

## **Prediction of off-site noise levels reduction in open-air music events within densely populated urban areas**

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### **ABSTRACT**

Performances in open-air settings create challenges in terms of noise pollution, which has to be controlled by the organizers within the limits set by the local authorities that aim to preserve the comfort and health of local residents. In this study, an integrated approach has been developed to control the off-site noise levels, in the framework of H2020 MONICA project. To this purpose, Kappa Futur Festival, an open-air multi stage Electronic music festival attended by more than 50 thousand people, has been considered as a case study. A comprehensive set of actions was put in place for off-site noise predictions using SoundPlan®, a noise modelling software. A measurement campaign through a noise monitoring network was performed during the two days event showing the relevance of the low-frequencies content. The data have been used for calibration of the simulation model. The simulations allowed to pinpoint which sound system, i.e. stage, could cause the dominant noise off-site so that potentially breaches the regulations. The results showed that future editions of the Festival would benefit from feasible mitigations and optimization actions, i.e. variations of stage loudspeaker arrays, stage orientations and FOH level control, by also preserving the optimal levels for the audience.

**Keywords:** off-site noise prediction, open-air events, simulation software

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## 1. INTRODUCTION

Music festivals around the world continue to grow with each passing year. If some of them are located in remote areas (e.g. the Burning Man festival in the Black Rock Desert, The Defqon 1 festival in Netherlands), others' kicker is precisely their location inside the city centres (e.g. Ultra Europe festival, Sziget Festival, Wireless Festival, Lovebox Festival). In those cases the challenge is two folded for the organizers: in addition to offer an adequate experience to the concert goers, it is necessary to control the sound propagation in the nearby areas [1]. With the growing interest and subsequent increased number of participants, the noise levels in the surrounding increased together with the number of affected communities complaining about such events [2]. The event, even if limited in time (lasting just few days), influences the life of the adjacent neighbourhoods: on the one hand wellbeing and health of its inhabitants could be compromised [3], on the other the event generally has a positive relapse on the city's economy [4]. When attempting to regulate noise from outdoor concerts, government authorities are conscious that noise limits need to consider the realistic sound levels that are needed to hold a successful concert, while still preventing unreasonable behaviour [5]. In a nutshell, there is a need for tools to plan those events able to consider at once the requirements of local authorities, local residents, participants and organizers.

Environmental noise predictions represent such a tool, commonly generated employing proprietary software packages. Producing an environmental noise model involves defining a series of noise sources to be investigate, describing acoustically significant features of the environment through which sound will propagate to the receiver (this includes the ground terrain, the built environment, and atmospheric condition, e.g. wind, temperature, humidity) [6, 7], and then applying a calculation method. The majority of the software involves ray tracing techniques and image-source models through the translation of standard predictive algorithms (such as ISO 9613 [8] and Nord2000 [9] able to consider coherency effects) into computational code. Aspects to be implemented are computational accuracy and differentiation in the assignment of standard atmospheric conditions to the sources. For the present work, noise modelling software SoundPLAN® from Braunstein + Berndt GmbH was selected because is one of the leading software products in the field of environmental noise prediction and it has been recently implemented with a stage layout import tool: the collaboration with d&b audiotechnik GmbH permits the direct use of ArrayCalc files considering all specific loudspeaker setups already defined by the stage planner, including complex directivities and delays.

In this study, Politecnico di Torino, in the framework of H2020 MONICA project and with the support of City of Torino and SPECTRA S.r.l., developed an integrated approach to control the off-site noise levels during the 2018 edition of the two days event Kappa Futur Festival. A measurement campaign together with a noise monitoring network allowed to collect data of noise levels in the neighbouring areas for calibration of the simulation model. The Sound Pressure Levels (SPL) at front of house (FoH) were also measured, so the specific signal spectrum of each stage was used for the simulations. The venue has been modelled based on 3D GIS City maps and the loudspeakers arrays have been imported from ArrayCalc. Simulations using SoundPlan® have been performed for the investigation of different off-site noise mitigation alternatives. Results allowed to pinpoint which sound system, i.e. stage, could cause the dominant noise off-site so that

potentially breaches the regulations. Future editions of the Festival would benefit from feasible mitigations and optimization actions, i.e. variations of stage loudspeaker arrays, stage orientations and FOH level control, by also preserving the optimal levels for the audience.

The paper is structured as follows. In section 2 the main features of the venue of the festival are exposed. Section 3 describes the measurement campaigns for the collection of the data, as well as the used instrumentation. Section 4 presents the model construction steps, the necessary inputs and the methodology employed during the simulations' phase. In section 5 the method is applied in different configurations and results are presented and discussed. Section 6 summarizes the present work.

## 2. VENUE DESCRIPTION

### 2.1 Festival Area

In this document the Kappa FuturFestival, an open-air multi stage Electronic music festival attended by more than 50 thousand people [10], has been considered as a case study. The 2018 edition of the Festival consisted of four simultaneously running stages located in different areas of Parco Dora.

Parco Dora is located in the Spina 3 area, in the north zone of Turin, and has an extension of approximately 938,000 m<sup>2</sup>. Until the 90s it was characterized by the presence of important production facilities, but from 2000 it has undergone a number of interventions to the current configuration. Nowadays, the Parco Dora is one of the largest green areas in the city, alternating naturalistic environments and re-functionalized industrial remains. On the south side, the Dora Riparia river is crossed by three footbridges. The surrounding neighbourhoods are mainly intended to residential construction and commercial activity, with several malls. A church, a museum, an environmental park and an hospital are the main buildings of interest in the area. A link road runs around the area and fits into a tunnel. Some tree-lined avenues are present.

In particular, Kappa Futur Festival takes place on a flat area inside Parco Dora, where a canopy, sign of the previous plant, stands out, extending over 80 m height and 300 m in length. This canopy covers the largest paved area of the park, while other areas are mostly grassy. Some fixed concrete barriers separate the northern areas.



*Figure 1. Satellite view of Parco Dora area. The red hatch surrounds the festival area.*

## 2.2 Stages disposition

Four stages called S1, S2, S3 and S4 were positioned inside the area as shown in Figure 2. The S3 stage is the leading one and houses the parterre completely under the mentioned canopy. It was placed in the east area with orientation from east to west, as the S2 stage 80 metres south. In front of them the S1 stage was located with the opposite orientation. The north-west area was occupied by the S4 stage with emission from east to west.

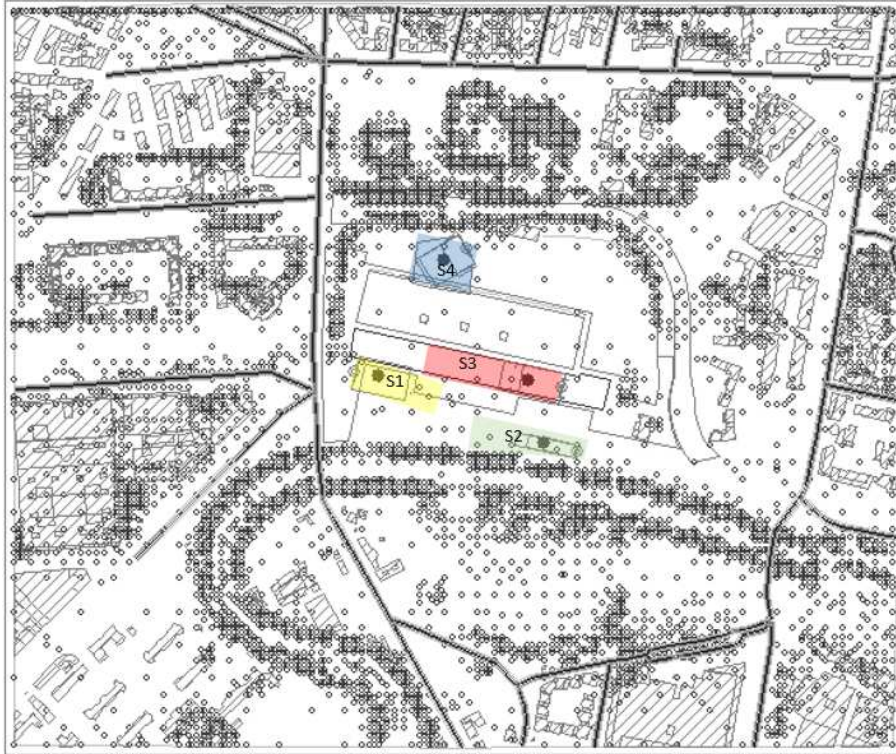


Figure 2. Venues configuration in the area

## 3. MEASUREMENT CAMPAIGN

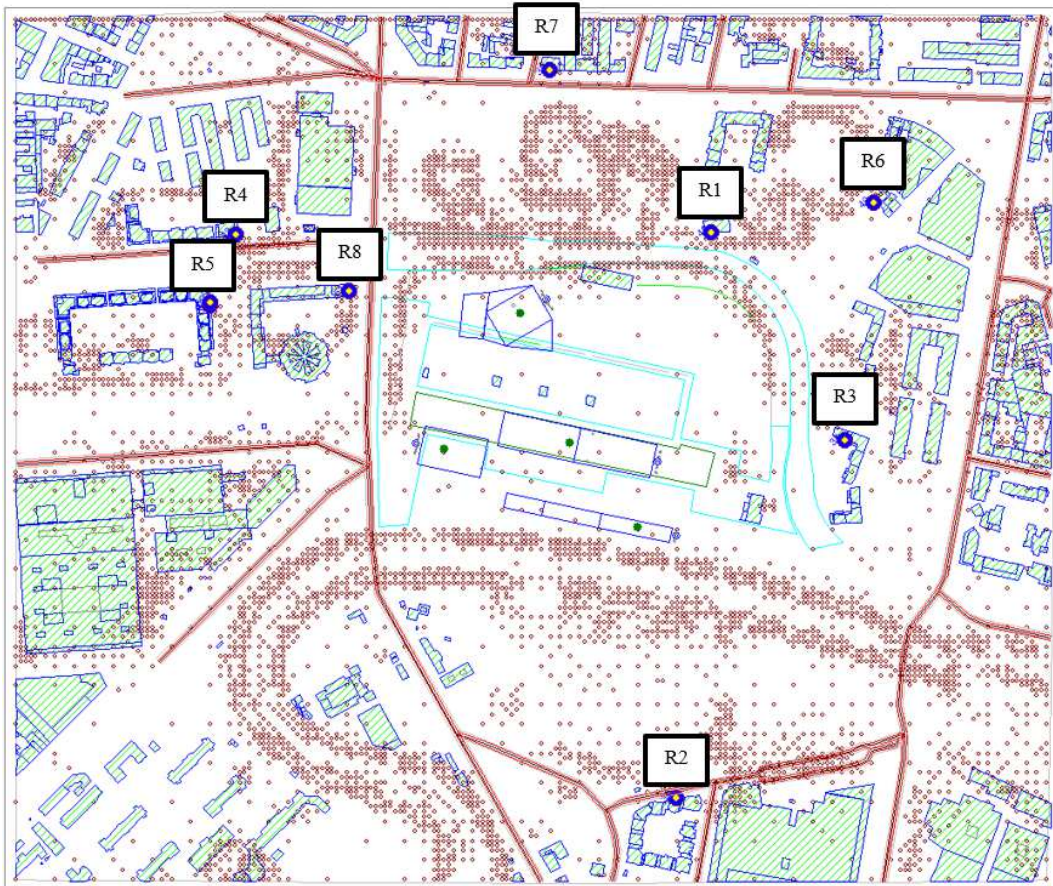
A set of acoustic measurements, both in-site and off-site, have been performed during the entire period of the event. Therefore, equivalent sound pressure levels ( $L_{eq}$ ) have been measured and the A- and C- weighted sound levels have been considered.

The noise measurements were documented with all relevant boundary conditions including the precise locations and heights of stages and measurement positions.

Data have been collected through:

- an NTi XL2 Sound Level Meter with a range of 10 - 110 dB and resolution of 1/3 octave for 10 minutes long measurements
- seven class 1 SLM
- nine IoT SMLs

A noise monitoring network allowed to collect data in the surrounding. More than 15 receivers were positioned for the event, but not all measurements have been used for this study. Just eight of them were selected and considered representative of the areas around the festival. Figure 3 indicates the eight points used for the model calibration later on.



*Figure 3. Receivers positions*

The SPL at each FoH were also measured in 1/3 octave bands down to 12.5 Hz. This allowed to assign the proper spectrum to each stage in the calculation models later on.

## **4. SIMULATIONS**

### **4.1 Software**

SoundPLAN 8.0 software was used to model the area affected by the festival. SoundPLAN allows the assessment of the impact of environmental noise through the simulation of sound propagation in outdoor.

The software is divided into packages that differ in function and type of noise treated. Sources can be vehicular traffic, rail and airport, or noise produced by plants or open-air events, as in this case.

It has no limits in the number of insertable objects and sources, nor limits on the size of the area of interest. This allows to simulate also extended and complex areas.

Data can be imported in different formats (DXF, ASCII, ArcView, etc.). SoundPLAN is based on dozens of national standards for the calculation of noise sources. The Ray Tracing method provides maps of noise propagation on large areas, but also global levels and their breakdown by individual sources. Among the available standards (all included in the basic module) there are those that refer to future European standards being published (COM2000-468). Moreover, the software structure allows the easy insertion of any new regulations.

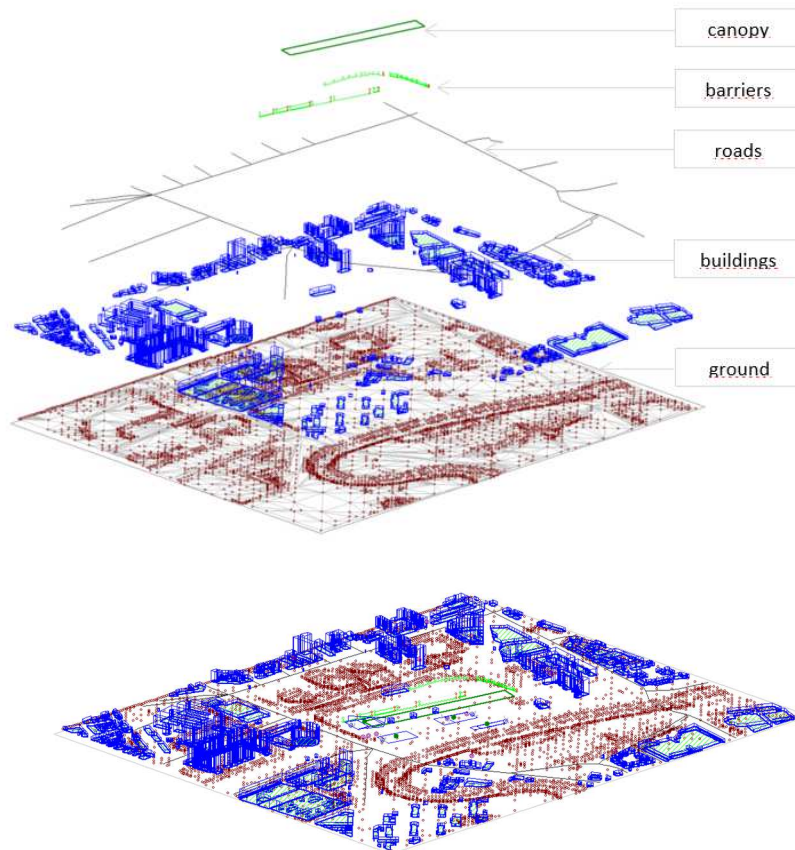
### **4.2 Model construction**

The model has been created importing GIS files provided by the City of Torino. SoundPLAN® works through layers ( the so-called "Geo-Files", contained in "Situations"

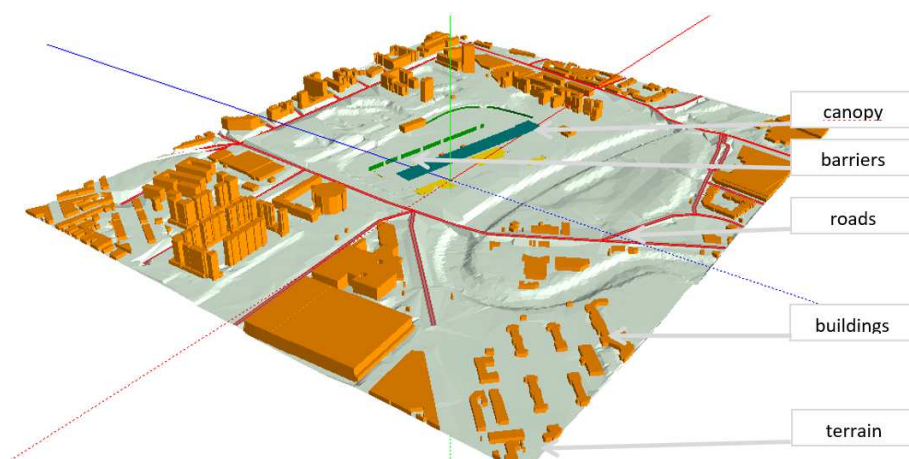
inside the "Project"): therefore, the elements characterizing the area (ground, buildings , roads, barriers, canopy) were saved in different files and then imported subsequently in SoundPLAN®. Ground data has been imported in ASCII data format, buildings and roads in ESRI shapefiles while barriers and canopy have been previously modelled in Google SketchUp® software and then imported. All the data were georeferenced.

The soil has been differentiated to take into account the proper sound absorption: "Ground Factor, G" scale runs from "hard = 0" to "soft = 1". G = 0 has been set for areas completely covered by grass, while G = 0.3 for paved areas and G = 0.2 for mixed ones.

The temperature and the relative humidity were kept constant (20 ° C and 60%).



*Figure 4. Imported layers for the 3D model in SoundPLAN*



*Figure 5. 3D model in SoundPLAN 8.0*

### 4.3 Sources and receivers

Stages were the unique sources of noise considered for this work. A stage is featured by the position of noise sources, the properties of loudspeaker array and the area for the spectators. These characteristics were stages designed with ArrayCalc d&b audiotechnik GmbH software by the sound engineers. Their configurations in terms of directivity, orientation and delay were taken into account: when importing a system design file into SoundPLAN®, the position and complex balloon data (= magnitude, phase and directivity) of every single loudspeaker source is automatically transferred as one stage object. The position and orientation of each stage was entered into SoundPLAN® according to plan scheme provided by the event organizers. The points visible in the simulation software are centered in the rear of the designed stage, facing the public.

In SoundPlan stage object, further points represent the position of the sound mixer where to calibrate the stage, called Front of House (FoH). Generally, the FoH locations correspond to the reference points, but not in this case. It is important to point out that the FoH points of Arraycalc did not correspond to the reference points actually used during the festival. Figure 5 shows the location of the ArrayCalc FoH and the reference points actually used.

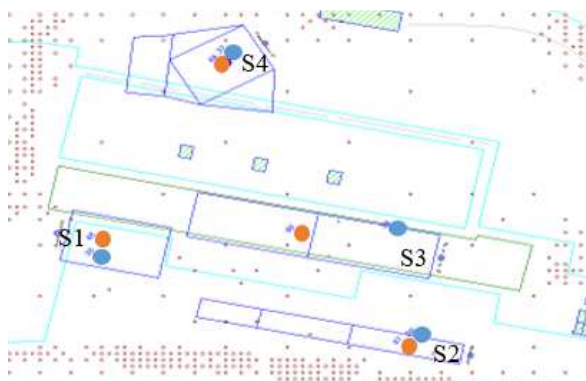


Figure 6. Plan with the four stages: red dots indicate ArrayCalc FoH, blue dots correspond to the reference points actually used during the festival

Through the object “free field receivers” in the software, the eight receivers have been inserted manually in the model as points. Their height has been defined manually too.

### 4.4 Calibration and simulations

Even if measurements have been performed during the entire period of the event, only the period between 19.00 and 19.30 of the second day of the festival was considered. During the event, the values varied widely and the mentioned half an hour was seen as a representative interval of the normal functioning of the stages in terms of performance. At this time, the stages were active all together and the event was at its peak. In this way the calculation could be “on the safe side” regarding the affected residential areas, rather than underestimating the potential impact.

The spectra from the FoH measurements were entered for the stages in the calculation models, as shown in Figure 4.

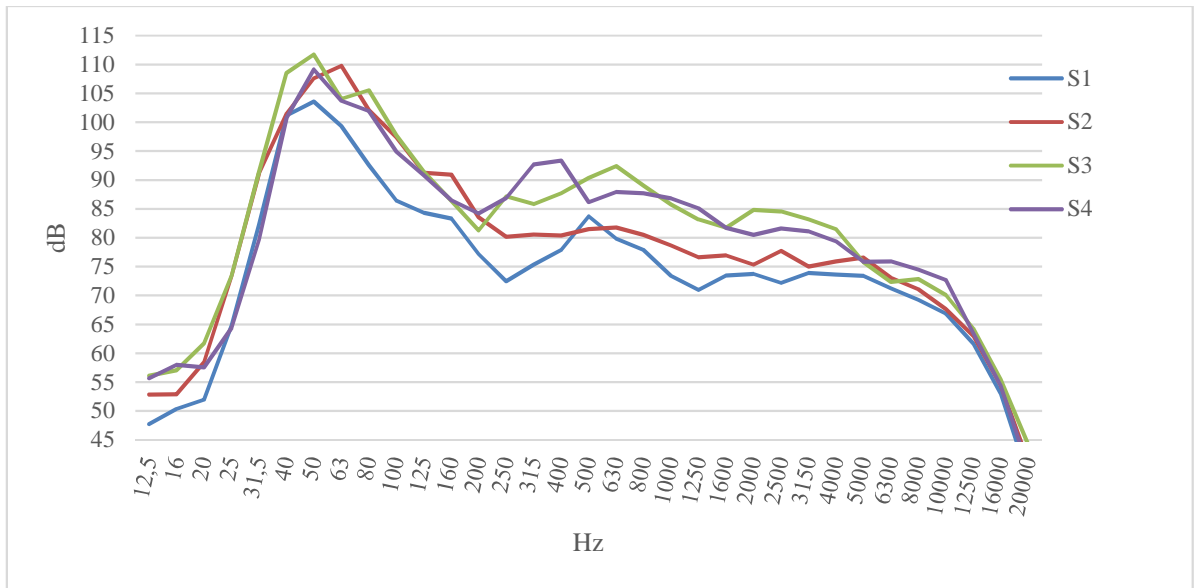


Figure 7. Measured spectra at the reference points

SoundPLAN® recalibrates the sound system for this given target at the defined reference point. Due to the fact that in this case the FoH and the reference points did not correspond, correction levels were inserted in the software in order to calibrate the stages according to the pressure levels in dBC at the reference points.

Table 1. Comparison between sound pressure levels of reference points and FoH

Stage	Total sound level at FoH inserted (dB)	SPL from simulations in reference points			SPL from measurements in reference points			SPL from simulations in FoH		
		(dBA)	(dBC)	(dB)	(dBA)	(dBC)	(dB)	(dBA)	(dBC)	(dB)
S1	111	91	110	111	91	109	110	92	110	111
S2	115	94	112	113	91	112	113	94	114	115
S3	115	100	114	111	97	113	114	101	114	115
S4	108	94	112	113	96	111	112	92	107	108

In this way, on average the simulation output overrated the measurement by nearly 3 dB(C) with a standard deviation of about 2 dB(C). Table 2 in the following page shows the comparison between the mentioned values.



Table 2. Comparison between sound pressure levels measured and calculated during the considered interval (19:00-19:30).

	Height from terrain	Leq				
		(dBA)		(dBC)		(dB)
Receiver	(m)	measured	calculated	measured	calculated	measured
R1	20	71	73	91	94	92
R2	31	68	71	89	92	90
R3	19	71	74	89	92	90
R4	34	71	74	87	90	88
R5	31	72	75	86	89	87
R6	50	65	67	85	87	86
R7	29	65	67	83	85	84
R8	6	74	76	86	88	87

Then, other simulations were run. In particular, it has been investigated the effect of the variation of:

- loudspeaker arrays
- orientations of stages
- FOH level control

In all these conditions has been considered as a constraint the optimal sound levels for the audience and the local authorities limits for the off-site levels set at 73dBA and 87dBC aiming to preserve the comfort of the local residents [1] [11].

## 5. RESULTS

The measured data showed the relevance of the low-frequencies content of the electronic music. Low frequencies are the most critical frequencies in the noise problem of outdoor concerts and the control of sound over large spaces with a feasible number of loudspeakers is only possible in that range [12]. Moreover the long monitoring showed that these levels variate depending on the performers' preference on stage (i.e. dj). The simulations showed a good match with the measurements in the first step i.e. calibration phase, thus accurate results could be obtained also for the mitigation alternatives. The variation of the typology of the loudspeaker arrays, i.e. from line arrays to gradient arrays, could lead to an improvement of the directivity at low-frequencies. Therefore, a decrease on the off-site noise levels behind the Main stage could be observed maintaining the unvaried FoH levels. The orientation of the S3 stage, which was first tested with a concrete noise barrier on the left side (north), lead to an evident improvement in the noise levels for the buildings in the North part of the area. Only the FOH levels have been modified for the other two stages.

## 6. CONCLUSIONS

The simulations allowed to obtain the single-stage transfer functions and continuous monitoring data allowed a detailed report about noise levels on the surroundings, suggesting new mitigations and optimization actions for the future edition of the Festival. Both the loudspeakers array directivity control for low-frequencies and stage orientation variation considering to use the existing noise barriers resulted to be efficient ways for noise level control.

The FOH level control resulted more problematic at the stages where the loudspeakers array directivity at low frequencies was not improved. Therefore, considering the improvement of such variation it can be suggested for all the stages. However, costs increase should be taken into account. Moreover, a real-time feedback addressed to the performer could help to maintain the optimal FOH levels.

## 7. ACKNOWLEDGEMENTS

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