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ACOUSTIC PREDICTIONS OF HIGH POWER SOUND SYSTEMS. SOFTWARE MODELLING AND VERIFICATION MEASUREMENTS

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1 INTRODUCTION

Computer modelling can be used as a tool to undertake detailed acoustic calculations for concert noise predictions. The accuracy of the results are highly dependent on the data and variables inputted into the modelling software and a thorough understanding of the software is required to correctly decipher the results. The latest computer modelling software has its limitations, however with a few basic assumptions it is believed an accurate model can be created for outdoor noise propagation during concerts. This paper discusses the input variables and verifies the output data with measurements taken during concert events.

2 BACKGROUND

2.1 IMMI modelling software

IMMI is an environmental acoustic, computer modelling software package that carries out calculations in compliance with a number of national and international noise standards. The relevant methodology for this study is ISO 9613-2 (Attenuation of sound during propagation outdoors). IMMI allows the input of digital terrain information and for the input for metrological conditions. The temperature and humidity settings can be controlled in the modelling software.

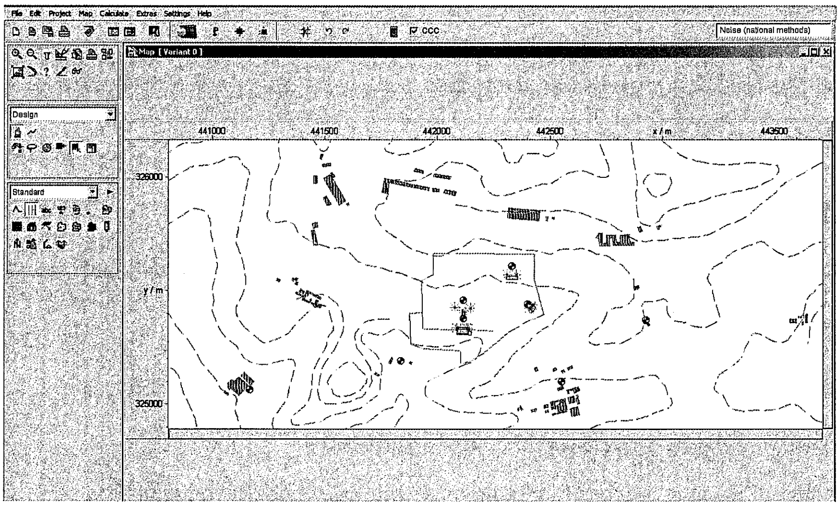


FIGURE 2.1 – IMMI USER INTERFACE

2.2 ISO 9613-2 Attenuation of sound during propagation outdoors: General Method of calculation

ISO 9613-2[1] provides an engineering methodology for the prediction of noise levels in the environment, predicted from sources of known sound emission. The method predicts the sound pressure levels under metrological conditions favourable to propagation from the sources (downwind propagation) in accordance with ISO 1996-2[2].

Calculations at receiver locations are based on the following calculation;

$$L_{ft}(DW) = L_w + D_c - A$$

L_w is the frequency dependent sound power level (dB) produced by the point source.

D_c is the directivity correction (dB) that describes the extents in which the sound pressure level deviates in a specified direction from the level of the omni-directional source.

A is the frequency dependent attenuation (dB) that occurs from the source to the receiver;

$A = A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc}$

A_{div} – Attenuation due to geometrical divergence
A_{atm} – Attenuation due to atmospheric divergence
A_{gr} – Attenuation due to ground effect
A_{bar} – Attenuation due to barrier
A_{misc} – Attenuation due to miscellaneous other effects (foliage, industrial sites etc.)

The calculations and terminology for these attenuation terms can be studied in ISO-9613-2.

2.3 Other software packages

Although IMMI and the model procedure in ISO-9613 are used for the final predictions, it is required that other software packages are used to generate and verify the input data for the model. IMMI is not designed specifically for the modelling of loudspeakers and as shown later cannot be relied on for the near-field model. Many loudspeaker manufactures have produced calculation software for their products and loudspeaker performance can also be verified in Enhanced Acoustic Simulator for Engineers (EASE). These specialist sound system design packages use complex mathematical algorithms to predict the response of a system based on the phase and magnitude response of individual sources. Other software can also be used as an auralisation tool to allow the user to accurately listen to the sound designs.

3 MODELLING PROCEDURE

Vanguardia Consulting has developed a unique technique involving the collaboration of a number of software packages to allow the prediction of environmental noise propagation over a large area for high powered concert systems.

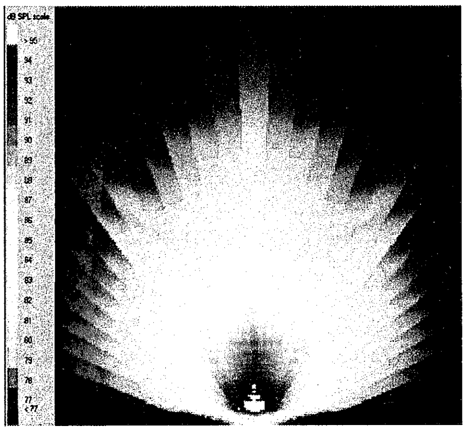
3.1 Point Source Approximation of a Loudspeaker Clusters or Array

3.1.1 Far-field point source propagation of a line array

The acoustic summation of multiple sources has been mathematically understood since the work of Olson in the 1950's. Loudspeaker manufacturers and sound engineers have used the principle of summation of an array of sources to continually increase the sound power levels and control of dispersion available during the history of amplified music. Since the early 1990's the concept of

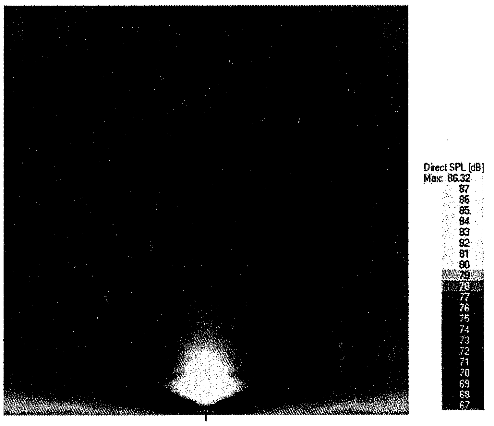
"Line Arrays" has been used to progress the design of systems to cover large distances. These systems differ significantly from a classic acoustic line source due to the fact the individual sources in the array are often highly directional and their directivity changes with frequency, unlike the theoretical omni-directional sources used for line source calculations. An important distinction of line array systems is the ability to produce a single wave form by combining the output of many drive units at higher frequencies. As often believed, a line array does not produce a single cylindrical wavefront. A line array does produce a 3dB with doubling of distance in the near-field, however the distance at which this occurs until is dependent on the length of the array and the frequency. Imagine standing 100m away from the stage, and the 10m line array seems just a relatively small object in the distance as shown in Figure 3.1 below. One of the limitations for calculations in accordance with ISO 9613 (and IMMI) is it only allows computation of a sound source which originates from a point source. Tables 3.2 and 3.3 below show sound pressure levels at increasing distances from a typical 12 cabinet line array in a number of well known acoustic software packages. The results conclude that at a far field position the line array can be approximated as a single point source (6dBA with doubling of distance), beyond a distance of approximately 80m for broadband levels. This distance is significantly less at lower frequencies where the wavelength is large in comparison to the size of the array. To produce line array theory at 50Hz frequencies would require an array size of approximately 70m, which is not practical in most real situations.

FIGURE 3.1 – Line Array at distance photo



Distance from Line Array source (m)	SPL (dBA)	Attenuation (dB) per doubling distance
10	96.4	
20	93.8	-2.6
30	91.9	
40	91	-2.8
50	88.5	
60	87.5	-4.4
70	86	
80	84.9	-6.1
90	84.1	
100	82.7	-5.8
110	82.1	
120	81.6	-5.9
130	81.1	
140	80.2	-5.8
150	79.4	
160	79	-5.9
170	78.7	
180	78.3	-5.8
190	78	
200	77	-5.7

FIGURE 3.2 – Typical 12 box Line array in Soundvision (No Air Absorption)



Distance from Line Array source (m)	SPL (dBA)	Attenuation (dB) per doubling distance
10	96.4	
20	93.5	-3.0
30	90.5	
40	89.2	-4.3
50	87.5	
60	86.0	-4.6
70	84.6	
80	83.3	-5.9
90	82.2	
100	81.2	-6.4
110	80.4	
120	79.7	-6.3
130	79.1	
140	78.5	-6.1
150	78.0	
160	77.5	-5.7
170	77.0	
180	76.4	-5.8
190	75.9	
200	75.2	-6.0

FIGURE 3.3 –Typical 12 box Line array in EASE (including Air Absorption)

3.1.2 Acoustic Centre

The positioning height of the point source has been a subject of detailed discussion. For a loudspeaker cluster situation it is obvious at what height to have the source, however with a line array this becomes more complex. Although it could be argued that the point source should be positioned half-way or 2/3 of the way up (due to the curvature of the array and directivity of individual units), in most situations a worst-case scenario has been modelled in which the point source is set at the height of the top box of the array or cluster. Verification of the results will later substantiate this assumption and alterations for future calculation can be made accordingly on the basis of specific cluster designs.

3.1.3 Directivity

IMMI and ISO-9613 allow the correction for directivity at defined degree intervals. Directivity can be taken from a number of software packages; however it is important that the software supports the complex phase interaction between adjacent cabinets. EASE directivity files are often a function of the distance from the source and this allows accurate prediction at varying distances. The directivity input for IMMI is fixed and an assumption of the distance in which the directivity is taken must be assumed. Cluster or array configurations are built and then used to compute directivity balloons or polar plots at a set distance using a complex summing algorithm. Low frequency sub directivity is discussed separately later.

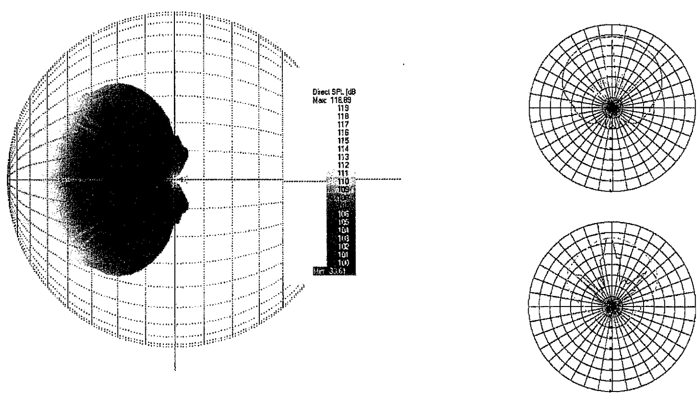


FIGURE 3.4 – Directivity at 4KHz for a typical Line Array.

3.1.4 Equivalent point source sound power

With a line array or loudspeaker cluster there are a number of sources within the configuration, which collectively have an associated sound power level at each octave frequency band. This data can be collected from various professional audio software packages and used as the equivalent point source power level. These levels are defined by those that produce an audio spectrum at the front of house mixer, typical of the event in question. Earlier Vanguardia research has made significant investigation into the typical spectrum for different types of music genre.

3.1.5 Low Frequency sub arrangement

The directivity for low frequency from subwoofer arrangement has a similar number of variables. The spacing, time delay and phase between individual sub bass loudspeaker units can appreciably alter the directivity and coverage, which must be carefully considered when undertaking any modelling exercise. The physical solution is larger due to the order of magnitude of wavelength at low frequency. Again this can be modelled in software using complex summation (although not EASE as this does not support frequencies below 100Hz).

3.2 Audience Area Coverage

It has been shown that the sound system can be approximated as point sources at large distances; however this is not useful for designing audience coverage areas in the near-field. Alternative software is needed to optimise sound coverage for the listener areas. This is often simulated in EASE or manufactures' specific software. The design process requires a balance between audience coverage and environmental impact. This is where the sound design is required to take place to determine cabinet heights/quantities/types, sound power levels and to optimise SPL coverage.

3.3 Stage and Site setup

Site information, ground contours and buildings can be imported into IMMI to provide an accurate representation of the surrounding landscape. The inclusion of site barriers and marquee attenuation can be incorporated into the design to provide specific details, however small or low density objects can be ignored.

4 VERIFICATION

4.1 Events

Computer models have been built and verified for a number of music events throughout 2008 and 2009. This includes a variety of venues, including multi-stage festivals, stadiums and outdoor parks for a diverse line-up from Metallica to Take That.

4.2 Metrological Conditions

To allow the comparison of predicted vs measured results, metrological conditions would ideally be in accordance with BS 7445[4] where selected weather conditions are reproducible and correspond to quite stable sound propagation. Under these metrological conditions an often worst-case scenario can be constructed. The following metrological conditions correspond to enhanced propagation from the source to the receiver.

- Wind speed between 1 and 5m/s
- Wind direction within an angle of +/- 45 degrees of the direction of the dominant sound source, with the wind blowing from the source to the receiver

- No strong temperature inversions near the ground
- No heavy precipitation

During concert and festival events these favourable weather conditions for the propagation of sound are not always experienced. Measurements are often taken at different locations situated around the site under varying conditions or locations set by the local council to meet licence conditions. The orientation to the down-wind direction is included in the summary results to allow comparison

4.3 Measurement Procedure

Simultaneous synchronised 1 minute L_{eq}, sound pressure levels were measured at the on-site front of house mixer position as a reference level and at the receiver location of interest. Weather conditions were recorded and the orientation to the stage or site was noted.

4.4 Results

The results show a summary for a sample of events of the predicted and measured sound levels at each location along with an approximate offset angle to the downwind direction.

Event 1 – Open Stadium

Measurement Location	Total Measurement Period (mm:ss)	Reference FOH L_{Aeq} (dBA)	Orientation to downwind (degrees)	Distance to Receiver (m)	Receiver Measured L_{Aeq} (dBA)	Receiver Predicted L_{Aeq} (dBA)	Difference (dB)
1	57:00	97.7	45-90	150	78.6	79.7	1.1
2	12:00	99.7	135-180	130	71.0	74.7	3.7
3	26:00	99.4	0-45	340	77.2	77.1	0.1

Event 2 – Multi-Stage Festival

Measurement Location	Total Measurement Period (mm:ss)	Reference FOH L_{Aeq} (dBA)	Reference FOH L_{Aeq} (dBA)	Reference FOH L_{Aeq} (dBA)	Orientation to downwind (degrees)	Distance to Receiver (m)	Receiver Measured L_{Aeq} (dBA)	Receiver Predicted L_{Aeq} (dBA)	Difference (dB)
1	32:00	101.0	90.0	97.9	180	1000	50.2	60.6	10.4
2	23:00	100.2	90.2	96.0	45	2300	51.7	52.8	1.1

Event 3 – Outdoor Park

Measurement Location	Total Measurement Period (mm:ss)	Reference FOH L_{Aeq} (dBA)	Orientation to downwind (degrees)	Distance to Receiver (m)	Receiver Measured L_{Aeq} (dBA)	Receiver Predicted L_{Aeq} (dBA)	Difference (dB)
1	15:00	97.2	0	415	75.7	75.2	-0.5
2	06:00	97.5	90	250	71.3	73.5	2.2
3	73:00	99.0	0	425	73.7	74.0	0.3

Event 4 – Outdoor Arena

Measurement Location	Total Measurement Period (mm:ss)	Reference FOH L_{Aeq} (dBA)	Orientation to downwind (degrees)	Distance to Receiver (m)	Receiver Measured L_{Aeq} (dBA)	Receiver Predicted L_{Aeq} (dBA)	Difference (dB)
1	21:00	94.9	45	180	77.7	78.9	1.2
2	10:00	94.7	0	280	73.6	73.7	0.1
3	20:00	94.5	180	85	77.5	74.5	-3.0

5 DISCUSSION

The verification exercise shows a close correlation between measured and predicted noise levels under certain conditions. As the predictions are carried out under favourable metrological conditions the results generate, as expected, an over estimate when outside a 45 degree cone each side of the downwind direction. This over estimation is shown to be exaggerated over longer distances as in Event 2. The findings also demonstrate that the model only holds in the far-field as demonstrated in Event 4, measurement location 3. An under estimate of 3dB is shown in the prediction, even though in the up-wind direction.

6 CONCLUSION

Using a number of varied computer simulations it has been shown that the calculation of a high powered concert loudspeaker system can be accurately modelled. Model predictions show that within the favourable metrological conditions described in 4.2 an accuracy of 2dB(A) can be expected. Where the receiver location happens to be in the up-wind direction of the source the model over predicts by up to 10dB(A) and this effect has been shown to increase with distance.

7 FURTHER WORK

This paper has demonstrated the model procedure and verification for broadband external loudspeaker propagation. Future projects will investigate the specific propagation of low frequency noise in urban and rural developments from high powered sub-bass sound systems.

8 REFERENCES

1. ISO 9613-2: Attenuation of sound during propagation outdoors – Part 2: General Method of calculation (1996)

2. ISO 1996-2: Description, measurement and assessment of environmental noise – Part2: Determination of environmental noise levels

3. IMMI- Noise Prediction user manual, Wolfel Software

4. BS7445-1: Description and measurement of environmental noise, Guide to quantities and procedures (2003)

5. Harry F. Olson. Acoustical Engineering, Professional Audio Journals (1991)