the island of Pag in the Northern Adriatic Sea is specific by the fact that it has been profiled over the years as the Croatian equivalent of Ibiza, a similar location in Spain. Both the club owners and the representatives of the local authorities tend to turn this location into a brand that would be recognizable not only in Croatia, but also internationally. Therefore, each year during high season the location hosts a large number of activities, such as concerts and festivals, as well as daily activities such as parties. Unfortunately, these efforts might come with a cost: high sound levels at the source have become a disturbing noise for the population and tourists residing in nearby towns, villages and resorts. A solution had to be found that would enable a coexistence of all concerned parties.

2. Description of the problem

As already stated, Zrće is essentially a beach located in the Bay of Pag. At the beginning, there was only one club built on this beach, but over time their number rose to five. With each newcomer the situation on the beach changed, in the sense that the overall sound pressure level and the resulting noise levels in surrounding area have gradually increased. Over time, the situation has

become difficult for the residents living in surrounding towns and villages, so after complaints the local authorities have decided to take steps in order to improve the situation. As a part of the solution, the study described below was made by the authors.

At the time this study was made, there were five clubs on Zrće Beach, and these five were included in the study. All of them perform their activities mainly outdoors; each one has an outdoor main stage accompanied with one or more auxiliary entertainment areas. The position of the sound systems in the clubs, and the configuration of the buildings and the terrain in the immediate vicinity of the clubs provide little or no noise reduction at the source. In other words, the sound generated by the sound system in each club propagates freely from the clubs. The clubs are open in the high season period from June 1st to September 1st every year. The events hosted by these clubs take place round the clock, both in daytime and during the night. In daytime, the so-called day-parties are organized, but the main events, which are also the loudest, take place during the night.

Although there are no villages or towns in the immediate vicinity of the beach and the clubs, the sound coming from the outdoor sound systems installed in the clubs has a high enough sound pressure level at the source to cause disturbance in several neighboring settlements, shown in Figure 1. Given the fact that the noise in this particular case is music with both tonal and impulsive components, the evoked disturbance is even greater. The closest settlement is the village of Caska at 900 meters north-northeast (NNE) of the beach, followed by the village of Škunca at 1200 meters WSW, Gajac resort at 1400 meters SW, the edges of the town of Novalja also at 1400 meters, but NW, the village of Vidalići at 2500 m ESE, and the village of Kustići at 3400 meters SE of the beach. The configuration of the terrain on the propagation paths provides little or no natural protection from noise, as some of these locations have a direct line of sight to the beach and the clubs on it, while the rest are only marginally shielded.

Figure 1. Zrće Beach as the noise source and the surrounding settlements affected by it

According to the current legislation [1,2], the maximum permitted outdoor noise level at night for all these locations is 45 dBA. This noise level is monitored at control locations in villages Caska, Vidalići and Kustići. However, in certain cases local authorities are allowed to override the national legislation. In this case the local authorities have passed an act which allows the stated value to be temporarily exceeded if an event of special significance for the local community is taking place.

3. The parameters of the model

To predict the propagation of noise from the clubs as the sources to the neighboring settlements as the zones that require protection, a model was developed for the Brüel & Kjær LimA Plus 7812 B software [3]. Before developing the model, the data on the topographic characteristics of the terrain was obtained, as well as the data on the sound systems used by each of the five clubs.

The model itself is based on the obtained topographic layouts of the entire area, described with isohypses in 5 m precision. The area of the beach and the clubs was described with enhanced precision of 1 m. Residential objects in the settlements that require protection have been added to the model, but only in the zones closest to the source. To maintain clarity, roads have also been added to the model, but have not been used in the calculations in any way.

All sources were defined as point sources. Two sources per club were defined, representing the left and right channel of the main sound system, which

makes a total of ten sources. The sources were placed to the height of 3 m above the main stage. Thirteen receptor points were defined altogether, all of them placed at the height of 2 m above the terrain. To control the sound level at the source, one receptor point was defined in each club and placed at the distance of 8 m from the sources. In the control zone, i.e. the settlements that require protection, 8 receptor points were defined altogether. All 13 receptor points are shown in Figure 2.

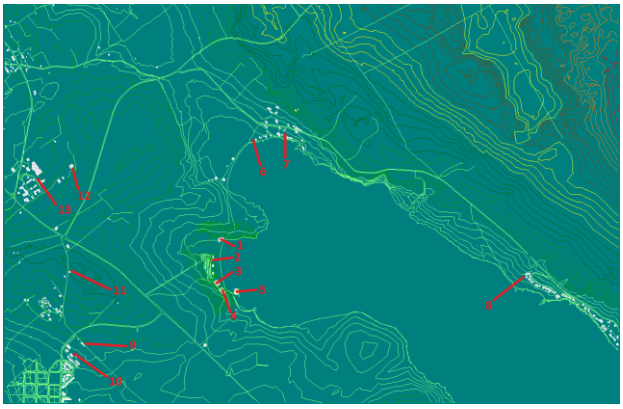

Figure 2. Receptor points defined for the calculations

Three cases were considered with regard to loudspeaker directivity and orientation and appropriate simulations were made. The first case was the worst-case scenario, for which all the sources in the simulation were defined as omnidirectional. In this case, all zones that require protection are maximally exposed to the sound coming from the sound systems in the clubs. However, such a scenario is unrealistic, as all sound reinforcement systems exhibit directional properties. The directivity of a system can be adequately controlled even at the lowest frequencies of interest by utilizing some of the common bass control techniques. In this case, however, the decision was made to leave the directivity of the sound systems omnidirectional at low frequencies.

For the remaining two calculations a generic sound source has been defined to represent all the sources included in the simulation. Its properties were derived from real sources, i.e. loudspeakers that form the sound systems in all five clubs. Since the sound system solutions chosen for implementation differ from one club to the next, and include individual loudspeakers as well as line arrays, the horizontal directivity of the generic sound source was defined as a compromise that would adequately represent both types of approaches used in implementation of real sound systems installed in the clubs. The polar patterns representing the horizontal directivity of the generic source are shown in Figure 3.

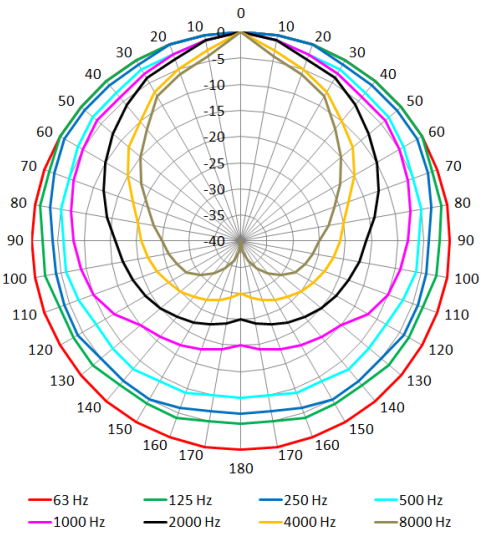

Figure 3. Polar patterns defined for the generic source

In the second calculation, generic sources that represent the sound systems in the clubs were oriented in optimal directions, so that the resulting noise levels at the protected locations would be minimized. The azimuthal directions chosen for all five clubs are in the range from 140-160°, which basically means that the sound systems should be oriented to the southeast or south-southeast. The reason why this choice was made is that there are no settlements in that direction except for the village of Kustići, which is, however, about 3400 m away. This way, the disturbance by noise would be more evenly distributed on all settlements, and the noise levels in the most exposed settlements closest to the beach would be reduced. The recommended orientation of the generic sources is shown in Figure 4.

Due to technical reasons, first and foremost the orientation of club buildings and the stages within, a third option was considered, in which the suboptimal orientation of the sound systems was maintained. Therefore, another simulation was made, but this time with real directions the sound systems were oriented towards. These azimuthal directions are 0°, 249°, 270°, 323°, 344°, i.e. the orientation of all sound systems lies within the northwestern quadrant, except for the backup system in one of the clubs that is oriented to the south-southwest at the angle of 190°. The real

orientation of the sound systems is shown in Figure 5.

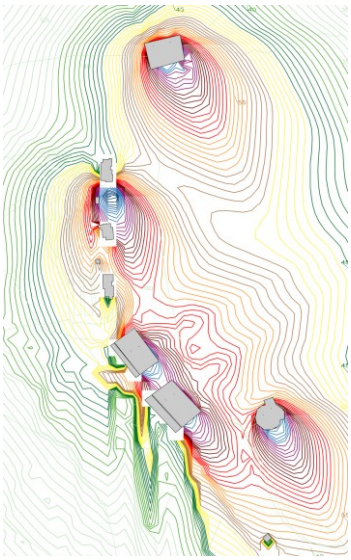

Figure 4. Recommended orientations of the sound systems in the clubs

Figure 5. Real orientations of the sound systems in the clubs

Besides the directional properties of the generic sound source, its frequency response and the overall level had to be defined as well. For this purpose, the levels in individual octave bands were adjusted so that a flat on-axis frequency response is obtained, and the overall target level obtained on stage was initially set to 105 dB(A).
Encouraged by the field data and the information obtained from the residents that the situation changes depending on the wind conditions in the area, meteorological statistical data for wind speed and frequency was obtained [4] and input into the simulation. Average wind speed dependant on direction and the distribution of wind direction frequency are shown in Figures 6 and 7, respectively.

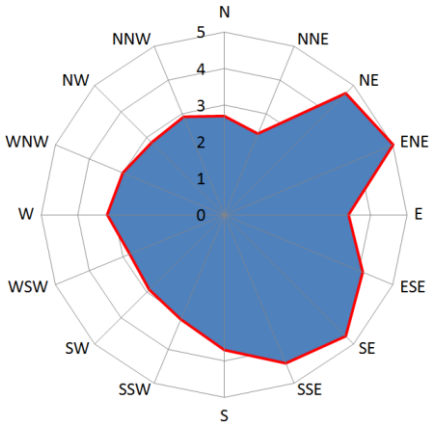

Figure 6. Average wind speed in m/s, dependant on direction, for Novalja region [4]

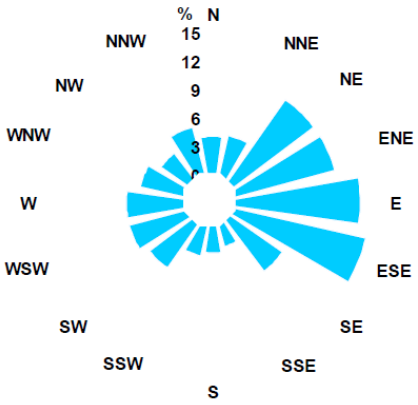

Figure 7. Distribution of wind direction frequency for Novalja region [4]

Figures 6 and 7 show that the wind that comes from land generally prevails over the one coming from the sea. Dominant wind directions range from northeast to east-southeast. At the same time, the northeast and the southeast direction show the highest average wind speed. It is worth noting that the northeast wind, locally referred to as “bura”, also shows the largest variance in wind speed, following the fact that this particular wind is not constant, but blows very erratically.
The data on wind was used in several stages of the investigation process, and the simulations indeed show a reduction of noise level in the villages

located in a general eastward direction from the beach and the clubs, namely Caska and Vidalići. On the other hand, all the other settlements, namely Škunca, Gajac and even Novalja itself suffer from increase of noise level as a result of wind. Since the wind conditions change drastically during the day, and depend greatly on the season of the year, the influence of wind on noise levels can be described only in statistical terms.

4. The results

The results of the simulations are shown in a summarized form in Tables 1 and 2. As expected, the worst-case scenario is obtained in the unrealistic case when all sources were made omnidirectional, as shown in the leftmost column of Table 1.
Since all loudspeakers used in sound reinforcement systems do have directional properties, the remaining calculations were made with a generic sound source with defined directivity to replace the main sound sources in each club. At first, the optimal solution was pursued, which included the reorientation of the sound systems in each club, if necessary. The simulation yielded the optimal orientation angles for sound systems in each of the clubs, as stated earlier. The overall equivalent A-weighted noise levels obtained for this particular situation are shown in the middle-left column in Table 1. It is evident that in most cases the overall noise levels exceed the 45 dBA value defined as the maximum permitted one in nighttime, sometimes by as high as 10 dB. It became evident that even with the optimal solution it would be impossible to fulfill the legislative provisions to the letter and still reconcile all wishes and requirements expressed by all interested parties.

Table 1. The overall equivalent A-weighted sound pressure levels on all receptor points for all simulations

		Equivalent A-weighted sound pressure level L_{Aeq} (dBA)			
Receptor point	Location	Omnidirectional sources	Recommended orientation	Real orientation	Real orientation, corrected level
1	Club 1	105.0	105.0	105.0	102.0
2	Club 2	105.0	105.0	105.0	102.0
3	Club 3	105.0	105.0	105.0	102.0
4	Club 4	105.0	105.0	105.0	102.0
5	Club 5	105.0	105.0	105.0	102.0
6	Caska near	62.9	54.9	56.9	53.9
7	Caska far	61.8	55.3	56.2	53.2
8	Vidalići	47.4	44.6	46.5	43.5
9	Gajac near	55.6	50.3	53.2	50.2
10	Gajac far	54.1	49.1	52.1	49.1
11	Škunca	53.9	47.0	53.8	50.8
12	Novalja near	56.2	46.9	53.2	50.2
13	Novalja far	46.9	39.7	44.5	41.5

However, the clubs stated that their layout is quite fixed and that reorienting the stage would lead to significant changes in their envisioned concept. To accommodate for that, another simulation was made, taking into account the actual orientation of the sound systems in the clubs. The club owners were warned in advance that this is not an optimal solution and that a compromise of some kind would have to be made. Specifically, they were told in advance that a level reduction at the source will probably be necessary. The results of the simulations revealed that the unfavorable orientation of the sound systems causes a level increase on all receptor points in protected areas, in the range from 1 to almost 7 dB.
Table 2 shows the contribution of each club to the overall level obtained for each of the 8 receptor points defined in protected zones. The values that have a prevailing influence on the overall level on each individual location are shown in bold font. It

is clear that all clubs share the responsibility of creating a noise disturbance for the surrounding area. To be fair to all the clubs, it was suggested that the level at the source, i.e. on stage be reduced by 3 dB in all the clubs, so that the overall levels in protected zones fall to acceptable values again. The results of this final measure are shown in the rightmost column of Table 1. The overall levels have indeed been acceptably reduced on the most critical receptor points.

Table 2. The contribution of each club to the overall noise level on protected locations for real orientation of the sound systems and corrected levels at the source

		Equivalent A-weighted sound pressure level L_{Aeq} (dBA)					
Receptor point	Location	Club 1	Club 2	Club 3	Club 4	Club 5	Total
6	Caska near	**48.2**	**48.7**	**48.5**	44.2	40.2	53.9
7	Caska far	**50.2**	45.8	45.9	42.2	41.4	53.2
8	Vidalići	34.6	31.8	**41.5**	32.5	33.2	43.5
9	Gajac near	37.2	38.5	**44.3**	**45.2**	**45.2**	50.2
10	Gajac far	34.4	37.4	**43.3**	**43.9**	**44.2**	49.1
11	Škunca	**44.8**	37.2	**44.4**	**45.5**	43.5	50.8
12	Novalja near	42.7	38.2	**44.1**	**44.9**	43.5	50.2
13	Novalja far	**36.8**	30.0	33.8	35.1	34.2	41.5

5. Conclusions

The results of the simulations show that the levels emitted by sound systems in the clubs located on Zrće Beach should be limited. Orienting the sources in optimal directions has a positive influence on noise reduction in protected zones. Due to the existing layout of the clubs and their infrastructure, it has proved to be complicated to achieve these optimal orientations. Therefore, noise levels in protected zones were calculated taking into account the actual, suboptimal orientation of the sound systems in clubs.

The results show that the equivalent noise levels do not exceed 55 dB(A) on any of the receptor points if the equivalent sound levels on main stages in the clubs are kept below 102 dB(A), calculated in free field at 8 m from both sound sources that represent the main sound system in each club.

Each club represents a dominant noise source on at least one receptor point, and most receptor points are dominantly influenced by noise coming from more than one club. Therefore, an equal level correction has been proposed for all the clubs as the only fair solution.

The final recommendations given to all interested parties were that the maximum sound levels in the clubs should be limited by means of limiters with built-in sound level meters. All loudspeakers that are not a part of the main sound system should operate at a level at least 10 dB lower than the level of the main sound system. The frequency response of the sound systems is to be kept flat, and should be equalized if necessary.

Following the results of this case study, measures were taken to reduce noise levels in residential areas surrounding the entertainment zone with the clubs. Additionally, the local authorities have been given the ability to monitor the sound levels in the clubs in real time.

References

[1] Noise Protection Act, Official Gazette of the Republic of Croatia 30/09, 55/13, 153/13 (in Croatian)

[2] Regulations on maximum permissible noise levels in living and working environments, Official Gazette of the Republic of Croatia, 145/04 (in Croatian)

[3] http://www.bksv.com (see the appropriate page for details on LimA)

[4] A. Bajić, B. Peroš: Reference wind velocity – influence of averaging period. Građevinar 53 (2001) 555-562. (in Croatian)