LOW FREQUENCY SOUND FROM OPEN AIR POP CONCERTS

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INTRODUCTION

Guidelines, based on the 'A' weighted sound pressure level, are commonly adopted, in order to assess the degree of annoyance caused by the noise emanating from open air pop concerts. These guidelines, typically allowing a set increase over the background noise level in conjunction with tried and tested control techniques, have been successful in minimising the environmental impact whilst not affecting the enjoyment value of the show [1]. However, as the 'A' weighted sound is now controlled, the propagation of the low frequency sound to distant residential areas has become a significant source of community disturbance. The low frequency sound being perceived as a persistent bass beat, in some cases barely audible and yet disturbing enough to give rise to complaints.

During the monitoring and control of noise from this year's Wembley Stadium pop concerts, measurements of low frequency sound were carried out following the request from the licensee, Wembley Stadium Limited, to investigate this aspect. This paper, a case study of the Wembley shows, presents the results of these measurements in relation to the geographical spread of complaints.

SITE LOCATION

Wembley Stadium, one of the largest sports stadium in the country, is situated in a north western suburb of London. It is surrounded on three sides by commercial and industrial premises. The nearest residential properties are approximately 150 metres to the south of the Stadium across flat ground. On the east side of the Stadium the nearest residences are approximately 350 metres away with commercial premises in between.

The Stadium is oval shaped, approximately 300 metres long and 200 metres wide; its length lies in an east-west direction. The stage and sound system for all concerts were situated at the western end of the Stadium occupying most of the west "stand" and extending on to the pitch area. The speakers were, therefore, directed towards the east.

The wind direction during most of the concerts was westerly varying from south west to north west. Hence with the speakers facing to the east, the weather conditions had the effect of enhancing the propagation eastward of the Stadium. This, together with the fact that the Stadium is near the top of a hill, meant that, on occasions, components of the music could be heard up to 10 kilometres (km) away.

SUMMARY OF THE CONCERTS

Twelve pop concerts were held at Wembley Stadium in an eleven week period from 11 June to 2 September 1988. Most of the concerts lasted approximately four hours with two longer concerts of six and ten hours.

Sound levels at the concerts were strictly monitored with close co-operation between officers of the Local Authority and acoustic consultants acting on behalf of the Stadium authorities. The Equivalent Continuous Sound Levels over 1 minute and 15 minutes (L_{Aeq1} and L_{Aeq15}) were measured throughout each concert at the Sound Engineer's Mixer Control and the L_{Aeq15} was measured at three residential sites near the venue (approximately 150, 350 and 600 metres away). Officers of the Local Authority also responded to complaints received on a "hot line" and carried out observations. The aim of the control exercise was to minimise noise nuisance and keep levels to below 98dB(A) L_{Aeq15} at the Mixer Control. As reported in a previous paper by the authors[2] such active noise control procedures are considered essential to minimise disturbance to neighbours and when successfully applied, complaint levels are significantly reduced.

COMPLAINTS OF NOISE

The number of noise complaints during concerts when the control limits in the stadium were met, were relatively low with less than twenty per concert being reported. The geographical location of the complaints were affected by numerous factors such as the sound level, frequency content, speaker orientation and wind direction [2]. In a majority of cases, given the predominant westerly wind and the sound system positioned in the West end of the Stadium, the complaints were due east of the venue.

A histogram showing the relationship of complaints to distance is shown in Figure 1. As would be expected, the highest number occurred nearest the Stadium, however, a significant number were also recorded from distances more than 5km from the venue.

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For nine of the concerts, the inside sound levels were controlled to the pre-set noise level (typically just below 98dB(A) L_{Aeq15}). In these cases, the number of complaints were low with complaints from distant locations (greater than 5km) being marginally greater than the number recorded nearer to the stadium. Conversely, for the three remaining concerts, when the 98dB(A) limit was exceeded, complaints were high, 80% arising from the local community in close proximity to the venue.

In conclusion, it follows therefore, that when the control limits are met, community disturbance is relatively low even at premises close to the Stadium. In this case, the complaints further from the venue are of greater significance and have warranted further investigation.

SOUND PROPAGATION TO DISTANT RESIDENTIAL AREAS

A simple prediction model has been used to calculate the sound pressure levels (SPL) at various distances from the Stadium, in order to highlight the range of frequencies likely to be at or above the background levels and, hence, be attributed to the cause of noise disturbance. A typical octave band frequency spectrum recorded during the events was used for the source spectrum and the appropriate barrier corrections were made using Maekawa[3] to allow for the attenuation offered by the Stadium facade. Energy loss due to distance and air absorption[4] was calculated for each octave band frequency (63Hz to 4kHz). The results are displayed graphically in Figure 2 and show the predicted sound pressure levels compared with the typical background noise level measured in the local residential area during the evening. A comparison of the predicted levels using this model with the measured levels is considered later.

Figure 2 illustrates the rapid attenuation of high frequency with distance with the 1kHz to 4kHz frequency bands being below the background sound level at 3km. At 5km the 63Hz to 250Hz octave band sound pressure levels are still above or marginally below the background level.

The other higher frequencies are well below the background level (20dB below at 1, 2 and 4kHz) and likely therefore to be inaudible even when affected by positive vector winds of 5m/s giving rise to an increase of the predicted levels of up to +10dB[5]. These predictions enforce the subjective response from complainants and Environmental Health Officers that low frequency sound is the cause of complaints at distances in excess of 5km, and likely to be the cause of complaints at distances of 3km.

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The principle of high frequency noise annoying more than low frequency noise when close to the source, and low frequency noise causing a greater degree of annoyance when far from the source applies well to the Wembley concerts. When the inside control limits are broken the high frequency sound propagates to the nearby areas producing high sound levels from where the majority of complaints arise. Conversely, when the control limits are met, the high frequency sound is reduced but the low frequency sound still propagates to distant areas and thus complaints arise.

MEASUREMENTS

Instrumentation

A small portable FFT analyser was used to monitor the low frequency sound from the concerts. The main practical considerations of using this system were:

i. Aliasing and frequency range
ii. Choice of window and its effect

For (i), aliasing was not a problem due to the signal being a "stationary" type in a fixed frequency band and the analyser incorporating anti-aliasing filters over the frequency range of interest (20 - 200Hz with a sample record length of 512 points).

For (ii), the Hanning Window was used in order to obtain adequate resolution by reducing the generation of side lobes in the frequency spectra of the signal.

Measurement positions

Where possible, the signal from the Stadium was sampled at or near complainants' dwellings or quiet residential areas where complaints had previously been reported. Measurements were also made inside the Stadium, 50m from the main sound system to assess the typical frequency spectra from the music. Sample background frequency spectra were recorded for comparison with the data during the concerts.

SUMMARY OF RESULTS

Over the duration of four concerts, held over a period of four weeks, in excess of fifty frequency spectra were obtained and subsequently analysed. It was noted that some frequency spectra lines (eg. 32,44, 64 and 98Hz) were more prominent than others, with levels ranging from 40 to 100dB (re 2×10^{-5} Pa) depending upon the measurement position. These maximum sound pressure levels at certain frequencies were continuous throughout most of the concert while the artistes were

performing, although they varied within discrete frequency ranges. The results are summarized below and typical spectra recorded at a distance of 3000m from the stadium are shown in Figure 3.

Typical Peak frequency (Hz)	Frequency Range (Hz)
32	30 - 35
44	40 - 48
64	62 - 65
98	97 -100

DISCUSSION OF RESULTS

To test the validity of the measurements, sound level predictions were made at the forementioned peak frequencies. The previously described model was used with the addition of taking account of the effect of the vector wind[5] prevalent during the concerts. A comparison of these data is given below:

Frequency (Hz)	32	44	64	98
Predicted SPL/dB	64	64	53	47
Measured SPL/dB	68	66	54	50
Predicted-measured/dB	-4	-2	-1	-3

Comparisons of the predicted and measured sound pressure levels shows the predictions to be marginally below the measured levels. However, the differences are small and it can be concluded that the low frequency sound generated from the Stadium events was responsible for the low frequency levels recorded at 3000m and beyond.

To start examining the possible ways of reducing the low frequency source levels, investigations were carried out to determine the instruments likely to cause these peak frequencies. Discussions with several concert tour managers and a sound company[6] revealed that more and more low frequency sounds are being generated by electronic devices coupled to either synthesizers or conventional instruments; the limiting factor being the frequency response of the sound system. Even without electronic effects the conventional bass guitar will generate frequencies as low as 41Hz.

Various ways of reducing the effects have been considered, such as narrow band frequency filters or active low frequency attenuators. Both ideas have many implementation problems given the present trend of popular music to use more of these electronic device to generate low frequency sounds which are an integral part of the music.

CONCLUSIONS

When the pre-determined control limits were met within the Stadium, complaints of noise were relatively low. In this case, the number of complaints from distant residential areas were higher than from nearby premises. Conversely, when the control limits were broken, the majority of the complaints arose from areas in close proximity to the Stadium.

Both the predicted and measured sound pressure levels show that complaints from distances around 3km from the Stadium were likely to be due to low frequency except under high positive vector winds. At distances in excess of 5km from the Stadium all complaints would have been due to the low frequency sound even under high vector winds.

Prominent low frequency sound pressure levels measured in distant areas from the source ranged from 30Hz to 100Hz. These levels are likely to have been generated by conventional instruments coupled to electronic devices and synthesizers capable of producing low frequencies limited by the frequency response of the sound system. With the present trend, of musicians making increasing use of these sounds, most forms of control will be difficult to implement.

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FIGURE 1: COMPLAINTS WITH DISTANCE FROM SOURCE
WEMBLEY STADIUM CONCERTS 1988

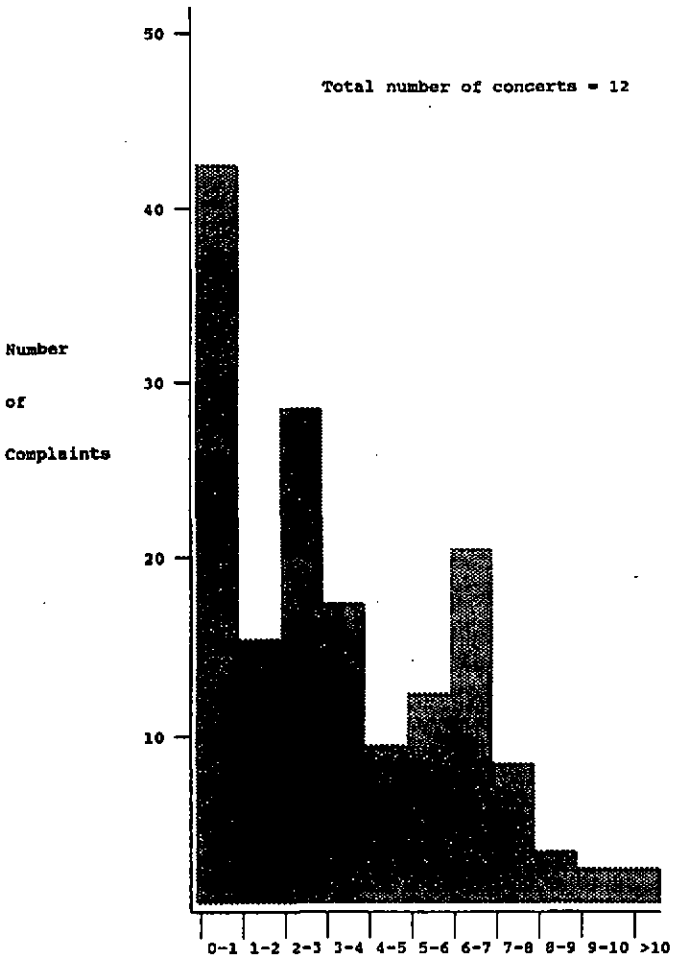

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FIGURE 2: Predicted Sound Pressure Level over Background Noise Level as a Function of Frequency and Distance

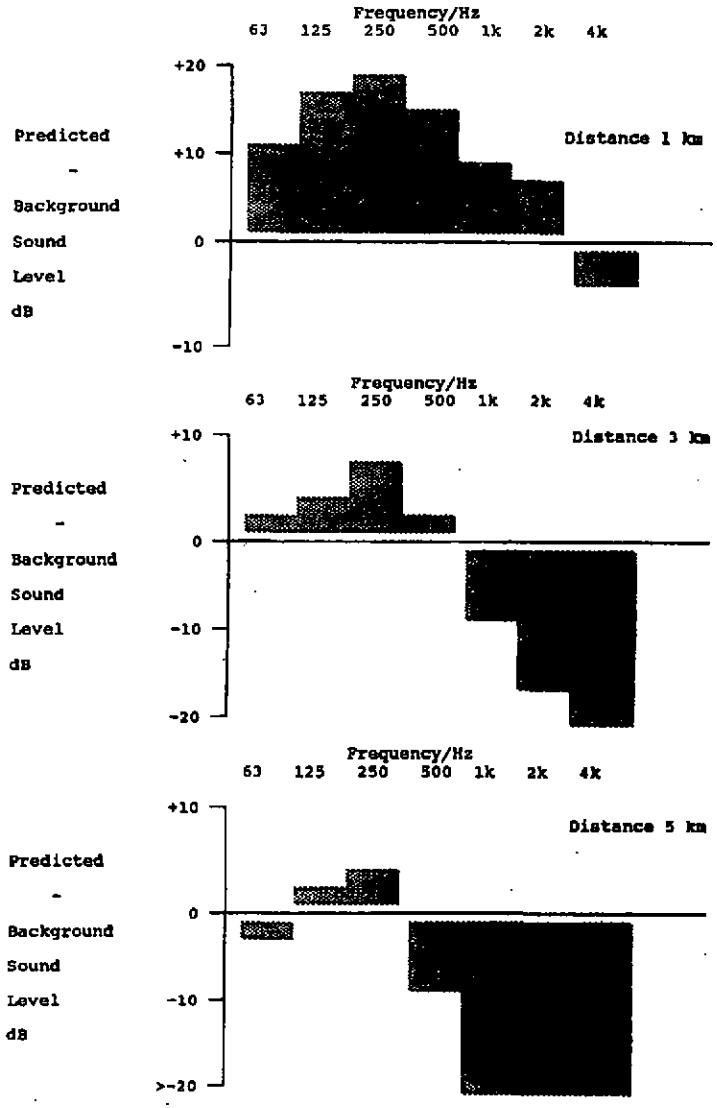

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FIGURE 3: SOME EXAMPLES OF SPECTRA RECORDED 3000 METRES FROM THE STADIUM