Management Of Networked IoT Wearables – Very Large Scale Demonstration of Cultural Societal Applications

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D4.7 ASFC System and Noise Monitoring System for Pilot 1-6 2

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Index:

1 Executive Summary

This document provides an update on the state of progress of Noise Monitoring System, Adaptive Sound Field Control (ASFC) System and Quiet Zone System since last review provided in deliverable D4.6. This update is based on feedback from demonstrations done at Kappa Futur Festival (2018 and 2019 edition), Fredagsrock 2018, Rhein in Flammen 2019 and Nuits Sonores 2019.

The main outcomes are:

- Sound reductions obtained with the ASFC are dependent on the geometry of the site. In order to get better results than those observed in previous demonstrations, special attention should be put on choosing the location where the system will be deployed since it is more likely to perform well in an open terrain than in an urban environment.
- The quiet zone system worked as expected during the last demonstration in Kappa Futur Festival 2019, where the focus was on the low frequencies attenuation. Further improvement will be to couple the active low frequency solution with the passive high frequency solution in order to cover the whole listening spectrum.
- The quality of data flow from IoT SLMs is highly dependent on the available bandwidth of network (WiFi or 4G). In case of limited bandwidth, the functionalities using the audio signal are compromised. In case of poor bandwidth, the level data (overall Sound Pressure Levels and spectra) suffer losses.

During year three (2019) a new pilot event has joined the MONICA project: Woodstower festival in Lyon, France. Organisers of this event have also expressed their interest on the Use Case Group Sound Monitoring and Control. A demonstration is previewed for the edition 2019 of this festival.

A description of the venue and the planned configuration for Noise Monitoring System for Woodstower festival 2019 is provided in this deliverable. Some special features for the Noise Monitoring System, as it is planned, are:

- The Decision Support System will be used to improve the Noise Monitoring System display on COP by providing relevant data to be displayed. This allows stakeholders to have a real time assessment of the event with regards to local regulation.
- Source Contribution will be estimated by using computed transfer functions. This method is adopted to avoid using audio signal from SLM (the quality of the internet connection on site is limited)
- Sound Heat Map model will be improved to get more reliable data (managing sources directivity and multi stages computation).
- Data from Sound Heat Map will be combined with data from crowd wristbands (position of each wristband provided by the tracking functionality) to estimate the sound exposure of the audience within a venue, were sound levels varies in time and in space.

2 Introduction

European research project MONICA aims to demonstrate how cities can use IoT technologies to manage sound and security at large, open-air cultural and sporting events taking place in the city. Six major European cities are involved as experimental sites, also called pilots: Bonn, Copenhagen, Hamburg, Leeds, Lyon and Turin.

During the process of requirement engineering (WP2), 4 pilots have expressed their interest on the Use Case Group Sound Monitoring and Control (Use Case Group 1) for their events: Bonn (Rhein in Flammen), Copenhagen (Friday Rock), Lyon (Nuits Sonores and Fête Des Lumières) and Turin (Kappa Futur Festival and Movida). Three systems are being developed and tested:

- Noise Monitoring System
- Adaptive Sound Field Control (ASFC) System
- Quiet Zone System

During year three (2019) a new pilot event has joined the MONICA project: **Woodstower festival** in Lyon, France. Organisers of this event have also expressed their interest on the Use Case Group Sound Monitoring and Control.

This document presents:

- A description of the three systems
- An update on the state of progress of systems since last review provided in deliverable D4.6.
- A description of the venue and the planned configuration for Noise Monitoring System for Woodstower festival 2019.

3 ASFC System, Quiet Zone System and Noise Monitoring System

3.1 General

The ASFC System, Quiet Zone System and Noise Monitoring System are the three main components of MONICA project dedicated to manage sound environment. These systems aim enhancing sound experience of the audience and mitigating noise annoyance in residential areas surrounding large scale events.

MONICA deliverables D4.1, D4.2 and D4.4 provide detailed information about ASFC System, Quiet Zone System and Noise Monitoring System. A brief description of each system (extracts from deliverables D4.1 and D4.4) and a simplified flow diagram are presented in 3.1.1 to 3.1.4.

3.1.1 ASFC System

Here below some extracts from deliverable D4.1 to describe the ASFC System:

“Loudspeaker systems for outdoor sound reinforcement typically consist of two loudspeaker line arrays and a set of subwoofers arranged in a horizontal array or as two left-right clusters. In the ASFC, these systems (primary sources) are extended by the use of additional low frequency loudspeakers (secondary sources). These are placed behind the audience in between the primary sources and the neighbouring region in which the sound from the event should be reduced (dark zone).”

“The basic idea is to optimize the radiation from the secondary sources in such a way, that the sum of sound pressures from the primary and secondary sources effectively reduces the total sound pressure level in the dark zone. Use of additional loudspeakers to control the sound in the dark zone must not negatively impact the sound experience in the audience area, the bright zone. This restriction must be included in the loudspeaker configuration design by either using directive loudspeakers facing away from the bright zone for the secondary sources or in the formulation of the loudspeaker signal optimization problem.”

“A well performing ASFC system will enable a high sound pressure level in the bright zone relative to the sound pressure level in the dark zone. A performance indicator for this problem is the acoustic contrast, which is the difference of the mean SPL in the bright zone to the mean SPL in the dark zone”. In terms of performance indicator, the acoustic contrast has been abandoned. Instead, the insertion loss (IL) is used. The IL corresponds to the reduction, in decibels, provided by the ASFC within the dark zone.

3.1.2 Quiet Zone System

Deliverable D4.1 provides also a description of the Quiet Zone System, some extracts hereafter:

“The quiet zone system is a noise barrier which makes use of active elements to cancel out low frequencies and passive elements to block high frequency noise. The goal here is to obtain the highest possible attenuation of noise across the whole listening spectrum..”

3.1.3 Noise Monitoring System

The following paragraphs were selected from deliverable D4.1 to briefly explain the Noise Monitoring System:

“The Noise Monitoring System consists of the Source Separation/Contribution techniques (T4.4), the Annoyance measures (T4.4), the Sound Heat Map (T4.3&4) and the Sound Level Meter (T4.2); the latter, including the first version prototype of the Sound Level Meter as well as its interface with the MONICA Cloud through the Sound Level Meter Gateway, is in detail described in deliverable D4.4, and is thus not further covered here.

Regarding the Source Separation/Contribution techniques, the aim is to estimate the amount of noise contribution - in sound pressure level in decibels (dB) over time or similar - that originates from the actual concert in the presence of background noise originating from other noise sources (such as traffic noise, people talking, etc.).

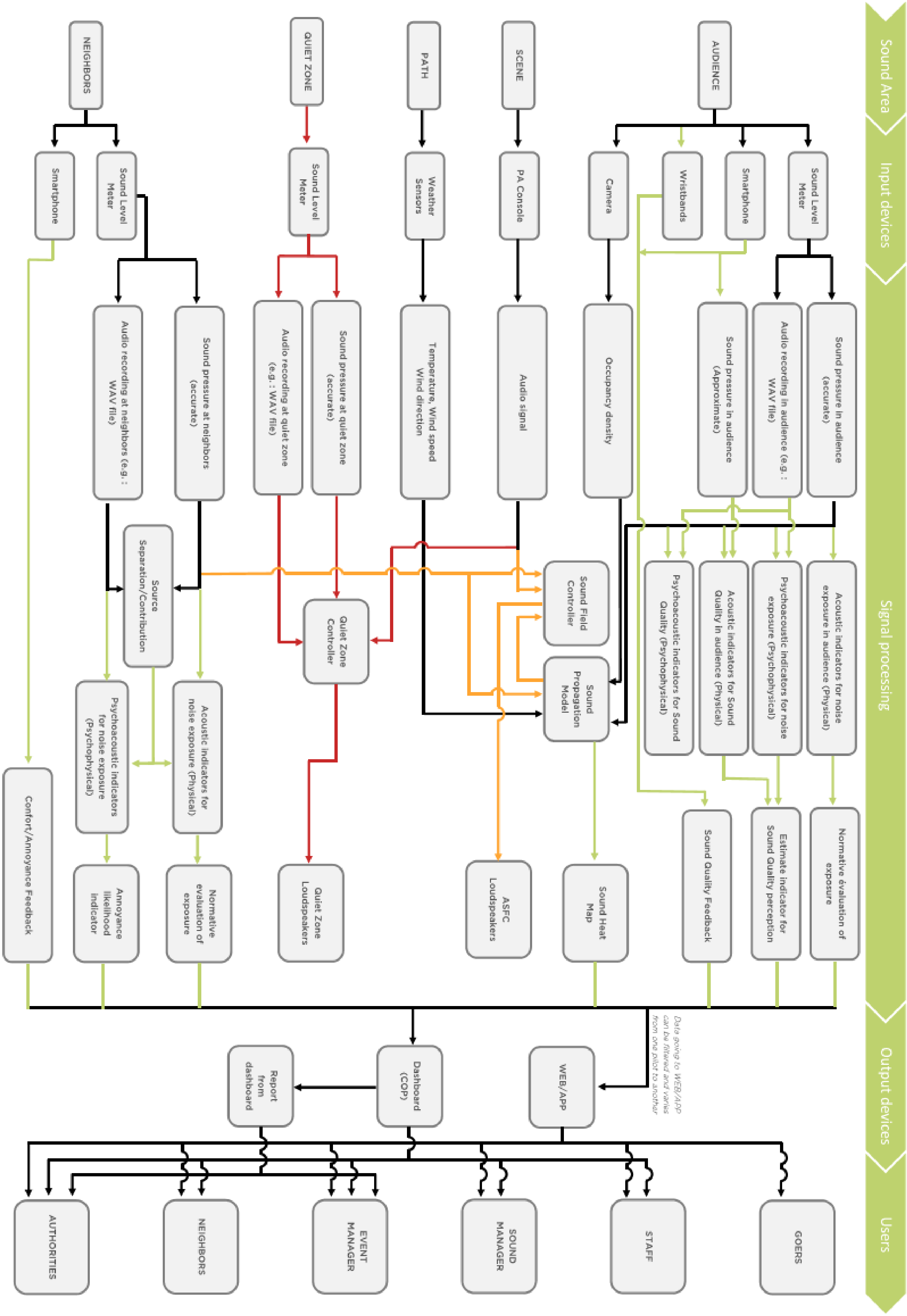
Thus, it should answer the question: Is the noise coming from the concert or from other sources?”

“The purpose of the Annoyance index is to give a more accurate estimate of noise annoyance, based on subjective perception data.

The Sound Heat Map will give an estimate of the sound pressure level (SPL) at other positions than the one being measured by the Sound Level Meter. This will be done using the forward sound propagation model developed in T4.3, based on the existing sound propagation model Nord2000". Currently, the Sound Heat Map uses a simplified computation model inspired by Nord2000 but not the full propagation Nord2000 model.

3.1.4 Flow diagram

Here below a simplified flow chart to synthetize how the different steps on every system are linked.


Sound Area
Input devices
Signal processing
Output devices
Users
Common
Noise Monitoring System
ASFC System
Quiet Zone System
AUDIENCE
SCENE
PATH
QUIET ZONE
NEIGHBORS
Sound Level Meter
Smartphone
Wristbands
Camera
PA Console
Weather Sensors
Sound pressure in audience (accurate)
Audio recording in audience (e.g. : WAV file)
Sound pressure in audience (Approximate)
Occupancy density
Audio signal
Temperature, Wind speed Wind direction
Sound pressure at quiet zone (accurate)
Audio recording at quiet zone (e.g.: WAV file)
Sound pressure at neighbors (accurate)
Audio recording at neighbors (e.g.: WAV file)
Acoustic indicators for noise exposure in audience (Physical)
Psychoacoustic indicators for noise exposure (Psychophysical)
Acoustic indicators for Sound Quality in audience (Physical)
Psychoacoustic indicators for Sound Quality (Psychophysical)
Sound Field Controller
Sound Propagation Model
Quiet Zone Controller
Source Separation/Contribution
Acoustic indicators for noise exposure (Physical)
Psychoacoustic indicators for noise exposure (Psychophysical)
Normative évaluation of exposure
Estimate indicator for Sound Quality perception
Sound Quality Feedback
Sound Heat Map
ASFC Loudspeakers
Quiet Zone Loudspeakers
Normative evaluation of exposure
Annoyance likelihood indicator
Confort/Annoyance Feedback
WEB/APP
Data going to WEB/APP can be filtered and varies from one pilot to another
Dashboard (COP)
Report from dashboard
GOERS
STAFF
SOUND MANAGER
EVENT MANAGER
NEIGHBORS
AUTHORITIES

3.2 State of progress

An overview of the state of progress of each system is provided hereafter.

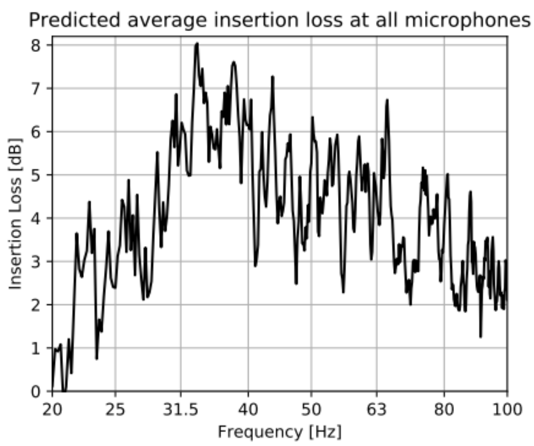
3.2.1 ASFC System

Kappa Futur Festival 2018

The ASFC system was tested for the first time in a real concert scenario at KFF18. The ASFC system was reducing sound from the Seat stage in an area outside the festival area. It was made of 20 subwoofers which were installed behind the audience of the Seat Stage in order to cancel sound in the court yard of the church, this area is the dark zone of the ASFC. (As compared to the quiet zone described below, we here want to attenuate the sound in a big zone.)

At this pilot a static version of the ASFC system was deployed. That is, the system is tuned once before the festival. During the festival, the system parameters stay constant.

The following graph shows the insertion loss as measured at some microphone positions and predicted at others where a measurement during the festival was not possible. For details we refer to the publication *Heuchel, Franz Maria, et al. “Sound Field Control for Reduction of Noise from Outdoor Concerts.” Proceedings of 145th Audio Engineering Society Convention, Audio Engineering Society, 2018.*



Kappa Futur Festival 2019

During the KFF19 the ASFC system was deployed in the same place as the year before.

A simplified adaptive version of the system was planned to be tested at KFF19, based on measurement of transfer functions in different weather conditions. However, due to a very short measurement time allowed (the deployment of the festival was delayed), we were not able to get enough data to test this adaptive part of the system. Instead, a static version was tested (as in 2018).

During the demonstration, the microphones in the dark zone (the area where the sound is reduced) could not be directly connected with the ASFC system in the festival area using a cabled connection because a railway was crossing between the two zones. Thus a compromised solution (parallel/remote recording on separate devices and post-synchronization using GPS time-stamp) was used, but the extra data transmission/processing time (up to 1 hour) effectively prevents a true adaptation to the current conditions. After two pilots with the remote recording approach (using B&K LANXI in 2018, and a DTU developed GPS time synchronization in 2019), it is now obvious that without a cabled or robust high bandwidth IoT connection, the deployment and data acquisition is strongly complicated and hard to achieve a good result.

The functionally and signal chain of the system worked as expected. Figure 3.1show the measured insertion loss during concerts on Saturday afternoon over frequency and space. The maximum insertion loss could not be improved in comparison to last year. However, the bandwidth of reduction was improved. In term of being audible the effect was noticeable, but not impressive. This can in part be explained by the high background noise level and spill over from other festival stages not being controlled. (In full scale outdoor experiments in Roskilde in June 2019, a similar measure of reduction was up to 20 dB, and a clear audible effect.) The main obstacles for achieving better reductions are 1) that the system works well in simple geometrical setting (and KFF is geometrically complex as compared to the test in Roskilde), and 2) the adaptive updating of the system was not working at KFF. We judge that point 1) is more important than point 2).

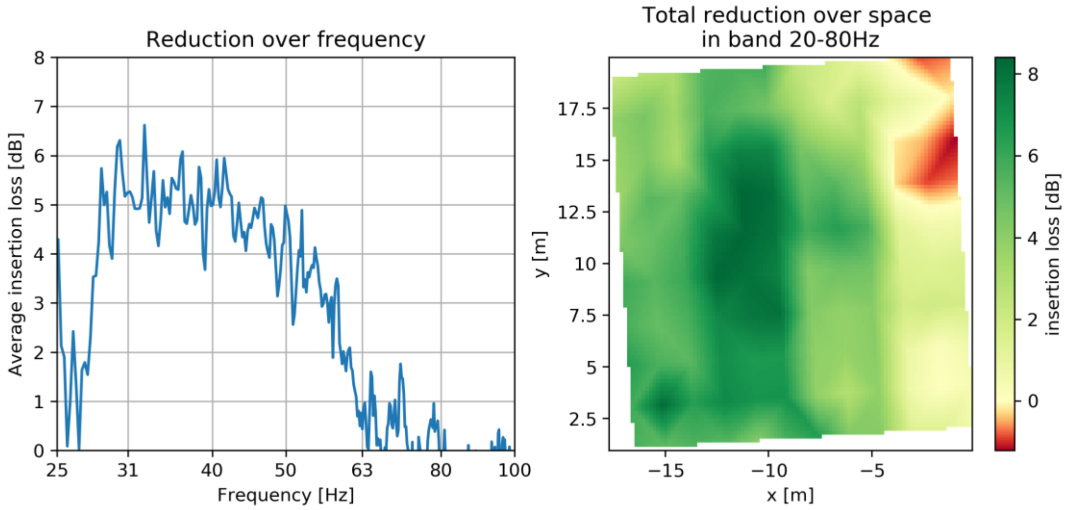


Figure 1: Insertion loss at Kappa Futur Festival 2019

The IoT SLMs were also installed in the dark zone to test resolving the data transmission issue. Since WIFI connection was not provided for the ASFC system and the dark zone, IoT SLMs ran with 3G/4G connection. As the number of crowds increasing before/during the event, the 3G/4G cellular connection was easily jammed. The IoT SLM could thus not be used. For a successful demonstration, either a cabled connection or stable network connection of IoT microphones are necessary. Due to a very short measurement time allowed, we were not able to get enough data to test the adaptive part of the system.

3.2.2 Quiet Zone System

The Quit Zone System was only deployed at the Kappa Futur Festival 2019.

During the Kappa Futur Festival 2019, the quiet zone system comprised of three subwoofers and three microphones. It was installed close to the audience area of the Burn Stage.

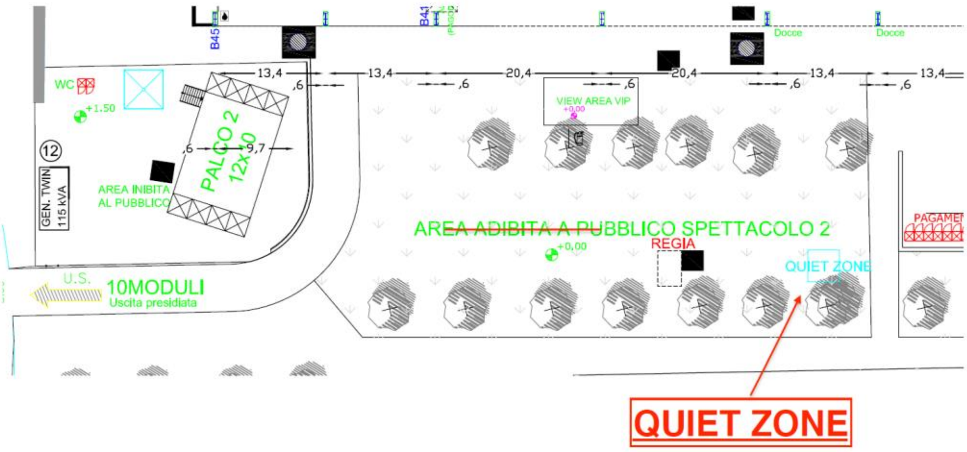


Figure 2: Quiet Zone System Placement

The approach here was to adaptively reduce the bass sound from the stage in a small designated area, with the goal to achieve a quiet zone of approx. 2 m^2. In the following figure is shown, the performance of the controller, during a period of ca. 20 sec. The controller has been switched on and off once during this time. The figure shows the reference signal from the console (blue), a measurement in a sweet spot, which is the "Error Microphone" in center position (orange) and another measurement microphone 30 cm behind the sweet spot (green). It can be seen that the two microphones measure a similar performance of >10dB(Z). The solution has also been robust against the noise in the error microphones, especially the low frequency noise from other stages. The quiet zone system worked as expected but the focus here was on the low frequencies attenuation, due to practical reasons. The next step will be to couple the active low frequency solution with the passive high frequency solution in order to cover the whole listening spectrum. The passive element had been tested in Tivoli in 2018.

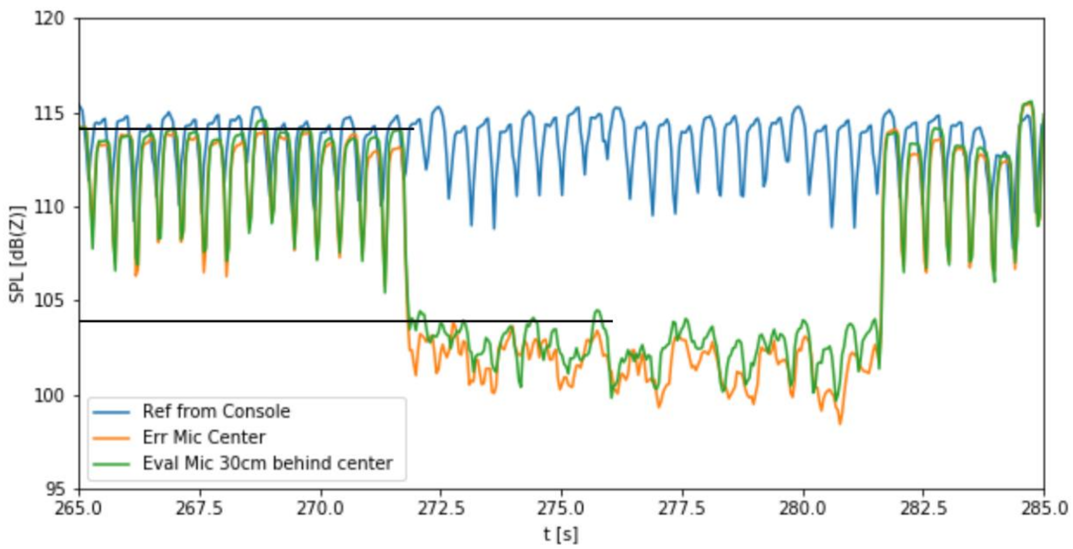


Figure 3: Performance of the Quiet Zone System, 20 sec recording with switching the controller on and off

The deployment of the quiet zone system is straight forward as the system needs the reference signals from the mixing console only and is self-contained otherwise. In the case that strong nonlinear processing is involved in the PA setup (e.g. compressors and limiters in the Power Amplifiers), it might be recommended to use "amp-sniffers", in order to retrieve the reference signals from behind the power amplifiers instead. In the specific case of deployment at the Kappa Future Festival, the installation of the quiet zone system took unexpectedly a lot of time because it needed to be moved and resized multiple times due to safety issues (the system was placed in passageway). Depending on the recorded measurement data analysis it might turn out that measuring sweep sounds through the main PA and initializing the quiet zone system with an analytic solution produces slightly better results. In that case, the measurement of such sweeps could be recommended. This process does not need any additional installations and the recording of the sweeps takes max. 5 minutes. But it has to be mentioned that the loudness of the sweeps should be in the range of the music that is played back during the event. So regarding official noise regulations, it is necessary to assign a designated time slot for these 5 minutes, and noise from other sources (e.g. stages, construction cars) should be prevented during this time frame.

3.2.3 Noise Monitoring System

Sound Level Meter

Tests of Sound Level Meter (SLM) IoT prototypes were carried during different pilot tests in 2018 and 2019. Since the KFF 2018 pilot test, the SLMs provides overall Sound Pressure Level (SPL) and Sound Level Pressure Spectra. Since Rhein in Flammen pilot test in May 2019, the SLMs can send audio recordings in FLAC format to the SLM gateway for data processing. This format achieves a lossless compression of the data. The last pilot test to date is KFF 2019.

Tests during the last pilot tests have shown an improved stability of the SLMs, without any specific issue regarding the device itself.

The critical point is the communication network. When the devices are setup to send only SPLs and spectra (without audio recordings), the transferred rate of data is very high (very small amount of losses). It requires typically 116 bytes of data every second for each SLM. If audio recordings are required, the performance of the communication network is important: the required data transfer rate is maximum 1 Mbit/sec/SLM (it is generally less thanks to the data compression). For KFF 2019, 2 SLMs were configured to send audio recordings. The transfer rate of these recordings to the SLM gateway was very low, because there was not any dedicated network where these SLMs were installed (outside of the venue). But during Rhein in Flammen 2019, all the 6 SLMs sent audio recordings with a small amount of loss, thanks to the selection of strong local network operator.

GPS functionality is currently implemented and working. GPS functionality allows both automatic location and GPS time stamps for synchronization of data.

Annoyance measures (Annoyance Index)

The analysis of acoustic measurements carried on pilot events (Nuits Sonores, Kappa Futur Festival, Fête des Lumières and Woodstower) showed that sound emissions at these events have a big amount of energy within the low frequency range (i.e.: from 30 Hz to 250 Hz). In addition to that, results from annoyance survey carried out for the Kappa Futur Festival in July 2018 (number of respondents: 156) and Woodstower 2018 (number of respondents: 338) revealed that:

- Annoyance is associated with noise for more than half of the respondents.
- There is a predominance of low frequencies in the emergence of this discomfort.

Thus, both subjective and physical assessments conclude on the importance of low frequencies in the expressed noise annoyance of outdoor large-scale events. Following these observations, a review of the state-of-the-art was conducted mainly focused on annoyance and low frequency noise [2]. The main findings of this review are:

- Noise annoyance depends on multiple factors. Acoustical dimension being one of them.
- A high inter-individual variability is observed on expressed annoyance of subjects under the same acoustic stimulus.
- Assessment of annoyance based on acoustical measurement can bring light to the main tendencies of community annoyance, but it cannot be used as a reliable predictor of individual annoyance.
- Conventional methods of assessing annoyance, typically based on A-weighted equivalent level, are inadequate for low frequency noise and lead to incorrect decisions by regulatory authorities.
- A-weighted level underestimates the effects of low frequency noises.

- Annoyance of low frequencies increases rapidly with level.
- Loudness, and particularly loudness percentile N5 (loudness which is exceeded the 5% of the time of observation) can be used for describing time varying sounds (taking fluctuations into account).

In order to take into account the previously described aspects, it was decided to investigate loudness (the Zwicker method according to [3]) of a set of sound recordings of festivals (recorded in audience and neighbour areas) and its correlation with C-weighted sound pressure levels recorded every second. C-weighted sound pressure levels and loudness showed a good correlation (R2>0.75). Even if loudness can provide a more precise description of the acoustical phenomenon in terms of sensorial response, C-weighted values are less time consuming and can be generally found on every professional sound level meters.

An annoyance index was thus proposed, build on three main rules:

- Easy to understand: linear scale from 0 to 10 (where 0 means “no annoyance” and 10 means “maximum annoyance”)
- Based on C-weighted sound pressure levels
- Comparison between sound levels during the event (contribution of event at receiver point in terms of LCeq,1 minute) and without the event (LC90 hourly from measurements before the event at receiver point during an equivalent time period)

A schematic view of the computation of the annoyance index is presented in Figure 4.

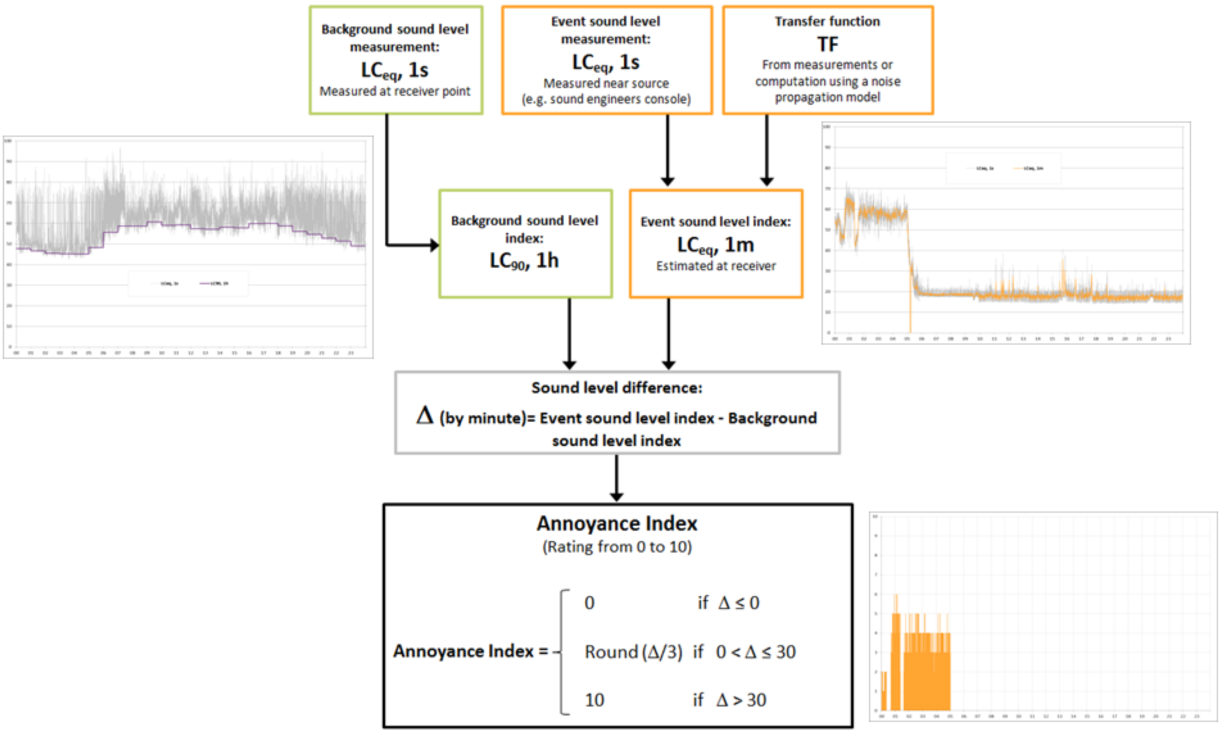


Figure 4: Computation of the annoyance index

The proposed annoyance index was tested using measurements performed during festivals in 2018 (Nuits Sonores, Kappa Futur Festival and Woodstower). Results obtained seem coherent: the most exposed areas showing higher annoyance index values.

Annoyance Index has been implemented in the SLM gateway and tested at Rhein in Flammen 2019. For Woodstower 2019 demonstrator both perceived annoyance surveys and acoustic measurements will be conducted on four municipalities around the venue. This will be the first time during the project that acoustic measurements and perception survey could serve for parallel analysis. However, as noticed in the state-of-the-art, noise annoyance is highly subject to inter-individual variability. Thus the annoyance index could preferably be named as “Annoyance Likelihood Index”.

Sound Heat Map

The propagation model of the ASFC system (which estimates the transfer-functions) could be used to compute a map of sound level distribution around the concert venue. However, this model has not been implemented and a preliminary *sound heat map module* has been developed by DTU. The computations are based on simplified point source wave propagation, inspired by the Nord2000 standard.

The model is built in 2D and requires the following input data:

- Position of sound sources
- Position of reflecting surfaces (walls)
- A computation area (surface and grid size)

The computation model uses Sound Pressure Levels measured by the IoT SLM located in front of the stage to dynamically adapt the power of each source included in the model. Then, the map is calculated and becomes available in MONICA cloud via a REST API (this preliminary module has been used since Rhein in Flammen 2018). Figure 5 shows an example of Sound Heat Map computed during Nuits Sonores 2019 demonstration and displayed on the Common Operational Picture (COP).

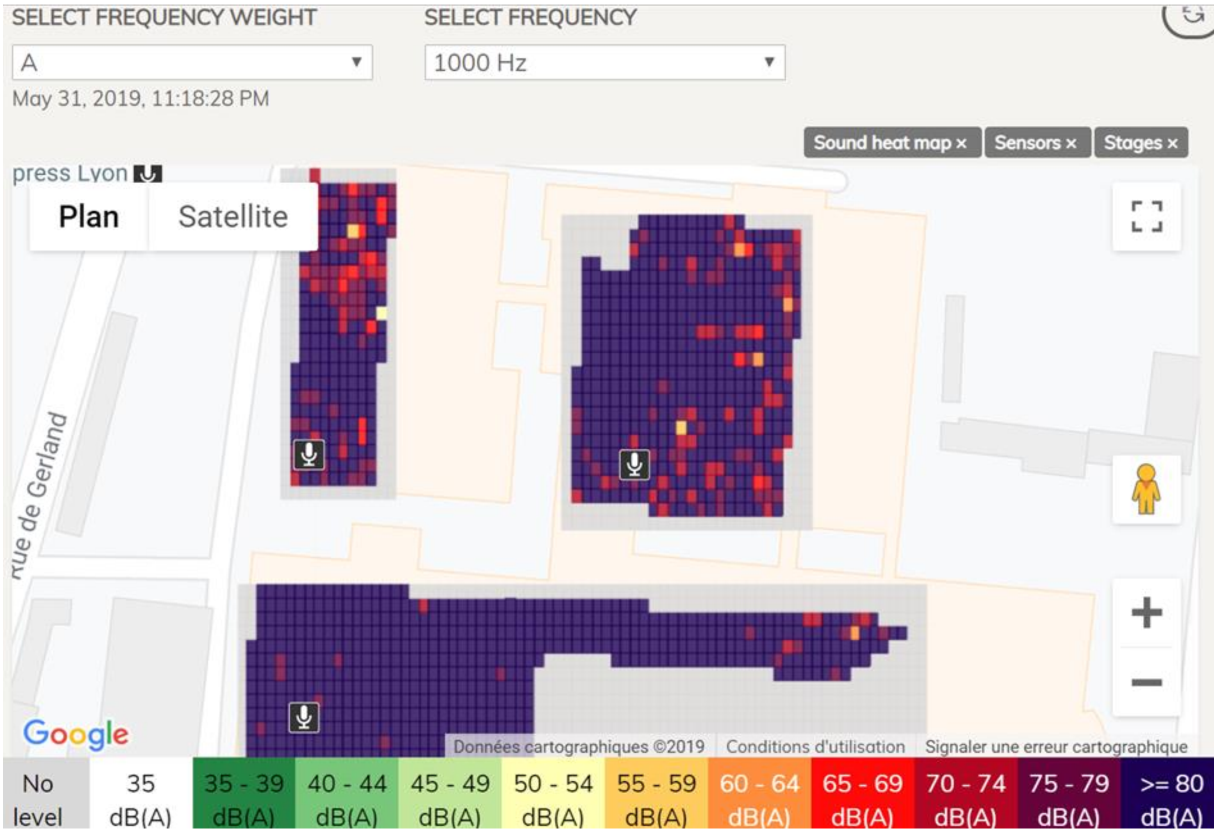


Figure 5: Sound Heat Map computed during Nuits Sonores 2019 demonstration

An updated version of the *sound heat map module* which allows using directive sources (cardioid) and is able to manage several stages is under development and is planned to be integrated for the Woodstower 2019 demonstration. In fact, directional sound systems (sub-woofer arrays as well as line arrays) are increasingly used and this is the case for stages in Woodstower festival. Acoucité has contributed to this task by providing some Python functions to DTU for managing the source directivity and the activation/deactivation of stages.

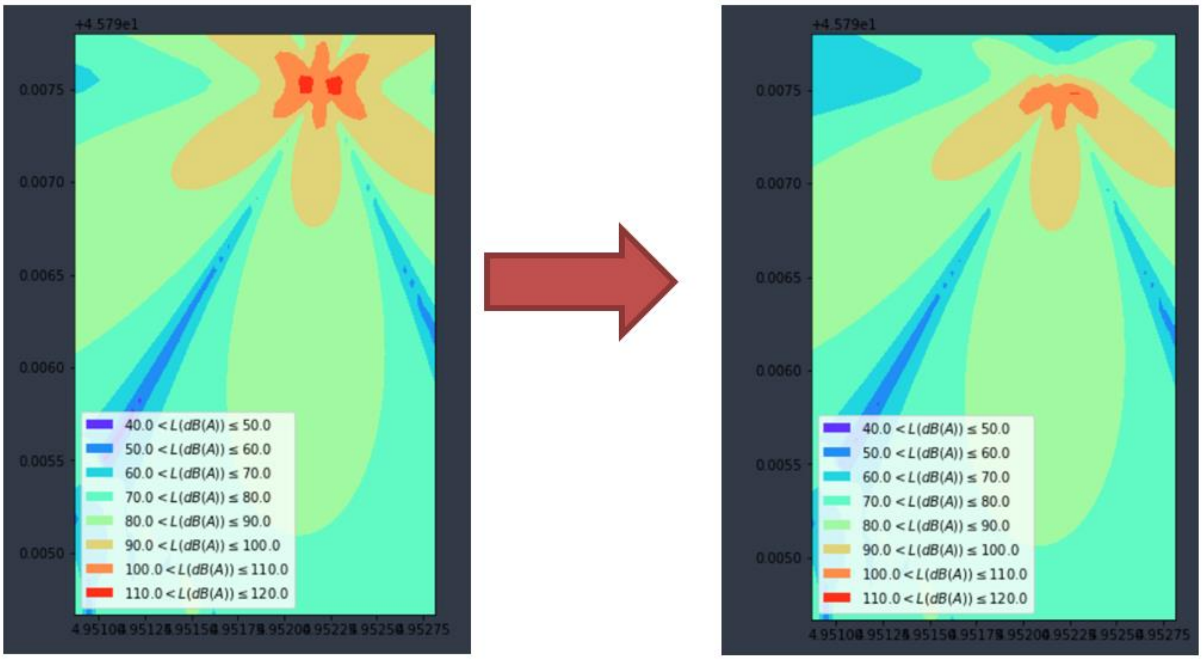


Figure 6: Managing sources directivity. Tests performed by Acoucité for the validation of the Python function. Omnidirectional sources displayed on the left picture and cardioid sources on the right one.

Source Separation/Contribution techniques

Two different algorithms of Source contribution method are implemented. One based on spectra data coming from the SLMs. The other one based on audio recordings. The later has been difficult to test so far, because of the requirement on the network. Also, the required synchronization between the different SLM recordings relies on the time clock provided by GPS. The last synchronization issues have been solved before the start of KFF 2019. The contribution analysis based on spectra has been tested for different pilot tests, including Nuits Sonores 2019 and KFF 2019 with success.

The source separation implementation aims at detecting unusual sounds such as gunfire and screaming. The implementation has been done. So far, it has not been tested during pilot tests because this was not required. The next possible test of the source separation could be Fête des Lumières in Lyon, December 2019.

4 Pilot: Woodstower Festival

Woodstower Festival takes place in the Grand Parc Miribel Jonage (a 22 000 hectares natural park located 15 minutes by car from Lyon, France) each summer since 2005. Every year, Woodstower offers a large program of music with different influences, from electro to rap and reggae, which brings together both exciting artists, international icons but also the best of the local artists. During the edition 2018 the festival gathered more than 33 000 people in three evenings.

The 2019 edition will take place from August 29th to September 1st.

A description of the venue and nearest residential areas is provided here below.

4.1 The venue

Edition 2019 of Woodstower Festival will include four stages (see Figure 7).

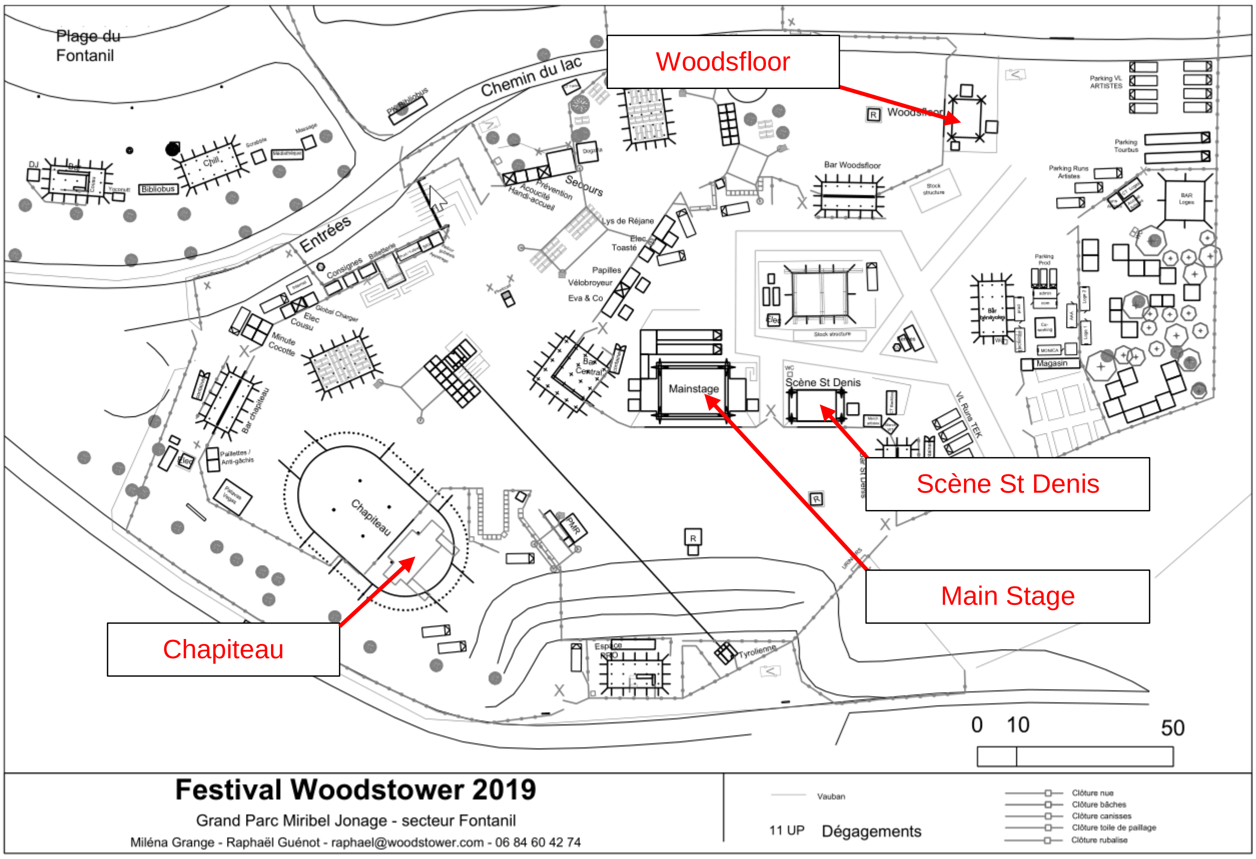


Figure 7: Woodstower 2019 Pilot area (4 stages)

4.2 The neighbours

One of the particularities of the festival is that it takes place in the middle of a natural park. The nearest residential areas are located at around 2 km from the venue. The next figure highlights the venue and the closest municipalities, which are expected to be the more critical receivers in terms of noise exposure.

Figure 8: Venue (highlighted in red) and closest municipalities (highlighted in yellow)

5 Planned configuration for Woodstower 2019

5.1 Noise Monitoring System

The Noise Monitoring System planned for Woodstower 2019 aims at helping the festival organisers and authorities to assess the sound emissions of the festival with regards to the requirements of the new French regulation[1] in terms of sound, in force since October 2018.

The decree establishes:

- Maximum allowable sound pressure levels in audience. The limit thresholds are provided in terms of A-weighted and C-weighted Overall Sound Pressure Levels (averaged over 15 minutes) and should not be exceeded at any place accessible to the public.
- Maximum allowable sound pressure levels in residential areas near the venue. The limit thresholds are fixed based on the background noise levels existing at the receivers (sound levels without the activity of the festival) and are provided in terms of A-weighted Overall Sound Pressure Levels and octave band spectra.

Thus, the Noise Monitoring System focuses on measuring the sound levels in audience and residential area, as well as providing a display interface (the MONICA COP) including relevant data. Further details are provided here after.

IoT Sound Level Meters in audience area

A total of 4 IoT SLMs are planned to be deployed in the audience area of the Woodstower festival. The devices are expected to provide overall sound pressure levels and 1/3 octave band spectra.

The IoT SLMs will be located near sound engineer’s console at each of the four stages in the venue.

[1] “Décret n° 2017-1244 du 7 août 2017 relatif à la prévention des risques liés aux bruits et aux sons amplifies”

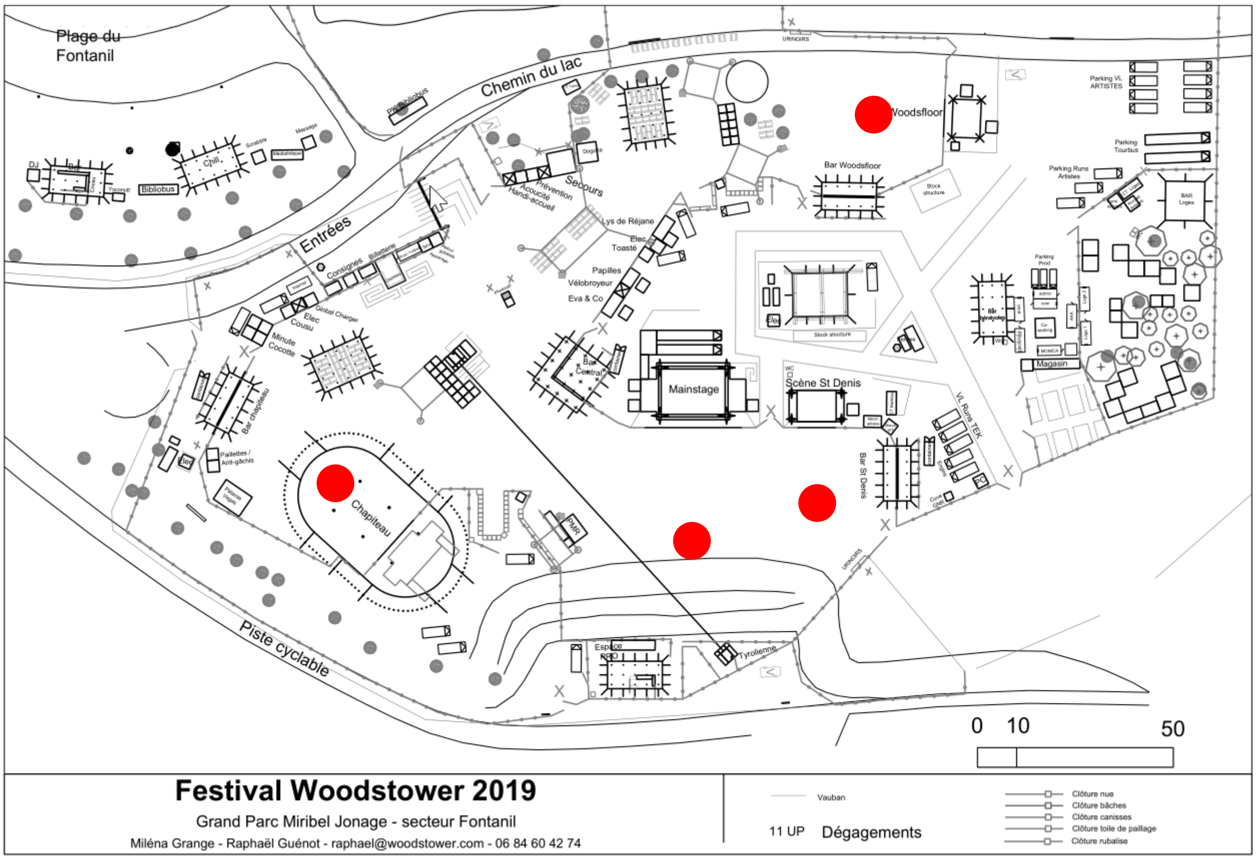


Figure 9: Woodstower 2019, IoT SLMs in Audience area (highlighted in red)

Connection will be made using a WiFi network specifically deployed for the MONICA project.

Sound Level Meters in residential area

A total of 4 IoT SLMs are planned to be installed at receiver points in residential areas located in municipalities around the venue of Woodstower festival. Specific location of measurement points is provided in Figure 10 and Table 1.

Figure 10: Municipalities were SLMs will be deployed

Municipality	Location of measurement point	GPS coordinates	
		Lat	Long
Miribel	City Hall	45,822395	4,952980
Neyron	City Hall	45,814751	4,932790
Vaulx-en-Velin	Inhabitant	45,787803	4,924371
Meyzieu	Inhabitant	45,774659	4,995161

Table 1: Location of measurement points in residential areas

Positioning of SLMs was planned to cover municipalities located to the north and to the south of the venue in order to include critical areas independently of meteorological conditions (i.e. wind direction varies from one year to another).

The devices are expected to provide overall sound pressure levels and 1/3 octave band spectra.

Data will be sent from SLMs to MONICA cloud using 4G connection through the MIFI device inside the IoT SLM box.

Decision Support System (DSS)

The Decision Support System planned for Woodstower 2019 is being implemented by CERTH (with the assistance of Acoucité) and includes:

- Setting thresholds with maximum allowable sound pressure levels: thresholds are obtained in accordance with regulatory statements. For the Audience, the thresholds correspond to fixed values (102 dBA and 118 dBC) that should not be exceeded in any place accessible to the public. For thresholds in neighbour area, the values are dependent on the background noise levels existing at measurement point. A **measurement campaign** to determine the background noise levels is thus required. These measurements have been conducted by Acoucité from 1st to 5th August 2019, at the measurement points described in Table 1.
- Computations to get relevant acoustic indicators from data sent by IoT SLMs: the data sent by IoT SLMs to the MONICA cloud corresponds to overall sound levels (in dBA and dBC) and 1/3 octave band spectra. This data is sent every second. Computations in DSS are of two types: 1) Sliding average with a time window of 15 minutes and 2) Converting 1/3 octave band spectra into octave band spectra.
- Setting alarms: Alarms are set to inform when thresholds are exceeded.

Mock ups for Noise Monitoring displayed on COP, which include variables computed at DSS level, are presented in Figure 11 (Audience) and Figure 12 (Neighbours).

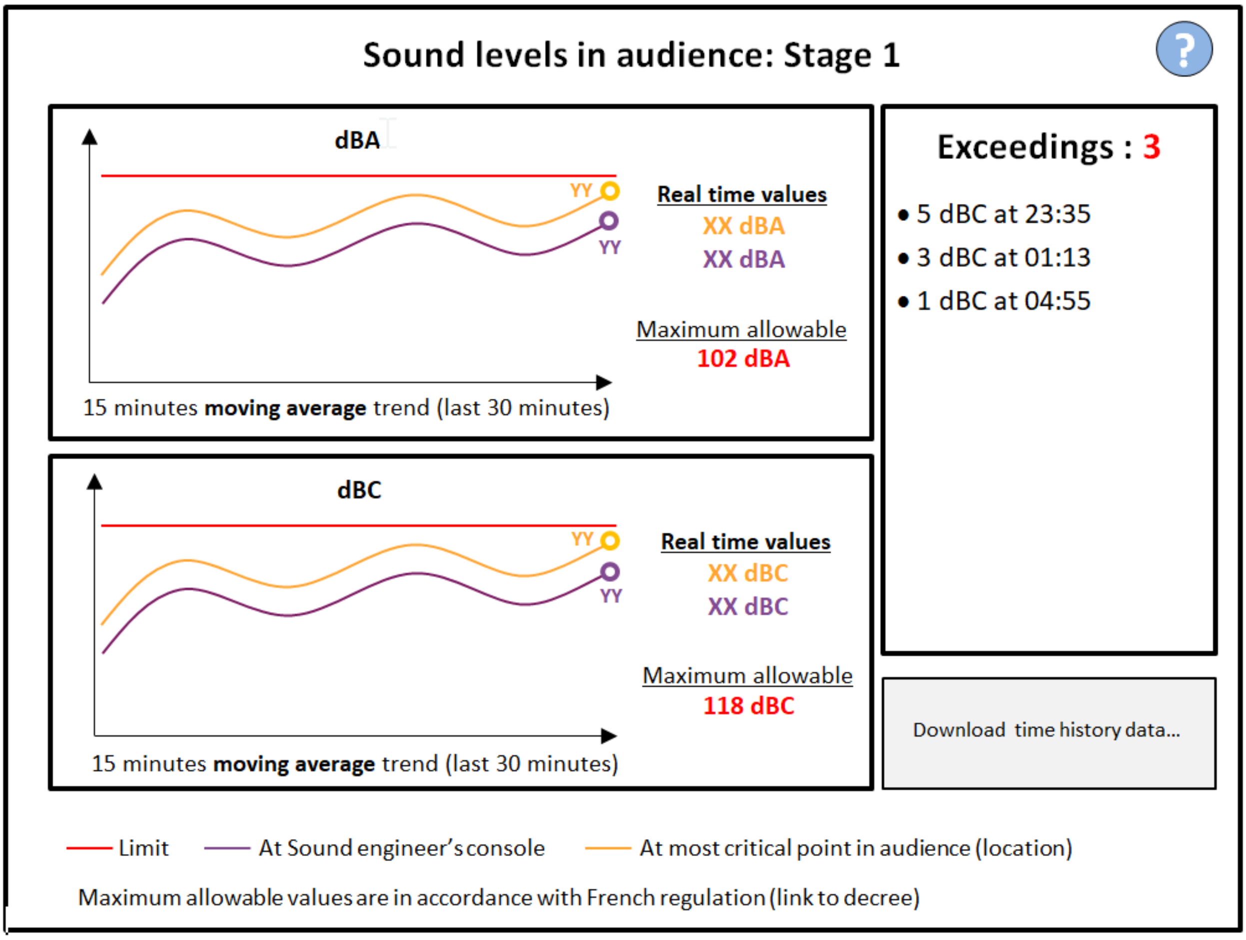


Figure 11: COP - Noise Monitoring display - Mock up for Audience

- A display like this one should be prepared for each stage
- Two windows are shown: one for dBA another for dBC
- The **purple values** shown in "Real Time" section (at the right of the graph) correspond to sound levels measured at monitoring position (near sound engineer's console, where the MONICA IoT SLM is installed) every second. If refreshing every second is a problem, the refresh time can be degraded up to 5 seconds.
- The **orange values** shown in "Real Time" section (at the right of the graph) correspond to purple values plus a correction factor/transfer function. This factor will be provided after preliminary measurements (pink noise) planned by Acoucité for Wednesday the 28th of August.
- The **purple curve** corresponds to a moving average, within a 15 minutes time window, of the purple values.
- The **orange curve** corresponds to the purple curve shifted by a correction factor (the same used to get orange values from purple values).
- The **red line** corresponds to the maximum allowable values (regulatory thresholds in France : 102 dBA & 118 dBC)
- The "Exceedings" section is a log of every exceeding identified during the night of show.
- A button will be implemented to allow downloading the measured data.

Computations required at DSS level are: Moving average and summations to get orange values and curve from purple values and curves.

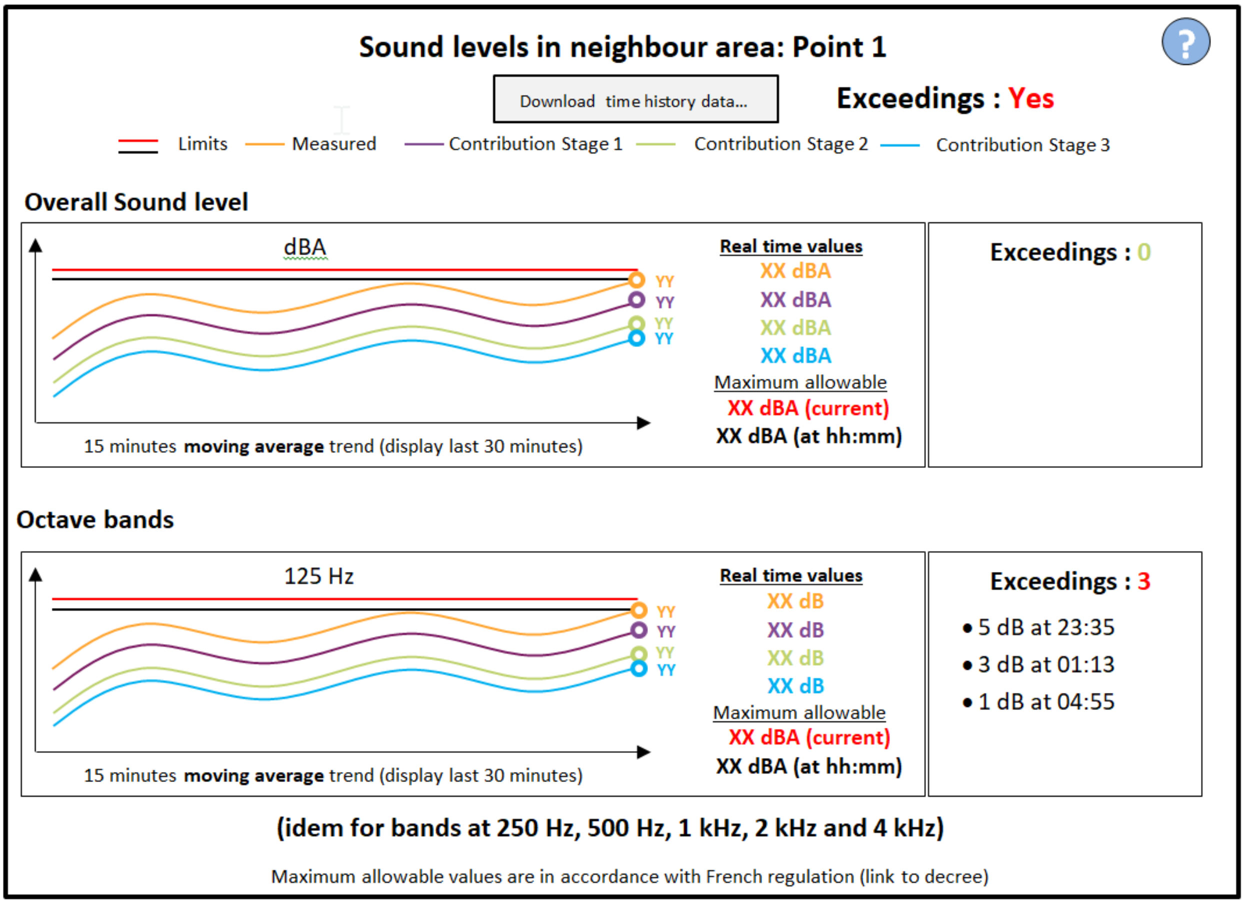


Figure 12 : COP - Noise Monitoring display - Mock up for Neighbours

- A display like this one should be prepared for each measurement point in neighbour area.
- Two windows are displayed: one for dBA and another one for Octave bands. In the octave bands window, only the 125 Hz octave band is shown in Figure 12 as an example. In the COP the octave bands of 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz and 4 kHz should be accessible in several tabs.
- The **orange values** shown in “Real Time” section (at the right of the graph) correspond to sound levels measured at monitoring position (neighbour’s balcony or garden where the MONICA IoT SLM is installed) every second. If refreshing every second is a problem, the refresh time can be degraded up to 5 seconds.
- The **purple, green and blue values** shown in the “Real Time” section (at the right of the graph) correspond to the contribution of every stage to the sound at this measurement point (in this example there are only 3 stages, but during Woodstower 2019 there will be 4 stages). The contribution of a stage is obtained by adding a correction factor/transfer function to the sound measured in front of the stage. These factors have been provided by Acoucité on August 15th and were obtained by using a computation model (in CadnaA Software) which includes the topography and obstacles. Conservative meteorological conditions were adopted.
- The **red value** shown in “Real Time” section (at the right of the graph) corresponds to the maximum allowable limit at the current time. This value varies depending on the time (one value per hour). The **red curves** in graphics are a graphical representation of red values to help the comparison/evaluation. This data is obtained from background noise measurements (provided by Acoucité)
- The **black value** shown in “Real Time” section (at the right of the graph) corresponds to the maximum allowable limit at the most restricting hour during the night of show (the minimum value that the red value will reach during the night). It helps the organiser to anticipate what will happen at the most restrictive hour. The **black curves** in the graphics are a graphical representation of black values to help the comparison/evaluation.

- The “Exceedings” section is a log of every exceeding identified during the night of show.

Computations required at DSS level are:

- Moving average from data every second
- Converting third octave bands (provided by SLM) to octave bands by summing the energy of the corresponding 3 third octave bands
- Contribution of each stage based on values measured in front of stages and transfer functions

Source contribution algorithm

Since the former source contribution algorithm developed by B&K (see end of section 3.2.3) requires a stable network and a relatively high bandwidth (audio signal is required), an alternative approach for determining the source contribution has been adopted. This approach was taken in order to avoid possible data loss. In fact, the festival is located far from the city center were bandwidth of internet connection is poor and with a reduced density of LTE antennas in the surroundings.

The alternative approach uses transfer functions for each pair of points stage/neighbour to estimate the contribution of each stage to neighbours from sound levels measured in front of a given stage. Transfer functions can be issued from measurements or simulation. In case of Woodstower demonstration, simulated transfer functions were used (since the receivers are located at long distances from the venue, getting measured transfer functions was not possible) as shown in Figure 13. This method has the limitations proper to the computation standard ISO-9613 but there is also another limitation related to that the computed transfer functions are “static”, it means that they are not updated with the changes in meteorological conditions). However, it represents a good backup solution for cases where the internet connection is limited. A possible improvement should be to compute, previous to the event, a set of transfer functions for different meteorological conditions and create a library of transfer functions. Then, during the event, the corresponding transfer functions can be chosen in real time if meteorological variables are measured as part of the system.. Figure 13 shows a map of computed overall sound pressure levels in dBA.

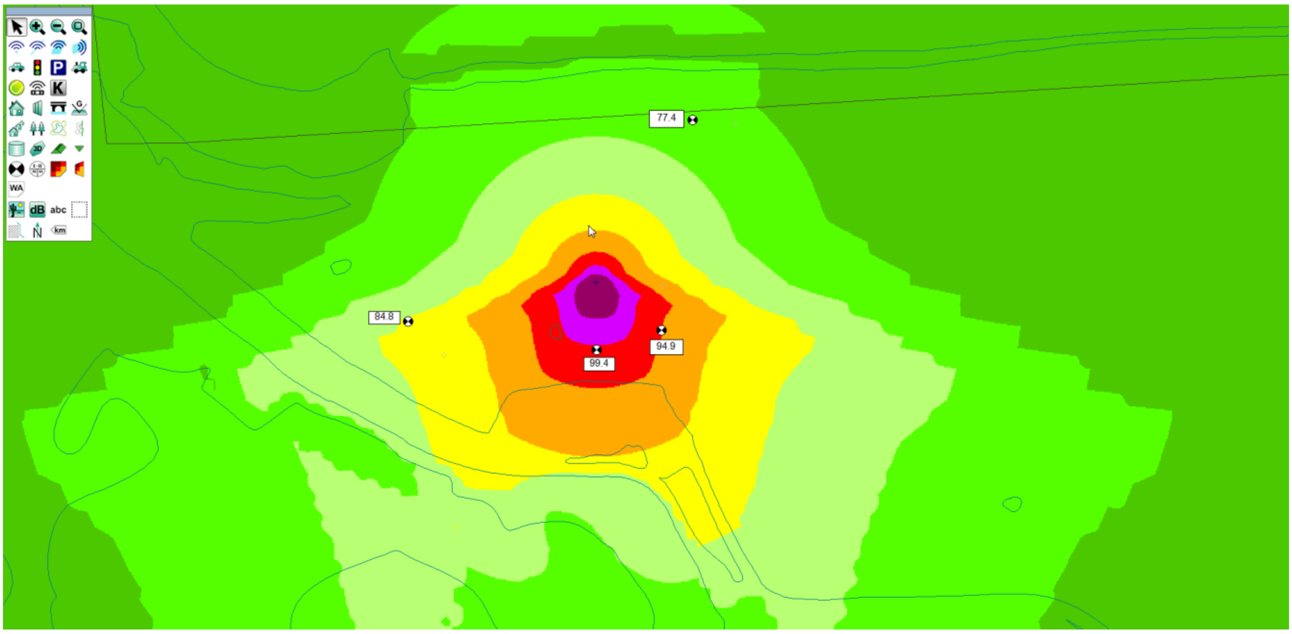


Figure 13: Computation model for outdoor sound propagation (built by Acoucité using CadnaA software) used for obtaining transfer functions for source contribution. Computations use ISO 9613 standard.

Complementary measurements

In order to provide with a more precise knowledge on the spatial distribution of sound levels in audience area, complementary measurements are required. These measurements will be performed "manually" (by using classical non IoT SLMs) using measurement equipment provided by Acoucité. These measurements will be conducted the day before the festival, once the sound systems are set up. The signal sent to the loudspeakers corresponds to pink noise. The sound levels for these tests are close to those used during concerts. Every stage will be run separately. The main objective of measurements is to identify the critical points in audience area (the points were the sound level reaches its maximum). Figure 14 shows similar measurements carried out during Nuits Sonores 2019.

Figure 14: Complementary measurements (using pink noise) carried out during Nuits Sonores 2019 demonstrator. Reference point located at sound engineer's console. Measurements carried out by Acoucité the day before the event.

5.2 Estimation of the exposure of audience to high sound levels

Crowd wristbands will be a part of the demonstration in Woodstower 2019. In order to take advantage of this opportunity it was decided to use the tracking feature of wristbands as part of Noise Monitoring System. In fact, by combining the position of wristbands and the computed Sound Heat Maps in the venue it is possible to estimate the sound exposure of each festival goer (wearing a wristband) during a whole night of concert. Within the Woodstower venue there are zones of high sound levels (near stages) and other quieter zones (bars, food trucks, toilets,…).This approach can help getting information on sound level vs time for every crowd wristband. Some further information about crowd wristbands deployment and Sound Heat Map implementation is provided below.

Crowd wristbands

A total of 10 000 crowd wristbands are planned to be distributed. Wristbands are provided by DEXELS. The distribution will be done by a team of volunteers, specially recruited for this task. A MONICA stand will be installed near the entrance to provide with details on wristband functionalities and information on the MONICA project.

In order to cover the whole venue, 16 base stations are planned to be deployed. The possible positioning of the base stations is presented in Figure 15.

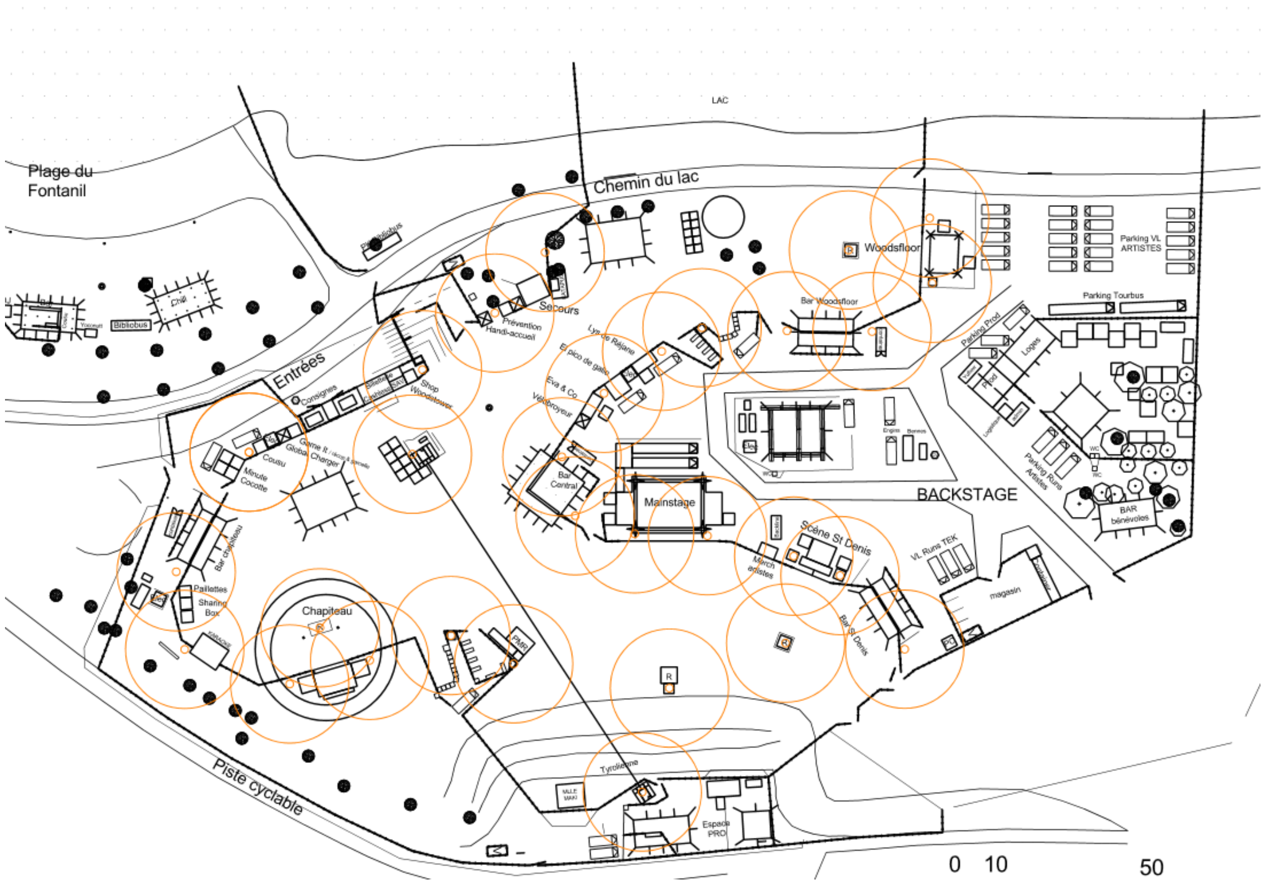


Figure 15: Identification of possible locations for base stations done by DEXELS based on layout provided by Woodstower.

Dedicated LAN and WiFi networks will be deployed. Installation will be done by a sub-contractor (Frekences) under the technical supervision of the MONICA partner RINICOM.

Sound Heat Map

In order to provide with more accurate results, the Sound Heat Map computation model has been updated by:

- Allowing the computation of several stages running in parallel
- Allowing using directive sound sources (cardioid directivity pattern)

Sound system information has been provided by Woodstower in the form of an ArrayCalc[2] file. A 3D view of the sound system model in ArrayCalc is shown in Figure 16.

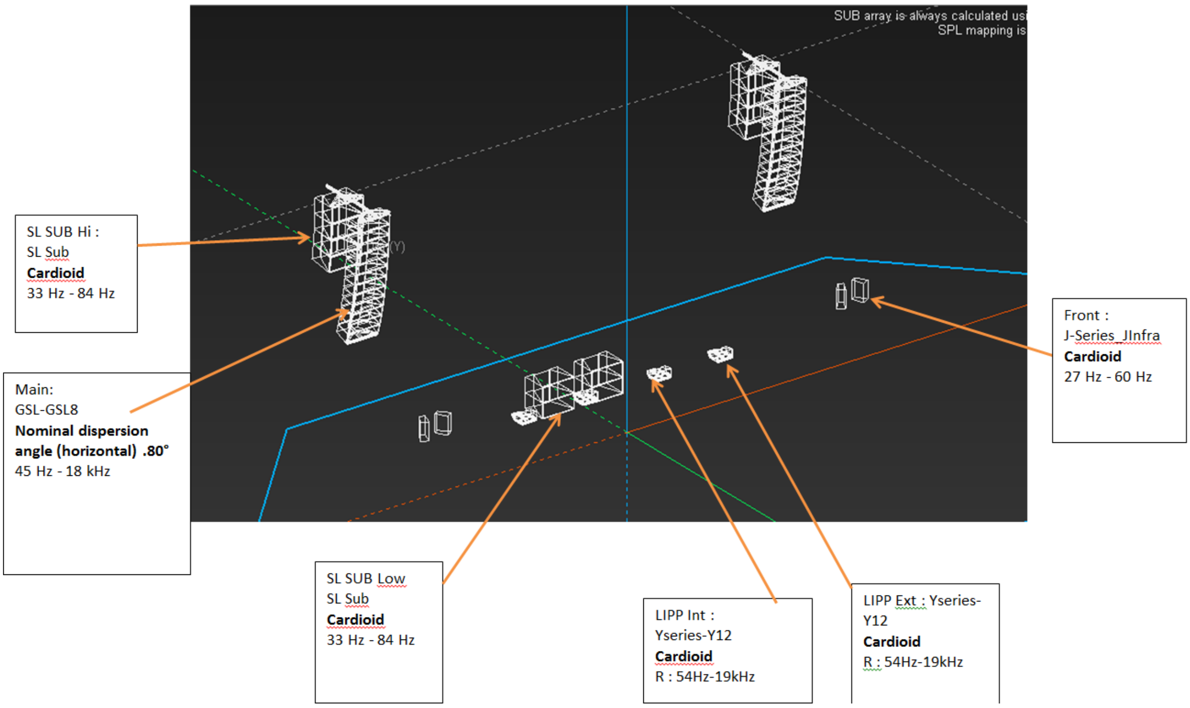


Figure 16: 3D view of the sound system model in ArrayCalc

For the Sound Heat Map a simplified model, including three sound sources for each stage, will be used.

5.3 Surveys

For general feedback about the sound, two perception surveys will be conducted for:

- Getting festival goers feedback in terms of sound quality
- Getting neighbours feedback in terms of noise induced annoyance

Cities' zip codes will be used to attribute the location to the respondents. More information (street etc.) will drastically increase the amount of computation treatment and the safety measures deployed to ensure the respect of the GDPR. The zip code precision will be sufficient to estimate the average annoyance in each city and its evolution during the festival.

For specific feedback, sound engineers will also be interviewed to assess the COP's functionalities related to sound monitoring.

[2] ArrayCalc is software provided by the loudspeaker manufacturer d&b audiotechnik. This software allows to choose different type of loudspeakers. The user can set the position and orientation of the loudspeakers, create arrays, create the geometry of the venue and set the amplitude and the delay of the signal for every single loudspeaker. One of the outputs from this model is a sound map of the venue (computed taking into account the phase between sound sources) were the resulting directivity of the system can be observed for each frequency band. This model can be used as input data for NoizeCalc, second software provided by d&b audiotechnik, to compute sound maps using an outdoor propagation model.

The three surveys are currently under construction [Appendix B page 29]. They will be conducted after the festival period by using the online service Survey Monkey. A link to the questionnaires is planned to be communicated to festival goers and neighbours through the festival communication tools (newsletters), through municipalities (letter to the mayor’s office, local magazine) and through Acoucité’s website and social networks accounts. The interviews with the sound engineers will depend on their work schedule.

6 Conclusion

A description and review of the state of progress of Noise Monitoring System, Adaptive Sound Field Control (ASFC) System and Quiet Zone System have been provided.

ASFC

The current sound field control system works in open terrain. However, even in the second iteration of the system in KFF, it failed to give similar reductions in an urban environment. Similar results are expected for a test at Tivoli. In order to get better results, special attention should be put on choosing the location where the system will be deployed (at least for the current version of the system) since it is more likely to perform well in an open terrain than in an urban environment.

Quiet Zone System

The quiet zone system worked as expected during the last demonstration in Kappa Futur Festival 2019, where the focus was on the low frequencies attenuation. Further improvement will be to couple the active low frequency solution with the passive high frequency solution in order to cover the whole listening spectrum.

Noise Monitoring System

The quality of data flow from IoT SLMs is highly dependent on the available bandwidth of network (WiFi or 4G). In case of limited bandwidth, the functionalities using the audio signal are compromised. In case of poor bandwidth, the level data (overall Sound Pressure Levels and spectra) suffer losses.

The Decision Support System has been used to improve the Noise Monitoring System display on COP by providing relevant data to be displayed. This allows stakeholders to have a real time assessment of the event with regards to local regulation.

Sound Heat Map has been improved to get more reliable data (managing sources directivity and multi stages computation). This data, combined with tracking functionality of crowd wristbands, can be used to estimate the sound exposure of the audience within a venue, were sound levels varies in time and in space. Accuracy of this approach is limited by positioning precision of wristbands and accuracy of the Sound Heat Map computation model.

Further demonstrators

A description of Woodstower festival venue, where an improved version of Noise Monitoring System will be deployed, has been given. The planned configuration of systems for the 2019 edition is included.

7 List of Figures and Tables

7.1 Figures

7.2 Tables

8 References

(EC, 2017) AMENDMENT Reference No AMD-732350-4 of the Grant Agreement number: 732350 — Management Of Networked IoT Wearables – Very Large Scale Demonstration of Cultural Societal Applications (MONICA).

(EC, 2017) Management Of Networked IoT Wearables – Very Large Scale Demonstration of Cultural Societal Applications (Grant Agreement No 732350) - D4.1 Validation of the ASFC and Noise Monitoring System Configuration 1Version 1.0 of 2017-12-29)

(EC, 2017) Management Of Networked IoT Wearables – Very Large Scale Demonstration of Cultural Societal Applications (Grant Agreement No 732350) - D4.4 Precision IoT enabled Microphone Sensor version 1 (Version 1.0 of 2017-12-21).

(EC, 2017) Management Of Networked IoT Wearables – Very Large Scale Demonstration of Cultural Societal Applications (MONICA). “D10.2 Acoustics Assessment Report of MONICA Pilot Sites”.

APPENDIX B : Surveys

COP interview

Questionnaire about the COP system

The goal of the questions below is to evaluate the COP system, how easy it was and the impact it has on completing your tasks and normal job.

The COP stands for Common Operational Picture and it is provided by the European project MONICA that has the goal to improve cultural events via the use of technology.

In addition to your opinion we are also going to collect some personal information about you like gender, age and job title. We will use this data to analyse the gender, age and role aspects of the solution and its evaluation.

All personal data will be stored until the end of the project (December 2019) on secure servers controlled by the project consortium. Only authorised project partners will have access.

By filling out this questionnaire you agree that we will process your data in line with our privacy policy.

If you have any questions or change your mind, contact our Data Protection Officer: Vincent Gissinger

(vincent.gissinger@acoucite.org).

1. It was easy to learn how to use the COP

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

2. I am satisfied with how easy it is to use the COP

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

3. I can could quickly complete my work using the COP

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

4. I can could effectively complete my work using the COP

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

5. The information provided by the COP is easy to understand

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

6. The organisation of the information on the COP screen is clear

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

7. The COP has all the functions and capabilities I expected it to have

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

8. The COP helped me to monitor the sound levels

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

9. The people wearing crowd wristbands were visible on the COP screen through crowd heat map

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

10. How often during your shift did you use the COP?

____
____
____

11. In your opinion, what's the most important thing COP helped you with?

____
____
____

12. What additional functionality did you expect the COP to have?

____
____
____

13. Overall, I am satisfied with the COP

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

14. Gender: Male Female Prefer not to say

15. Age: 18-24, 25-34, 35-44, 45-54, 55-64, 65+

16. Role:

Thank you very much for your participation.

Neighbour Questionnaire

The aim of this questionnaire is to have your opinion about the the Woodstower Festival.

[GDPR introduction]

1. What do you think about Woodstower festival?

- I love it
- It's fine
- Neutral
- I don't appreciate it much
- I don't appreciate it at all

2. Do you feel any discomfort or disturbance caused by the event?

- Yes absolutely
- Yes a little bit
- Neutral
- No not much
- No not at all

3. What are the main causes of discomfort or inconveniences? (Please select all that apply)

- Noise
- Waste
- Insecurity
- Other (please state)

4. How is the noise compared to last year?

- Better than last year
- No change since last year
- Worse than last year
- This is my first year
- I don't know / can't remember

5. Over the three days of the event, when is the noise level at its highest?

- -Thursday's night
- Friday's-night
- Saturday's night
- Equal Throughout

6. What type of sound do you hear? (Please select all that apply)

- High-pitched (cheering, whistles, music)
- Low-pitched (bass, vibrations)
- Both
- No sound at all

7. Are you more annoyed by high-pitched or low-pitched?

- High-pitched (whistle, cheering)
- Low-pitched (bass, vibrations)
- Both
- Sound levels do not bother me

8. In relation to the noise, it annoys you:

- At certain times
- Continuously
- Not bothering at all

9. During the festival, does your sleeping pattern continue as usual?

- Yes

- Not at all (my sleep pattern is affected)

10. Do you leave your windows open during the festival?
- Yes
- No
- I close the window despite the heat, because of the noise

11. Do you feel the need to leave your apartment because of the festival noise?

- Always
- Sometimes
- Never

12. How would you rate your noiser annoyance on scale from 0 to 10?
(0 = not annoyed at all, 10 = extremely annoyed)

____

13. The event organisers are involved in an EU project where innovative technologies are used to monitor the sound level of the music at Woodstower festival, how do you feel about that?

- Very satisfied
- Moderately satisfied
- Neutral
- Moderately dissatisfied
- Very dissatisfied

---

14. What kind of acoustic insulation do you have?
-none -old double glassed windows –recent double glassed windows

15. ZIP code

16. Floor (0 for ground level):

17. Gender:
o Male
o Female
o Prefer not to say

18. Age:

- o 18-24
- o 25-34
- o 35-44
- o 45-54
- o 55-64
- o +65

19. Anything else about this questionnaire or the festival?

Thank you for participating.

Visitor Questionnaire

[Introduction to context and GDPR]

1. Is this your first year at Woodstower?

- Yes
- No

2. During the festival, what did you think of the sound level?

- Too loud
- Loud
- Neither too loud nor too low
- Low
- Too low

3. During the festival, what did you think of the balance of sound in terms of low frequencies sounds? (bass , vibrations)

- Too much bass
- Well balanced
- Not enough bass

4. During the festival, what did you think of the balance of sound in terms of high frequencies sounds? (high-pitched, screams, whistles)

- Too many high-pitched sounds
- Well balanced
- Not enough high-pitched sounds

5. In the end, over the duration of the festival, how would you rate the sound quality, on a scale from 0 to 10 (0 = poor / 10 = excellent)

6. The event organisers are involved in an EU project where innovative technologies are used to monitor the sound level of the music at Woodstower festival, how do you feel about that?

- Very satisfied
- Moderately satisfied
- Neutral

- Moderately dissatisfied
- Very dissatisfied

7. In general, what do you think of Woodstower? (1 = poor / 5 = excellent)

8. Did you use the MONICA connected wristband?

-Yes -No

9. The MONICA wristband was comfortable to wear

- Agree - Neutral - Disagree

10. The MONICA wristband was easy to use

- Agree - Neutral - Disagree

11. Comparing to previous years, I prefer the event with the MONICA wristband

- Agree - Neutral (this was my first visit) - Disagree

12. Although the MONICA wristband tracking is anonymous, in terms of privacy, how do you feel about others tracking your location?

- I'm ok with it
- I don't like it
- Other (Please state)

13. I was able to participate in the light show

- Yes - Neutral - No

14. Overall, I am satisfied with the MONICA wristband

- Agree - Neutral - Disagree

15. Gender: Male Female Prefer not to say

16. Age: 18-24, 25-34, 35-44, 45-54, 55-64, 65+