



Game Changer

Bluetooth® LE Audio wireless streaming presents a radical paradigm shift for live music and sporting events. Al Walker, Founder and CEO of Inline Audio, looks at this reinvention of the live experience.

Imagine a going to a live music concert with perfect sound quality for every seat in the house. Where there is no need to bring earplugs as volume level is an individual choice, and where the view of the stage is unimpeded by huge speaker arrays blocking sight lines.

Or going to a sporting event with live commentary throughout, perhaps a football match with dedicated streams for home and away team supporters, or a motorsports race with the option to also listen in on the team radio discussions about race position and pit stop strategies.

We are all familiar with the one-to-one pairing offered by Bluetooth Classic Audio, wirelessly streaming from our mobile devices to our earbuds, headphones, and personal speakers. As headphone jacks are removed from mobile devices, wireless earbuds and headphones are becoming the norm, be they premium branded offerings or mass market clones, and replacing their wired predecessors.

Instead of this one-to-one pairing, the emerging Bluetooth LE Audio standard offers one-to-many broadcast streaming, with potentially an unlimited number of users subscribed to a single source. This new technology will permeate our lives in many ways, including how we experience live entertainment. Whilst current models of wireless earbuds and headphones still employ Bluetooth Classic Audio,

in the next couple of years we will see the shift to LE Audio as the major manufacturers of smartphones and other mobile devices integrate this functionality.

Silent discos have been a niche part of club culture for many years, with the participants wearing wireless over-ear headphones in place of a regular sound system. Whilst perhaps a surreal sight for unfamiliar onlookers, it is a phenomenon that provides a signpost to a near future experience of live entertainment.

As inner cities become increasingly gentrified, performance licences for nightclubs and music venues are often at risk due to complaints from incoming new residents who seek the prestige of a premium city centre lifestyle but don't necessarily want the noise disturbance that goes with it.

With LE Audio, the silent disco goes mainstream. Whilst some may prefer to hang on to their over-ear headphones, wireless earbuds offer a far more discreet and portable solution for such events, small enough to put the charging case into a pocket rather than the need to carry around a bulky headphone case.

We can expect wireless earbuds to become just something that everyone keeps with them to access streams from the myriad applications of LE Audio that will be encountered in everyday life.



Silent Discos - A signpost to the future of live events

Having an audience listen via LE Audio wireless earbuds parallels the use of in-ear monitors (IEMs) by the musicians performing onstage. And in the same way that the use of IEMs has very effectively reduced onstage volume levels, this move to an in-ear experience for the audience reduces noise pollution and so the complaints from local residents.

Historically, the role of a PA system used for live music is that of sound reinforcement, with the Front of House mix engineer adjusting the mix of audio signals in conjunction with the sound coming directly from the stage to provide an overall balanced sound image. However it is now possible to effectively eliminate this direct sound with guitarists replacing their amp stacks with digital modellers and drummers and percussionists using Perspex screens to limit sound spill, or indeed using electronic drum kits to replace their acoustic counterparts. And obviously for playback-only venues such as nightclubs, there is no direct sound from the stage anyway.

Loudspeakers are notoriously inefficient in converting electrical signals into acoustic sound waves. In contrast the amount of energy required to wirelessly stream the Front of House audio mix directly to each persons' earbuds is negligible. As live concert touring looks to reduce its carbon footprint, eliminating much of the PA system would cut down significantly on energy consumption, both for the venue itself and the fuel required to transport multiple heavy speaker boxes and amplifier racks from city to city.

Touring becomes less expensive as a result, as the requirement for trucks, drivers and stage crew is reduced. Crew wellbeing is also enhanced with less time spent doing load-in, setup and load-out, allowing more time for rest and recuperation.

Larger venues can be expected to retain existing house PA systems, but with announcements limited to only those required for health and safety compliance, including for voice alarm use, do not need to have anything like the power requirement of full-blown concert sound reinforcement systems.

Stage designers will welcome the elimination of large speaker hangs and ground stacks, improving sight lines around the venue as well as presenting a more aesthetically pleasing appearance for the audience. It is also no longer necessary for the FOH mix engineer to spend time equalising the PA system frequency response in an attempt to compensate for the venue acoustics.

With the acoustic response no longer a consideration, the audience hears the best possible sound balance regardless of where they are in the venue. And if people want to talk, they can just take out their earbuds and do so at normal conversational volume, with no need to shout over the music and causing annoyance to other attendees.

The use of subwoofers can be retained in venues to give the physical sensation of the music without the same noise pollution issues, and is particularly relevant for nightclubs where dancers need to feel the beat as least as much as hear it.

Residency shows may well be the first to trial the in-ear concert sound experience, with earbuds available for sale as show merchandise or included in ticket price in addition to attendees preferring to use their personal pairs. Physical tickets can include a QR code that allows access to the audio stream, and for paperless events, there exists the opportunity to create mobile apps that link the event purchase to audio stream access.

LE Audio provides an effective way of regulating exposure to high sound pressure levels with the aim of preventing long-term hearing loss among club and live music devotees. For anyone who ever wished they'd brought earplugs to a gig, it allows the setting of a comfortable listening level and the management of sound exposure on a personal basis.

This ability to control the overall volume level and the associated concerns about sound pressure level exposure times enables access to shows for those with hearing conditions such as tinnitus. Whilst the change to an in-ear experience will likely be

driven by a generational shift in the consumption of live entertainment, Boomers and Gen-Xers may too welcome the opportunity to limit sound exposure levels especially when experiencing such age-related hearing issues.

For jurisdictions that mandate the data logging of venue sound exposure, and indeed PA system muting in the event of excessive volume levels, moving to an in-ear experience can remove the need to do so for legal compliance.

Latency is a key issue in live sound reinforcement, the well-known Haas effect puts an upper limit on the difference in the arrival time of sounds at a person's ears from multiple sources for them to be perceived without a delay or echo. The actual figure is somewhat dependent on the programme material, varying from perhaps five milliseconds (ms) for transient sounds such as clicks to 100 ms for music without any significant percussive content, but a limit of 40 ms is considered typical. If full-bandwidth wireless LE Audio streams are to be successfully combined with the acoustic sound from subwoofer speakers then the Haas effect needs to be taken into account.

The Low Complexity Communication Codec (LC3) used for audio encoding and decoding in LE Audio supports sample rates from 8 kHz to 48 kHz. The digital mixing console systems used for live shows operate at 48 kHz or 96 kHz, so either require no sample rate conversion or a simple divide-by-two conversion respectively to interface to an LC3 codec transmitter operating at 48 kHz allowing for seamless integration.



Concert touring can reduce its carbon footprint by eliminating the need to transport heavy PA system speaker cabinets and amplifier racks from city to city

The end-to-end transmission latency between the transmitter and receiver (referred to as Initiator and Acceptor in the LC3 codec specification) is split into three stages, defined as the Encoding Delay, Transport Delay, and Presentation Delay.

The LC3 codec uses either a 7.5 ms or 10 ms frame length to which a further 2.5 ms needs to be added for the encoding process at the Initiator. Using the performance-optimised 10 ms frame length gives a total Encoding Delay of 12.5 ms, assuming that the incoming signal feed is already in digital format as will be the case when sourced from a digital mixing console system.

The Transport Delay is variable depending on the need for retransmission in the event of data packet errors, but is typically a few milliseconds, and includes the provision for synchronisation of multiple streams. The Presentation Delay is incurred at each Acceptor as the incoming data packets are turned back into an audio stream, and may be from as little as 5 ms to several hundred milliseconds.

At 20 degrees Celsius, sound takes 3 ms to travel one metre (with this figure decreasing as the temperature rises) and so the acoustic propagation delay due the distance between the subwoofers and the audience needs to be matched with the end-to-end latency of the LC3 codec within the Haas effect limit.

For larger concert halls, rather than having high power subwoofers located only at the stage as with conventional PA systems, the installation of multiple smaller subwoofers throughout the venue will ensure that the Haas effect limit is never exceeded regardless of where the audience members are located. This approach also further eliminates the amount of PA system equipment that needs to be transported from venue to venue by touring acts.

The LE Audio Basic Audio Profile (BAP) mandates that an Acceptor must support around 40 ms of buffering for the decoded audio data before it is rendered back as an audio stream. However if the whole transmission process is fully optimised, the lowest end-to-end latency that can be achieved is a little over 20 ms, well within the typical limit of the Haas effect.

This idealised latency figure is however subject to multiple environmental factors including that people, especially in large groups, are effective absorbers of radio frequency energy being mostly comprised of



Motorsports fans get to listen in on heat of the moment conversations between drivers and support teams

water. The presence of other transmissions in the 2.4 GHz ISM band, particularly from the WiFi and Bluetooth radios in the audience's mobile phones, also needs to be addressed.

For the highest supported 48 kHz sample rate, as will be used for music streaming in general, the end-to-end latency is therefore significantly increased from the idealised minimum figure, in part also due to the fact that data packets are far from guaranteed to arrive in the expected sequence. Maximum values are typically in the range of 80 ms to 140 ms for stereo streaming depending on whether transmission is optimised for low latency or high reliability, or a trade-off made between these two considerations.

Even with these larger latency figures, the mental synchronisation of the visual image of the stage with the received acoustic sound may be less of an issue than might be expected thanks to our own internal buffering processes. The human brain is quite tolerant of such situations, as evidenced by the use of large video screens at outdoor music festivals, with no conscious perception of lip-sync issues by the audience even when a considerable distance away from the stage. The brain really only gets upset when the audio arrives before the associated visual images.

Looking further into the future, with the advent of wireless earbuds and headphones supporting spatial audio formats, we might project a fully immersive concert sound experience without the need for yet more PA system speakers and amplifiers to provide the rear surround channels, that anyway would be prohibitively expensive especially with the trend towards greener touring. Indeed we can look to the integration of LE Audio earbuds with other wearables as part of an augmented reality experience even better than the real thing.

Stadiums and arenas around the world are often used for both live music and sporting events, and many of the considerations discussed so far apply equally to the latter. Sports venues do not generally have live commentary over the PA speaker system during play, as it is a major distraction for the participants.

Sports commentary, being speech-based, can use lower sample rates compared with live music applications. For team games, this allows multiple streams featuring dedicated commentary channels for each team's respective supporters plus a perhaps less partisan one offering a more objective view provided by the TV rights broadcaster commentary.

Stream selection can be via the respective team apps and be included as part of the club membership, or scanned from a QR code on the ticket or displayed inside the stadium. As with concert merchandise, sports teams can offer their own branded earbuds to supporter club members.

In addition to the race commentary, team radio is a key part of the motor racing experience with conversations between drivers and support teams forming part of the event experience. The opportunity to listen in on the sometimes frank exchanges on race position strategies, tyre selection and pit stop scheduling adds to the drama of being at the event in person and creates a theatre of the mind as the field of view of the circuit is usually limited for individual spectators.

Whilst it is obviously possible right now to listen to commentary at an event on earbuds using mobile data, it is also an effective way to burn through a monthly plan. This is especially true when an event takes place over hours, let alone days, as well as being an issue for regular attendees.

5G is often touted as a universal panacea to solve all technology issues. However as with previous generations of mobile data services, it is not something that phone companies will be willing to provide on a free or complementary basis for sports fans to enjoy live commentary in the way that it is practical to do using LE Audio.

The use of wireless earbuds will be obligatory for live music to hear performances, and therefore represents a fundamental change to the concert experience.

In contrast, live sports commentary services can be offered as a value-added proposition to the existing spectator experience on an opt-in basis and therefore lead in the adoption of LE Audio for live events.

The LE Audio Opportunity

This is the beginning of a new wireless audio paradigm and an opportunity to create the enabling products that will revolutionise the live experience, as well as many other aspects of our lives.

As a Bluetooth SIG Adopter Member and an active participant in the development of LE Audio technology applications, Inline Audio is well placed to help companies gain a first mover advantage in the emerging market for LE Audio products. With our mutual non-disclosure agreement policy, companies can talk in confidence about realising this next generation of wireless products leveraging LE Audio technology.

For more information, please contact: [**leaudio@inline.audio**](mailto:leaudio@inline.audio)

About Inline Audio

We are a brand and product launchpad for the professional audio industry. We go beyond existing product categories to create original design concepts with and for those who share our values and commitment to innovation. Those with vision, who take a leadership role and move our industry forward.

[**www.inline.audio**](http://www.inline.audio)

The logo for Inline Audio, featuring the word "INLINE" in a spaced-out, uppercase font above the word "AUDIO" in a similar spaced-out, uppercase font. The letters are white and set against a dark blue background.

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