Acoustic characterisation of the noise emitted by a padel court

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In recent years, padel has rapidly become one of the most widespread sports practices, thanks to its similarities with tennis and squash, its dynamic nature, and the small size of the playing field. This last characteristic has facilitated the proliferation of courts, which can be built both indoors and outdoors. In the latter case, the noise generated during play can freely propagate to nearby receptors and potentially cause annoyance. Therefore, a thorough study of the acoustic impact of these facilities is necessary, especially when they are built near residential areas. An accurate prediction of acoustic impact requires precise emission data as input. At present, scientific literature regarding sound power data associated with noise from padel courts is rather scarce. This study provides sound power data based on experimental measurements. Furthermore, using ambisonics techniques, the research aims to highlight possible noise mitigation measures applicable to the sources.
Keywords: padel game, acoustic emission, sound power spectrum, directivity, Ambisonics

Caratterizzazione Acustica del rumore emesso da un campo da padel
Negli ultimi anni, il gioco del padel si è velocemente introdotto fra le pratiche sportive più diffuse grazie alla sua affinità con il tennis e lo squash, la sua dinamicità e le dimensioni ridotte del campo. Questa ultima caratteristica ha favorito il proliferare di campi da gioco, che possono essere realizzati sia al chiuso che all'aperto. In questo ultimo caso, il rumore emesso durante il gioco può propagarsi liberamente fino ai ricettori limitrofi ed essere potenzialmente causa di disturbo. Si rende quindi necessario un accurato studio dell'impatto acustico di queste strutture nel caso in cui vengano realizzate in prossimità di zone abitate. Una accurata previsione di impatto acustico richiede in input dei dati di emissione accurati. In questo momento la letteratura scientifica riguardante i dati di potenza sonora da associare al rumore emesso da campi da padel è piuttosto scarsa. Il presente lavoro fornisce dati di potenza sonora basati su misurazioni sperimentali. Inoltre, attraverso l'uso della tecnica ambisonics, si è voluto evidenziare quali possono essere eventuali opere di mitigazione acustica applicabili alle sorgenti.
Parole chiave: gioco del padel, emissioni acustiche, spettro di potenza sonora, direttività, Ambisonics

1 | Introduction

Padel is a sport characterized by a high degree of dynamism and engagement. It originated in Mexico in the 1960s and began to gain recognition in Italy in 1991, thanks to Martin Calvelo. After learning about the FIGP (Italian Padel Federation) event, Calvelo organized the first friendly match in Bologna involving Spain and Argentina, marking the sport's initial introduction to the Italian public.

Although it was initially considered a niche sport, padel has experienced an explosion in popularity over the past five years, showing extraordinary growth both in terms of players and dedicated facilities. The Italian Tennis Federation (FIT) has played a crucial role in this process by officially integrating padel into its activities starting in 2014 – a key step that provided greater visibility to the sport and facilitated its development. While sharing some similarities with tennis, this sport also features distinctive characteristics that make it unique.

Padel rules are relatively simple, and the game is played on a smaller court compared to tennis, with the following main differences and specific features:

- Playing Field: The padel court is rectangular, measuring 20 meters in length and 10 meters in width, divided into two halves by a central net. It is surrounded by walls, which are an integral part of the game. Unlike tennis, which is played on an open court, padel is played within an enclosed area with glass or solid walls positioned behind and along the sides of the court.
- Racket: The padel racket is solid, without strings, and generally smaller and lighter than a tennis racket. It features holes on the surface to reduce weight and enhance control.
- Ball: The ball is similar to a tennis ball but tends to be slightly less pressurized, which reduces its speed compared to a tennis ball.
- Serve: In padel, the serve is performed underhand, whereas in tennis it is typically overhead.

- Shots: Padel is less focused on powerful baseline shots and more on tactical and fast-paced play, often involving the use of the walls.
- Number of Players: Although it can be played in singles, padel is most commonly played in doubles.

In summary, although it shares a common foundation with tennis, padel is a sport with its own rules and dynamics, where speed and strategy blend together, making it accessible and enjoyable for players of all ages and skill levels.

Beyond the technical and strategic aspects of the game, the acoustics of padel courts have attracted the interest of some studies and research, although this is not yet a widely explored field compared to others such as architectural design or the acoustics of football stadiums and indoor arenas.

However, with the growing popularity of padel, some experts and professionals have begun to focus on the acoustic impact of these spaces, considering various aspects such as "on-court" noise (running, hitting, ball rebounds against the enclosing structures), as well as the inevitable sounds produced by players during matches and mechanical noise, especially in the case of indoor courts.

The rapid expansion of padel courts in urban and suburban areas has raised concerns about their acoustic impact on nearby residential zones. Studies commissioned by national federations and acoustic consultants, such as those by the French Tennis Federation [1] and the Netherlands padel federation [2], consultants like Dale and Clarke in the UK [3,4] or National Agencies for the environmental protection [5] have shown that padel generates significantly more frequent and louder impact sounds than traditional tennis, primarily due to ball strikes on glass walls and the open structure of the courts. Technical analyses highlight the importance of sound emergence, court orientation, and ambient noise context in assessing disturbance levels. Recommendations include acoustic barriers, semi-covered structures, and strategic placement to mitigate noise, as emphasized in white papers and environmental reports. These findings underscore the need for integrated acoustic planning in padel facility development.

The article is structured as follows: Section 2 describes the main aspects related to noise generation; Section 3 deals with the description of the case study and the measurement techniques adopted in the experimental phase; Section 4 collects the main results; Section 5 discusses the results and finally Section 6 draws the conclusions.

2 | Main sources of the padel game

The noise generated by padel gameplay is a technically interesting aspect, involving several factors related to the dynamics of the game, the design and material of the racket, the structure of the ball, and the type of court surface.

We will now examine each of these aspects in detail.

Regarding the racket, as illustrated in Fig. 1, it can have different shapes: Teardrop-shaped: the hitting surface is circular with a slightly straighter lower part, suitable even for beginners. Diamond-shaped: the upper part of the hitting surface is flattened, allowing players to impart greater power to the ball. Round-shaped: the centre of gravity is shifted toward the lower part of the racket, bringing the impact point closer to the handle. This reduces the lever effect, consequently lowering ball speed, but at the same time allows for greater control.

Fig. 1 – Different shapes of the padel racket
Diverse forme della racchetta da padel

A common feature of all padel rackets is the presence of holes on their surface, varying in size. These holes significantly affect the noise produced when the ball strikes the racket, as they contribute to energy dissipation. When the ball hits the racket, part of its kinetic energy is transferred to the racket itself, and the perforations absorb and then disperse this energy. Moreover, the material of the racket also influences the hardness and tonal quality of the sound. The most used materials are fiberglass and carbon fibre. The main difference is that fiberglass allows for greater ball output due to its lower rigidity and higher flexibility, resulting in a less sharp sound. Carbon fibre, on the other hand, tends to produce a drier noise because it is lightweight, rigid, and highly resistant. The internal part of the racket is made of rubber which plays a fundamental role in reducing noise by absorbing vibrations.

From an acoustic perspective, it is also important to consider the speed at which the ball hits the racket (a faster, more powerful impact tends to produce a sharper sound) and the angle at which the ball approaches it. A more pressurized ball tends to produce a louder and sharper sound, as it resists impact more and compresses less before releasing energy. Conversely, a less pressurized ball tends to generate a lower-frequency, less pronounced sound, as it is less reactive and deforms more upon impact, absorbing a greater portion of the energy.

The padel court (Fig. 2) is generally rectangular, and according to the official rules, its standard dimensions are 20 meters in length and 10 meters in width. The rectangle is divided in half by a net (10 meters long and 0.88 meters high at the centre), with service lines placed 6.95 meters from the net. The area between the net and the service lines is further divided in half by a perpendicular line, called the central service line, which splits this area into two equal zones. All lines must be 5 centimetres wide. The padel court is enclosed by four walls (with a minimum height of 3 meters and a maximum of 4 meters), which can be divided into back walls made of glass and side walls, which also include metal mesh structures. This metal meshes serve both as support for the glass walls and as access gates or doors to the court.

Fig. 2 – Example of a padel court
Esempio di un campo da padel

The glass used for the walls plays a fundamental role in the acoustic behaviour of padel courts since the ball striking the glass generates noise. This noise depends on the type of glass used in the construction of the court. The most commonly used material is tempered glass (UNI EN 12150-1), which is highly impact-resistant and safer, as it does not shatter and the fragments remain attached to the frame. However, this type of glass tends to produce a louder and sharper sound when hit by the ball, as its rigidity causes the sound to be released more directly. Another type of glass that can be used is laminated glass, which, due to its intermediate layer, better dampens sound by absorbing impacts and reducing noise. It is also interesting to note that the thickness of the glass affects its acoustic properties: thicker glass tends to produce a louder sound because its greater mass retains more energy, causing the ball impact to generate stronger vibrations that propagate through the glass, resulting in a sharper and more intense sound. Thinner glass, having less mass, tends to vibrate less and may reduce noise intensity, although it might be less resistant and less sound insulating.

The flooring of a padel court is designed to have a certain capacity for rebound, and it can be made from various materials, each affecting the acoustics of the court differently. The most common solution is synthetic grass, composed of synthetic fibres combined with sand to mimic the appearance of natural grass. This surface tends to have good sound absorption properties, mainly due to its porosity. Synthetic grass allows for different installation types, including monofilament, texturized, and fibrillated options. When the ball bounces on synthetic grass, the sound tends to be dampened, also thanks to the sand, which helps reduce vibrations and gives the ball a softer bounce. Although synthetic grass is quite durable, it requires regular maintenance to prevent wear, and this aspect limits its use. Another type of flooring is resin (cement), which, being a much more rigid surface, does not absorb vibrations effectively. As a result, the ball impact produces a louder sound. This material is highly durable and weather-resistant, with relatively simple maintenance, but it offers less comfort compared to other surfaces. A third common material is rubber (or other elastic materials), especially used in indoor courts. These materials can come in sheets or rolls and are designed to provide an elastic surface that cushions impacts. Rubber has a high damping capacity, and it is rather soft. When the ball bounces on these surfaces, the noise tends to be muffled. It is a resilient material and offers a very comfortable surface for players, reducing the risk of injury.

As concerns the noise type during playing, environmental and anthropogenic factors also play a crucial role in determining the intensity, quality, and propagation of sound, as well as its impact on the surrounding environment. The main source of anthropogenic noise is the number of people playing simultaneously, which increases overall noise through cheering, frustration, laughter, movement sounds, and footfalls. This aspect is particularly pronounced during padel tournaments or organized sporting events, where larger crowds and spectators are present, often accompanied by amplification systems such as loudspeakers.

In Italy, studies on this topic are still limited. One example is the research conducted by ARPA (Regional Environmental Protection Agency), which investigated the case of padel courts in Ascoli Piceno that were shut down due to public complaints about excessive noise [5]. For this reason, we chose to explore this issue further by studying the padel courts at the University of Brescia, conducting experimental tests directly on-site.

3 | Materials and Methods

3.1 | Description of the case study

The area under investigation is in Brescia, Via Branze 39 and is adjacent to the University of Brescia (Fig. 3). This site was selected as a significant example for evaluating the acoustic impact produced by sports activity in a real-world context.

Fig. 3 – Area considered in the study
Area considerata nello studio

The court is an outdoor facility (Fig. 4), with a rectangular area measuring 20 x 10 meters. The back walls and part of the side walls are made of 12 mm thick tempered glass, while the remaining side sections are enclosed by galvanised steel fencing. The glass side walls are 3 m high. The court is covered with a high-quality rubber surface.

Fig. 4 – Picture of the padel court during the measurement session
Fotografia del campo da padel durante le misurazioni sperimentali

3.2 | Instrumentation and measurement techniques

Six microphones (model: BSWA MPA 416) were positioned on tripods at a height of 1.6 m at various distances from the padel court. The positions of the microphones around the court are shown in Fig. 5.

The microphones were connected to an OROS OR 36 analyser to record sound levels simultaneously at the multiple representative points within the area of interest. The recorded data were later post processed using the OROS NVGate software to obtain the 1/3rd octave spectra in the frequency range 20Hz-10 kHz. The players (students who volunteered to assist with the measurements) were asked to engage in the sporting activity as they normally would, as if our presence had no influence on their gameplay, to obtain realistic and representative measurements of typical match conditions.

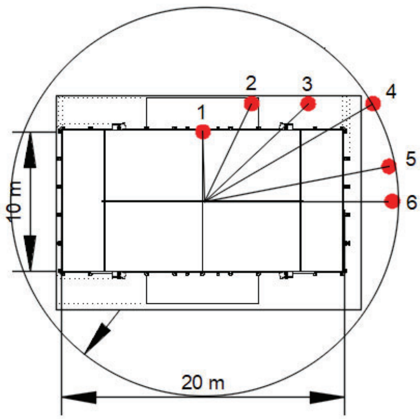

Fig. 5 – Plan view of the court. The red dots represent the microphone positions and the outer circle the distance used to normalize the sound pressure levels
Pianta del campo. I punti rossi rappresentano le posizioni dei microfoni e il cerchio esterno la distanza usata per normalizzare i livelli di pressione sonora

Once the microphones were activated, the sound emissions were recorded for 15 minutes for each one of the following playing conditions. During the measurements, the players were asked to play:

- Without celebrating the scores, so distinct acoustic data focused solely on the sounds produced by racket-ball-wall/nets impacts were recorded.
- Playing normally, including typical moments of celebration and vocal expressions during different phases of the match.

The procedure used to determine the sound power level and the directivity index is the following. First, it is necessary to compute the average sound pressure level generated by the source. Since one of the results to achieve is the directivity index, under the assumptions that the source has a double symmetry in the emissions and is equivalent to a point source that can be placed at the centre of the court, it is convenient to project the measured sound pressure levels at a common distance. The chosen distance is 14 m, since receivers 4, 5 and 6 are placed very close to such distance. Such projection can be made using the following equation:

$$L_{p14m} = L_{pi} - 20\log\frac{14}{d_i} \quad (1)$$

Where L_{pi} is the equivalent sound pressure level measured at the distance d_i for a time span sufficient to characterise the noise emitted during the gameplay. Assuming that a scheme similar to the one proposed by the ISO 3744 standard [6] can be applied, the sound power level is equal to:

$$L_W = \bar{L}_{14m} - K_1 - K_2 + 10\log S \quad (2)$$

Being $\bar{L}_{14m}$ the space average of the sound pressure level evaluated at a distance of 14 m (representing also the sound intensity at the same distance, being negligible the difference between the two quantities), K_1 and K_2 the correction coefficients used to consider the effect of the reflections and of the background noise. In the case at hand such coefficients were considered negligible since the measurements were made outdoors and the background noise was at least 15 dB lower than the sound pressure level measured in each position for every frequency band of interest. S is the surface of the half sphere, with a radius 14 m, enveloping the source.

Finally, the Directivity Index (DI) can be determined as:

$$DI(\theta) = 10\log\frac{I_\theta}{I_0} \quad (3)$$

Where I_θ is the sound intensity measured at a certain distance (14 m in our case) and at a certain angle θ for the actual source, while I_0 is the sound intensity caused, at the same distance, by an omnidirectional sound source having the same sound power as the source at hand. The sound power level, as well as DI, can be computed for each one of the 1/3rd octave frequency band of interest and will be presented in the results section.

During the entire measurement session, an Insta 360 X2 camera and a ZOOM H3 ambisonic microphone were placed inside the playground to get more information about the noise produced by the impact of the ball on the racket and the influence of the reflections. These data were further post processed using a script based on the work of Martellotta [7].

The noise measured by the ambisonics system can be projected as an intensity vector on the picture taken with the 360-camera using the following equations:

$$\begin{cases} I_x = \dfrac{W \cdot u_x}{\rho \cdot c} \\ I_y = \dfrac{W \cdot u_y}{\rho \cdot c} \\ I_z = \dfrac{W \cdot u_z}{\rho \cdot c} \end{cases} \quad (4)$$

Where the W component represents the omnidirectional (pressure) signal (essentially the zero-order component of the sound field); u_x, u_y and u_z represent the first order particle velocity components in the three axes of the microphone. Basically:

- W: is the omnidirectional (non-directional) component, captures the overall sound pressure.
- x: is the front-back directional component (figure-eight pattern along the front-back axis).
- y: is the left-right directional component.
- z: is the up-down directional component.

Some pictures featuring the sound intensity field will be shown in the results and discussion section.

4 | Results

The following sound power level values and spectra, as well as the directivity index pattern, refer to a doubles match involving four male amateur players. Of course, higher-level players can produce louder sound emissions. As an example, the Dutch guidelines recommend to use power levels of 91 dB(A) for acoustic impact predictions. According to the playing conditions adopted for the measurements, the spectra of the A-weighted sound power level can be reported for the evaluated conditions: without celebrating the scores and normal play (Fig. 6) and including typical moments of celebration and vocal expressions (Fig. 7).

Since four of the six microphones used for the measurements were placed beyond the glass screens, the sound power level generated inside the court was evaluated considering only the pressure levels measured by the two microphones not affected by the screening effect of the glass walls (Mic1 and Mic 2). The overall sound power levels derived in the two cases are:

- 89.2 dB(A) *re* 1 pW in the case without screams;
- 91.1 dB(A) *re* 1 pW in the case with screams.

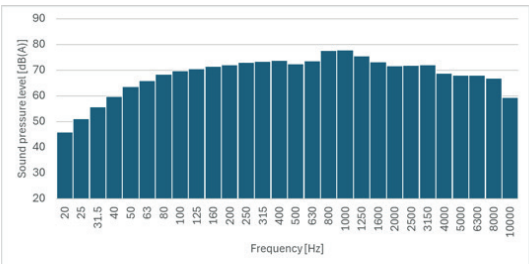

Fig. 6 – A-weighted sound power spectrum when playing without screaming
Spettro del livello di potenza sonora pesato A senza urla

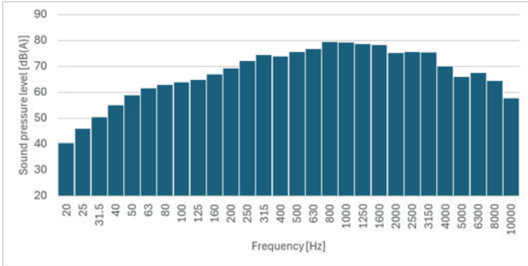

Fig. 7 – A-weighted sound power spectrum when playing with screaming
Spettro del livello di potenza sonora pesato A con urla

It can be deduced that the difference between the two cases is around 2 dB and that the contribution of the screams is higher than the one deriving only from the impact of the ball on the rackets and the structures. Still the influence of the screams strongly depends on the players and then the measured sound power level in such condition must be considered only as an example.

Fig. 8 shows the directivity patterns obtained using the sound pressure level measured by the 6 microphones in the frequency bands from 125 Hz to 5 kHz.

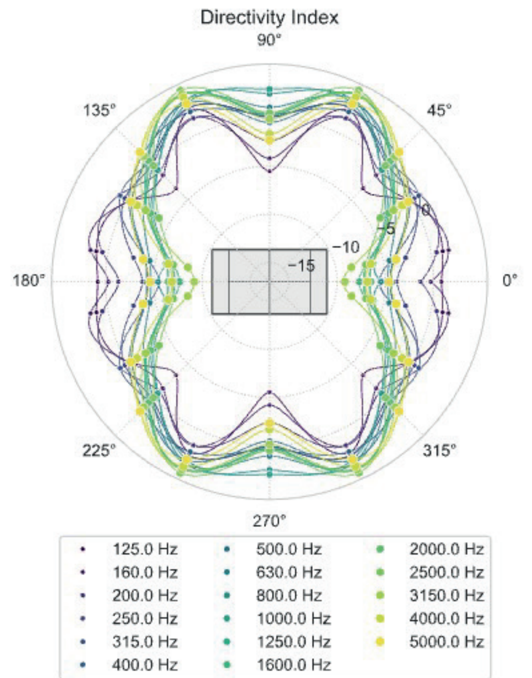

Fig. 8 – Directivity Index plot with screams
Grafico della direttività con urla

As for the ambisonics measurements, an experimental study was conducted with the aim of analysing the acoustic behaviour of a padel court during real gameplay situations. The focus was set on the impact between the ball and the racket — the most typical and recurring impulsive event of this sport — and on the resulting sound propagation within the enclosed environment of the court. The collected data were analysed using a dedicated software capable of combining the audio signals ~~spectrogram~~ with a directional sound mapping overlaid on the spherical image of the scene. The following images represent two distinct moments of the acoustic phenomenon under examination. The first corresponds to the exact moment of the impact (red area in Fig. 9), the second to the sound reflections that occur immediately afterward (green area in Fig. 9).

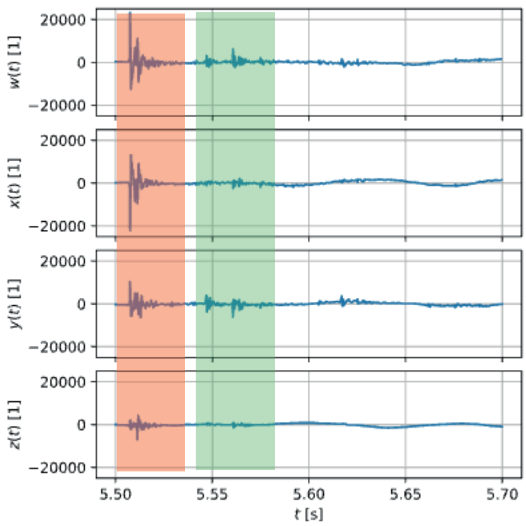

Fig. 9 – Time series of the global, -x, -y and -z channels of the ambisonics microphone
Registrazione dei canali globale, -x, -y e -z del microfono ambisonic

The time series show how the acoustic energy of the direct sound is concentrated in a very short time interval (starting around 5.5 seconds and with a time span of 30 milliseconds).

In the first 360° image (Fig. 10), it is possible to observe the environment at the moment of impact between the racket and the ball. This event naturally generates a broadband, dry sound. The 360° panoramic view of the padel court allows for visual localization of the point of impact, thanks to the player's position and the tension of the action. At this stage, the acoustic map does not yet show significant coloration around the court, as the sound energy has just been emitted by the impact with the racket and has not yet fully interacted with the surrounding environment.

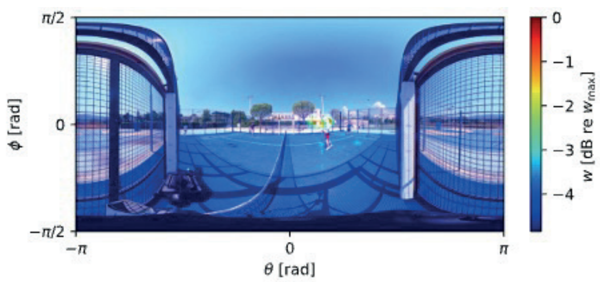

Fig. 10 – Immersive image showing the impact time
Immagine immersiva che mostra l'istante dell'impatto

In the next image (Fig. 11), taken just a few tenths of a second after the first, the effect of sound reflections caused by the previous impact can be observed. The green area in the time series of Fig. 9 shows a certain amount of residual energy in a more attenuated and temporally distributed form. The software now clearly highlights the directionality of the sound within the visual scene. The coloured map overlaid on the spherical image reveals the paths taken by the sound wave as it bounces off the surfaces of the court: the walls on the short side of the court, the floor and the lateral structures. Areas with brighter colours represent directions from where higher sound intensity is arriving, while blue and green tones indicate weaker reflections. This visualization is particularly useful for understanding the spatial distribution of sound energy within the court and the areas where a sound absorbing material can be more effective.

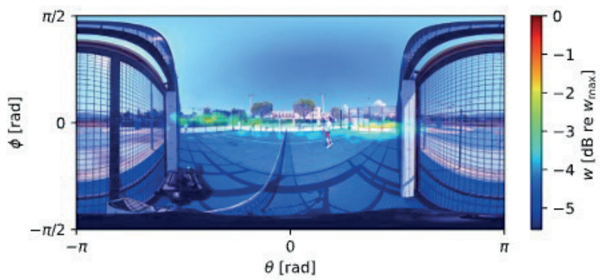

Fig. 11 – Sound map of the reflections after the ball impact
Mappa sonora delle riflessioni successive all'impatto della palla

5 | Discussion

Noise from padel courts can be modelled based on the data reported in the previous section. The most important point is to understand the type of source to be used in the model. For the determination of the DI a point source was introduced in the previous sections. Still, this type of source cannot represent the real distribution of the noise emission on the playground, because the players are continuously moving on the court during the game. Moreover, the position is not known "a priori". For this reason, it can be more sensible to use an area source having the same dimensions of the court (10 m × 20 m)

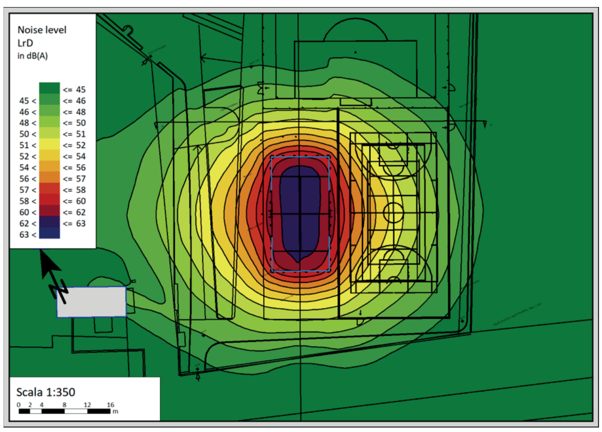

Fig. 12 – Predicted sound pressure level distribution [dB(A)]
Distribuzione del livello di pressione sonora [dB(A)]

with a sound power spectrum distribution that corresponds to the spectrum shown in Fig. 7. The overall sound power level associated with the area source is 93.7 dB(L). Applying such sound power level data to a model implemented in SoundPLAN, the resulting sound pressure level distribution at 4 m height is the one reported in Fig. 12.

The difference between the predicted and the measured sound pressure levels at the receiver position 1 is less than 1 dB, proving the acceptability of the sound power level determination. Fig. 13 shows the sound pressure level distribution on a vertical section placed along the main axis of the court.

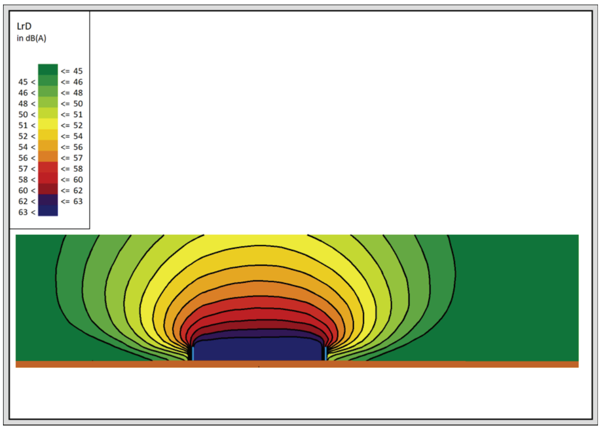

Fig. 13 – Vertical sound pressure level distribution [dB(A)]
Distribuzione verticale del livello di pressione sonora [dB(A)]

It can be observed that, as an effect of the reflections, the sound pressure level inside the court is almost constant in any position.

In any case, the sound power levels possess a maximum around 800-1000 Hz. These are frequencies for which the dB(A) attenuation is very low and then they result to be particularly annoying for the neighbourhood.

As concerns the directivity, the polar plot shows that the higher frequencies escape the court boundaries on the long sides, where there are no barriers, while the lower frequencies can easily pass over the screens and propagate at long distances. Such behaviour must be considered when designing new sports centres to minimize the noise impact.

6 | Conclusions

The study presented in this manuscript provides a comprehensive acoustic characterization of noise emissions from a padel court during real gameplay conditions. Through a combination of field measurements, spectral analysis, and ambisonics-based spatial mapping, the research has highlighted the primary sources of noise, their spectral content, and their spatial distribution.

The results show that the dominant noise emissions originate from the impulsive impacts between the ball and the racket or surrounding structures, with peak sound power levels occurring around 800–1000 Hz — a frequency range particularly critical due to minimal A-weighting attenuation and high perceptual sensitivity. The contribution of vocal expressions, while present, was found to be more significant than the mechanical impacts.

The directivity analysis revealed that higher-frequency components tend to escape through the long sides of the court, where barriers are typically absent, while lower frequencies propagate over the perimeter screens. These findings are crucial for informing the design of future padel facilities, particularly in urban or residential contexts where noise mitigation is essential.

The use of ambisonics technology proved effective in visualizing the spatial behaviour of sound within the court, identifying key reflection zones and focal points. This information can be leveraged to implement targeted acoustic treatments, such as absorbent materials or structural modifications, to reduce the environmental impact of padel-related noise.

Overall, the methodology and results presented here contribute valuable data to a relatively underexplored area of environmental acoustics and offer practical insights for urban planners, facility designers, and policymakers aiming to balance recreational development with acoustic comfort.

Conclusioni

Il lavoro presentato in questo manoscritto fornisce una caratterizzazione acustica completa del rumore emesso da un campo da padel durante condizioni reali di gioco. Attraverso una combinazione di misurazioni in campo, analisi spettrale e mappatura spaziale basata su tecniche ambisonics, la ricerca ha evidenziato le principali sorgenti di rumore, il loro contenuto spettrale e la loro distribuzione spaziale.

I risultati mostrano che le emissioni sonore dominanti derivano dagli impatti impulsivi tra la pallina, la racchetta e le strutture circostanti, con livelli di potenza sonora massimi concentrati intorno agli 800-1000 Hz – una gamma di frequenze particolarmente critica per la percezione umana, in quanto poco attenuata dalla curva di pesatura A. Il contributo delle espressioni vocali, sebbene presente, è risultato più significativo rispetto agli impatti meccanici.

L'analisi della direttività ha rivelato che le componenti ad alta frequenza tendono a fuoriuscire dai lati lunghi del campo, dove solitamente non sono presenti barriere, mentre le basse frequenze si propagano oltre le schermature perimetrali. Queste osservazioni sono fondamentali per la progettazione di nuovi impianti sportivi, soprattutto in contesti urbani o residenziali dove la mitigazione del rumore è essenziale.

L'impiego della tecnologia ambisonics si è rivelato efficace per visualizzare il comportamento spaziale del suono all'interno del campo, identificando le principali zone di riflessione e i punti di focalizzazione. Queste informazioni possono essere utilizzate in modo mirato per implementare soluzioni di trattamento acustico, come materiali assorbenti o modifiche strutturali, al fine di ridurre l'impatto ambientale del rumore generato dal padel.

Nel complesso, la metodologia e i risultati presentati contribuiscono con dati preziosi a un ambito ancora poco esplorato dell'acustica ambientale e offrono spunti pratici per urbanisti, progettisti e decisori politici interessati a conciliare lo sviluppo delle attività sportive con il comfort acustico del territorio.

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