Proceedings of the Institute of Acoustics

A MONITOR LOUDSPEAKER SYSTEM FOR A MOBILE RECORDING VEHICLE

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1. INTRODUCTION

In an accompanying paper [1] the acoustic design of a mobile recording vehicle was discussed. The design was of the Non-Environment type [2], and the dimensions of the "control room" were 2 m 05 x 2 m 05 x 4 m. The practicable layout for the vehicle necessitated that the mixing console should be across the width of the truck, and should be as close as possible to the monitor wall. This resulted in each wall being within 1 m of the ears of the recording engineer, a floor about one metre below and a ceiling about one metre above. The distance from the listening position to a line drawn through the centre of the two loudspeakers was also about one metre. The brief for the design required a monitoring level capability of around 105 to 110 dB, and that the vehicle should be sufficiently linear for serious mixing for CD releases.

2. THE PROBLEMS

2.1 Side wall reflexions

Placing the loudspeakers in the end of what is effectively a close tube is not a particularly easy means of achieving a linear response. In fact, mobile recording vehicles through the ages have been plagued by the problems thus created. The first problem to arise is due to the proximity of the side walls. In a 2 m by 2 m wall, there is little space to get an adequate stereo separation, so, inevitably, the loudspeakers must be sited more or less adjacent to the side walls. At high frequencies, where the wavelengths are less than about twice the distance from the centre of the loudspeaker to the wall, severe comb-filtering can result from wall reflexions. In fact, perhaps even more disturbing, the side wall reflexions can produce severe smearing of the stereo image, not only because of the displaced phantom source of the reflexions (the mirrored room effect) but also because the reflexions can return within the 0.7 ms time window before the Haas Effect begins to apply. Such reflexions can be ruinous for the clarity of perception [3, 4] as the Precedence Effect (of the first-arriving signal dominating) does not apply.

The solution for the above problem is to position an effective absorber system alongside the loudspeaker. The absorber must be effective down to frequencies where wavelengths will be sufficiently long that the reflected wave will return to the listener substantially in phase. For a path length distance between the direct and reflected waves of around 30 cm, this would mean very effective absorption down to 300 Hz, or so, which may not be easy to achieve, but geometry can help the situation to some degree, as shown in Figure 1. Here, the loudspeakers are built into a wall such that the side wall absorbers could only return energy back to the listener which emanated from 50° or 60° off axis. The effectiveness of the absorber determines the strength of the reflected waves. However, to achieve this in a narrow vehicle means bringing the engineer very close to the loudspeakers, and available width will limit the efficacy of the absorbers.

2.2 Close-range monitoring

At some distance, all multi-element loudspeakers exhibit a geometrical near-field, where the drivers covering different frequency ranges are perceived as separate sources, except, of course, for co-axial designs. In fact, co-axial designs initially appeared to be the optimum engineering solution for this problem, but the owners of the mobile studio in question expressed a lack of satisfaction with the sonic qualities of the co-axial loudspeakers commercially available in the size and power ranges required. The chosen solution was to use a pair of Quested Q405s, which existed only in prototype form. These are shown in Figure 2, and in form are something of a hybrid between a d'Appolito array and a co-axial array.

At the crossover frequency of 1.4 kHz, all five drivers operate, and the slightly elevated quincunx layout ensures a reasonably symmetrical horizontal and vertical directivity. Of course, at angles of 40° or 50° off axis, the ¼ wavelength differences, due to the different distances to the nearest and furthest pair, would begin to give rise to response irregularities, especially in the vertical plane where the driver pairs are spaced further apart, but in this case no such problem could occur. In such a vehicle, it is simply not possible to remain within any practical working area and be more than 20° or 25° off axis. This fact is illustrated by Figure 3, which also shows the cancellation at the crossover frequency, with the tweeter polarity reversed, with all five sources radiating, and at four positions within the working area. The cancellation, and hence the interference patterns, remains remarkably constant, with clean, steep sides. If any multiple-source smearing was present, such clean cancellation could not be achieved.

2.3 Directivity and total power

Most loudspeakers, designed for free-standing in conventional control rooms are designed to have a linear amplitude response when so mounted. Due to the omni-directional directivity of the low frequencies, though, below around 300 Hz, the total power response tends to increase as the frequency lowers, and the directivity patterns broaden. However, due to room reflexions, the concept of a linear axial response from free-standing loudspeakers in a conventional room tends to be a contradiction in terms. In the case under discussion, here, the loudspeakers were mounted in a rigid monitor wall, which, due to the increase in radiation resistance provided by the constraint of the radiating angle, created a boost in the axial response below 250 Hz, or so.

What is more, conventional rooms also allow a degree of lateral and vertical expansion of the sound waves, but in a truck of the dimensions being discussed here, and given the incomplete absorption or transmission of the low frequencies by the walls, floor, and ceiling, the enclosure thus created would tend to act like a plane-wave tube. This has the effect of further increasing the low frequency radiation resistance, and boosting the output still further. The effect can clearly be seen from Figure 4. Nevertheless, this boost does provide a useful extension of headroom. Effectively, the increased resistive loading also increases the sensitivity of the loudspeakers, and because no non-minimum phase delays are involved in the response disturbance, (such as is the case where reflexions combine with the direct signal after having travelled a different path length) the problem lends itself to correction by relatively simple electrical equalisation. In these cases, the linearisation of the amplitude response will also tend to linearise the phase response; consequently improving the time response. Corrective equalisation to lower the response elevation at low frequencies will increase the headroom by the same amount. This is an important factor to consider when trying to use the smallest practical source size to produce the required 110 dB at one metre output capability.

2.4 Attaching a sub-woofer

The above system, alone, was deemed to be lacking in bass for full-range monitoring purposes. It was decided to employ a sub-woofer system to augment the lower octave, or so, below 70 Hz. In general, the authors are not inclined towards using single sub-woofers on stereo systems for critical listening, but in this case, special circumstances applied, which not only demanded their use, but also allowed them to be used without the usual drawbacks. The sub-woofer was to be cited within a quarter wavelength of the stereo pair at the crossover frequency. Indeed, if a pair of sub-woofers were to be used, they would also, inevitably in this case, be located within a quarter wavelength of each other, and hence would tend to act as an acoustically coupled pair for mono signals. The space saving benefit of using a single 15-inch woofer far outweighed any acoustic disadvantages, and offered the advantage of reducing the low frequency variability of panned images. The sub-woofer would also tend drive the room like a plane wave tube.

As the room was rather absorbent, even at low frequencies, any modal activity would be very weak. Furthermore, in a space so small, the only mode which could develop in the sub-woofer rang would be the first axial, front to back mode at around 57 Hz, below which, a pressure zone response would be in effect, giving a weakened, but highly linear response. The use of the sub-woofer and its associated crossover would also prevent excessive low frequencies from entering the main stereo pair, thus easing their workload and increasing their reliability at high output levels. What is more, as the pressure zone exhibits an entirely minimum phase response, it can be electrically boosted, if required, without any detrimental effect.

2.5 The appropriate equalisation

In reality, it is impossible to predict the precise absorption characteristics of a mobile recording vehicle, or the exact loading effects created by the acoustic characteristics of the space. The problem is too complex, and too little is known of the inherent properties of the structure. However, because of the reasons previously described, it could be assured that, in the vehicle under discussion here, the response irregularities would be of a predominantly minimum phase nature, so an empirical method of evaluation the extent of the problems and the required corrective measures would be adequate.

After the installation, pink noise was put into the system, and a simple real-time spectrum analyser reading was taken. In highly damped rooms with low decay times and few reflexions, this is a viable technique. A high quality, multi-ban, stereo parametric equaliser was then used to linearise the response, before listening tests were carried out. The equaliser was then adjusted until the optimum subjective response was agreed upon by a group of recording engineers listening to "known" material. Subsequently, the equaliser was re-adjusted to the nearest simple, smooth response correction, before the system was auditioned for a final check of its sonic acceptability.

The next step of the operation was to record the pink noise on a DAT, from the output of the equaliser. The tape was then taken away for analysis, and the transfer function of the equaliser was plotted. A hard copy was sent to Quested Monitoring Systems, for production of an equaliser card to match this response. The crossover used in this system was a BSS, modified to Quested specifications, and sonically optimised. It had provision for the insertion of custom equalisation cards, and hence was a very practical choice for such circumstances.

2.6 Results

The response of the final system in the recording vehicle is shown in Figure 5, which is a very commendable response indeed for a mobile van. The step function response is shown in Figure 6. Subjectively, the owners of the vehicles, and their current clients, have shown great satisfaction with the results.

3 REFERENCES

[1] Newell, Philip R., Holland, Keith R., "Acoustic Considerations for a Mobile Recording Vehicle". Proceedings of the Institute of Acoustics, Reproduced Sound 14 (1998)

[2] Newell, Philip R., Holland, Keith R.,"A Proposal for a More Perceptually Uniform Control Room for Stereophonic Music Recording Studios". Presented at the 103rd AES Convention, New York (1997). Preprint No 4580.

[3] Haas, H., "The Influence of a Single Echo on the Intelligibility of speech". Journal of the Audio Engineering Society, **20**, p 146 (1972).

[4] Poldy, C. A., "Loudspeaker and Headphone Handbook". Ed. Borwich, J., p 529, Focal Press, Oxford, UK (1994)

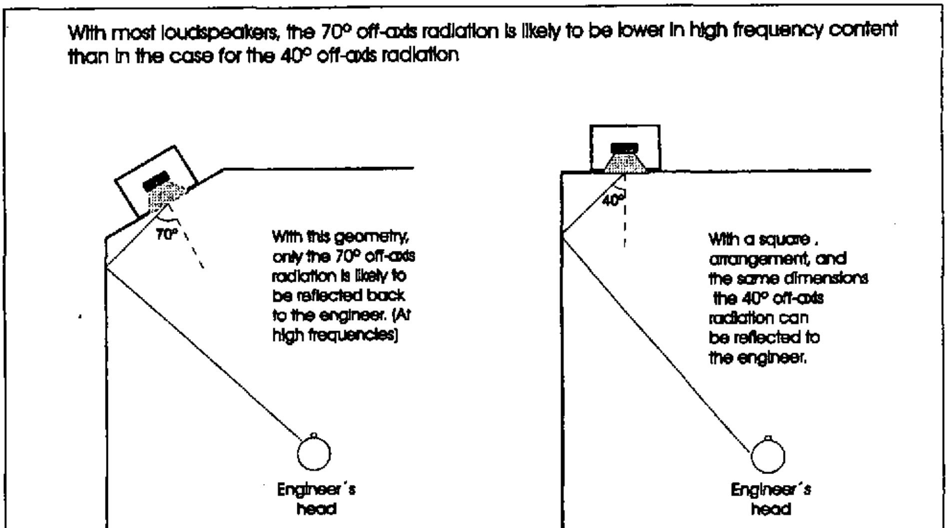

Figure 1 Effect of Angling the Loudspeakers

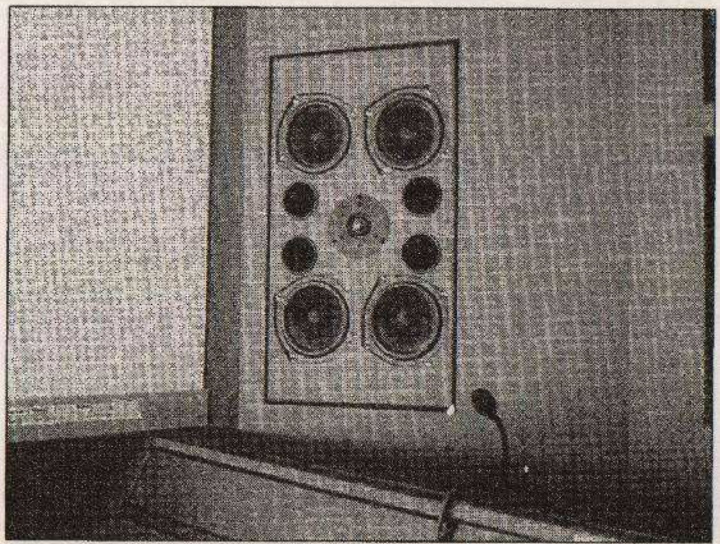

Figure 2 Physical Layout of the Q405

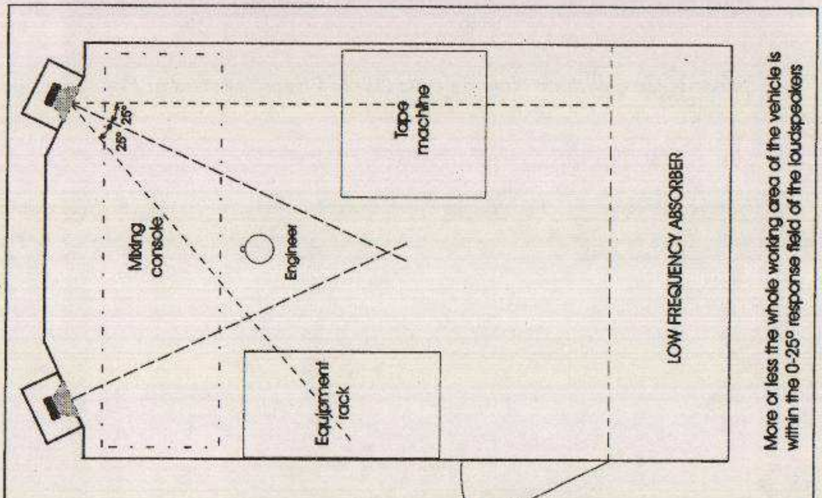

Figure 3a Loudspeaker Coverage Area

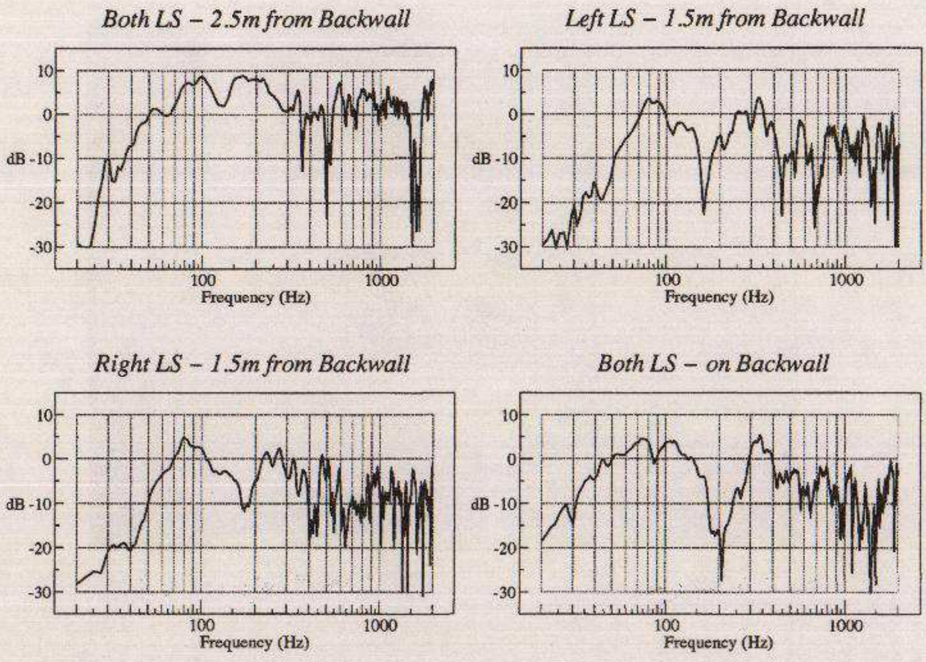

Figure 3b Cancellation Notches from Out of Phase Tweeters at Four Positions

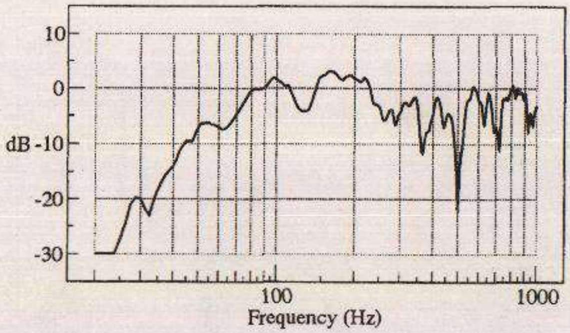

Figure 4 Axial Response of one Loudspeaker without Sub-woofer or Equalisation

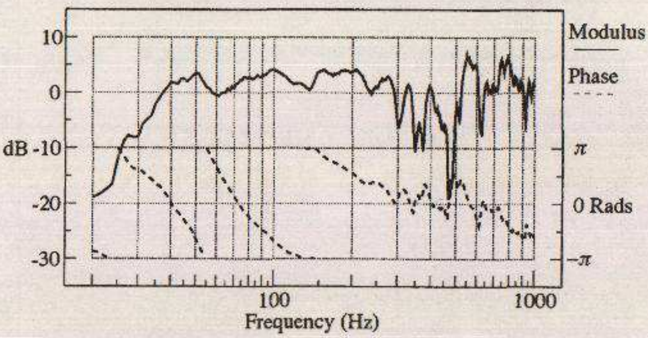

Figure 5 Frequency Response of Finished System

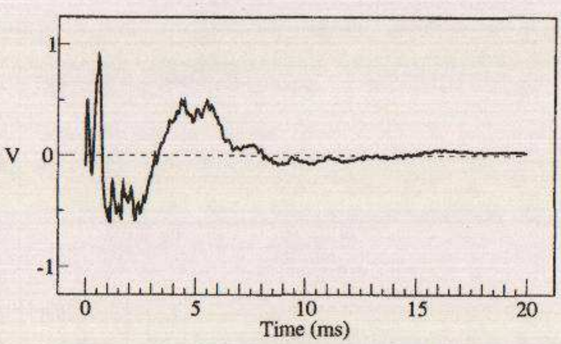

Figure 6 Step Response of Finished System

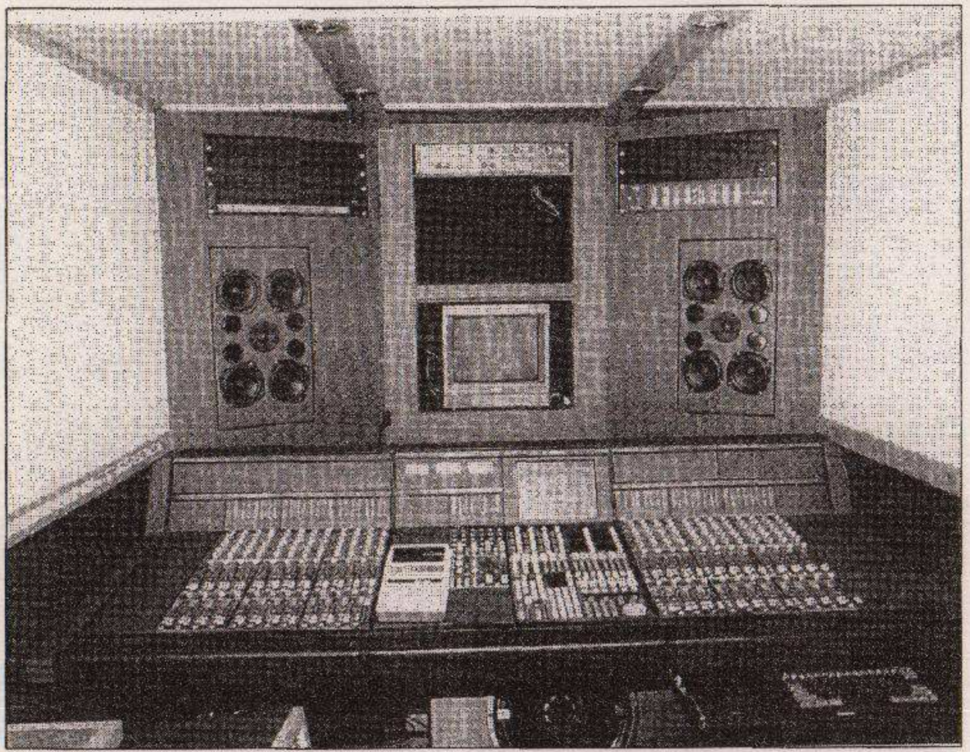

Figure 7 The Completed Monitor Wall