

## GUIDE TO ACOUSTIC MEASUREMENT IN BULLRINGS

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### Resumen

Se presenta una guía para la realización de mediciones acústicas en las plazas de toros. El objetivo es la caracterización acústica de este tipo de espacios al aire libre a partir del tiempo de reverberación y el resto de parámetros acústicos siguiendo las directrices de la norma ISO 3382 y la comparabilidad de mediciones acústicas y simulaciones para los diferentes tipos de plazas de toros. La guía analiza aquellas prescripciones de la norma que tienen alguna influencia en las medidas acústicas en las plazas de toros. A partir de la identificación de las fuentes sonoras y zonas de audiencia características de los festejos taurinos, se proponen las localizaciones y se sugieren las combinaciones de fuentes y receptores más adecuados para estudiar la casuística del entorno acústico en el que se desarrolla el espectáculo taurino. También se realizan algunas consideraciones de tipo práctico, tales como tipologías, ejes y coordenadas a considerar para referenciar fuentes y receptores. Como ejemplo de aplicación de la guía se presenta la desaparecida Plaza de Toros Monumental de Sevilla.

**Palabras clave:** Plazas de toros, Guía de medidas acústicas, ISO 3382, Acústica de espacios al aire libre.

### Abstract

This paper presents guidelines for acoustic measurements in bullrings. The aim is to facilitate the experimental measurement of reverberation time and other acoustic parameters in these open-air spaces in accordance with the ISO 3382 standard, and to enable the comparison of acoustic measurements and simulations for various types of bullrings. The guidelines analyse those items in the standard that exert a certain influence on acoustic measurements in bullrings. Based on the identification of the sound sources and on audience areas characteristic of bullfights, the locations are proposed and the most suitable source-receiver combinations are recommended for the study of the acoustic environment of bullfighting. Practical considerations are also made, such as typologies, axes, and coordinates to be taken into account when referencing sources and receivers. As an example of the application of the guidelines, the process for the measurement of the since demolished Monumental Bullring of Seville is presented.

**Keywords:** Bullrings, Guidelines for acoustic measurement, ISO 3382, Open-air space acoustics.

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## 1 Introduction

The internationally accepted acoustic characterisation method combines experimental on-site measurements and the use of computer simulation techniques of sound fields in order to understand and predict the acoustic behaviour of enclosures. The execution of experimental measurements to ascertain the reverberation time and other acoustic parameters in performance halls, following the guidelines of the ISO 3382-1 standard [1], is the procedure commonly used for the acoustic evaluation of rooms that is based on impulse responses. It is worth noting that Part 1 of the ISO 3382 standard has its field of application in general venues without specifying a specific type, while Part 2 of said standard [2] refers to ordinary venues, and Part 3 [3] to spaces of open-plan offices.

With the prescriptions of the old ISO 3382 standard [4, 5], and especially since 2009 with the current ISO 3382-1 standard, numerous performance spaces have been evaluated for the determination of their acoustic quality. These spaces include not only those mainly intended for listening to music and speech such as concert halls, opera halls, auditoriums, and theatres, but also places of worship such as temples, mosques, churches, cathedrals, and synagogues, not forgetting other open-air venues such as ancient Greek and Roman theatres, and modern auditoriums for large-scale musical concerts.

The ISO 3382-1 standard refers essentially to enclosed spaces or rooms, for which there is a major consensus on the validity of the assessment of their acoustic behaviour. There are, however, currently several uncertainties regarding the evaluation of acoustics in open-air spaces with the parameters defined in the aforementioned standard, since these spaces have a characteristic sound field that is distinct from the reverberated field of enclosed rooms.

Bullrings are venues for holding bullfights and festivities, and most are conceived as open-air venues. This communication presents guidelines for the acoustic characterisation of bullrings based on the reverberation time and other acoustic parameters following the guidelines of the ISO 3382-1 standard, and for the comparability of acoustic measurements and simulations to be carried out in various bullrings.

## 2 Analyses of the ISO 3382-1 standard

As already mentioned, the ISO 3382-1 standard specifies the methods for measuring reverberation time and other acoustic parameters in auditoriums based on impulse responses, while describing the measurement procedure. This section analyses those aspects and prescriptions of the standard that affect the way in which acoustic measurements are to be carried out in spaces where sound propagation is influenced by factors such as geometric divergence from the source, air absorption, the effect of the ground, and the reflections produced by surfaces and construction elements that surround these spaces, as is the case of bullrings.

Of the various states of occupation that are contemplated in the regulation, the state of inoccupation is the one used, due to the practical impossibility of carrying out measurements under controlled conditions during an actual bullfight, due to the development of the fight itself and the noise of the public.

The positions of the sources should be placed where the natural sound sources of the bullfighting festivities are generally located, as described in Section 3. The omnidirectional source employed is

located 1.5 m above the ground, “to avoid low-frequency modification of the output power of the source in the frequency range of the measurements”, as indicated in the standard.

The microphone positions, conveniently distributed, should be placed in representative positions where the spectators (rows, boxes, grandstands, etc.) and the participants (narrow passageway between inner and outer barriers and ring) are accommodated, so that they provide information on the possible systematic variations and anticipate the main acoustic influences and disturbances. Nevertheless, to comply with the norm, it should be ensured that the microphones are at least 2 m away from each other, at least 1 m away from reflective surfaces, and away from the positions of the source. The microphone positions should be placed at a height that corresponds to the height of the listeners' ears: 1.2 m above the ground for the localities of the general public, and somewhat higher for those who stand in the passageway.

Bullrings are open buildings that are generally circular and uncovered, where it is not to be expected that widely differing reverberation times will result that would have to be analysed and measured separately, as prescribed by the standard when dealing with enclosures that fail to present an acceptably uniform distribution or that feature communicating volumes. This assumption is based on the fact that buildings are conceived both formally and functionally with a clear objective: that the quality of observation and the consequent enjoyment of the bullfight are similar for all attendees.

However, and as the standard prescribes in its Annex A, “the various measures are not statistical properties of the entire auditorium and will vary systematically from seat to seat”, it is therefore essential to define an adequate number of source and microphone positions. In bullrings, to comply with the norm specifications, a minimum of three source positions should be employed, located in positions representative of the sounds that are heard during the bullfight, as described in Section 3, and with reference to the axes that are defined in Section 5. These axes will also serve as a reference for the positions of the receivers.

Finally, the standard prescribes the information that must be provided together with the measured results. From among such information, that related to the enclosure volume deserves a special mention, for which the standard specifies that “if the room is not completely enclosed, an explanation should be given of how the stated volume is defined”. The volume to be considered in the measurements of bullrings comprises the content by their delimiting surfaces, the fictitious sky surface that covers the bullring defined by its highest edge or ridge, and the fictitious surfaces of apertures defined by the access contour to doors and vomitoria.

### **3 Identification of sound sources in a bullring**

Soundscape, defined by Davies *et al.* [6] as “the totality of sounds within a location, with emphasis on the relationship between perception, understanding and interaction of the individuals or society with the sound environment”, is based on the basic definition created by Schafer [7] in the Word Soundscape Project (WSP). In a bullfight, this soundscape is determined by the environment to which the sounds belong, by their configuration, by the way in which they are produced, and by the way in which they propagate naturally in the environment. Sounds exist that are characteristic of a particular environment, and these determine its sonic uniqueness.

The sounds that are heard in a bullfight, such as music, the audible expressions of the spectators, the bullfighter’s shouts, the actions of the animal, and how these are hybridised with the intercalation of silences, form its soundscape. Therefore, for the purpose of these guidelines, it can be considered that

voice, music, and ambient sound are the main sources of sound, which together recreate the spectacle and allow it to be understood. At this point, it should be borne in mind that a bullfight is mainly a visual spectacle, where sound enriches it in such a way that it can be properly understood.

The sound sources that play a major role in a bullfight are described below (voice, music, and ambient sound) together with several basic concepts thereof, and how their hybridisation constructs the whole, which implies a bullfight solely with sounds.

### 3.1 Voice

During the bullfight, although the silence of its protagonists predominates, they do not remain mute. There are numerous occasions on which, in a similar way to theatrical performances, the dialogue between bullfighters, between bullfighters and their assistants, picadors, and *banderilleros* (who stab the bull with *banderillas*), with the people of the passageway, even with the attending public. There is also an irrational dialogue between bull and bullfighter, when the latter uses certain vocalisations to call the bull in an imperative way and provoke an onslaught, such as the interjections “Hey!”, “Aha!”, and “Toro!”.

The physical characteristics of the voice themselves (duration, tone, timbre, and intensity) transmit values when one speaks, which listeners perceive and interpret as emotions, sensations, or feelings. Psychoacoustics teaches us that listening is not simply a physical or mechanical phenomenon based on the propagation of sound waves, but that various sensory, perceptual, and emotional issues also come into play. The listening experience is determined not only by the physical and physiological point of view but also from the point of view of experience and memory. Any sensory activity involves memory, both by recognition and by remembering, as occurs with listening to sound.

### 3.2 Music

*“The bullfight is a festival with music. Music is part of the bullfighting ritual ... Music, during the bullfight, is like one more dimension of the colourfulness itself, and is inseparable from the festival”.* This sentence from the chapter “Los Toros en la Música” (Bulls in Music), from Volume 7 of the bullfighting encyclopaedia “The Bulls. Technical and historical treatise” [8], introduces a broad topic on bullfighting music. It limits that which is directly related to the celebration of the bullfight to two manifestations: the bugle calls to signal the change in the 3 stages of the bullfight (*los cambios de tercio*) and the interpretations of *pasodoble* in the repertoire of the musical bands that perform in the bullrings.

#### 3.2.1 Bugle calls to indicate a change in the stage of the bullfight

Commanded by the president of the bullring, these changes in the stages of the bullfight are announced to the public through sounds of bugles and timpani, to order the clearance, *despeje*, of the bullring and the start of the *paseo*, the entrance of the bull and to indicate the three stages: that of the spears, *varas*; the second of *banderillas*; and the last stage whereby the bullfighter engages and kills the bull. With a long note, the bullfighters are warned that the bull is to be returned to the bullpen.

The fanfares are usually played by two bugles and a set of two timpani. Bugles are frequently replaced by one or two trumpets, and sometimes timpani are dispensed with or replaced by another type of drumroll. In some bullrings, traditional instruments typical of the region are used, such as shawms and bagpipes.

The musicians in charge of playing these bugle calls are located, as a rule, in the place of the bullring diametrically opposite to the presidency, and each time the president takes out a handkerchief they play the corresponding fanfare, which serves as a notification to everybody, bullfighters and public included.

These short bursts of music owe their origin to the "ordinance" of the Infantry or Cavalry forces that watched over the order in the bullfighting festivals. Currently, there are a great variety of bugle calls, most of which have a common origin, based on four or five prototypes.

### 3.2.2 The music band

In all bullrings, since the beginning of the 19<sup>th</sup> century, the intervention of a music band has been mandatory, responsible for the musical entertainment. These bands are not regulated by any bullfighting regulations and follow, like many other aspects of the spectacle, along the lines of traditional customs. The purpose of the music band is to offer spectators a sample of the unique, genuinely Spanish, and very popular sound of the joyous "*pasodoble*".

The music band is made up of exclusively wind instruments (wood and brass), with the minimal addition of percussion. These bands are usually located in the upper part of the bullring, generally in a box reserved for this purpose, in the area out of direct sunlight. The number of musicians that make up each band is highly variable from one bullring to another, and can even depend on the particular circumstances and occasion.

Interventions from the music band take place at the following moments of the bullfight: at the beginning, during the "*paseo*" or parade of the bullfighters and their assistants, until the entrance of the first bull is commanded; in the interims, during the removal of each dead bull and/or the bullfighter's applauded return to the ring until the next bull enters the ring, and also when a defective bull is returned to the corrals; and, finally, at the request of the public, and, when the director of the band considers it opportune to liven up the third stage of the bullfight in which the bullfighter engages the bull. In certain bullrings it is customary for the band to start playing when the matador takes the *banderillas*.

The musical genre performed in bullfights is the "*bullfighter pasodoble*". The *pasodoble* is a musical composition, written in 2/4 time signature subdivided into quavers and tempo *allegro moderato*, which has a clear origin in military marching (late 18<sup>th</sup> century and early 19<sup>th</sup> century), and its name is derived from an agile infantry step. In the opinion of the musicologist Manuel Delgado-Iribarren [8, 9], the *pasodoble* gained popularity since its primitive patriotic character was derived from playful variants. "*And thus, the pasodoble would end up becoming popular, authentic, romping, street dance music. And, of course, the pasodoble would end up becoming bullfighting music*".

### 3.3 Ambient sound

Ambient sound is of vital importance since it contextualises and locates the listener in the space and even in the time in which events occur. Ambient sound encompasses two environments:

- The public, including sounds that have highly visible and specific sources and are less unnoticed, such as the shouts of *olé!* and applause.
- The sound of the surroundings, including sounds that may have no clear source and are not as audible, such as the sound of the city, breeze, rain, and some weather conditions that emit unnoticed sounds.

Since a bullfight is an act involving great influx of people, the actions of the protagonists can be masked by sounds that overshadow them, mainly from the public and music. For this reason, it is useful to focus on the essentials of the spectacle, in an effort to utilise the cleanest sounds and to grant prominence to the bull, bullfighters, and music. The expressions of the public that are part of the soundscape of the bullfight, however, should not be left aside.

Spectators spontaneously add sonority to bullfights by providing applause and ovations or, when warranted, with whistles and shouts of disapproval that occasionally degenerate into a "division of opinions" or a strong "anger" at the bullfighters or at the president. When there is bullfighting brilliance, the public rhythmically accompanies the passes of the bullfighter's cape with an elongated "olé", and if the pass is very fast, then the syncopated version "óle" is imposed. The so-called "tango clapping" is used to reject a bull, while chanting "another, another, ..." or "out, out, ...". This rhythmic clapping also sounds when the audience becomes bored. There is also no shortage of surprising solo speeches made by some spectators.

### **3.4 Hybridisation of sounds**

In a bullfight, all the aforementioned sources of sounds are found, and since this is a multi-source environment, they should not be taken separately. In the bullfight, all sounds are essential; without one of them the soundscape could not be fully understood, which means that they are naturally hybridised, even though each has its function and plays a specific role.

## **4 Identification of receiving positions in a bullring**

For the purposes of these guidelines, the part of the bullring intended for the public is considered a listening area or audience. For greater precision, the barrier or fence that surrounds and separates the circle of land where bulls run and fight delimits the bullring into two acoustic zones: the ring, also called the arena, where two white circular lines delimit the three concentric areas; and the listening area, which includes the passageway, front rows, stands, and boxes.

The fence or barrier immediately next to the ring itself, which serves as a defence for the bullfighter over which he/she can jump when pursued by the bull, is, as a general rule, 1.6 m tall, and is 1.3 m tall for that of the passageway, since the level of the floor of the latter barrier is higher than that of the ring. The circular passageway where the bullfighters, their assistants, and employees of the bullring take refuge, and which runs between the main barrier and the fence delimiting the first-row seats, is usually 1.6 m wide. In the fence, on the side of the ring, there are a convenient number of rectangular "burladeros", which are short fences of the same height and construction of the barrier but placed parallel to it within the ring, with a separation of only approximately 35 cm, so that the bullfighter can take refuge behind them by entering from the side and the bull cannot enter. Moreover, within the passageway there are "burladeros" to shelter employees and helpers who, due to their jobs, must remain between the barriers. All these people follow the spectacle with special attention through sight and hearing, which is why the passageway is considered a listening area of prime importance.

It is common practice for each spectator who attends a bullfight to do so while occupying a seat or specific location from among those arranged in the various designated areas. These localities are grouped into areas with different names [8]. The "front row area" of seating is the circular part of the building, built of stonework or brick, that surrounds the arena behind the barrier in a stepped graduated way, as in Roman circuses and amphitheatres. This constitutes the widest area for spectators in

bullrings. The first row of the tier is called the barrier, and the counter barrier is the name of the second row. A circular access aisle is usually between these two lower rows and the large number of rows that then continue upwards, of which the first row is called the front row, with the other rows numbered from bottom to top.

All the stands that make up the tier are divided into various sectors, also numbered, and separated from each other. The separation and price of each of these sectors varies depending on whether it is in the shade or direct sunlight, or close to the centre of the shaded area. Each sector has access through an open door in the stands in the form of a short tunnel or cannon, called a vomitorium.

Above these sectors, one or two floors are erected in the form of a continuous balcony with a railing and the grandstand that its width allows. In the shaded part of the lower tier, and in some bullrings of the upper tier, there are usually the “private boxes”: compartments of seats that have the same characteristics as those in theatres. The central box is usually ornamented, especially in bullrings where the presence of royalty and/or military leaders has been frequent.

## 5 Reference axes and other practical considerations

In this section, practical considerations are made for the better execution of acoustic measurements in a bullring, such as the axes and coordinates in order to reference sources and receivers, and the environmental conditions to be controlled in a space influenced by the sunlight in certain areas.

Bullrings are organised according to the logic of their use and construction based on axes that determine the layout and composition of their elements [10]. There are therefore three differentiated axes (Figure 1):

1. Presidency-bullpens. Formerly, the main entrance (exterior) was made to coincide with the balcony (interior), usually located in the shade, and, on the opposite side of the *plaza*, the bullpens and corrals are located.
2. Sun-shade. The orientation of this axis of sun and shade, which varies according to the latitude of the building and is relative to the time of day of the spectacle, is especially interesting in the analysis of bullrings, since it explains the location of the defining elements on the floor plan of the building.
3. Urban area-main entrance of the bullring. With the passage of time, this axis has gained greater interest, thereby making the main gate of the bullring coincide with the main routes of urban growth.

This system of axes is found in many bullrings, although it is not fulfilled perfectly in all. In certain cases, the urban axis, the interior axis of the presidency-bullpen, and the solar axis all coincide.

From the acoustic point of view, for the correct location of the positions of sound sources and receivers, and especially for better comparability of acoustic measurements between the different types of bullrings, the sun-shade axis, or simply solar axis, is the most pertinent for several reasons: the disposition of the public for the different sectors of shade and sun; the production of the bullfight itself, which is concentrated most of the time in the shaded zone; and the influence on the sound propagation by factors such as the geometric divergence from the main sources of voice and music that are located in the shaded area, and the refraction produced by vertical gradients of the ground temperature.

In order to graphically show the arrangement of these axes, and also as a tribute to a building that today would stand as a monument had it not been demolished in 1930, the Monumental Bullring of Seville is presented. This bullring, of major significance and inaugurated in 1918, was prompted by Joselito El Gallo, who was the intellectual promoter of other monumental bullrings such as those of Madrid, Pamplona, and Barcelona, as can be observed in Figures 1 and 2 [11].

Starting from the solar axis, a rectangular coordinate system is proposed for the positioning of sources and receivers, with the origin of coordinates in the centre of the ring and with semi-axis  $X^+$  as the semi-solar axis in the South direction, and  $Z^+$  axis as the vertical axis, thereby using the vector position  $(x, y, z)$ . Alternatively, a cylindrical coordinate system can be used, with the same previous origin and the semi-axis  $X^+$  as the polar axis, using the radius ( $r$ ), azimuth ( $\phi$ ), and elevation ( $z$ ). To facilitate positioning, the 12-hour clockwise nomenclature is also proposed.

In order to complete this section, the importance of measuring with a thermo-hygro-anemometer must be borne in mind, in addition to that of the temperature and relative humidity of the air as prescribed by the ISO 3382-1 standard, with an accuracy  $\pm 1^\circ\text{C}$  and  $\pm 5\%$ , respectively. Moreover, the speed of the air should be included as another atmospheric variable that is decisive in these outdoor spaces with areas of sun and shade.

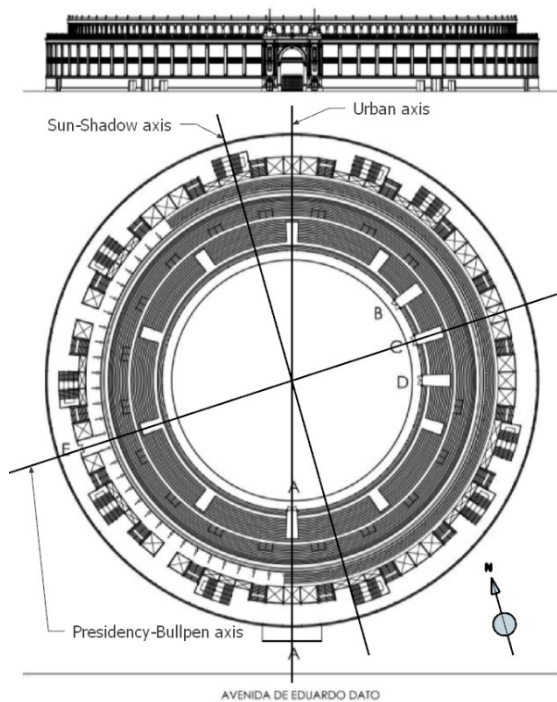


Figure 1 – Main elevation and floor plan of the stands and boxes of the Monumental Bullring of Seville: (A) Main Entrance, (B) Gate of Bullfighters and their assistants, (C) Bullpens, (D) Gate for the removal of dead bulls, (E) Royal Box. Source: Carrasco *et al.* [11].

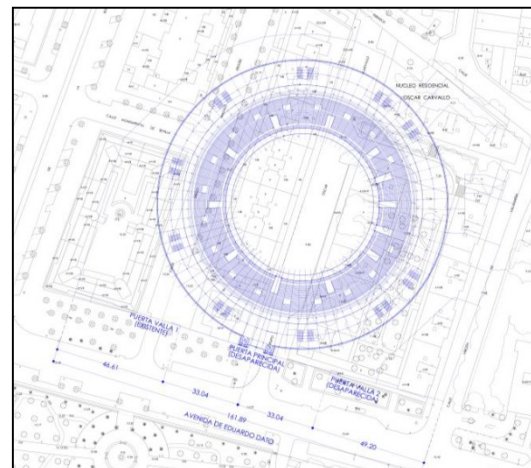


Figure 2 – Floor plan of the Monumental Bullring of Seville, super-imposed on the current plot of the area. The Main Entrance of the bullring would be close to number 37 of Eduardo Dato avenue. Source: Carrasco *et al.* [11].



## 6 Proposal for the location of sound sources for acoustic measurements

Having identified the main sound sources that exist in the bullfights and how they are hybridised in a multi-source environment, the a priori detailed analysis of the sound field in bullrings seems complex. However, to successfully undertake the measurements to be carried out for acoustic characterisation and comparability with different equipment and bullrings, the following locations of sound sources are proposed:

- 1<sup>st</sup> The first position (S1) in the centre of the ring is considered as a reference, due to its central symmetry and equidistance to all points of the bullring; it is also a frequent position of the bull.
- 2<sup>nd</sup> The second position (S2) is chosen in the second of the three delimited concentric areas of the arena in the shaded area, where most of the bullfighting takes place. Specifically, it should be located at the intersection of the 7 m line, which indicates the terrain where the picadors should be located, with one of the radii between those numbered 6 and 12, depending on their proximity to the "*burladero*" of the matadors.
- 3<sup>rd</sup> The third position (S3) should be located in a central place in the box reserved for the music band, which is usually located in the upper part of the bullring in the shaded section.
- 4<sup>th</sup> The fourth position (S4) should be placed in the place where the buglers and timpani musicians are seated, who, as a general rule, are located diametrically opposite the presidency.
- 5<sup>th</sup> The fifth (S5) and following positions (S6, S7, ...), are located in the stands in order to characterise the ambient sound of the audience. Specifically, it should be located at the intersection of a middle row of the front row area of seating with one of the 12 numbered radii. No upper limit is specified for the number of these audience ambient sound positions, and depends on circumstances and availability.

However, there are bullrings that, due to either size or custom, may not encounter all the sound sources indicated, which would therefore entail precise changes to be made, while always maintaining a minimum of three positions of sources, to comply with the specifications in the ISO 3382-1 standard.

Continuing with the example of the Monumental Bullring in Seville, Figure 3(a) graphically shows the proposed location of the sound sources.

Recent pieces of research in other types of enclosures have analysed the influence of the location of sound sources on the acoustic parameters measured, and have made use of the concept of Just Noticeable Difference (JND) to identify the perceptible differences. They have concluded that, although the position of the source bears little influence on the spatial averaging of the reverberation time, it does affect the remaining acoustic parameters, especially the value of  $G$ , the sound strength, which decreases with the source-receiver distance, and hence the significance of standardising the source and receiver positions, such as that observed below.

## 7 Proposal for the location of receiver positions for acoustic measurements

The arrangement of the public around the passageway, lower sections, stands, and boxes, and the central symmetrical configuration of most of the bullrings, facilitates the location of the receiving positions. However, it must be taken into account that certain bullrings present irregularities in the outline of the ring itself: some are octagonal, and others even quadrilateral, which would entail making adjustments in the positioning. There are also bullrings that incorporate elements and areas that break

the uniformity of their architecture, such as special boxes and sectors with uneven seating, that force corrections to be made and alternatives to be sought to the proposal presented below.

The number and location of receiver positions is a function of the bullring capacity and the expected spatial variability of the results. Bullrings are venues with a large capacity; most can contain in excess of 2000 occupants, as indicated in Table 2 of Annex A of the ISO 3382-1 standard, and therefore a number greater than the 10 microphone positions specified in the standard would be necessary. The final choice regarding the number and location is a result of compromise between the need to have an acceptable level of precision in the variation of the results in terms of the JND of the acoustic parameters of interest and the time available to carry out the measurements. A good practice, once the measurements are carried out, would be to analyse the spectral average values of each of the acoustic parameters and their spatial dispersions in terms of the respective differential thresholds (JND).

The receiver positions should be selected taking the sun-shade axis as a reference, between the listening areas in which listeners are usually found, more specifically at the intersections of the passageway barrier or the rows of the lower sections, stands, and boxes with any of the 12 reference radii. They are distributed by taking advantage of the central symmetry and by avoiding those areas that lack direct sound, which in turn depends on the positions of the sources, especially in stands and boxes when the sources are displaced from the centre of the ring, which determine the source-receiver configurations as can be observed in the following section.

As an example, Figure 3(b) shows the location of 12 receiver positions in the former Monumental Bullring in Seville.

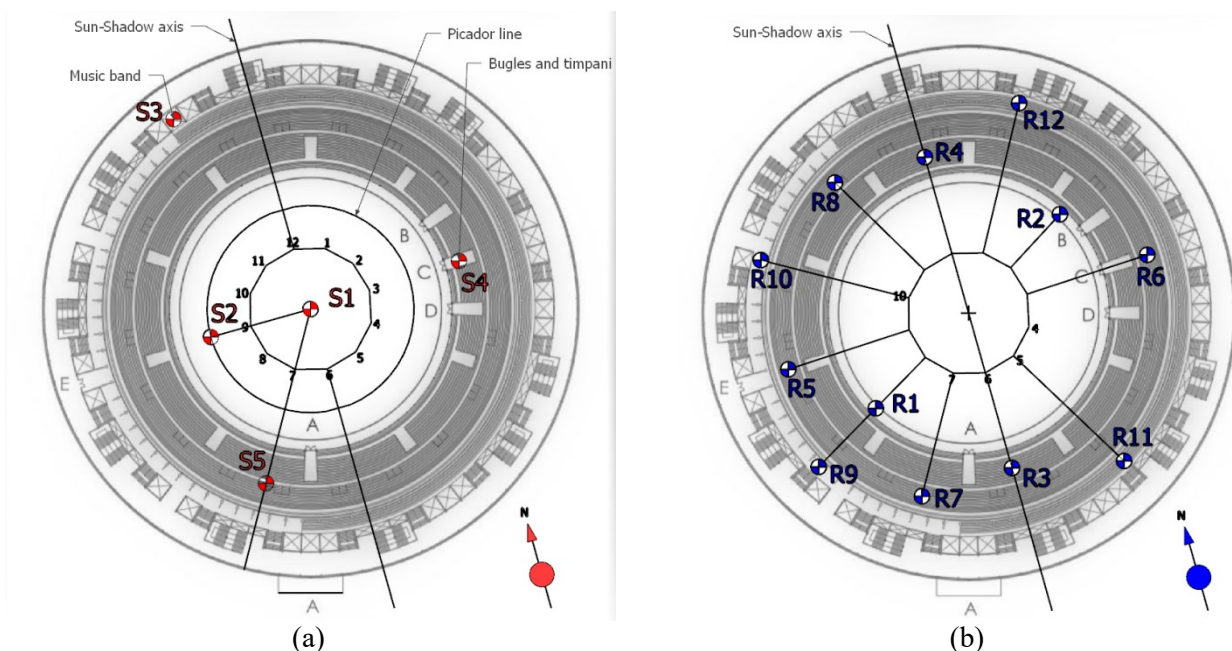


Figure 3 – Ground plan of stands and boxes of the Monumental Bullring of Seville. Proposal for the location of sound sources (a) and receivers (b).

The following criteria must be met in order to meet the requirements of the ISO 3382-1 standard: the microphone positions should be arranged away from each other by at least 2 m; reflective surfaces at a distance of less than 1m should be avoided; and receivers should be moved away from source positions, and placed at a height of 1.2 m above the ground to represent the seated public.

Measurements are repeated with the source rotated in at least three directions. The resulting parameters related to the different directions of the source are arithmetically averaged. For listeners who are standing in the passageway, the height should be 1.6 m, as an exception to the rule.

## 8 Source-receiver combinations

The configuration of the bullrings as open buildings that are generally circular and uncovered does not present any spatial complexity as occurs in other types of venues. A high number of source-receiver combinations is therefore not necessary for their acoustic characterisation, since they are designed both formally and functionally with a clear objective: the quality of observation and the consequent enjoyment of the bullfight are similar for all attendees. However, the multi-source character in which the bullfight takes place does require a good number of combinations for the correct definition of its sound field, and therefore for sufficient acoustic information to form a good understanding of its sound.

Special attention should be paid when establishing the various source-receiver combinations in terms of the different zoning of sun and shade, and the existence of areas that lack direct sound depending on the position of the source, which often happens in certain stands and boxes when the sources are out of sight of the spectator.

The acoustic characteristics of a bullring depend to a great extent on the combination of source-receiver positions taken into account. A complete description of its acoustic behaviour implies the use of the largest possible set of source-receiver combinations. However, time constraints often prevent such a degree of detail since moving the microphones with their cables to many points is a time-consuming activity.

A “minimum” measurement set-up should include at least three source locations (S1 and two others), depending on the primary purpose of the measurement, and the minimum number of receiver positions. However, in order to make better use of the measurement session, it is recommended that apart from the S1 source position, which should always be used in combination with all receivers, when more than 2 source positions are used, a smaller number of receivers can be employed in accordance with the scheme shown in Table 1.

Table 1 – Recommended source-receiver combinations.

Source	Receivers in passageway and lower rows	Receivers in stands and boxes
S1, centre of the ring	All	All
S2, 7 m line of the picadors	All	75%
S3, music band	75%	50%
S4, bugles and timpani	50%	50%
S5..., public	50%	50%

## 9 Conclusions

The objective of these guidelines for acoustic measurements in bullrings is the acoustic characterisation of this type of outdoor space based on the reverberation time and on the remaining

acoustic parameters as specified in the guidelines of the ISO 3382-1 standard, and the enhanced comparability of acoustic measurements and simulations for the various types of bullrings.

In these guidelines, those prescriptions and aspects of the ISO 3382-1 standard that have certain influence on acoustic measurements in bullrings are first analysed. The sound sources and the characteristic audience areas of bullfighting festivities are described and identified, and several practical considerations are made for a better execution of acoustic measurement in a bullring, such as the axes and coordinates to provide references for the sources and receivers, and the environmental conditions to be controlled in a space influenced by sunlight in certain areas. The guidelines propose several locations for the sound sources and receivers according to the configurations encountered in the various bullrings, and the since demolished Monumental Bullring of Seville is presented as an example of application. Finally, the most suitable combinations of sources and receivers are suggested to address the casuistry that approximates the acoustic environment in which the bullfight takes place.

The proposed guidelines, largely based on the authors' experience in measuring the acoustic characteristics of a large number of venues, take practical, architectural, and bullfighting aspects into account. Further suggestions for the improvement of the measurement method are welcomed.

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