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TIME/INTENSITY TRADING IN STEREOPHONY

A R McKenzie & I H Flindell

Institute of Sound & Vibration Research, The University, Highfield, Southampton, SO9 5NH

1. INTRODUCTION

1.1 Stereophonic Sound

Stereophonic sound was originally invented in the 1930s as a method of increasing the realism of reproduced sound by allowing the listener to identify the apparent location of individual instruments or voices, and to form a better impression of the acoustics of the recording space (Blumlein (1933), Keller (1981)). The programme material is reproduced through a pair of spaced loudspeakers in such a way as to create the illusion of a continuous sound stage between them.

The stereophonic illusion exploits a number of the mechanisms used in natural hearing, whereby the brain can detect the lateral direction of a sound source from differences in amplitude, phase, and time of arrival of the sound at the two ears. In conventional stereophony, amplitude and phase differences are produced by the interaction of the signals from both loudspeakers as they arrive at each ear. Steady state signals can be reproduced at the two ears exactly as if they had come from a real source located between the two loudspeakers, but the situation with respect to transient signals is far more complex. In general, the between-the-loudspeaker virtual images resulting from correctly reproduced steady state signals appear to determine the acceptability of the stereo image, despite the possibility of conflicting sensory cues arising from the reproduction of programme transient content.

1.2 Off-centre Listening

The listener must be positioned equidistant from the two loudspeakers for the separate signals to combine correctly at his two ears. This is not a significant problem for a single listener but there are obvious difficulties where a number of listeners needs to be catered for simultaneously. In off-centre listening, the sound from the nearer loudspeaker is not only louder, but its signals are received earlier at the ears. Clark et al (1958) considered this factor briefly in terms of the location of pure tones, but it is the precedence effect (Haas (1951), Wallach et al (1949)) which presents the greatest difficulty.

1.3 The Precedence Effect

The precedence effect describes the psychoacoustic phenomena whereby the listener localises on the source direction of the first arriving sound. Subsequent arrivals of the same sound from different directions merely reinforce the initial impression, without betraying their different origin. The evolutionary value of the precedence effect is probably that it assisted in communication and source localisation in complex acoustical environments such as inhabited by troglodytes. The main problem with the precedence effect is that it can lead to the stereophonic image collapsing into the near loudspeaker in the case of off-centre listening, and thus destroying the illusion of a continuous sound stage between the loudspeakers.

The effect is not well documented for stereophonic programme material. Most experiments have been based around re-centralising a monophonic image which has been shifted by delaying one channel. In addition, continuous low frequency sounds, and continuous high frequency sounds are affected differently. For low frequency continuous sounds, the ears are able to analyse the phase information in order to determine the apparent direction of a virtual image between the loudspeakers. Phase information becomes ambiguous at higher frequencies and amplitude differences at the two ears take over. Transients can produce ambiguous localisation effects when reproduced by stereophony. Although continuous tones are fairly rare for normal music sources, the balance between transient and continuous sounds affects the results of these time/intensity trading experiments and leads to some interesting anomalies. For instance, Wallach et al (1949) reported that for off-centre listening to a (presumably monophonic) recording of an orchestra, the sound seemed to be located closer to the more distant loudspeaker, whereas a scratch on the record seemed to be located in the near one.

1.4 Time/Intensity Trading

Time/intensity trading describes the way in which the effects of time differences between the arrival of signals from the two loudspeakers can be offset by increasing the amplitude of the delayed signal in order to attempt to overcome the precedence effect. Of particular interest are the studies of Brittain & Leakey (1956), Enock (1964) and more recently Davis (1987) who have all applied amplitude compensation to offset the near-loudspeaker image collapse caused by off-centre stereophonic listening. The results of such studies have been specifications for loudspeakers which compensate for time of arrival differences with directivity controlled amplitude differences, for different angular positions in the listening area.

Despite claims of relative success for these systems, there are two factors which appear to have been largely overlooked. First, almost all the published data for time/intensity trading relationships has been based on experiments using speech or pulsed noise and tones. The most common stereophonic programme material is music, which generally comprises a mix of many different kinds of transient and continuous signals. Second, previous time/intensity trading experiments appear to have been carried out without using stereophonic programme material. The effects of optimum amplitude compensation on the fusion, spread and stability of the virtual images produced by off-centre stereophonic listening have not previously been reported in the literature.

1.5 Aims of Research

A psychoacoustic study was carried out to establish the optimum amplitude compensation required to offset the near loudspeaker image collapse caused by off-centre stereophonic listening. This included an assessment of the ability of the technique to restore an effective stereo illusion as present for central or 'hot-spot' listening.

2. EXPERIMENTAL DESIGN

2.1 Experimental Parameters

Stereophonic and monophonic programme material was presented over a pair of loudspeakers with the left loudspeaker signal delayed by various amounts. Listeners were required to alter the amplitude between left and right loudspeakers to obtain the optimum sound balance. When values of amplitude offset had been obtained for all programme items for all delay times, listeners were able to compare the sound from amplitude compensated time delay with the original stereo sound and with the time delay condition.

2.2 Programme material

Programme material consisted of three recordings available on compact disc and three recordings especially made for this study:-

1.	The Lazarus Heart (popular)	-	Sting (from CD "Nothing Like the Sun")

2.	Easy Money (female vocal)	-	Rickie Lee Jones (from CD Rickie Lee Jones)
3.	Schone Ida (chamber music)	-	Bella Musica de Vienne (from CD Vienne Danses 1850)
4.	Human Voice	-	Monophonic speech recorded in Studio 2, Surrey University Music Department
5.	Hi-Hat	-	Monophonic sampled hi-hat sound taken from Akai S900 sampler song-writer package
6.	Strings	-	Monophonic sampled low frequency string sound taken from Akai S900 sampler noise gated to create slow attack and release envelope to ensure no transient information was included.

Careful attention was paid to programme material consistency to avoid significant changes in the relative proportions of transient and steady state content over the sample durations. The first two selections had to be edited slightly to ensure that this was the case.

The compact disc recordings were copied from a Marantz CD75II compact disc player onto a Sony DTC 1000 DAT recorder and the other three recordings were made straight onto the DAT format.

2.3 Time Delays

Each programme item was reproduced with the left channel delayed relative to the right by 0, 0.5, 1, 2, 4 & 6 milliseconds using a Yamaha SPX900 Professional Multi-Effector Processor which was controlled via a Midi interface installed on an Opus PCII Personal Computer. The undelayed signal was passed through a second processor to ensure matched sound quality for both channels.

2.4 Balance Control

The controller bias inherent in the method-of-adjustment experimental paradigm was avoided by using two buttons (increase volume to the left, and increase volume to the right) on a control box. The buttons gave no position feedback to the listener as to how far he had physically adjusted the balance between the loudspeakers. The control box was connected to the PC which in turn controlled an IHR Two Channel Digitally Controlled Attenuator. The attenuator was programmed to maintain constant energy at the listener position to avoid changes in overall loudness of the combined signal from the two loudspeakers. The constant energy summing rule is generally appropriate for constant overall loudness, except where there are significant coherent components in the left and right channels when a constant pressure summing rule may be more appropriate (or some compromise rule between the two).

2.5 Presentation Method

The experiment was carried out in a small anechoic room and then repeated in a simulated living room at the Institute of Sound and Vibration Research, University of Southampton. Listeners were seated equidistant from a pair of Kef C35 co-incident source loudspeakers mounted on rigid stands with the two loudspeakers and the listener forming the three corners of an equilateral triangle. The loudspeakers were driven by a Quad 306 power amplifier from the outputs of the digitally controlled attenuator. Listeners were able to adjust the balance between left and right channels by pressing an "L" and and "R" button on the control box. A block diagram of the equipment used is shown in Figure 1.

2.6 Listeners
Six male listeners were used for this experiment, all of whom had some experience in listening to and assessing the quality of sound presentation systems and methods. This number of listeners was not considered sufficient to obtain results which are truly representative of the entire adult population but it is adequate to obtain information on specific effects.

3. EXPERIMENTAL METHOD

3.1 Time/intensity Trading
Each programme was played without time delay as a reference condition to establish a baseline for subsequent judgments. The listener was then asked to adjust the balance between the left and right channels to obtain the optimum sound balance for each of the delay conditions.

Programme items and delay times were presented in such a way that each listener adjusted the balance for each of the six delay times for each programme item before moving onto the next. The order of presentation of programme items and the order of presentation of time delays were balanced so that each delay time followed every other delay time once and only once and so that the order of presentation of delay times was different for each listener. The order of presentation of programme items was also different for each listener, each programme item following every other programme item once and once only over the duration of the experiment. This procedure was adopted to reduce order effects as far as possible.

3.2 Subjective Assessment
Listeners were instructed that they should switch between the three buttons to compare true stereo presentation, amplitude compensated time delay as set by the listener in the first part of the experiment and time delay only. They were asked to rate the sound of the amplitude compensated channel in terms of the precision with which they could identify the various stereo images, the uniformity of the way the sound was spread between the two loudspeakers and their overall preference, given that the true stereo condition scored 10 and the time delay condition scored 0. They were also told that they could select ratings above 10 or below 0 if appropriate.

This was carried out for each of the six programme items for a delay time of 1mS; this being the shortest time delay for which localisation on the time advanced loudspeaker has been reported in the literature and lateralisation studies using headphone presentation have shown that fusion becomes weaker as time delay is increased (e.g. Harris (1960)).

RESULTS AND ANALYSIS

4.1 Amplitude Compensation
The results of the amplitude compensation experiment are shown as a mean over listeners for the anechoic and real room conditions in Figures 2 & 3 respectively. It is clear that the results are very different for the different programme items. Under anechoic conditions, the results for items 2, 4 and 5 are all very similar. This is possibly because attention is focused on the singer for item 2, rendering it similar to the voice of item 4. Item 5 is virtually a pure transient and the results obviously reflect the transient nature of the human voice. It is not clear why this similarity between items is not reflected in the results from the listening room. The results for item 6 are very similar for anechoic and listening room conditions. The abrupt downward turn in the amplitude compensation function is brought about by the phase information generated by the time delay ceasing to indicate which channel is leading and

which is lagging in the absence of any other time of arrival information. The results for item 3 confirm the observations of Wallach et al under both conditions who found that orchestral music was located nearer to the distant loudspeaker for off-centre listening. Item 1, a highly produced popular music recording, shows little difference between the anechoic and listening room conditions.

It is interesting that the result for OmS time delay is negative for all programme items. It is considered that this is an experimental artefact caused by all programme items being biased to the right side by the time delay effect. Listeners hearing an untreated condition as a check and not recognising it as such are apt to bias it to the right as well. Preliminary calibrations confirmed that the sounds were presented to the listener with no left/right bias relative to the original recordings.

4.2 Subjective Ratings

The results of the subjective ratings of image clarity, spread of sound and overall preference are shown as a mean over listeners for the time delayed amplitude compensated condition in Figures 4 and 5 (anechoic and listening room respectively). The greatest success for amplitude compensation is for item 1, the popular music recording as heard in the listening room. This item does not depend on pin-point stereo image location but rather relies on an overall spread of sound between the channels, generated by time related electronic processing at the recording stage. Hence it is a much easier matter to re-spread the image using amplitude compensation. Item 3, the chamber music, benefited least from amplitude compensation under anechoic conditions. In the listening room, however, a reasonable degree of success was achieved. The worst results were obtained for stereo image in the listening room for items 5 and 6, the hi-hat and the low frequency strings. This is because these two programme items are very precise single images, both heavily dependent on time cues for their localisation. As soon as the time cues become distorted, no amount of amplitude compensation can restore the original image and an image which is smeared between the loudspeakers results. It is not clear, however, why this was more evident in the listening room than the anechoic room.

Correlations were carried out between subjective ratings of stereo imagery and spread of sound between the loudspeakers with overall preference. Results shown in Table 1 show to what extent stereo image and spread of sound are important to listeners when forming their overall preference for the sound in each listening condition and for each programme item. Results are not conclusive due to the small number of listeners used but general trends are for imagery to be considered more important in the anechoic room and for overall spread of sound to be more important in the listening room. It is interesting to note that both imagery and spread of sound are better correlated with overall preference in the anechoic room than in the listening room overall. This may indicate that there is some other factor tied in with overall preference which is more apparent in a real listening situation. The other interesting point is the negative correlation between imagery and overall preference for programme item 6 in the listening room. It is possible that the nature of the programme material in this instance made for a better sound when it had a less well defined image and that the semi-reverberant conditions in the listening room augmented this effect.

4.3 Implications for Loudspeaker Design

The results of the amplitude compensation experiment can be expressed in terms of the loudspeaker directivity required to achieve the optimum amplitude difference between the loudspeakers to compensate for off-centre stereophonic listening.

As discussed in the Introduction, and assuming no significant colouration due to loudspeaker directivity, the main effects of off-centre listening are greater amplitude and earlier arrival of sound from the nearer loudspeaker. Compensation for the lower amplitude from the further loudspeaker by manipulation of the directivity function is relatively straightforward and the required characteristic, based on -6dB per doubling of distance and a constant energy for constant loudness summing rule as the listener moves in a line parallel to the loudspeakers, is shown in Figure 6. The plots extend from -30 to +19 degrees in order to cover listening positions from opposite one loudspeaker to opposite the other (see Figure 7). No directivity information is specified for angles outside these limits since this is of more important for room reflections which are not considered here.

Amplitude compensation for time delays from the further loudspeaker is more complicated since it depends on a number of different factors. Firstly, the amount of compensation depends on the programme material as reported in the literature and confirmed by results obtained in this study. Secondly, for a continuous tone, it depends on the fundamental frequency of that tone (see the results for Item 6). Thirdly, the amount of time delay, and hence amplitude compensation, depends not only on the angle of the listener to the loudspeaker, but also on the distance from the loudspeakers. This is because the time delay depends on the absolute path difference between the loudspeakers rather than the ratio of the path differences as for the amplitude difference. It implies that, in practice, the required directivity of the loudspeaker only applies for a given listening arrangement.

The required directivity, as determined by the experiments reported here are shown for two sample programme items (Item 6 - anechoic, Item 5 - listening room) in Figures 8 and 9 for an inter-loudspeaker difference, a, of 2.5 metres and listening positions on a line 2.16 metres from the line of the loudspeakers. Thus, listening at the hot-spot is at 2.5 metres from each loudspeaker. The compensation for amplitude difference as well as time delay effects are both included in these two plots. As for Figure 7, the plots extend from -30 to +19 degrees. The inclusion of time delay effects causes the required directivity to roll-off at a rate which is dependent, to a large extent, on the programme material and, as discussed above, the distance a. It is also dependent on the way the signals from the two loudspeakers are required to add together at the listening position. For the purposes of the directivity plots drawn up here, a condition of constant energy along the line of listening positions was specified. If this were not required, however, the directivity plots would be different again.

5. DISUSSION AND CONCLUSIONS

The results of the time/intensity trading experiment indicate the amplitude difference between the two channels required to offset the early arrivals of sound from the nearest loudspeaker for off-centre stereo listening. The data clearly separates the different programme material and it is possible to make broad groupings of the data according to sound type.

The ratings of the improvements obtainable from amplitude compensation for time of arrival differences were judged to be as good as the original stereo programme material in terms of spread of sound for item 1 in the listening room. Results were not so encouraging for other programme items, although there were some significant improvements.

The correlations between stereo imagery and spread of sound between the loudspeakers with overall preference indicates that spread of sound is almost as important as stereo imagery, and sometimes more so, when listeners form an overall impression of the stereo sound.

The required loudspeaker directivities shown for items 5 and 6 indicate the type of directional characteristic that is required from a design intended to produce compensation for off-centre listening. Clearly, a variable directivity loudspeaker design is required which is able to alter its characteristic from compensation for amplitude difference only (Figure 6) to the extreme condition (item 5 - listening room) represented by Figure 8. The most important issue to consider, however, is what form these directional characteristics should take outside the angle of -30 to +19 degrees, as that will determine the way energy from the loudspeakers excites the early reflections in a real listening room.

TABLE 1 - Correlation Between Image and Spread of Sound with Overall Preference

Stimulus	Listening Condition			
	Anechoic		Listening Room	
	Im	Sp	Im	Sp
1	.7692	.9528	.9542	.7896
2	.9632	.8363	.9751	.3326
3	.9372	.7090	.8236	.7072
4	.3770	.0364	.9773	.7333
5	.9567	.8430	.1151	.5387
6	.9089	.5900	-.1720	.4695
Overall	.9100	.8029	.7137	.7395

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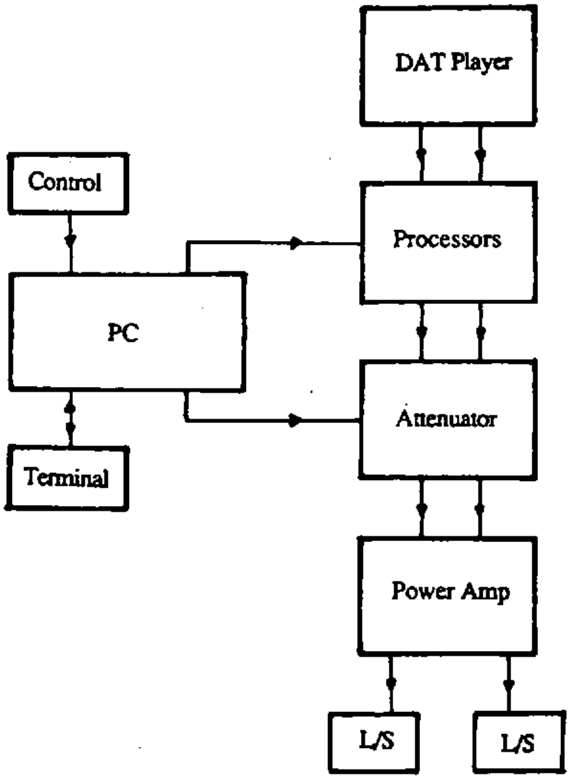
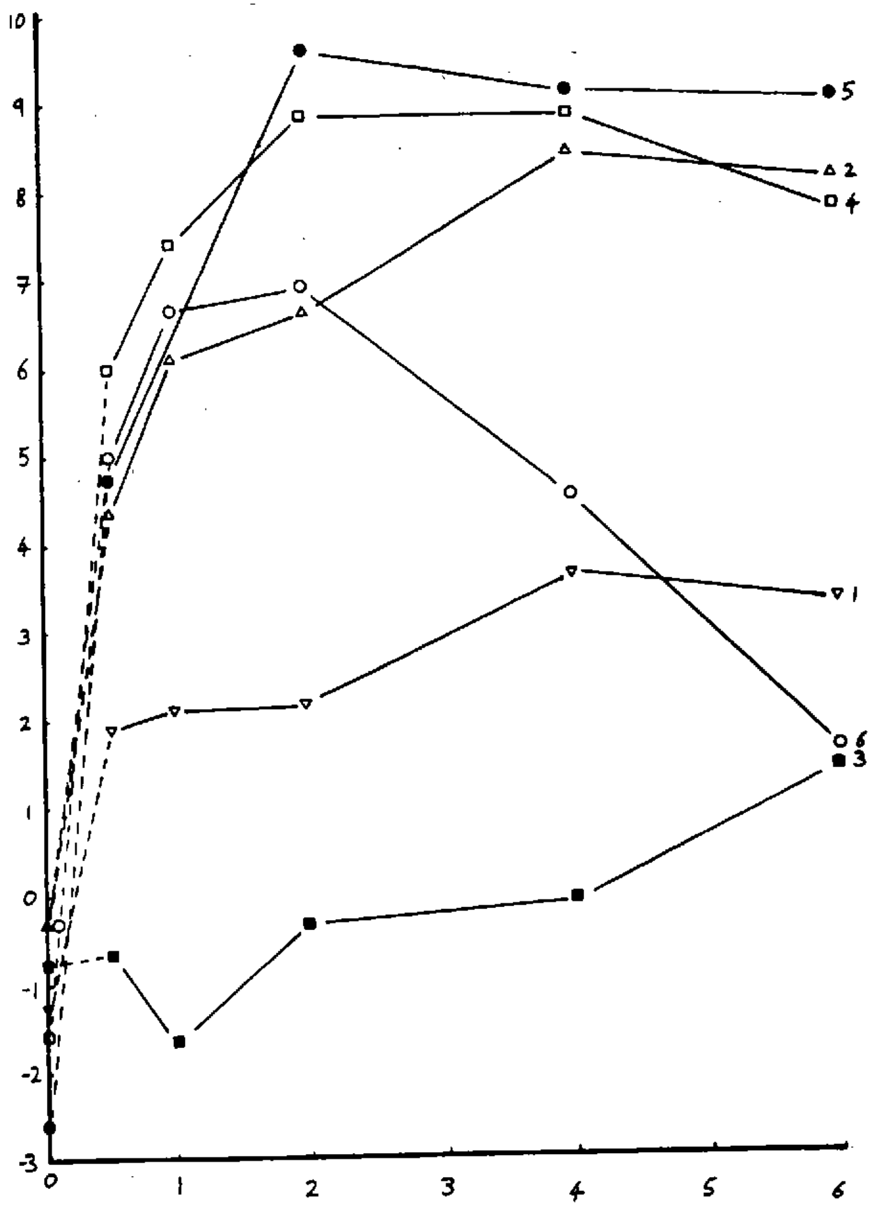


Figure 1 - Block Diagram of Equipment

Amplitude Difference (dB)



Time Delay (mS)

Figure 2 - Time/Intensity Trading
Anechoic Room

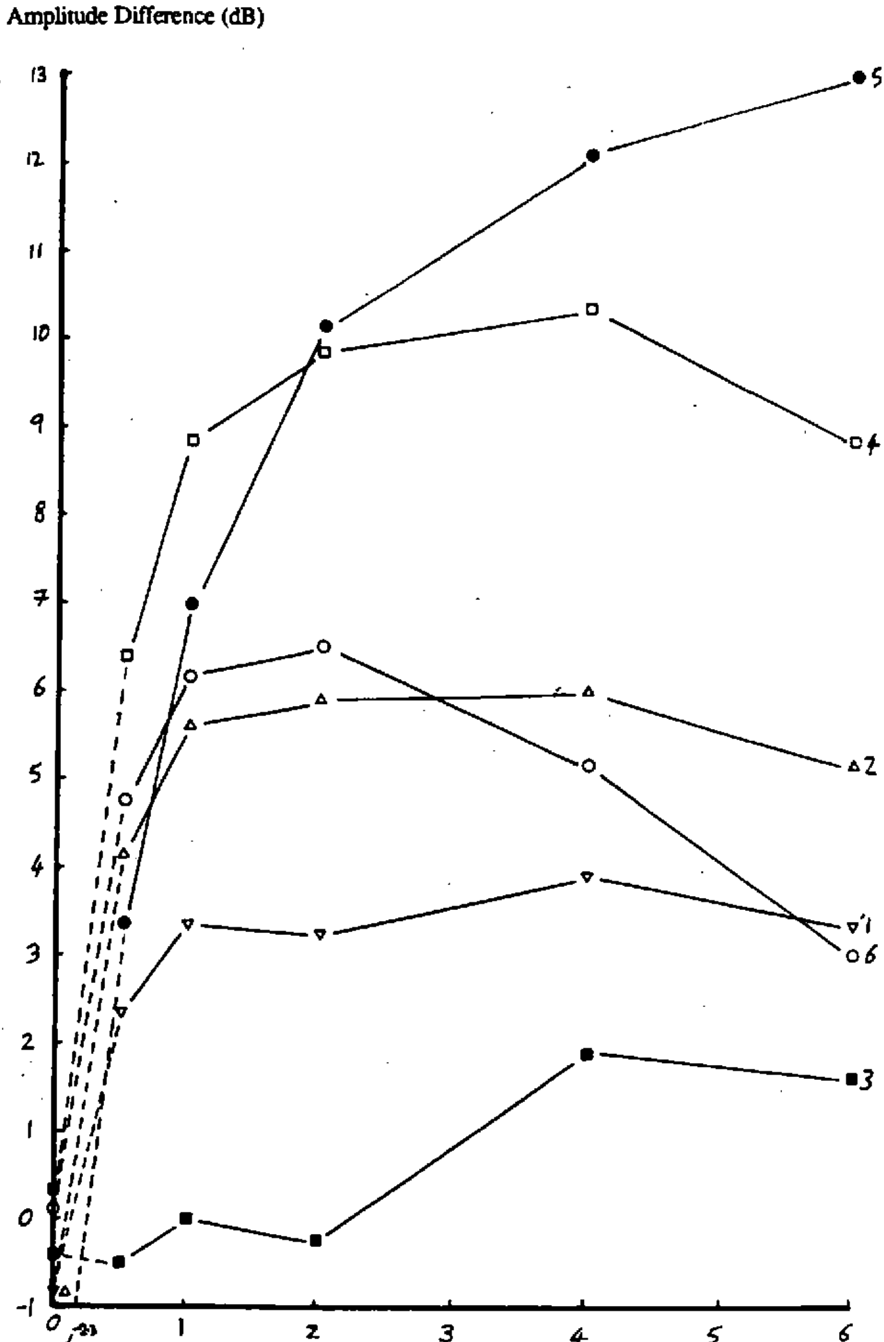


Figure 3 - Time/Intensity Trading
Listening Room

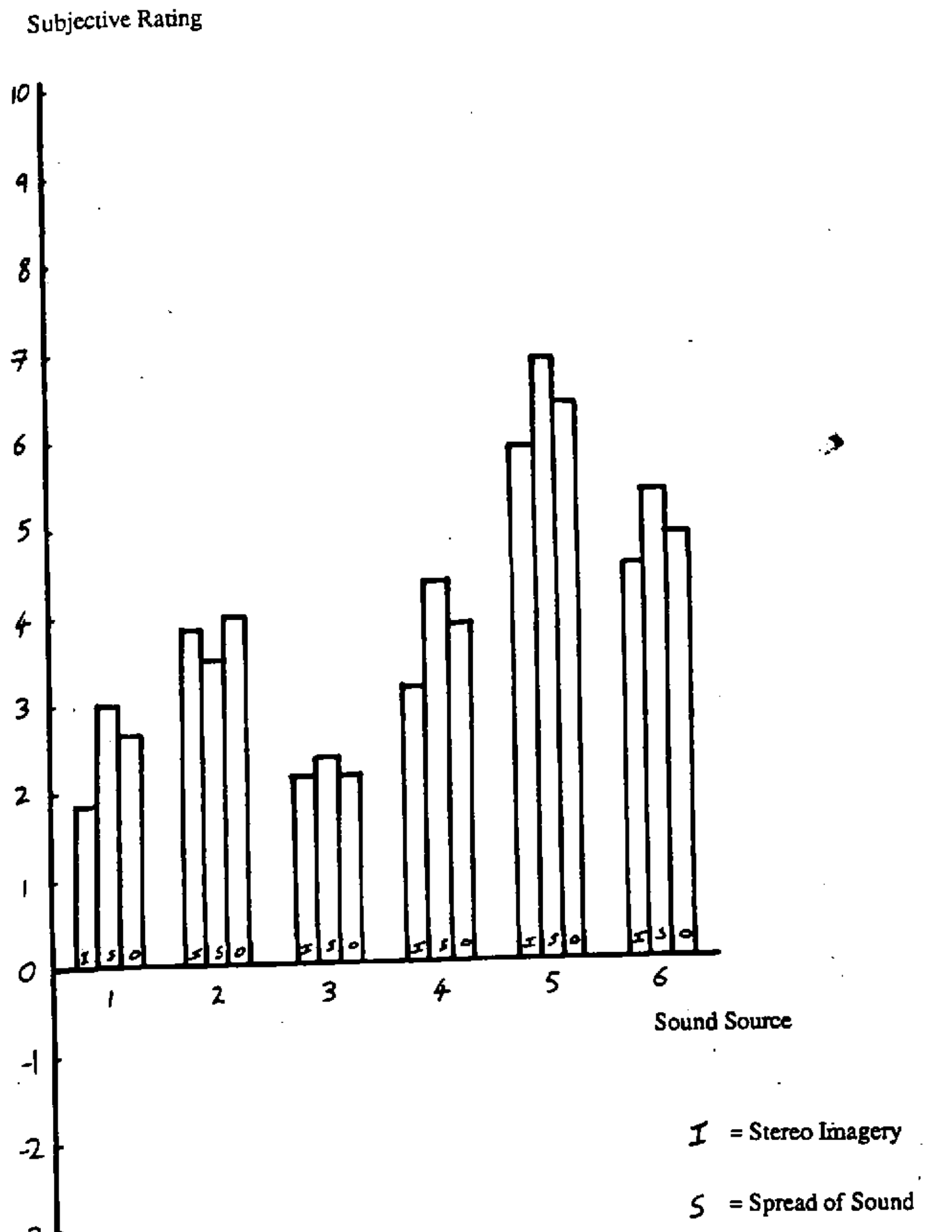


Figure 4 - Subjective Ratings
Anechoic Room

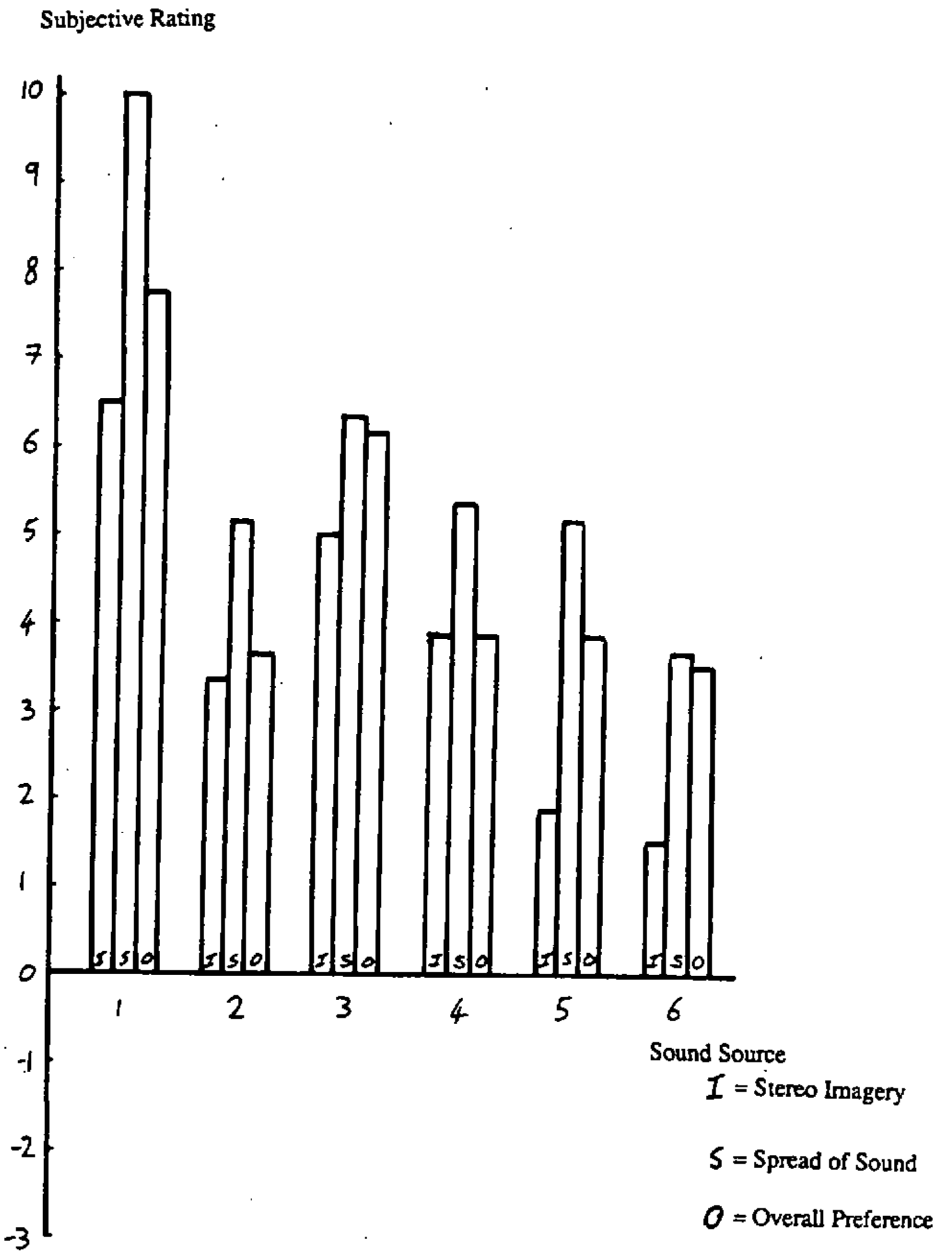


Figure 5 - Subjective Ratings
Listening Room

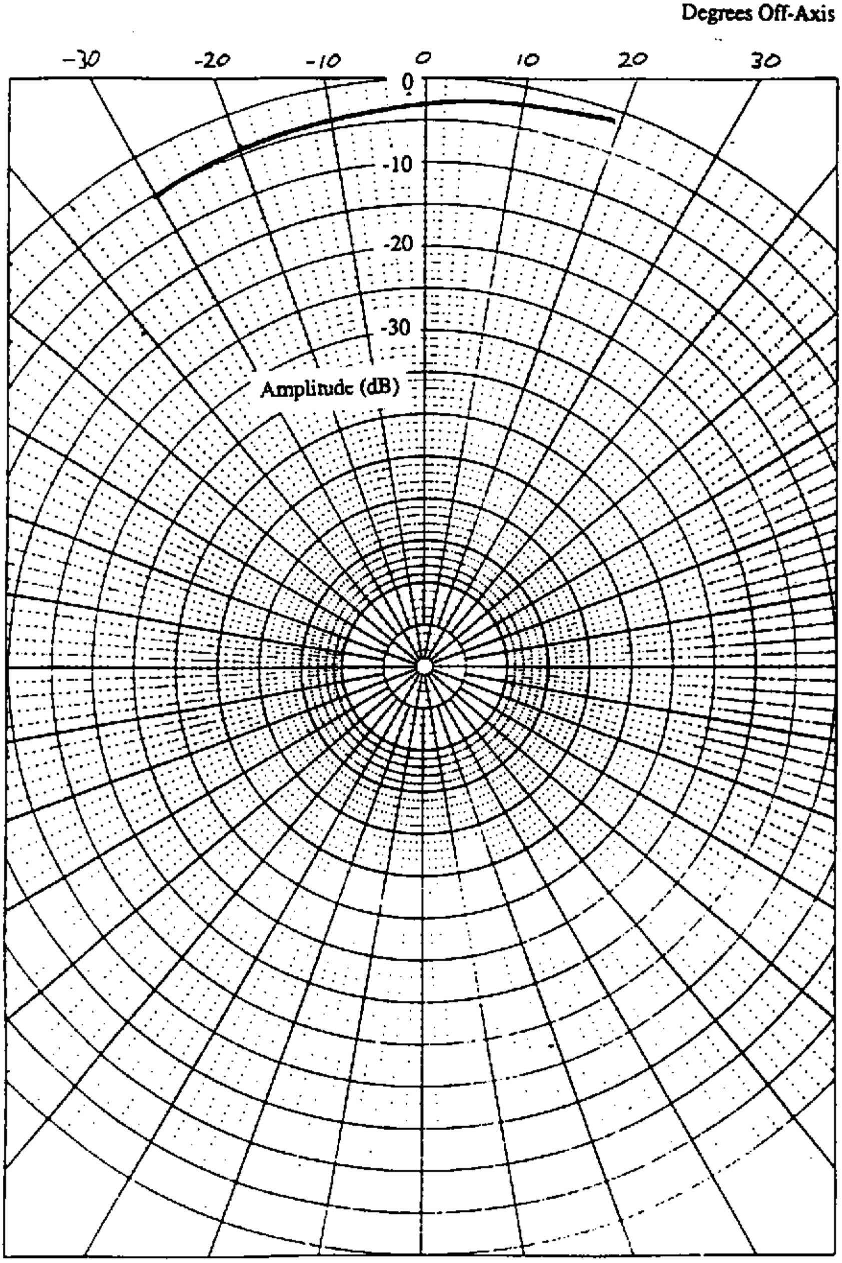


Figure 6 - Required Loudspeaker Directivity
Compensation for Amplitude Difference Only

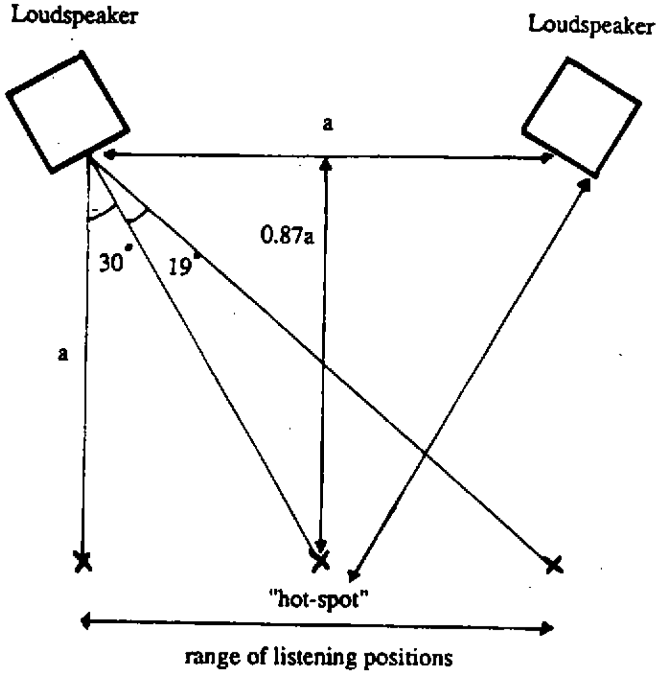


Figure 7 - Plan of Loudspeaker/Listener Arrangements for Directivity Plots

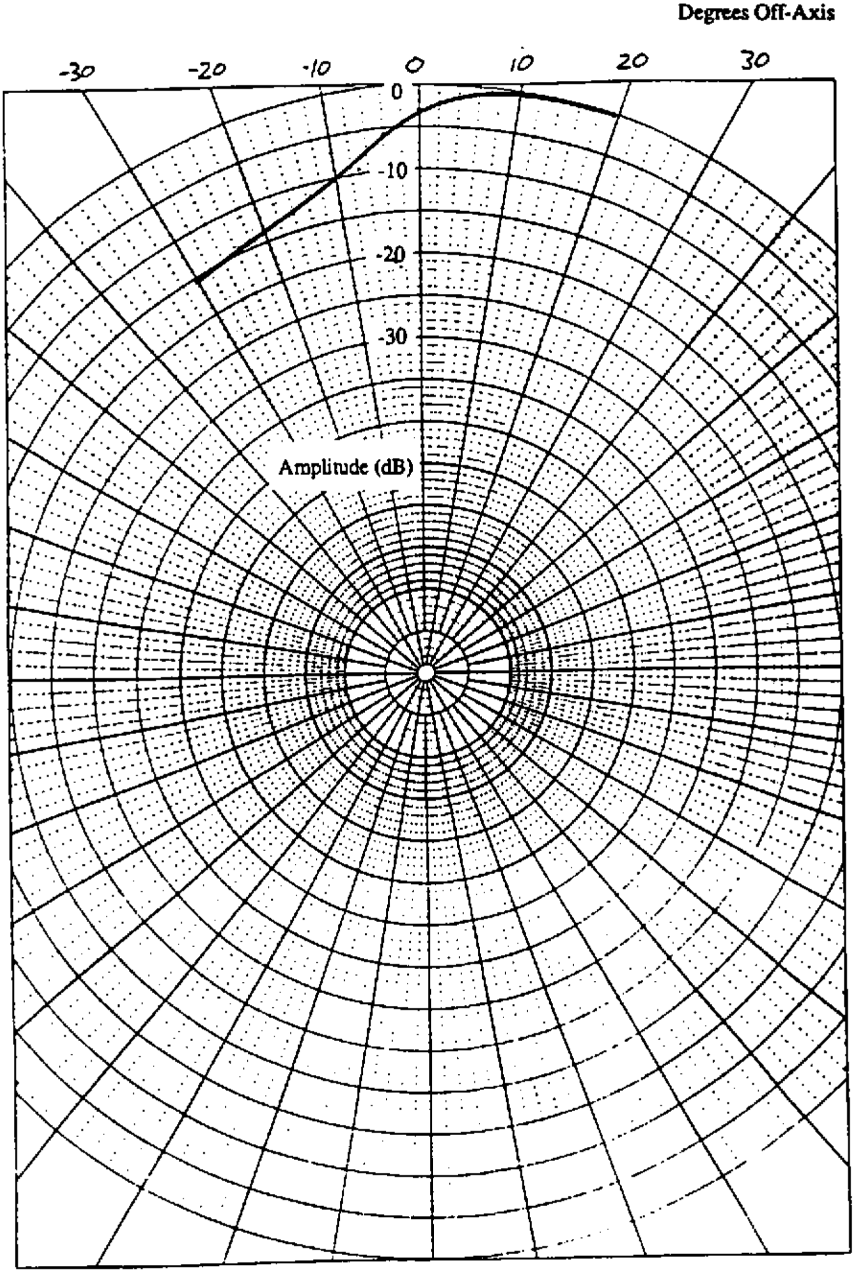


Figure 8 - Required Loudspeaker Directivity
Source 5 (Listening Room)

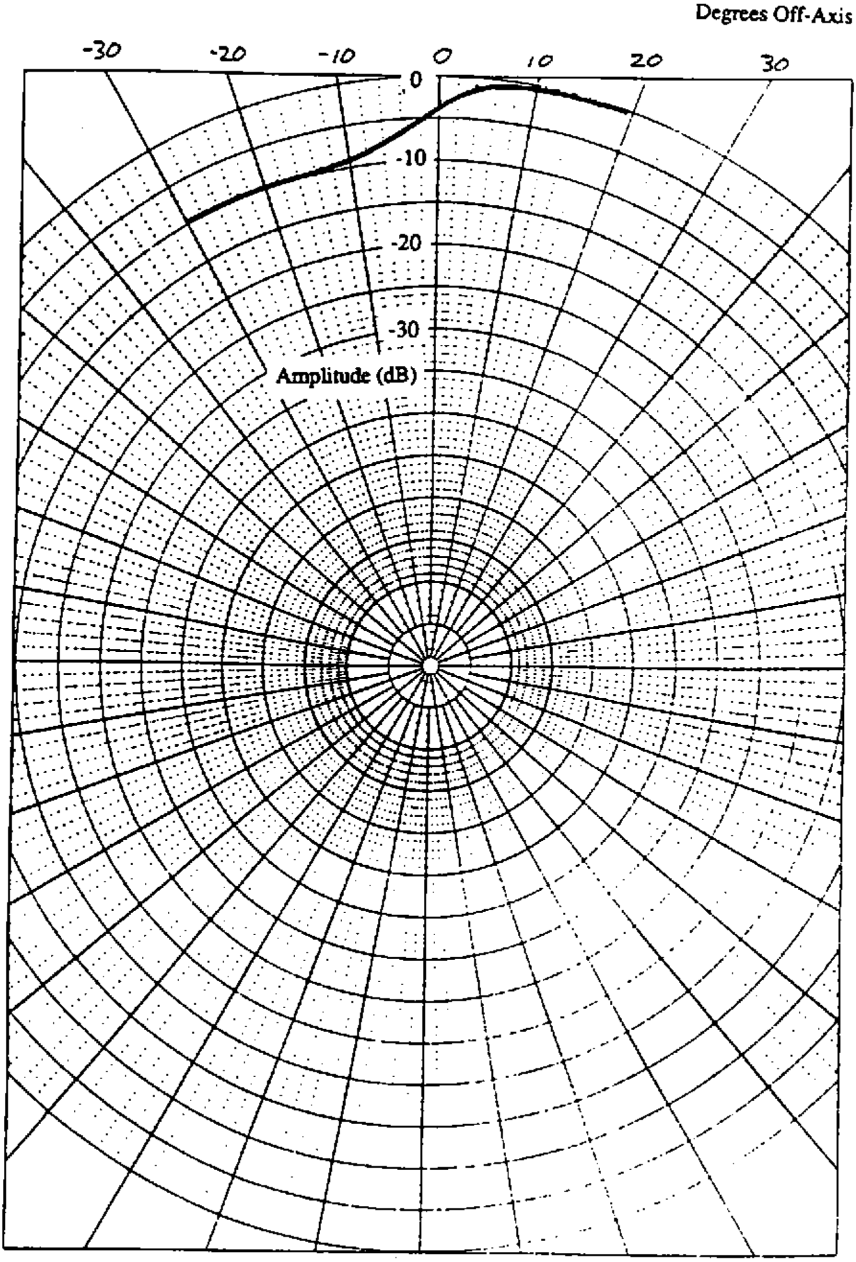


Figure 9 - Required Loudspeaker Directivity
Source 6 (Anechoic Room)

RECORDING AND MIXING STUDIOS FOR DIALOGUE, MUSIC AND SOUND EFFECTS IN MONO AND STEREO.

Courtenay Nicholas

This paper details the acoustics and construction of a Recording and Mixing Studio facility in London.
The client owns a 4 storey building in Soho, which is a steel framed structure with glazed and brick walls. The property was originally designed as a light industrial factory unit and consequently has reasonable floor loadings. There are currently 3 dubbing theatres in the building, the first of which is in the basement. The studio detailed in this paper was constructed on the 2nd floor and represents the forth studio/dubbing theatre for this client.

The clients requirements for his studio can be summarised as follows:-

1. High acoustic isolation.

2. Studios with as large a floor area as possible.

3. As much headroom as possible, to help overcome the psychological effects of large floor areas with high aspect ratios.

4. The ability to work from either in studio video projectors, or external film projector.

5. Very low internal noise levels, so that voice work, foley effects etc. may be undertaken in the studio.

6. Full air-conditioning.

7. High aesthetic quality.

8. Separate voice booth with visual contact, and high values of acoustic separations.

9. Second Voice Booth, which could operate totally independent of the studio with different programmes and materials, to an adjacent control area.

The above requirements may be easily satisfied in a site outside London, but in Soho with limited floor areas and restricted heights, this can be a major problem.

The solution to the acoustic isolation was :-

1. To seal all glazed windows (these could not be removed or blocked up).

2. To construct a decoration facade with mineral wool behind to the cavity.

3. To block up behind the decorative facade with heavy density concrete block.

4. Structurally decoupled the studio by 28mm of foamed closed cell neoprene, and mineral wool slabs.

5. High performance prefabricated studio construction. (The studio walls and roof, were constructed from prefabricated steel panels with mineral wool, and gyproc infill. The floor constructed from twin layers of 18mm timber with a laminated steel infill).

6. The outer barrier wall to the offices were constructed along stud partition principles, with double gyproc to each side. All cavities were filled with acoustic absorption. For the main studio and its associated voice booth, twin wall isolation was deemed to satisfy. Whereas for the separate voice booth, a three wall system was employed

AIR-CONDITIONING

Being an existing building with a slab to slab height of 3.16m, which was further reduced by a crisscross matrix of beams at 2.675m, meant that every millimetre had to be utilised. Ducts could not be accepted within the studio for reasons of height and aesthetics. Therefore a plenumed cavity installation with many air tight compartments was employed. This had the advantage of allowing air, to circulate around the beams, and other obstacles with a minimum of space. The air-conditioning plant airhandler, was mounted externally to the studio with acoustically lined boxes, and secondary silencers to the supply plenums. From the supply plenums the air entered the studio through ventilation panels, which silences the air, as it passes along an acoustic labyrinth incorporated in the depth of the panel.
A cross flow ventilation pattern was established by allowing the air to enter, and exit the studio through special perimeter recessed interstice that also provided feature lighting. The design level for the ventilation system was NC15.

STEREO RECORDING AND MIXING STUDIOS

ACOUSTICS

With studios having such a high aspect ratio, and with the hindsight of previous experience. Proprietary acoustic ceilings were done away with, as they were found to be the cause of many early and other unwanted reflections. To overcome these problems and meet the high aesthetic requirements of the ceiling a stretched fabric of tented configuration was introduced. This in conjunction with the fabric finished walls, and carpeted floors, produced a very low and flat reverberation time.

As the studios were aimed towards future trends with stereo television and surround sound with Dolby SVA. Surround soundspeakers were introduced and mounted at high levels in the studio side walls, and behind the mixer. The radiation patterns of the speakers were selected, and positioned with angles that ensured an even spread of sound over the critical monitoring/listening areas.

To aid stereo imaging the studio layout was carefully considered, and all surfaces that could give unwanted reflections were either angled or absorption covered.

All speakers were hidden behind the fabric finishes, so as to help with stereo imaging, unfortunately, due to space and no acoustically transparent projector screens being available the central loudspeakers had to be mounted below the screen.

WAREHOUSE STUDIO ACOUSTICS

K.A.Rose

Acoustic Architect.
BBC Architectural and Civil Engineering Department, London

In 1987 the BBC decided for totally differing reasons to convert two warehouses, one at Elstree and the other at Liverpool, into studio facilities.

The first of these at Elstree was originally a paint store, currently derelict, but was considered ideal by the programme-makers for conversion into a permanent indoor set for the "Allo Allo" comedy series. This requirement was brought about by the need to produce at least 26 episodes over the winter of 1987/88, on the basis of recording one episode a week, and the previous open-air set in Norfolk was considered to be unsuitable for winter filming.

At this point the BBC Architectural and Civil Engineering Department were called in and presented with the task of making the area suitable for a permanent set with all the necessary lighting, ventilation and acoustic treatment, but with only four months to complete the venture.

Structural and acoustic surveys were carried out in July when it was found that the building structure was unsuitable for supporting anything substantial from it as the walls, albeit 225 mm thick, stopped at the eaves level with the gable end walls above this level and the pitched roof only being covered with corrugated cement sheets. In addition to this the derelict warehouse was adjacent to a large staff car park with low flying light aircraft passing over at regular intervals.

The internal floor area of the warehouse is 34.08 m x 27.8 m with a height of 5.2 m to the eaves and 8.2 m to the ridge. Approx 6350 m^3 volume with an average reverberation time of 3.31 seconds over the range 250 Hz to 4000 Hz.

The BBC engineers decided that the best solution to the high loading plus long spans required was to opt for one of the structures designed for the North Sea oil rigs for protection against weather. This provided a lightweight structure which was erected in under two weeks.

A 50 mm thick acoustic blanket, made up from 105 kg/m^3 density mineral wool, reinforced with chicken wire and covered both sides with glass fibre fabric, was fixed to the framework. This treatment proved to be extremely efficient mainly due to the vertical scaffolding structure being a metre thick with a 1.2m fire track being required all round the perimeter of the studio, thus providing a 2.2 m airspace behind the blanket. The blanket was also draped on wires on top of the roof trusses. This produced a measured reverberation time of around 0.5 seconds in the empty studio shell which livened up when the "market square" appeared. This set helped marginally to reduce the noise levels from external sources but even so it was necessary to take a number of programme retakes as car or aircraft noise became audible (fortunately not too often during normal working hours).

Despite the shortcomings of the studio from a noise/sound insulation point of view the sound supervisor pronounced the area as extremely satisfactory for this type of light entertainment programme.

The second studio at Liverpool is situated in one of the former dockside warehouses at the Brunswick Business Park where the BBC leased two warehouse units from the Mersyside Development Corporation. The BBC allocated 557 m^2 of the total 1997 m^2 floor area to a permanent TV Studio with flexible seating for an audience of 150 and the remainder for dressing rooms, workshops, make-up etc and scenery handling areas.

But the main feature is that apart from some rigging, most technical facilities, like scanners and VT equipment, are driven into the warehouse adjacent to the studio and used to provide control room facilities for the studio.

This warehouse studio was constructed in a far more substantial manner than the Elstree studio with solid masonry walls all the way up to the pitched roof. The roof itself had been replaced with a sandwich aluminium decking roof with the fibreglass infill providing sufficient damping to prevent rain noise being heard in the studio. The old warehouse timber roof trusses were originally designed to carry large loads and were currently underloaded with the lightweight roof. Therefore the local authority engineers were only too happy to see additional loads applied to the trusses in the form of lights, acoustic treatment etc.

External noise sources were far quieter than at Elstree with road traffic noise screened by internal storage areas leaving only noises from the waterfront as the one problem area.

Again the 50 mm acoustic blanket was used, supported off a vertical scaffolding with a significant airspace of at least 1 m behind the blanket and also from the underside of the roof trusses supporting the pitched roof. Here the blanket was supported on wires with a maximum airspace behind the blanket of 7 m to the underside of the ridge. The blanket in front of the walls is protected from damage by a cyclorama spaced approximately 1 metre in front of it.

The structural dimensions of the studio area are 22.45 m x 27.57 m with a height varying from 6.5 m to 13.5 m giving an approximate volume of 6300 m^3. The measured average reverberation time with audience seating and a studio set is 0.4 seconds over the frequency range 250 Hz to 4000 Hz.

CONCLUSIONS

Warehouse studios can never be designed to the same standard as traditional TV studios or be used for the same variety of programmes. However they do have a place in the broadcasting chain for light entertainment or audience shows where the background noise levels are not so critical.

Points to remember:

(i) Choose a site that is away from noise.

(ii) External roof must be suitably damped to reduce rain noise.

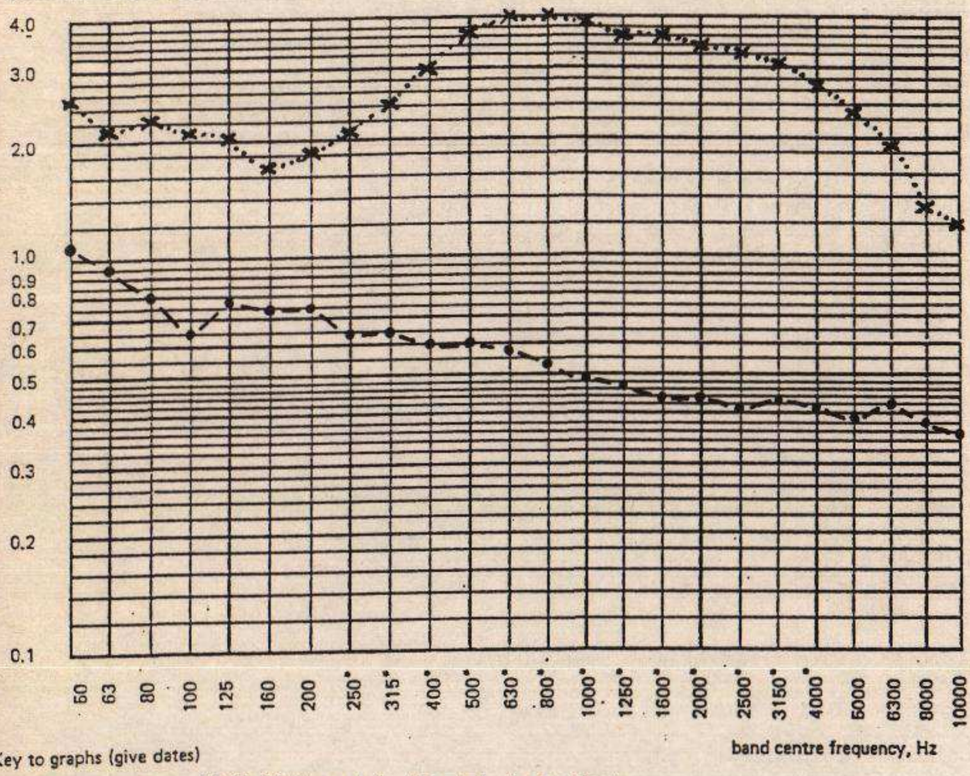
(iii) The use of an acoustic blanket can reduce the internal reverberation time to an acceptable level provided that a significant airspace is provided behind the blanket.

(iv) The blanket must be protected from damage.

(v) The blanket should be covered with a cyclorama where the acoustic treatment is in shot i.e. behind an audience.

(vi) Programme re-takes must be budgeted for.

BBC ARCHITECTURAL AND CIVIL ENGINEERING DEPT. **A**



Key to graphs (give dates)

●———● 27.9.89 Acoustic blanket installed.

×— — —× 24.7.87 Prior to treatment being installed.

△———△

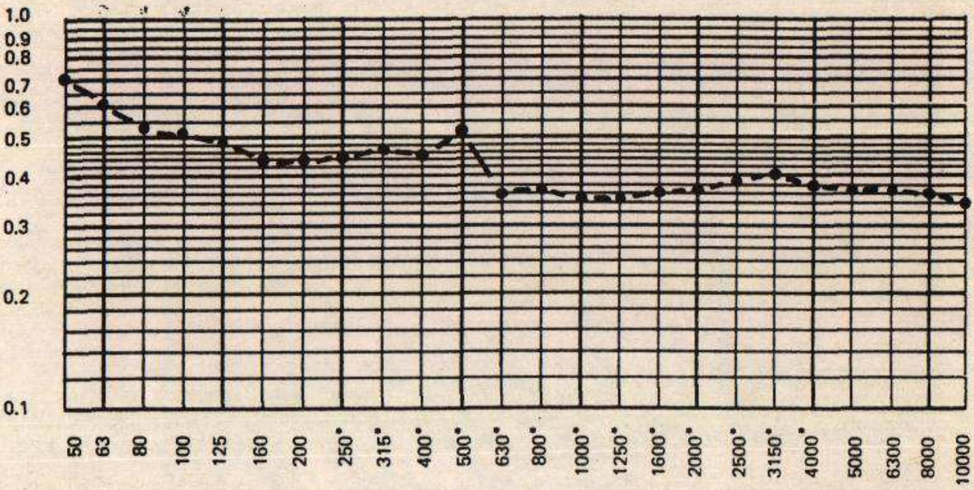
Volume 6980 m³

Design R.T. — secs.

Average of frequencies marked* ●● 0.51 ×× 03.31 secs.

ELSTREE. REVERBERATION TIME

WAREHOUSE STUDIO ACOUSTICS



Key to graphs (give dates)

●——● 18.8.88 5 microphone positions.

×– – –×

△——△

Volume 6307 m^3

Design R.T. secs. Average of frequencies marked* 0.40 secs.

LIVERPOOL. REVERBERATION TIME