MULTI-CHANNEL REVERBERATION AT LIMEHOUSE STUDIOS

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INTRODUCTION

Limehouse Studios was conceived as the biggest independent TV production centre in Britain. The design of two main studios with floor areas of 600 m^2 and 300 m^2 started in 1981. The owners, Limehouse Productions Ltd, wanted the larger studio, Studio 1, to be particularly good for musical performances. Although it was foreseen that it would be used mostly as a general-purpose TV studio, it was required to be the best available TV studio for symphonic music, opera, ballet and musicals.

An immediate conflict arose because it was known that a studio with maximum acoustic absorption was required for most productions (especially those involving the spoken word) while a studio with little absorption was required to satisfy performers of symphonic music and any live audience.

The conventional method of dealing with the problem is to design TV studios with maximum installed absorption. When symphonic or operatic performances are required, the sound engineer adds reverberation electronically so that the ultimate listener is not aware that the performance has taken place in a studio having unsuitable acoustics.

The performers and any listeners in the studio are, however, well aware of the unsympathetic acoustics. Although professional musicians adapt very quickly to a poor acoustic environment it is very unlikely that they can give of their best in a conventional TV studio. The very top-ranking performers who are in a position to dictate their working conditions refuse to perform in certain concert halls and recording studios which they consider to be unsatisfactory. Conventional TV studios are inevitably considered unsatisfactory by such performers.

VARIABLE ACOUSTICS

A possible solution to the conflicting acoustical requirements was to provide means of varying the effective acoustic absorption of the studio. This could be done:

(a) mechanically, using shutters, blinds or louvres

and/or

(b) electroacoustically.

The degree of variability required, the merits and drawbacks of both methods, and the practicability of using them in the proposed studio were examined.

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DEGREE OF VARIATION DESIRABLE

Dead condition

A dead acoustic has traditionally been required for most TV studio uses because audible reflections from the walls and ceiling conflict with what the viewer expects from the scene shown by the camera. Thus for most TV studio purposes it is desirable to install the maximum possible absorption. This minimizes reflections from the walls and ceiling, permitting the maximum microphone-subject distances.

In a studio, the level of reverberant sound (which arises from the totality of reflections) depends on the total absorption present. However, the deadness of a room is not generally judged by the total absorption but by a related quantity, the reverberation time (RT), which depends also on the volume of the room, (about 6,500 m^3 for Studio 1).

For drama, a low RT has been a traditional requirement. The improvement in directionality of microphones over the past twenty years or so led to the question whether it was still necessary to maintain these low values or whether some relaxation was possible. Common sense would suggest that very low RTs are not really necessary, especially as the acoustics of most drama scenes are dominated by scenery flats which act as substantial sound reflectors. Support for this view was indicated by examples of programmes which originate from areas which can hardly be very dead: the glass-walled foyer of Birmingham's Pebble Mill complex is an obvious example.

Initially it was assumed that a relaxation to 1.2 s would be acceptable for general-purpose use. Calculations indicated that an increase to about 2.0 s could then be achieved. However subsequent discussions suggested that some sound engineers would not find any relaxation very acceptable. This is illustrated by the examples of Studios 3 and 4 at the BBC's Television Centre. Although of equal volume (about 11,000 m^3), Studio 3 was commissioned with an RT of 0.78 seconds while Studio 4 had an RT of 1.1 seconds. Subsequently, users decided that the higher RT of Studio 4 was of no material advantage and the RT has now been reduced to match Studio 3. One reason given for maintaining a low RT is the greater usage of wider angle shots. These generally require increased microphone-subject distances which result in lower ratios of direct sound to reverberant sound and direct sound to background noise. Thus it was considered that an RT of 0.7 seconds was the appropriate design target in the dead condition.

Live condition

The preferred reverberation time for listening and performance depends on the type of music, eg:

Chamber music	1.4 - 1.6 s
Opera	1.2 - 1.6 s
Brahms symphony	2.1 s
Requiem Mass	2.5 - 4.0 s

No variable-acoustic system seems capable of providing an RT greater than about 2 seconds in a room of about 6,500 m^3. Thus, a reasonable target for the maximum RT was 2.0 seconds. This would exclude good acoustics for only a narrow range of music, ie, large-scale romantic works having a large orchestra, choir and/or organ.

VARIATIONS ATTAINABLE IN PRACTICE

Mechanical systems
Because of obvious limitations for a TV studio, variation in surface absorption is restricted mainly to the walls and, to a lesser extent, the ceiling. Calculations, and practical experience with radio studios, suggested that the mid-frequency RT could be varied by a factor of about 1.6. This is an over-simplification because the ratio of RTs attainable depends on the range of values chosen. The lowest RT depends on the maximum area of absorbent that it is practicable to install, which itself depends on the areas of walls and ceiling used for other purposes. The maximum RT is limited by the absorption of the people present in the studio and, at high frequencies, by the absorption of the air in the studio.

Taking the provisional target for the dead condition of 0.7 seconds, a factor of 1.6 would allow an increase to 1.1 seconds. This was well short of the target for the live condition, and barely adequate for operatic performances.

Electroacoustical systems
Of the several electroacoustic systems on the market, it was concluded that the Multi-channel Reverberation System invented by Franssen [1] was most likely to satisfy the requirements of Limehouse. The reasons for this are given below.

It appeared that the ratio of R.T.'s attainable would be about 1.6, i.e. the same variation achievable with a mechanical system.

Combined systems
Neither the mechanical nor the electroacoustic systems alone would provide the desirable full range of RTs, ie 0.7 to 2.0 s, a ratio of about 2.9. If both systems were installed, a ratio of about 2.6 could be achieved, eg, 0.7 s to 1.8 s, quite close to the desired range. Cost limitations precluded such a solution.

The decision to choose the MCR system rather than a mechanical system was based partly on the estimated cost and partly on the time it would take to develop and install a satisfactory mechanical system. The lower range of RT variation was accepted.

REASONS FOR CHOOSING THE MCR SYSTEM

There were several reasons for choosing the MCR system rather than one of the alternative electroacoustic systems. We had listened to demonstrations of the system in a small theatre in Eindhoven with an orchestra, solo trumpeter and solo pianist. It was clear that this installation created a useful change of acoustic environment and was free of unpleasant characteristics. We had also heard the system in a radio studio in Baden-Baden, which had a volume similar to that of Studio 1, Limehouse. A very important factor in favour of the MCR system was that the positions of the microphones and loudspeakers could be decided well in advance of installation since adjustments at the commissioning stage are only electronic in nature. Thus the microphones could be positioned to avoid conflict with the numerous motorized lighting hoists.

VARIATIONS OTHER THAN RT

While good acoustics depend strongly on the average RT it was recognized that there are many other factors which contribute. Subjectively important factors include the volume of the sound, definition and tonal quality. Objective factors which are believed to be important are the variation of reverberation time with frequency, low interaural coherence and high early lateral energy. If there is sufficient freedom of choice in loudspeaker and microphone placement, an MCR system should be capable of improving most of these factors. In particular, the increase in loudness may well be more important than the increase in reverberation time.

An important requirement for an orchestra is the presence of adequate short-term reflections directing energy from one part of the orchestra to another; without these reflections it is difficult to achieve a good ensemble and the correct internal balance. Restrictions on the placement of loudspeakers in a TV studio meant that we could not rely on the MCR system to provide these. However, panels to provide these acoustic reflections need not be very large and could probably be provided by the scenery workshop if and when required.

DESIGN PROBLEMS

Two particular difficulties were foreseen in designing the system for Limehouse:

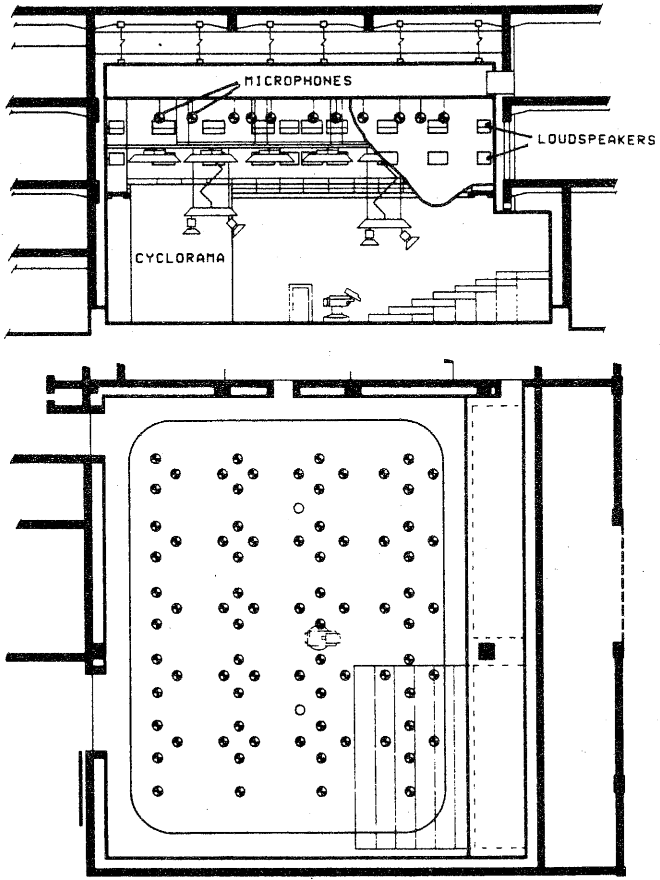
1. The cyclorama cloth would prevent the installation of loudspeakers at a height below 7.5 m.

2. The theory of the MCR system is based on the existence of a diffuse sound field. At first sight, it seemed that this condition would not be met in the studio, a rectangular box with highly reflective floor and very absorbent walls and ceiling.

SPECIFICATION

The MCR system proposed for Limehouse was similar to the modern developments of Franssen's ideas described in the recent literature [2,3]. Seventy-nine channels each consisting of an omnidirectional microphone, pre-amplifier, filters, power amplifier and loudspeaker form the essential part of the system, the transducers being placed as shown in Figure 1. The electronic equipment is housed in three racks outside the studio. Two additional microphones monitor the sound level. If it exceeds 111db the amplifier gains are reduced temporarily to prevent distortion. Control of RT is via a 9-position switch on a handheld controller from the studio floor or via an over-riding control panel on the mixing desk in the sound control room.

In specifying the performance of the system attention was focused on four aspects, namely reverberation time increase, sound power increase, power handling and noise level.



Dimensions of studio (average)
l=25m w=23m h=12m
V=6560 cu m S=2570 sq m

Figure 1. Studio 1, Limehouse

At the time of ordering the system, the natural reverberation time of the studio was unknown. A table of possible reverberation times was prepared to allow for this unknown factor (Table 1).

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Table 1. Specification of reverberation times

Octave bands:		125 Hz - 2000 Hz		4000 Hz	
$\bar{a}$	T(0)	T79(1)	T79(2)	T79(1)	T79(2)
0.30	1.16	1.7	1.95	1.55	1.7
0.35	0.96	1.4	1.6	1.25	1.4
0.40	0.81	1.15	1.3	1.05	1.15
0.45	0.69	0.95	1.05	0.85	0.95
0.50	0.59	0.8	0.9	0.7	0.8

$\bar{a}$ = average absorption coefficient of the room surfaces (Eyring formula)
T(0) = RT with MCR system switched off
T79(1) = RT with MCR system switched on and no colouration of any sound
T79(2) = RT with MCR system switched on and no serious colouration of music

The sound power level increase was specified as 2.1 dB in any octave band between 125 Hz and 4000 Hz except where the system was required to produce a reverberation time/frequency characteristic differing from the natural characteristic.

The maximum sound level of the MCR system was to be 91 dB (long-term average), with limiting at sound level peaks exceeding 107 dB SPL.

The noise level introduced by the system proved difficult to specify. The supplier was prepared to say that the self-noise of the MCR system alone was 21 dB $\pm$2 dB SPL (unweighted) and that for microphones in the diffuse sound field the system noise level would be raised by 2.1 dB with the system switched to full gain. However, the noise from other sources, such as ventilation inlets would also be amplified by the system and was outside his control.

Electrical noise induced from thyristor-controlled lighting cables was recognized as a possible problem. This was guarded against by the use of star-quad microphone cable.

FINAL TESTS

After a very careful commissioning period, the system was tested objectively. The results of reverberation time measurements are shown in Figure 2. For these tests there were no sets in the studio.

All the other objective requirements of the specification were satisfied, although it must be admitted that an accurate measure of the sound power gain was impracticable.

Subjectively, colouration attributable to the system was satisfactorily low on voice and surprisingly acceptable on handclaps even at the maximum setting (corresponding to T 79(2) of Table 1).

Thus, concern about lack of diffusion appeared to be unfounded. No doubt the large amount of equipment for lighting, seating, etc, helped to improve the diffusion.

The high position of the loudspeakers does not appear to be a problem; although the reverberant sound appears to be elevated, this is not an unusual occurrence in tall studios.

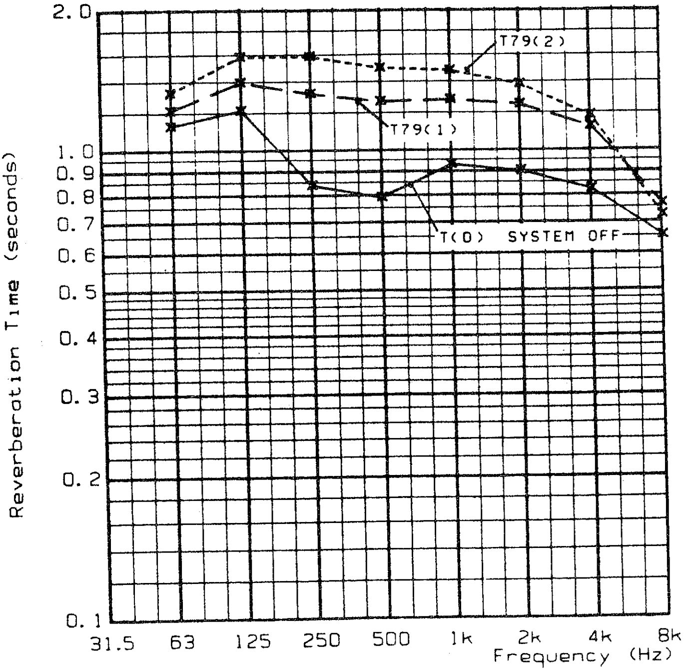

Figure 2. Reverberation times for specified settings. Empty studio

EXPERIENCE OF USERS

Limehouse Productions Ltd have found the system to be very satisfactory indeed. Although the system is capable only of part of the variation that was originally thought desirable, the users feel no need for anything greater. Musicians including operatic singers have expressed their appreciation of the system and, rather surprisingly, the system is often used for dramatic productions.

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REFERENCES

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