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BBC

RESEARCH DEPARTMENT REPORT

The design of the LS3/4 loudspeaker

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Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

RESEARCH DEPARTMENT

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It uses SI units in accordance with B.S. document PD 5686.

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(PH-27)

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THE DESIGN OF THE LS3/4 LOUDSPEAKER

SUMMARY

A description is given of the design and performance of a compact two-unit loudspeaker for use in mobile control rooms. Both the frequency range and the quality of reproduction are similar to that of the studio monitoring loudspeaker type LS5/5 from which this design was developed; the power handling capacity, whilst less than that of the LS5/5, is quite adequate for the purpose.

1. INTRODUCTION

In the past, sound monitoring has been carried out in mobile control rooms (MCRs) by means of an adaptation of the LS3/1 loudspeaker mounted on the ceiling of the van, specially equalized to compensate for the peculiar acoustic conditions.

The sound quality obtained in these circumstances, however, left something to be desired; furthermore, with the advent of the LS5/5 and LS5/6 loudspeakers,[1] the LS3/1 became obsolescent and, when the new colour MCRs were planned, a substitute loudspeaker was called for.

As the sound power required under these conditions is not as high as in a studio control room, consideration was given to a small commercial loudspeaker; however an examination of the maximum power output levels capable of being radiated by this loudspeaker showed that it would neither be powerful enough for the purpose, nor have adequate bass response. This report describes the development of a loudspeaker suited to the requirements.

2. DESIGN CONSIDERATIONS

2.1. Units

In the layout of the colour MCRs (CMCRs), the relevant operator (sound mixer) is seated centrally in the working space with the monitoring loudspeaker fixed to the ceiling approximately 0·7 m from his head. At such a short distance, there would be unacceptable variations in the sound quality with small changes in head position if a loudspeaker utilizing three spaced units (as in the LS5/5) were used. A preliminary consideration showed, however, that with the smaller power requirements it should be possible to design a two-unit loudspeaker with substantially the same characteristics as the LS5/5 (other than maximum power output), thus giving a compact arrangement suitable for close listening.

The response/frequency characteristic of the 200 mm diameter loudspeaker unit LS2/2 described in Ref. 1 was shown, there, to cover most of the frequency range needed for a small bass unit and calculations indicated that it should have adequate power handling capacity for an MCR.

It was furthermore decided that the bass end of the frequency range could be extended by changes to the spider and to the surround material without substantially affecting the response at higher frequencies. Since the sound pressures required were not great, the high-frequency end of the spectrum could well be handled by the low-flux-density version of the high-frequency unit used in the LS5/5.

2.2. Cabinet

As the loudspeaker was intended to be mounted on the roof of the van, the depth had to be kept small. This clearly favoured a side-by-side arrangement of the two units, and this disposition was also the best from the point of view of sound distribution; in an MCR it is most important to have a good distribution of sound in the vertical plane, because the sound mixer may move his head over an appreciable angle in this plane (the loudspeaker is relatively close) and another listener may be standing behind him. The two units were therefore placed side by side in a horizontal plane and the front panel arranged at an angle to the roof so that the sound mixer was nominally on axis. The cabinet was made of oak-faced 9 mm birch plywood, the panels being damped with Mutacell and the air space with polyurethane foam. In an MCR this form of absorbent is greatly to be preferred to the glass fibre type, as the vibration to which the whole loudspeaker is normally subjected causes glass fibres to shed sharp particles which can affect the performance of the units; a foamed absorber is also much easier to fix in position and more convenient to handle. The internal volume permissible for the cabinet is 0·06 m^3 with an external volume of 0·07 m^3.

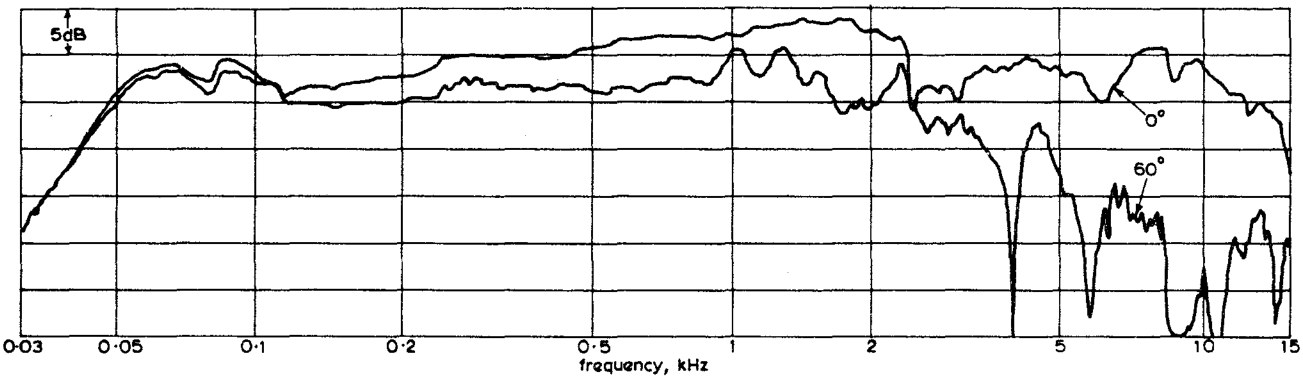

Fig. 1 - Response/frequency characteristics of unequalized low-frequency unit (with slit) in cabinet. Curves at 0° and +60° in vertical plane

3. DESIGN

3.1. Prototype

The prototype was required quickly and in the time available (less than 4 weeks) it was not possible to obtain a more compliant spider or to modify the surround of the low-frequency unit as intended. The crossover network was designed to equalize the low-frequency unit down to 80 Hz, the change to the high-frequency unit provisionally taking place at 3 kHz. The remaining bass loss was made up to the extent of 10 dB by an equalizer placed ahead of the power amplifier and, under these conditions, the axial frequency response was made uniform down to 45 Hz.

The prototype was given a field trial in CMCR No. 1 and it was clear that the sound levels produced were adequate for this application and that the quality of reproduction was good. It was, however, found that, under certain conditions,* overloading of the amplifier took place at the bass. This was not altogether unexpected in view of the conclusions as to bass pre-emphasis arrived at elsewhere.[1]

3.2. Final Model

In order to improve the bass response of the low-frequency unit in the final model, the surround material and the spider stiffness were changed as originally intended. Measurements indicated that the surround contributed the main stiffness; the surround not only acts as a centring device but also acts as a mechanical impedance termination for the cone and thereby affects the frequency characteristic of the unit. The unmodified LS2/2 unit uses 0·62 mm (0·025 in.) thick plasticized p.v.c. known as Nappatex and this was replaced by a surround of the same material and shape but with half the thickness. Measurements showed that although the resonance frequency had indeed been considerably reduced the axial response/frequency characteristic was appreciably inferior to that of the LS2/2. As it was not possible to obtain this material in intermediate thicknesses, other materials had to be used and that finally chosen as the best compromise was a compliant translucent p.v.c. 0·5 mm (0·02 in.) thick; this gave a good axial response and a resonance frequency of the unit in free air of only 33 Hz.

Manufacturers were again approached to obtain more flexible spiders, but without much success. It appears that the one already used in the LS2/2 is as compliant as can reliably be produced in this size, those which are more compliant becoming warped to an unacceptable extent. To extend the bass response still further and increase the power handling capacity it was therefore decided to use a vented cabinet. Experiments were carried out to determine the optimum vent resonance frequency for the modified unit in the 0·06 m^3 cabinet, the final figure of 40 Hz giving a uniform axial characteristic down to 45 Hz.

As with the LS5/5 loudspeaker, the radiation is made more omnidirectional by employing plates in front of the unit to form a slit. The same spacing as used in that loudspeaker was adopted but, for the reasons given earlier, the slit axis was made horizontal so that the improvement in directional properties was in the vertical plane. The response/frequency characteristics of the unequalized low-frequency unit under these conditions at 0° and +60° to the axis are shown in Fig. 1. The unit has been coded LS2/4 to distinguish it from the unmodified unit LS2/2 used in the LS5/5 loudspeaker.

Consideration of the off-axis characteristics indicated that a crossover to the high-frequency unit at about 3 kHz would be required; as expected this is the same frequency as that used for the upper crossover in the LS5/5 loudspeaker. Crossover networks similar to those for the LS5/5 were used, and as the sensitivities of individual low- and high-frequency units were known to vary from sample to sample, an auto transformer was used to enable the relative power levels fed to the units to be adjusted without having to change the crossover components.

* e.g. with input signals accompanied by excessive wind noise.

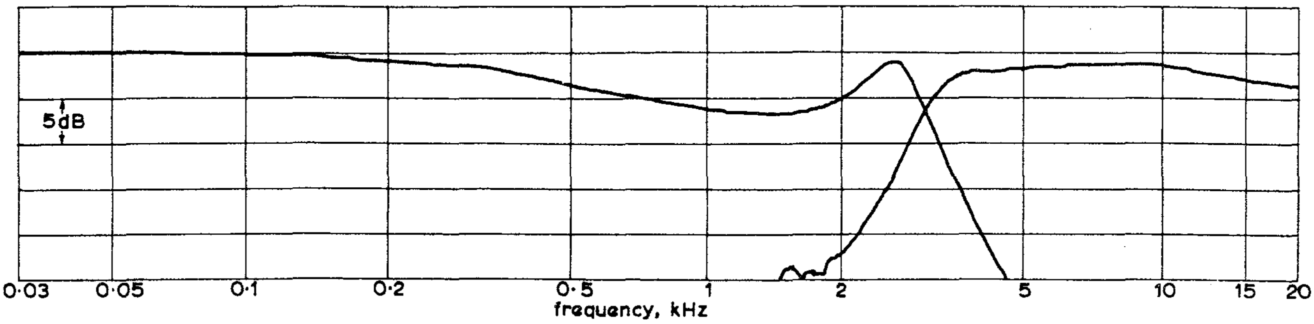

Fig. 2 - Voltages applied to l.f. and h.f. units

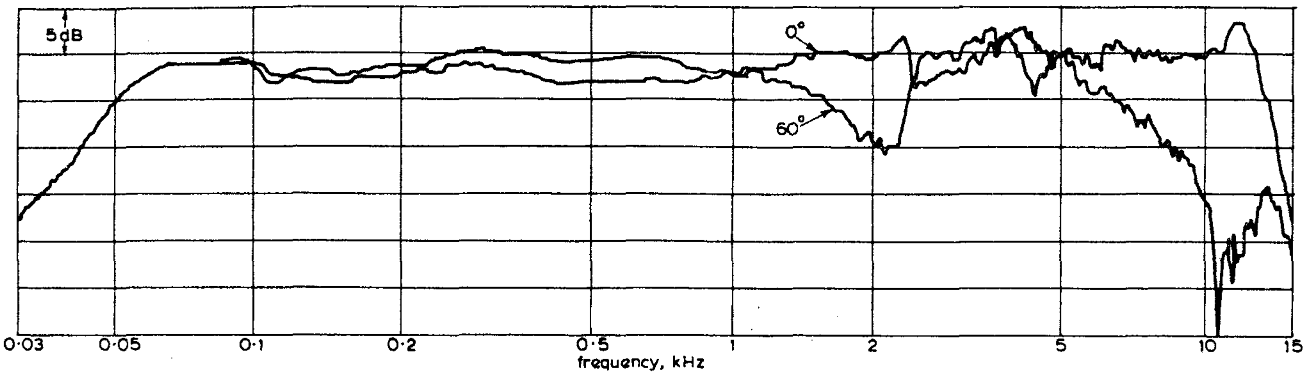

Fig. 3 - Response/frequency characteristics of complete loudspeaker. Curves at 0° and +60° in vertical plane

The networks were designed to equalize the overall axial response/frequency characteristic at the same time as performing their nominal task.

4. PERFORMANCE

4.1. Listening Tests

Listening tests were carried out on the completed loudspeaker and the results were in general satisfactory. There were, however, some signs of a lower-middle colouration below the frequency at which the 200 mm unit is used in the LS5/5. Treating the cone with a second layer of p.v.a. Plastiflex type 1200P removed the colouration without seriously affecting the response/frequency characteristic; the small effect which occurred was compensated for in the crossover network. The voltages applied under these conditions to the two units are shown in Fig. 2.

4.2. Response/Frequency Characteristics

The response/frequency characteristic of the complete loudspeaker on the axis and at +60° in the vertical plane is shown in Fig. 3. It will be seen that the response is as extended as that of the LS5/5 although of course the power handling capacity is somewhat lower.

4.3. Overload Performance

Harmonic and intermodulation distortion measurements were made on the axis, for a sound level of 1 N/m^2 at a distance of 1·5 m, and the results are given in Figs. 4 and 5. These test results are strictly comparable with those obtained with the LS5/5 loudspeaker, see Figs. 22 and 23 of Ref. 1. It is noteworthy that even at this sound pressure the levels of distortion are of the same order as those from the LS5/5.

The maximum sound level of a pure tone which the loudspeaker can produce at a distance of 1 m is about +4 dB with respect to 1 N/m^2, the limitation being due to overheating of the voice coils. With a more powerful amplifier it is estimated that with typical programme a midband sound level of +10 dB with respect to 1 N/m^2 could be produced at this distance before acoustic overloading of the units occurred. This level is 5 dB above that capable of being radiated by the small commercial loudspeaker considered earlier; moreover the undistorted output at 50 Hz of the LS3/4 is +23 dB above that of the commercial loudspeaker.

4.4. Impedance

The modulus of the impedance of the loudspeaker is shown in Fig. 6; the nominal rated figure is 25 ohms.

4.5. Reproducibility of L.F. Units

Eight low-frequency cones were made so that Equipment Department could produce loudspeakers for the remainder of the initial order. The spread in axial frequency characteristics is given in Fig. 7 and will be seen to be very small.

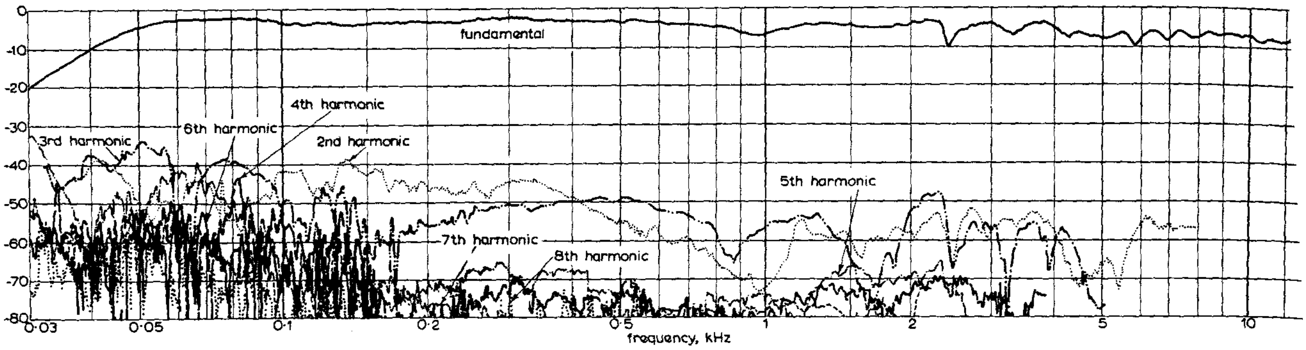

Fig. 4 - Measurements of harmonic distortion for a sound level of 1 N/m^2 at 1·5 m on axis

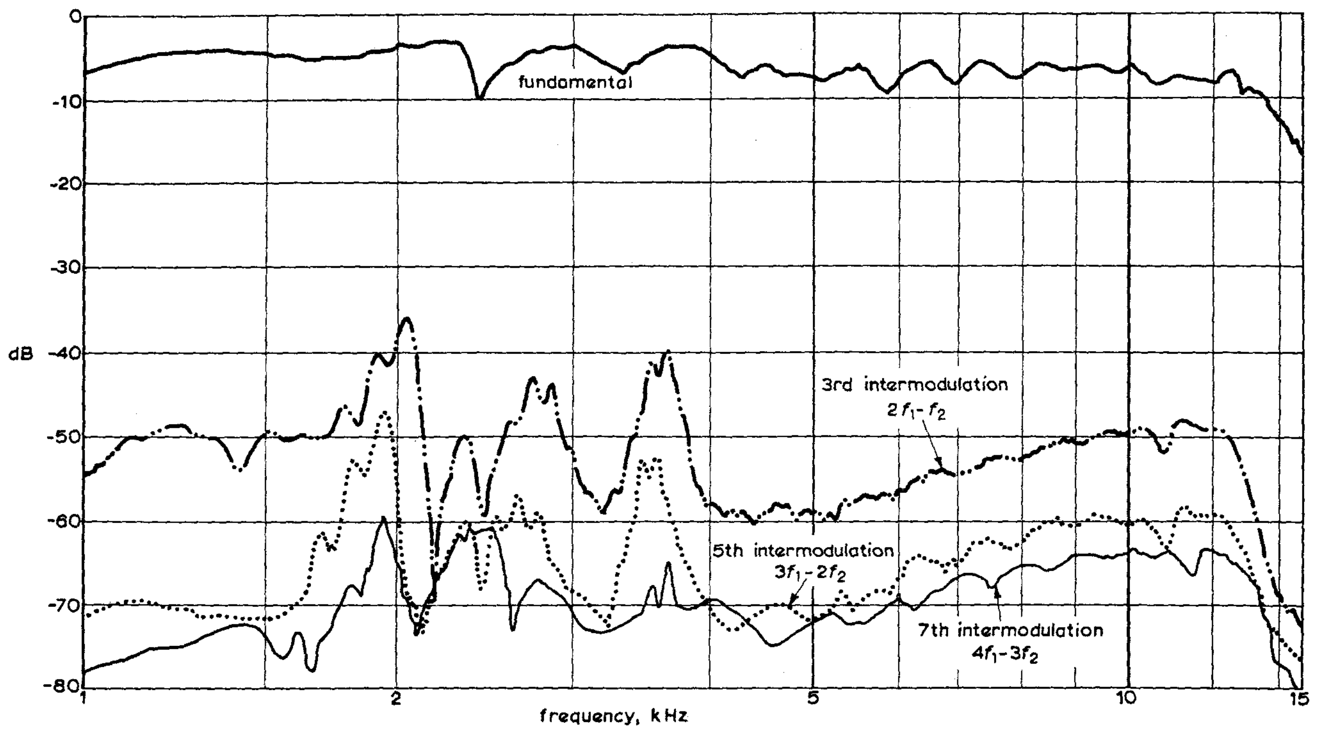

Fig. 5 - Measurements of intermodulation distortion with frequencies f_1 and f_2 and a sound level of 1 N/m^2 at 1·5 m on axis

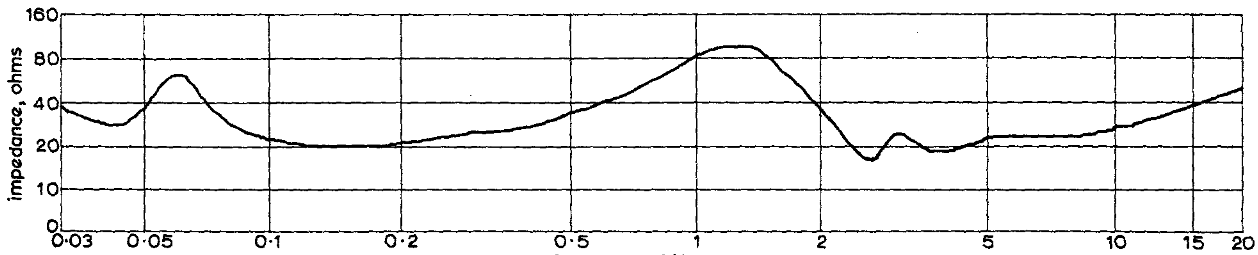

Fig. 6 - Modulus of impedance

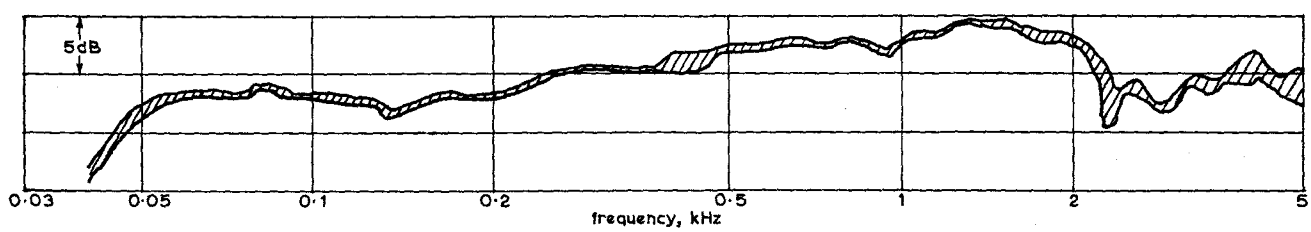

Fig. 7 - Spread in axial response/frequency characteristics of eight unequalized low-frequency units

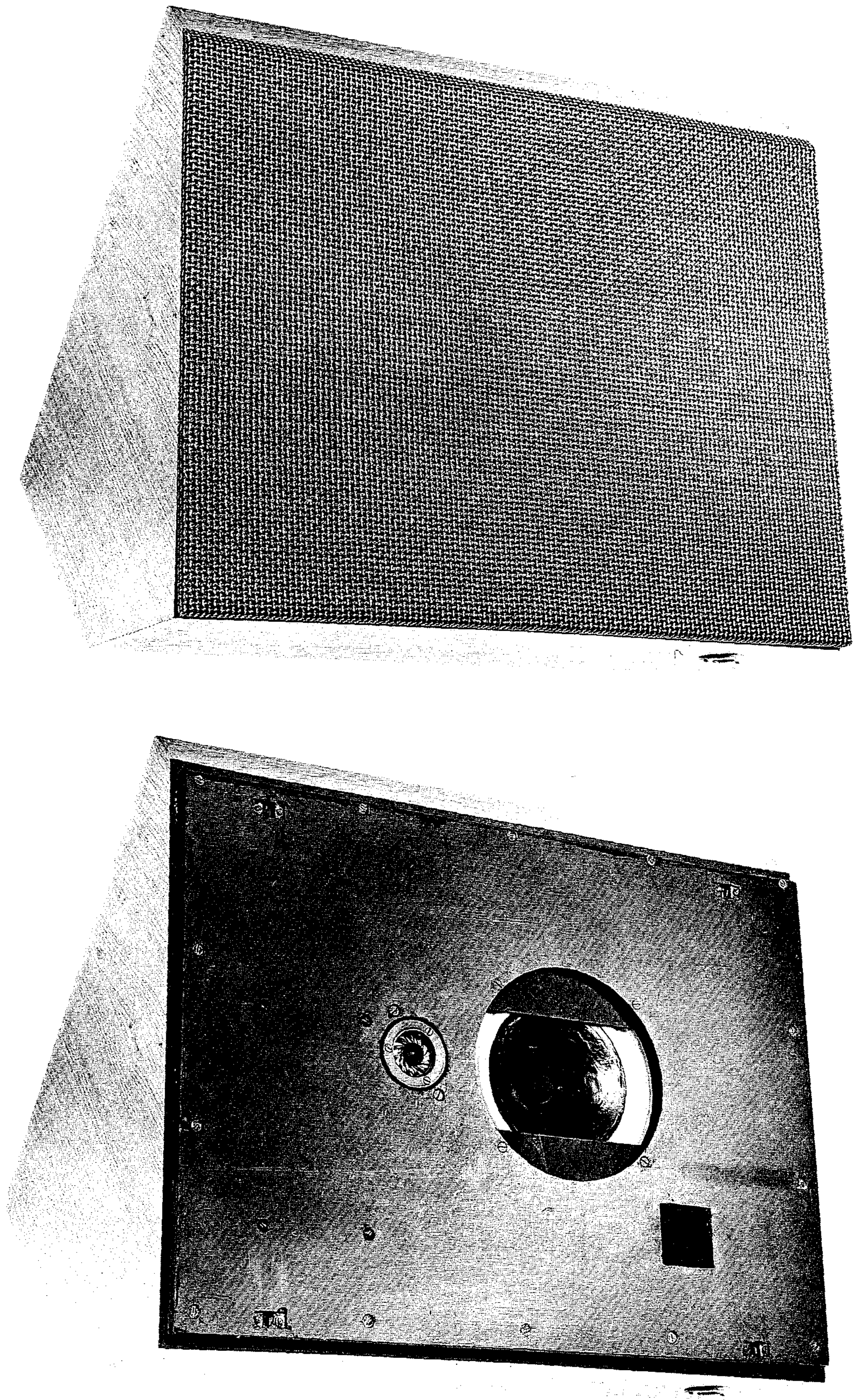

Fig. 8 - Appearance of loudspeaker

4.6. General Comments

The appearance of the loudspeaker with and without the front Tygan grille is shown in Fig. 8.

Although this loudspeaker was developed for a specific location in a television mobile control room, the performance makes it suitable for many other situations in which high quality combined with only moderate power output is required. A stereo pair has been made for use in a Transcription Recording Unit (TRU) vehicle with normal listening distance and gives good image resolution. The control cubicles of most talks studios would be adequately served by a loudspeaker of this design, at a considerable saving in expense compared with a full-sized monitoring loudspeaker; for this purpose a differently shaped cabinet might be more acceptable on aesthetic grounds, but the necessary alterations could be made without difficulty.

5. CONCLUSIONS

Knowledge gained in the development of the studio monitoring loudspeakers (LS5/5 and LS5/6) has made possible the production of a very much smaller loudspeaker of similar sound quality with a power output adequate for use in colour television mobile control rooms.

This loudspeaker would be equally suitable for use in radio outside broadcasts and in the many studio control rooms where the quality but not the available power of a full-sized monitoring speaker is required. As the manufacturing cost is only about half that of a studio loudspeaker, a considerable saving would result.

6. REFERENCES

1. The design of studio monitoring loudspeakers types LS5/5 and LS5/6. BBC Research Department Report No. PH-13, Serial No. 1967/57.

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