40 YEARS OF SOUND MANAGEMENT AT CONCERTS AND FESTIVALS

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1 INTRODUCTION

The music industry has seen a substantial change over the past 40 years, as has the sound management at concerts and festivals which has evolved and developed due to new technology, research, legislation and experience. This paper will review:-

- The change in the Music Industry
- The evolution of touring sound systems
- The development of noise guidance and Codes of Practice
- Noise Management Plans
- Development of sound monitoring

In the UK alone, live music contributed almost £1 billion in Gross Added Value (GAV) to the economy and employed over 28,000 people. Furthermore, 29 million people enjoyed live music in the UK in 2017[1].

This extensive growth has occurred whilst there has been a demise of the record industry brought about by the digital age of downloads and now free streaming of music. Artists now have to tour as this is their main source of income rather than just touring to market their album. This has meant that there has been a much greater demand for tours and festivals which has in turn significantly increased the number of events and the adoption of new venues, all which increases the potential risk of environmental noise disturbance. The UK music comparison of sales by CD, Vinyl, downloads and streaming shown in Figure 1[2], clearly shows the rapid rise in streaming. The growth in global live music as compared to recorded music revenues is shown in figure 2[3].

Figure 1 Music Sales in Millions

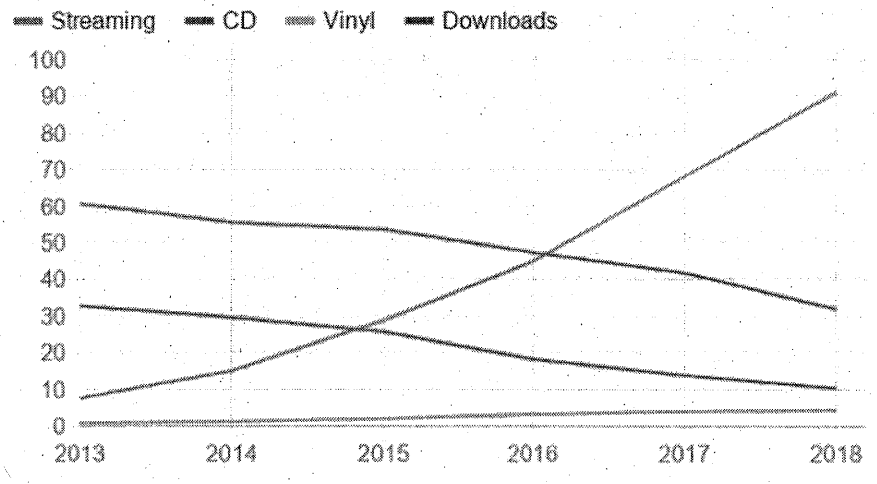
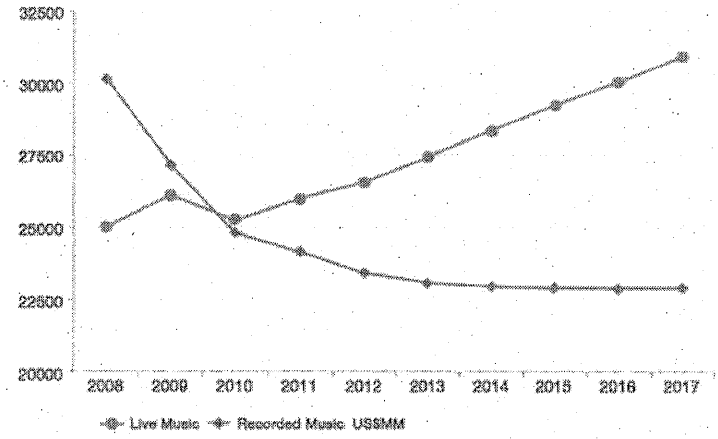


Figure 2 Global Live music vs Recorded Music Revenues US$M



2 THE EVOLUTION OF TOURING SOUND SYSTEMS

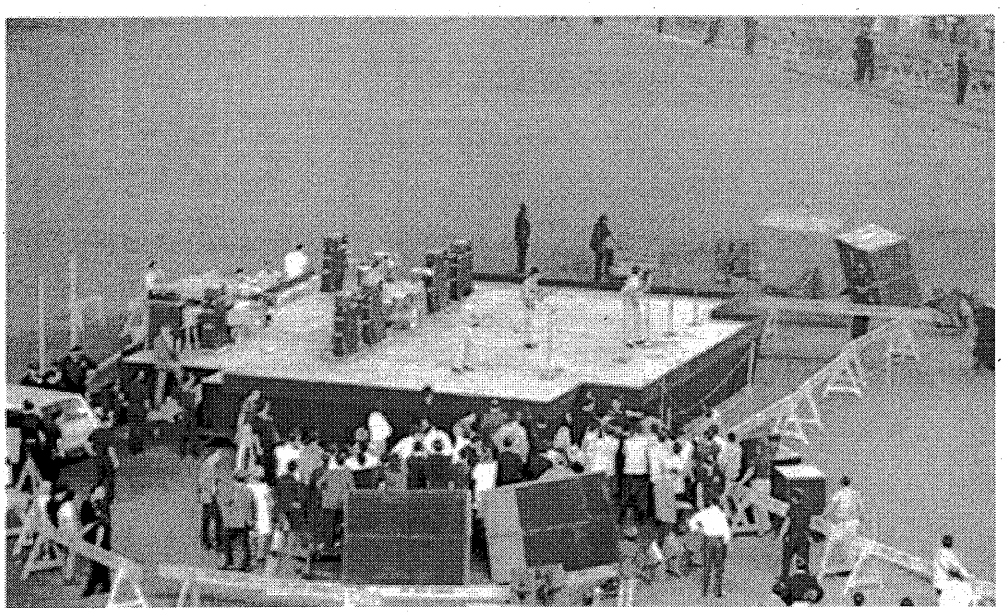
A touring PA system must deliver the required sound pressure level (SPL) coverage and sound quality to a specified audience area which changes with every stop on the tour. Sound reinforcement requirements at both indoor and outdoor music events have continually evolved all over the world alongside the changes in popular music genres, performance and consumption. Modern audiences expect (whether they realise it or not) to experience rock or pop music at levels at or above 98 dB LAeq 15 minute and with a frequency response of ±3 dB between 40 Hz and 15 kHz.

From the invention of the moving-coil loudspeaker in the mid-1920s, until the early 1990s, the vast majority of commercial PA systems would be based on simple acoustic theory, in which multiple loudspeakers of varying driver width, stacked together from the floor of the stage and projecting into the audience, would provide a coverage attenuating at 6 dB per doubling of distance – acting as a point source.

Point source PA systems were virtually the only commercial option for a long time and worked well enough in fixed installations in theatres, cinemas and dancehalls. The use of one touring PA system provider across multiple venues began with Clair Brothers in 1966, whose sound system impressed the touring crew of Frankie Valli and the Four Seasons enough to bring them on tour.

The Beatles Shea Stadium concert in New York City in 1965 was widely considered the first open stadium concert – the point source PA system used, and the problems the Beatles faced in overcoming crowd noise, are well-documented in photographs, bootleg recordings and interviews. This would set the precedent of ever-increasing audience sizes and expectations beginning to outgrow the traditional PA system.

Figure 3 – The Beatles in Shea Stadium



The Grateful Dead's "Wall of Sound" touring PA in 1974 and the use of Martin Audio systems by acts like Pink Floyd and The Who are examples of how PA systems based on a simple point source theory continued to be used at the highest commercial level of rock and pop entertainment throughout the 1970s and 1980s. With increasing coverage areas and frequency response demands, audio engineers and event production designers continually tried to achieve sound of a level and quality that allowed for the satisfactory enjoyment of the entertainment.

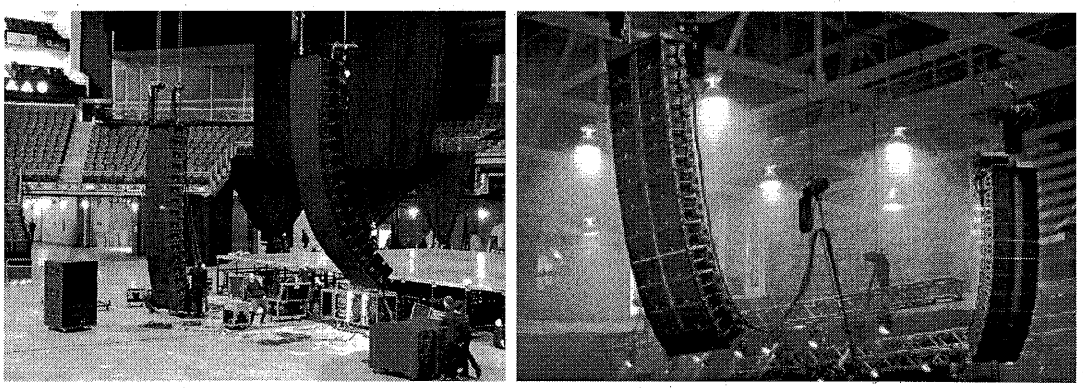
The answer came from a piece of acoustic theory first proposed by Harry Olson in his book, Elements of Acoustical Engineering[4]. Olson had theorised that a linear array of point sources, stacked vertically within the same speaker casing, would result in a directivity pattern equating to an approximated acoustic line source. This would create sound pressure levels that drop off at a rate of 3 dB per doubling of distance as opposed to 6 dB from a point source. The result would be increased consistency in sound pressure level and response across the audience coverage area. This theory was expanded upon by Leo Beranek in Acoustics[5].

Line array loudspeaker theory was adopted more readily by designers of home listening loudspeakers. For large-scale live audio, it wasn't until the French company L-Acoustics (and the designer Dr. Christian Heil) progressed the design in 1992 that the technology became viable for large-scale PA. The proprietary technology developed by L-Acoustics, including a horizontal waveguide, was named VDOSC, which continues (with updated versions) to be used today as a touring PA system. Since then, most major PA manufacturers have steadily adopted the line array design and are continually in competition to develop systems offering superior control of sound dispersion over frequency across vast audience areas.

Line array sound systems are typically flown (i.e. rigged in suspension above the stage) and can be articulated (physically J-shaped so that the bottom cabinets point at the front of the audience). When a line array system is specified, consideration is given to the length of the array as a whole and the spacing and angling of individual cabinets, which strongly influences the audience coverage and frequency response of the system. A typical line array PA system, used on a large rock or pop tour

today, may consist of two main stage right and left hangs, (around 12 – 18 individual loudspeaker units or boxes), and two side hangs (of 6 to 8 boxes). The audience area may then have further cover by the use of delay hangs of a similar size to the stage side hangs.

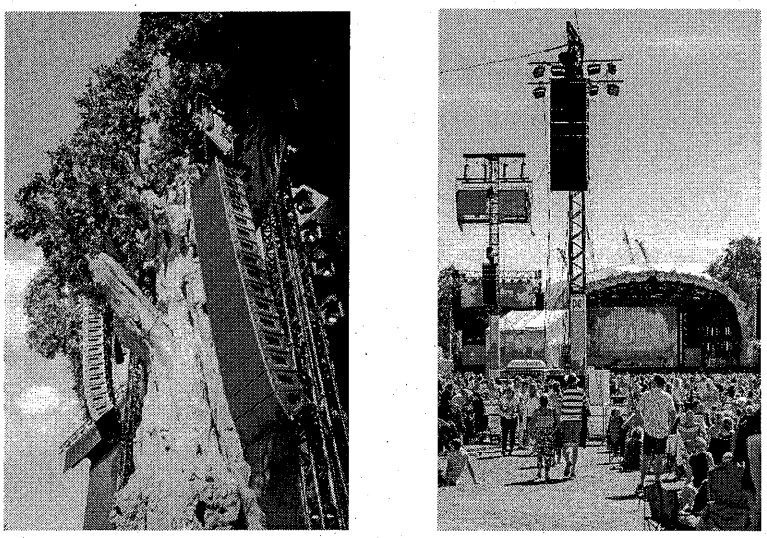
Figure 4 - Typical Installation of a Line array System



The most recent evolution of touring PA design has come from the application of Digital Signal Processing (DSP) methods to live audio work. Computer processing power has allowed loudspeaker designers and engineers to apply Finite Impulse Response (FIR) or Infinite Impulse Response (IIR) filtering algorithms when modelling how a loudspeaker will be placed in a venue of a given size, projecting at a given audience coverage area. These filters are applied to the DSP driving the PA system which can then apply delays or amplitude information to individual units or even drivers within the array, resulting in a very accurate control of sound dispersion and frequency response. A number of tests have been carried out to assess these filters with line array systems.

The application of DSP methods to line array theory was pioneered in the UK by Martin Audio with the release of their MLA system in 2008. Figure 5 shows the MLA stage hangs at Hyde Park. The MLA system is hugely successful in offering engineers previously impossible levels of control over the dispersion of sound throughout large audience areas. Most major PA manufacturers including Meyer Labs, d&b Audiotechnik and L-Acoustics have followed suit, developing both a physical DSP for their line array products and proprietary modelling software which allows a DSP filter setting unique to an individual act, tour and/or venue, to be applied to the system.

Figure 5 – The MLA system in use in Hyde Park



3 THE DEVELOPMENT OF NOISE GUIDANCE

3.1 Background

The development of Noise Guidance can be traced back over hundreds of years. Under the Disorderly Houses Act of 1752, places of entertainment and houses used for music and dancing in London and Westminster and within twenty miles from there were required to obtain a licence from the Justices of the Peace. These could be issued or refused after presentation of a petition by a new owner, or one wishing to renew a licence.

The Theatre Regulation Act of 1843 laid down a nationwide system of licensing. This allowed all theatres in the Cities of London and Westminster, and the boroughs of Finsbury, Marylebone, Tower Hamlets, Lambeth and Southwark to apply for a Lord Chamberlain's licence which enabled them to perform drama. This Act therefore forced small saloon theatres to apply either for a magistrates' music and dancing licence which permitted drinking but did not allow dramatic entertainment, or a Lord Chamberlain's licence which permitted them to present drama but forbade drinking in the auditorium. The Local Government Act of 1888 transferred most of the administrative functions of the Quarter Sessions to newly created county councils. As the London County Council (LCC) operated a committee structure, it administered the system of theatre licensing through its Theatres and Music Halls Committee. This became the Entertainment (Licensing) Committee from March 1931 and in 1941 its functions merged with those of the Public Control Committee. Another aspect of LCC regulation of places of public entertainment involved regulating the behaviour of performers and members of the audience because at times they were deemed to be unruly. The London Government Act of 1963[6] established the Greater London Council (GLC) which then inherited the functions of entertainment licensing from the London County Council in 1965.

The current legislation giving power to exercise limited control on premises where entertainment is being held originated from provisions within the London Government Act 1963. The London Government Act 1963 gave the Greater London Council by virtue of section 52 and Schedule 12 to that Act the power to attach conditions related to public safety (on or after 1st April 1965). Although there was no direct mention of noise or nuisance within this Act there was clear authority for the GLC to add conditions to any licence issued.

The Local Government (Miscellaneous Conditions) 1976[7] extended these powers. Again, the emphasis was on public safety, but it did take one step further by including the requirement for the 'minimisation of disturbance'.

After 1965 these rules were codified into the Technical Standards and the Rules of Management for Places of Public Entertainment issued by the GLC.

3.2 GLC Codes of Practice

The GLC produced a series of publications specifically related to safety, health and welfare at events. There were three editions. Edition 1 was restricted to one day events and contained the following recommended limits.

$L_{A50,\ 15min}$ (with concert) ≤ $L_{A50,\ 15min}$ (without concert) +10dB

between the hours of 07.00 – 20.00hrs

Editions 2 and 3 extended the guidance to include up to 3 days/year and made the use of LAeq rather than LA50.

$L_{Aeq,15\ min}$ (with concert) ≤ $L_{Aeq,\ 15min}$ (without concert) +10dB

similarly between the hours of 07.00 – 20.00hrs

In all 3 editions between the hours of 20.00hrs and 23.00hrs the limit was reduced to

$L_{Aeq,15\ min}$ (with concert) ≤ $L_{Aeq,\ 15min}$ (without concert) +6dB

Following the abolition of the GLC in 1986 and the transfer of the entertainments licensing responsibility to London Local Authorities, many of the new licensing authorities used these GLC publications as a basis for their own licensing requirements.

3.3 Code of Practice on Environmental Noise Control at Concerts – Noise Council

This Code of Practice[8] was published in 1995 by the Noise Council. The Noise Council was established by a group of professional bodies concerned with problems relating to noise in the community. The working party comprised of specialists who were experienced in the particular problems associated with environmental noise from concerts.

The 1995 code gives general guidance on concert definitions and terminology, noise guidelines, noise management procedures and references. It also contains recommended noise limits underpinned by research of some of the authors and best practice at the time.

The recommended noise limits contained within the 1995 Code held between the hours of 0900 and 2300hrs are summarised in Table 1 (see below).

Concert days per calendar year, per venue	Venue Category	Guideline
1 to 3	Urban Stadia or Arena	The MNL should not exceed 75dB(A) over a 15 minute period
1 to 3	Other Urban and Rural Venues	The MNL should not exceed 65dB(A) over a 15 minute period
4 to 12	All Venues	The MNL should not exceed the background noise level by more than 15dB(A) over a 15 minute period.

Table 1 – The Noise levels within Table 1 of the Noise Council Code 1995

There are a series of important notes attached to the table which deal with indoor events (up to 30 per year) and events which continue beyond 2300hrs. After 2300hrs it suggests that music should not be audible within noise sensitive premises (with windows open). It does however qualify this guidance by stating that the use of inaudibility in not universally accepted as an appropriate method of control but in 1995 there was insufficient evidence to give more precise guidance.
There is also a note on low frequency noise. There is recognition that noise in terms of dB(A) may underestimate the intrusiveness of low frequency noise and accepts that it may be necessary to set

an additional criterion to manage low frequency noise impact or apply additional control conditions within the premises licence. The background to the limits set in the Code are presented in an IOA paper[9] with suggested potential improvements published in 2006[10]. More than 20 years on, this Code still provides the backbone of concert noise management today. It is long overdue for review.

There is currently a working group hosted by CIEH including representatives from the ANC and IOA which is reviewing this document as it has become out of date, in particular because of the introduction of the Licensing Act 2003[11]. As well as taking account of this, the opportunity will be taken in this revision to clear-up some ambiguities in the Code and to provide some additional explanation in places. The publication will become a 'Good Practice Guide' which sits alongside other GPG's providing advice and guidance on various noise issues.

The 1995 code placed emphasis on the need to minimise disturbance and annoyance to the local community. The Licensing Act 2003 introduced the concept of the *"Promotion of the Prevention of Public Nuisance"* which set the threshold at a different level. The Licensing Act 2003 aimed to provide a balanced package of freedoms and safeguards. It has an important role in the prevention of public nuisance perpetrated by a minority but gives the responsible majority more freedom and choice about how they spend their leisure time. The majority of events held in the UK now follow the adopted guidance in one form or another but its review is now well overdue.

The key points currently under discussion are:

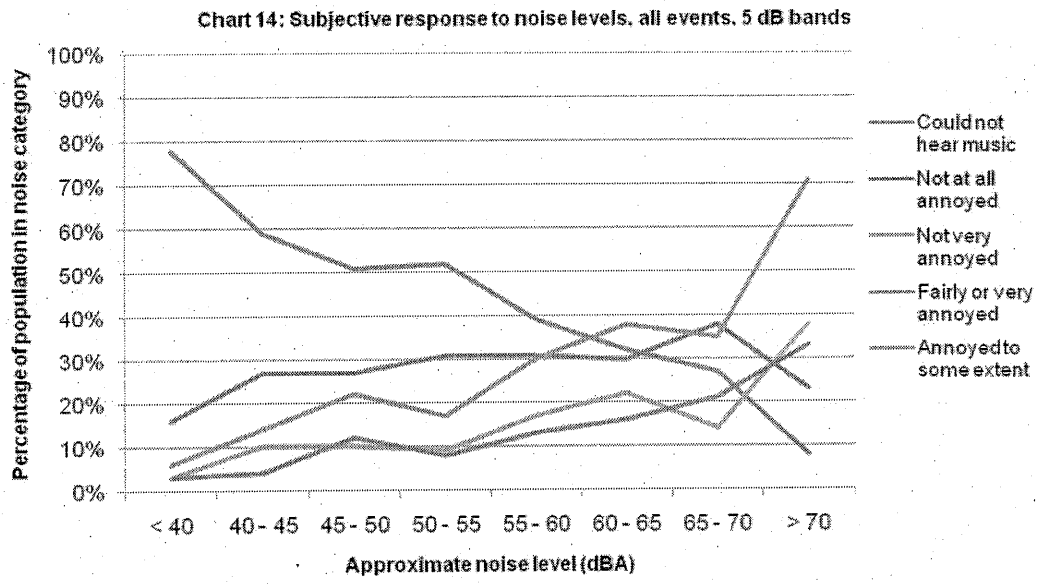
1. The latest DEFRA Research [12,13]
2. Licensing Act 2003[11]. A deregulatory piece of legislation which changed the test to the Prevention of Public Nuisance not disturbance/annoyance.
3. Noise level with concert numbers and Venue Category.
4. Use of Low frequency limits (frequency or "C" weighting).
5. Night time noise criteria – objective rather than subjective ie 'inaudibility'

In 2011 as part of an attempt to 'refresh' the 1995 Code, Defra commissioned IPSOS Mori and Napier University [12,13] to carry out research into attitudes towards environmental noise from concerts. A noise monitoring study was also commissioned by Defra[14] to support this research. This was undertaken jointly by Vanguardia and RPS.

The overall aim of the research was to prepare and conduct face-to-face social surveys of nearby residents, in order to understand the attitudes to environmental noise from these concerts. Concert attendees were also included within the scope of the research to establish that the sound levels within the event were sufficient to not hamper concert-goers' enjoyment of music events.

Presented below is a summary of the key findings of this research project. Figure 6 below shows the percentage of all respondents giving a subjective response within each of the 5 dB estimated noise exposure bands.

Figure 6: Subjective response to noise levels (NANR 292)



Although the review of the Code is not yet complete it is likely that the table with guidance levels will have a LCeq index to facilitate the control of low frequencies.

It is anticipated that the setting of the music noise levels at offsite locations will be complemented by a risk-based assessment to justify any deviation from the norm or to account for any local factors.

Work on the review of the 1995 Code is expected be out for consultation early in 2020.

4 NOISE MANAGEMENT PLANS

The preparation and submission of a noise management plan (NMP) has been an integral part of the management of noise at (outdoor) events for many years.

Historically, the NMP used to be limited to basic pieces of information. This would most likely have been a site plan, licence conditions, maybe a rudimentary calculation of the predicted offsite noise levels and a list of agreed monitoring locations. The monitoring locations would normally have been agreed with the local authority (who sometimes facilitated the liaison with a local resident) but many times would be located due to practical considerations.

In the early days, before mobile phone technology and efficient radio comms the offsite monitoring locations may be situated in the vicinity of a public telephone box. This enabled the offsite consultant to phone in any issues and/or find out where any complaints have been made. This was very time consuming. Things have moved on considerably since then. The use of Whatsapp is now used extensively along with communication tools now linked with real-time monitoring equipment.

40 years ago the only way to collect information was to have someone sitting somewhere watching a sound level meter and noting the levels. Where possible these levels were transmitted by radio but as explained this was not always possible. At the very least they were written down in a notebook for reference later on. Offsite noise monitoring was resource heavy with people permanently stationed at various locations around the venue.

It is generally accepted that properties in the vicinity of a large-scale music event will be able to hear music noise. It is a matter of balancing the needs of the local community who reside beside a venue

with the enjoyment of thousands of people who will attend the event. For a venue to remain sustainable it is important that the neighbouring community accept the inevitable disruption and do not perceive that there is a significant loss of amenity. It is for this reason that a good NMP is essential as it will set out what the likely impact will be, how long it will last and what steps will be taken to minimise it. The document should be a collaboration between the event organiser, the acoustic consultant, the landowner/venue operator, the local authority and the local residents.

Clearly licensed premises holding regulated entertainment have to live in harmony with their neighbours, and by their very nature can often cause some disturbance to people living nearby. The aim of the Noise Management Plan should be to document reasonable measures to reduce the noise impact of sources associated with the premises whilst they are operating.

Sometimes a NMP is required by a condition on a licence but more often these days the NMP is required to support the application for a licence. The NMP will demonstrate that consideration has been given to the likely noise issues and will detail the proposed methods of noise management. It is likely that the document will suggest suitable noise limits to be applied to offsite noise sensitive receptors and will also detail the mitigation measures that are to be adopted to minimise any impact. These days as a minimum a NMP should include but not be limited to:

1. the hours of operation of the planned event
2. the licence conditions relating to noise
3. the location of potentially noise-affected premises and predicted noise levels at those locations
4. the planned location and orientation of stages, public address or audio systems
5. the predicted levels at noise sensitive locations (agreed with local authority)
6. details of notification to residents including details of the event
7. details of relevant person in attendance on the day of the event

It is common practice nowadays to include detailed noise contour mapping to illustrate the predicted noise levels around a venue. Vanguardia use IMMI industry standard environmental noise modelling software to predict the noise impact at noise sensitive properties and determine the most appropriate site layout that would minimise the noise impact at residential locations. Topographical contour and ordnance survey data for the venue and surrounding residential area will be imported into the software and used with the sound source directivity derived from the calculated polar directivity provided by the appointed sound system supplier.

Vanguardia's relationship with sound system manufacturers and suppliers means that audience coverage areas can be directly input into IMMI from the various supplier software packages and a noise level contour plot is produced showing the distribution of sound to offsite locations based on the methodology of ISO 9613-2:1996 [14].

These days it is normal to include an illustration of the output from the computer model within the NMP. For multi stage events, the sound level contribution from each stage is predicted and shown for each off-site location thus allowing for stage orientation/optmisation having regard to noise management.

Increasingly there is a requirement by local authorities to provide real time monitoring with a direct feed to local stakeholders. An example of a condition with this requirement is:-

'The noise consultant shall make use of a monitoring system that allows for real-time correlation between performance stages and off site monitoring locations.'

There are a number of real-time waveform pattern recognition devices (discussed later in this paper) available on the market now. They are particularly useful at multi stage events enabling fast identification of 'problem' areas leading to swift remedial action thus reducing the likelihood of a breach of licence condition.

5 DEVELOPMENT OF SOUND MONITORING

In the late 1970's and early1980's, sound monitoring comprised of a simple Class 1 sound level meter placed at the FoH (front of house sound mixing location) indicating instantaneous sound pressure levels with ad-hoc monitoring undertaken off-site at various community locations. The need for more consistent reporting brought in the use of logging systems adopting short term LAeq's both at the FoH positions and off-site. To indicate the time-level histories a level recorder was used in the 1980's/90's so that the change in level with time can be displayed to all stakeholders including the sound engineer, venue, promoter and local authority. Figure 7 shows the use of a level recorder used at a Rolling Stones concert at Wembley Stadium in 1990. It also shows the use of the in-house sound system designed at Wembley which was the first digitally controlled system installed in a stadium.

Figure 7 - Sound Monitoring at Wembley Stadium with the use of the in-house sound system[16]

At the turn of the century, new digital systems were developed using digital displays with further facilities of software specifically developed for the sound engineer to see a graphical presentation of the level and the amount that the level needs to be reduced to meet off-site limits. All sound level indices with frequency can be displayed depending on the venue and nature of the event. See Figure 8.

A significant breakthrough and change in the way sound is managed at events was the more recent development of systems that operate in real time and work on a network such that sound levels and frequency data from each stage and from each off site location can be displayed on a central control panel. The information can also be displayed at each on and off-site position and on mobile devices/smart phones as required. A further and more useful development is the use of correlation tools which analyse the waveform from each stage every 15 seconds at each 1/3rd band frequency. See Figure 9. This enables the contribution of music noise from each stage to be calculated and displayed along with the measured Total noise level at each frequency. See Figure 10. This has significant advantages especially for multi-stage events. The system can:-

- detect which stage is causing the highest sound levels off-site
- establish which frequency is generating the highest off-site levels
- calculate the ambient noise, the Music Noise Level (MNL) as compared to the total measured LAeq noise level, This is invaluable for sites with high existing ambient noise climates so that the MNL can be established.

Figure 8 – Use of the Metrao Real-time noise analyser at an event

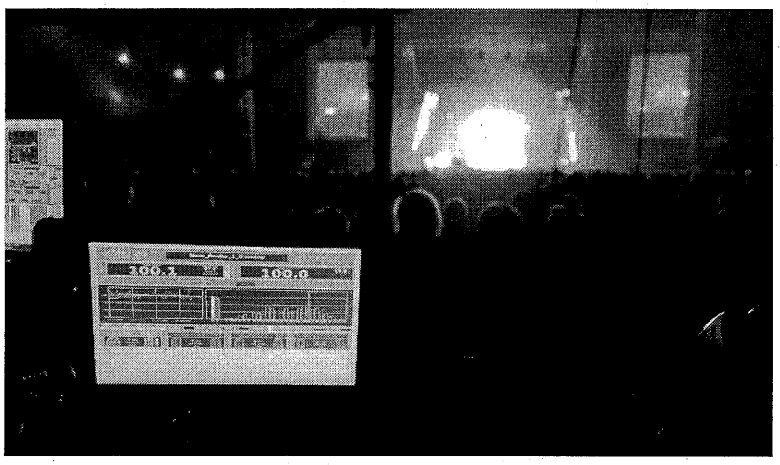


Figure 9 – Illustration of Sound Waveform analysis from on and off-site

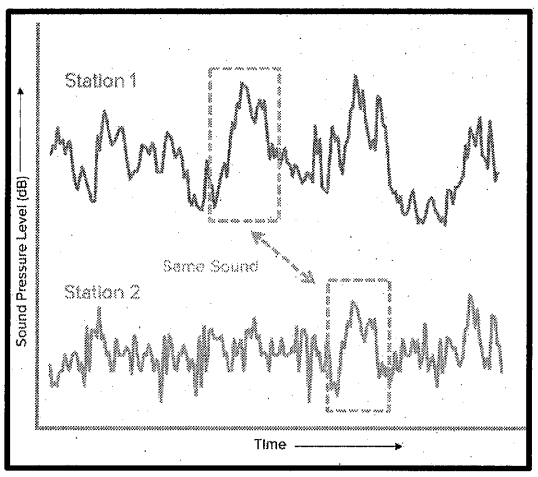
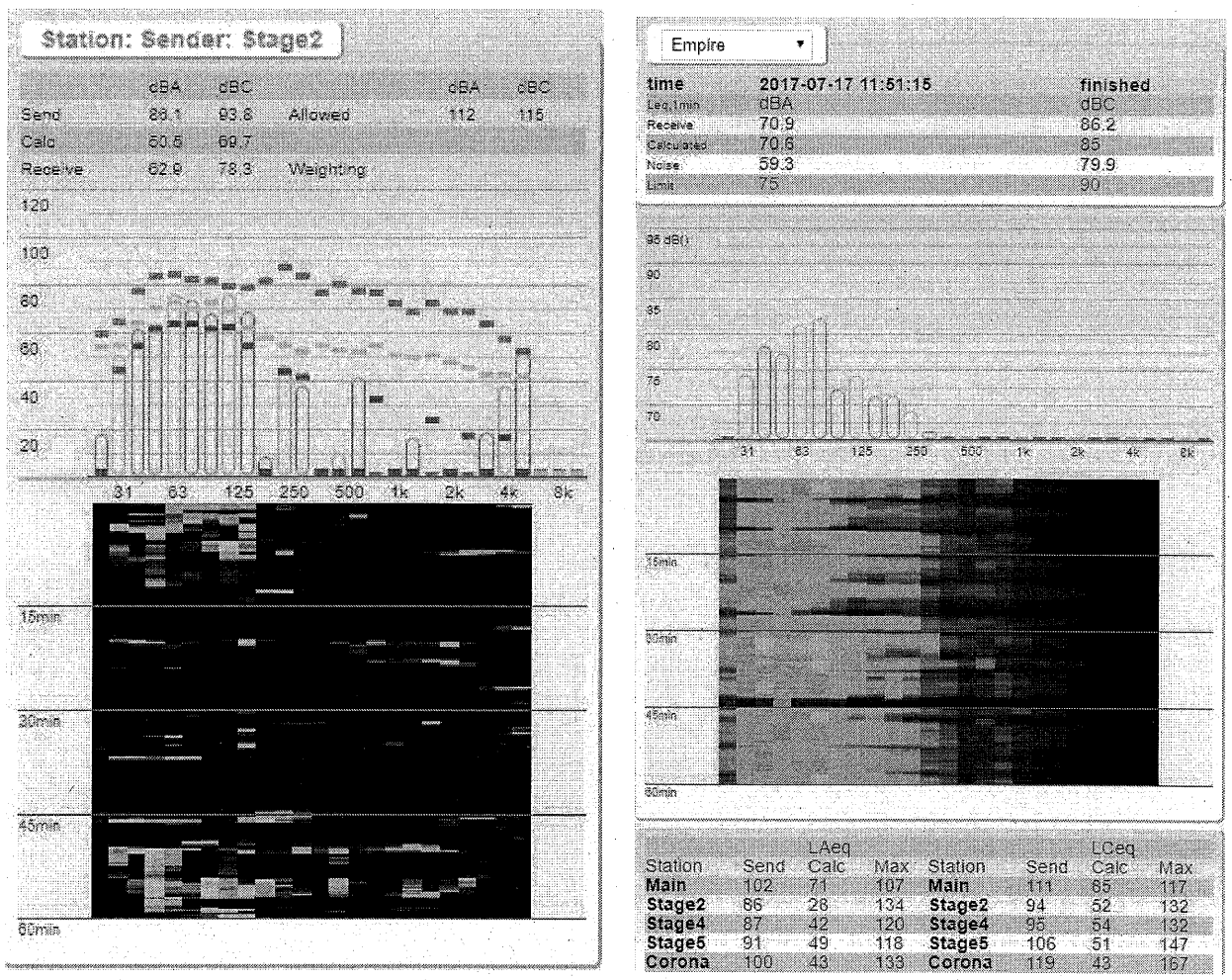


Figure 10 Showing the Metrao Correlator Measuring and Prediction noise off-site



6 SUMMARY

There have been significant changes in legislation, sound system technology, sound management techniques and sound monitoring systems as the demand for 'live' music continues especially as the change in the music industry has meant that artists need to tour to generate revenue. The thirst and demand for live music is only likely to continue and further increase so the development of new technology and management systems will be important in order to assist the balance for the rights of people to enjoy themselves against the rights of people not to be duly disturbed.

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