Tip-Top Top

Adding modern mid-range and HF sections to pair of bass horns

FOUR years ago, two articles describing a domestic concrete horn loudspeaker system[1] were left somewhat open-ended, with a promise of more data to follow when the middle and high frequency aspects had been finalised. At the time it seemed very likely that KEF's domed mid-range unit employed in the Carlton speaker would soon be available, and I expected to use this and have the final article written within a few months. However, the Carlton ran into manufacturing difficulties and for a long period I simply tampered with crossover components in order to achieve maximum smoothness and minimum coloration within the confines of the original drive units. To describe these changes and counter-changes would require a separate article, but as the mid-range horn and T15 tweeter used in the 1967 system have now been abandoned I will simply discuss the final arrangement, which incorporates only the main bass horns from the original scheme. A steady trickle of enquiries concerning this anticipated follow-up article has continued since 1967, so I hope these notes will interest at least the fanatical fringe of DIY loudspeaker constructors.

Various commercial speakers have been in and out of my home during those four years, each with its own characteristics and colorations. Many had a more analytical mid-range performance or more extended extreme treble, but generally they suffered from various subtle or not-so-subtle boxy colorations or exhibited what can best be described as 'nasal' qualities when switched for A/B comparison with my built-in system, while the latter was always preferable in the extreme bass. For such comparisons, incidentally, it is best to use single-speaker-mono, which can be devastatingly revealing of colorations that get somewhat obscured (on a short-term basis) by the distractions of stereo. These juxtapositions played their part in prompting some of the re-balancing operations mentioned above, but they were depressing in revealing the great difficulty of achieving low coloration *and* smoothly extended response in any assembly based on moving-coil units.

Then the IMF Monitor speakers came along. On that mono test—and despite a very wide and smooth frequency span—they sounded if anything *less* coloured than mine. Such minimal coloration as could still be detected seemed due, in all probability, to slightly restricted rear loading employed for the Monitor's mid-range unit and to minor resonances in the transmission-line enclosure handling the bass. Certainly the Professional version of the same speaker, featuring an even more rigid cabinet, seems if anything less coloured still.

If the mid, top and super-top parts of the IMF were used with my bass horn, the latter would replace the 'line', while the specially treated KEF B110 used for middle frequencies could have more generous rear-loading; thus both the conjectured sources of remaining minor colorations could be dealt with. Such thoughts were passing through my mind when John Wright, designer and manufacturer of the IMF speakers, offered to let me have a pair of experimental panels cut to accommodate the mid and HF drive units in their correct relative positions (to preserve phase relationships), fitted with full crossover systems and the B110s. Then Messrs. Rola–Celestion proffered pairs of HF1300 tweeters and HF2000 super-tweeters, so I graciously accepted both donations in the cause of high fidelity and set about some fairly

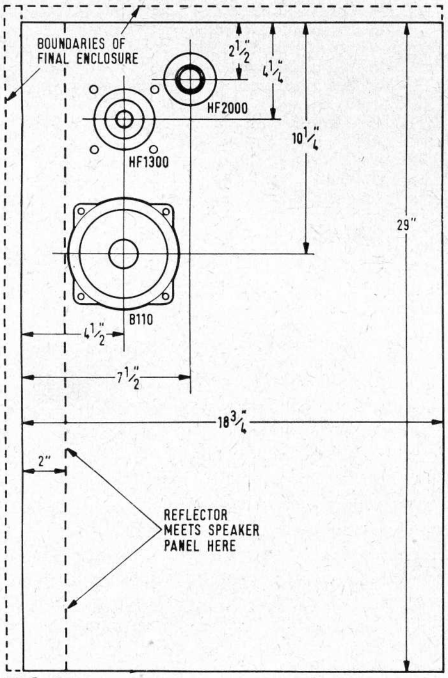
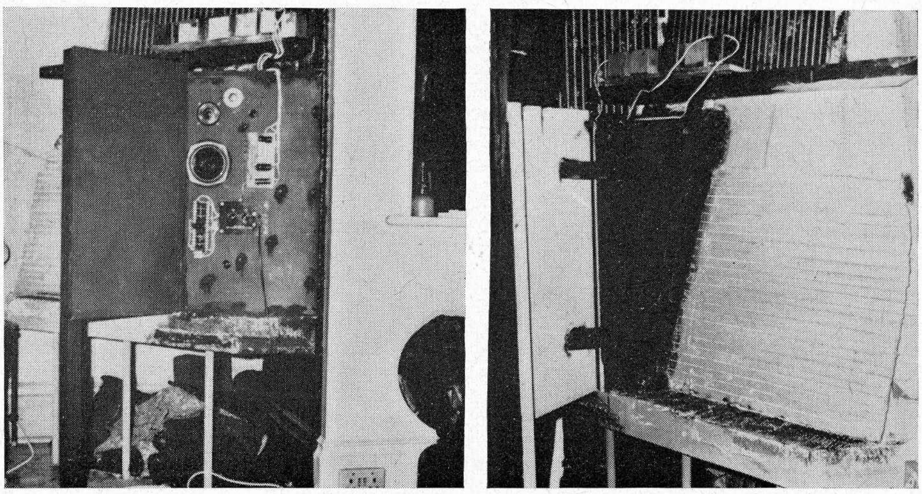


FIG. 1 LAYOUT OF RIGHT-HAND PANEL

Fig. 2 Left **(a)** frontal view of right-hand system, showing stereo reflector in position. Right **(b)**, left-hand system seen from the side.



BY JOHN CRABBE

drastic sonic surgery. For a full description of the IMF speaker's evolution readers are referred to a pair of articles by John Wright[2], while my own bass horns were of course detailed in the aforementioned 1967 feature. The present article simply concerns their marriage, and by a happy coincidence the IMFs are separately reviewed in this issue by Frank Jones.

Layout of drive units on the panels supplied is shown in **fig. 1**; this is the right-hand one of a mirror-image pair. For ease of adjustment, the crossover circuit board and a sub-panel carrying some mid/top switched level controls were also mounted on the front. I decided to position the two speaker panels on the outer ends of the 4 in. deep concrete 'shelves' forming the bass horn mouths, where the room walls provide natural boundaries (**fig. 2a**). This gives a wide stereo image and places the drive units just a little above seated ear level, the latter expedient helping to open up the sound by giving a slight sense of height to recorded ambience or distant performers. However, an open baffle of these dimensions will not provide adequate loading for a mid-range unit down into the low hundreds of Hertz, so it was decided to construct an IB enclosure by fitting further panels of ¾ in. chipboard to form a top and side, sealing these against the horn and wall (**fig. 3**). A combination of wooden stiffening members and concrete fillets seemed to produce a rigid and (sonically speaking) relatively inert 'box' having an enclosed volume of approximately 2 cu. ft. With practically no parallel surfaces, and all the internal space stuffed with BAF wadding, this seemed a very suitable alternative to the short tube used behind the B110 in the IMF.

Then came the question of a suitable crossover frequency. In my original system the KEF B139 units employed to drive the bass horns were crossed over to the mid-range at 300 Hz, though to avoid minor colorations in the upper bass it would have been better to place this point a little further down. Consequently I decided to aim at 200 Hz for, while the IMF's normal lower crossover is nearly an octave above this, the B110 will work well down into the bass if suitably loaded—as it now was. The 200 Hz was very nominal, for with the mid-range unit's position fixed in relation

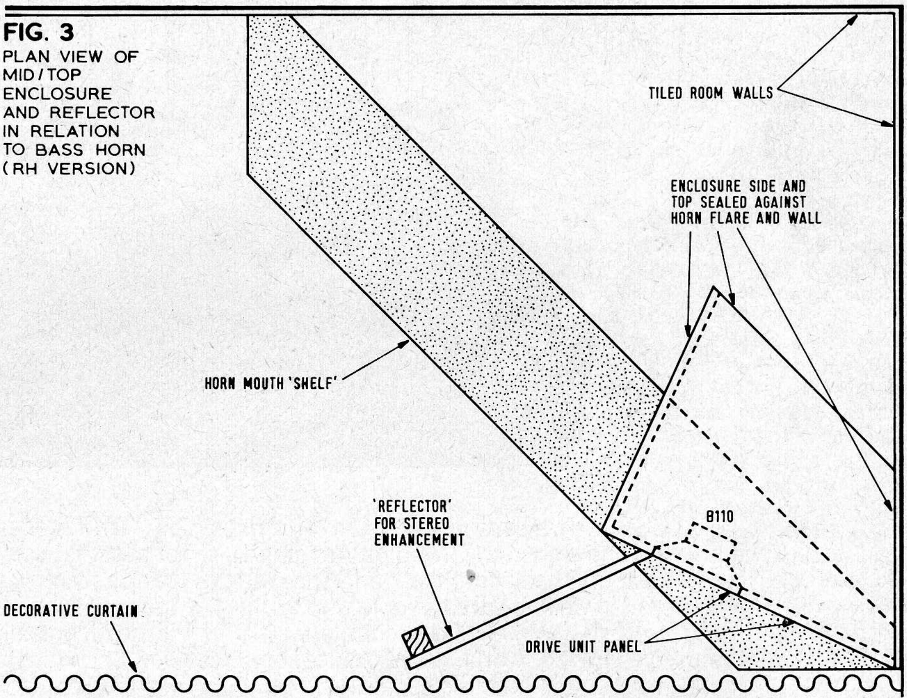


FIG. 3 PLAN VIEW OF MID/TOP ENCLOSURE AND REFLECTOR IN RELATION TO BASS HORN (RH VERSION)

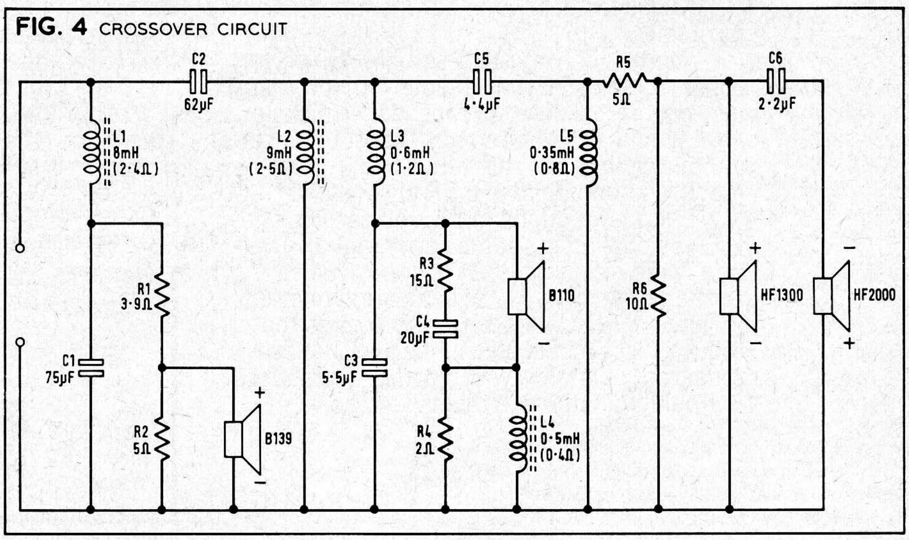


FIG. 4 CROSSOVER CIRCUIT

to the bass horn mouth it would be necessary to use a frequency at which the outputs were in phase. Matters were also complicated by differing electro-acoustic conversion efficiencies between horn-loaded B139 and IB-loaded B110. By dint of much listening to a range of sine-wave tones in the relevant frequency region—as heard in a multitude of listening positions via both mid and bass units—it transpired that: (i) the efficiency difference was 7½ dB, and (ii) with this corrected, outputs were fully in phase at 235 Hz—so this was the frequency chosen for the crossover. For any readers who might be interested enough (foolhardy enough!) to follow in my footsteps, I suggest a reference back to the earlier articles for some notes on the acoustic phasing of bass and mid-range units (p. 618, reference No. 1), as the conventional labelling of speaker terminals in relation to direction of cone motion is not necessarily relevant when there is an acoustic path length difference of several feet between the two units and the listener's ears!

I will not burden the reader with a detailed description of balancing and adjustments higher up the frequency scale, but simply give the final total crossover circuit (**fig. 4**), which also includes the drive unit phasings adopted for correct performance with my particular horns. The apparently reversed phase on the super-tweeter is deliberate. This circuit is a fairly straight-forward evolution from the IMF configuration, with altered L/C values to lower the bottom divider frequency, a resistive attenuator (R1/R2) for the bass unit (retaining a source impedance of under 3 ohms for damping purposes), use throughout of paper capacitors, and various other minor changes. The bass/mid efficiency difference of 7½ dB mentioned earlier is redressed mainly by R1/R2, but also partly by different resistive losses in L1 and L3. Actual total attenuations for the three bands are as follows: bass 9½ dB; mid 2 dB (increasing to 3 dB above 600 Hz, see later); treble, 9 dB. These are voltage ratios, but as the HF units are of 4 ohms impedance against 8 ohms for mid and bass, *power* attenuation on the tweeters is only 6 dB. Thus at the top end of its range the B110 receives 3 dB more drive than the HF1300, which makes sense as it has a long-throw coil and is therefore relatively inefficient. HF efficiency is equalised mainly by a series resistor (R5), a practice not normally recommended with moving-coil units because of impedance changes with frequency. However, as C6 brings the HF2000 super-tweeter steadily into play the total effective impedance in series with R5 (units and R6) remains substantially constant over the HF band.

FIG. 5 INPUT IMPEDANCE

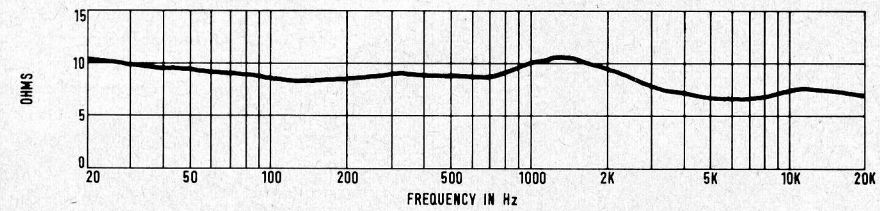
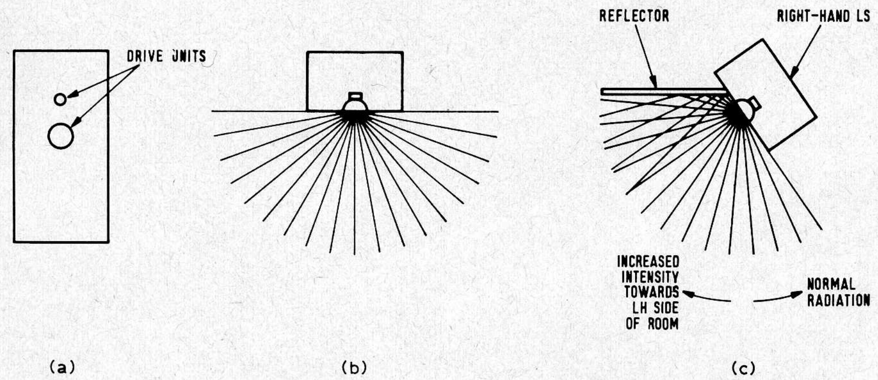


FIG. 6 DERIVATION OF STEREO REFLECTOR



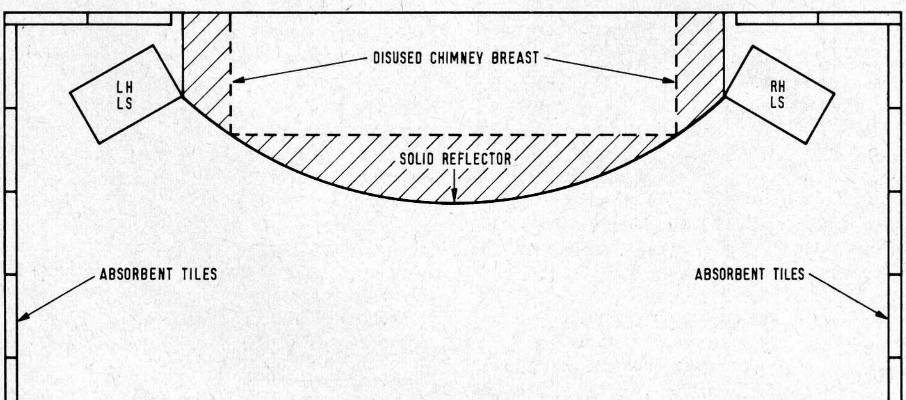


FIG. 7 POSSIBLE ROOM ARRANGMENT FOR IMPROVED STEREO STABILITY

It was extremely useful during measurements and adjustments to have available the switched mid and HF attenuators incorporated in the IMFs, though the final positions adopted have been translated into fixed resistors in fig. 4. As with many practical crossovers, some of the values depart from textbook recommendations in the cause of the smoothest or flattest *acoustic* response—which, after all, is what we listen to.

The electrical impedance curve resulting from fig. 4 is given in **fig. 5**, which could conveniently be designated as 'nominal 8 ohms'. In fact this curve is flatter than any I have seen for a commercial speaker and remains between 6¾ and 10¾ ohms over the whole audio band. Note that the system is essentially 8–10 ohms at low frequencies, falling to 7–8 ohms higher up.

One small curiosity in the circuit is the inductance/resistance/capacitance combination associated with the B110. The R4/L4 part of this puts a small step in the mid-range response centred around 600 Hz (Z of L4 equals R4 at this frequency), tending towards full drive to the B110 on moving from this frequency down to its lower crossover point at 235 Hz, but with a slightly reduced drive above this. R3 and C4 simply enable R4/L4 to attenuate correctly at all frequencies within the mid pass-band by compensating for the B110's rising impedance characteristic. This 'step' was found desirable subjectively for a proper balance between the 'warmth' and 'presence' regions, both largely within the mid-range unit's compass, though both measurement and calculation show that the actual change is only about 1 dB—which the ear (my ear!) can still pick out.

The explanation of all this is our old friend diffraction, whereby when a speaker unit is mounted in a cabinet there is a dimension-related frequency below which the sound starts to spread around to the rear, thus reducing the acoustic energy density in the forward direction. In short, the output apparently shelves down by a decibel or so below a certain frequency. Most modest speakers simply take this in their stride and are designed to give an acceptable overall response in typical domestic surroundings, but the better professional monitoring types have built-in compensation[3]—sometimes even variable to cater for free-standing or next-to-wall positioning, the latter reducing diffraction losses and thus demanding less electrical correction.

Reference to fig. 1 shows that the mid-range unit is near enough to the panel edge for diffraction to commence well *above* 600 Hz, and one would imagine that the step back to the bass horn structure is in any case too small for there to be a significant change of acoustic solid-angle. So why the 600 Hz step? The explanation (conveniently thought-up *after* compensation had been introduced on subjective grounds!) is that the two speaker panels have been extended by means of the large 'reflectors' seen in figs. 2 and 3, which may have been puzzling the reader. The 15 in. width of these seems to account for the step-effect (modest compared with that arising from a completely free-standing cabinet), but why are they there?

Stereophony is the answer. The one respect in which the new mid/top system seemed inferior to the old was in stereo performance—by which I mean the ability to present a stable stereo image over a reasonable listening area rather than just on the central bisecting line. The classical Brittain/Enock approach to this has been expounded many times in this magazine[4], but one possible artifice to help in achieving an appropriate greater sound intensity on the side of the listening area farthest from a speaker (to reduce Haas-effect image shifting) has not to my knowledge been described before, even though it may have been used. The idea is to make use of short-path oblique reflections to reinforce the acoustic energy density on one side only of a speaker cabinet. Imagine a speaker in which the mid-range and tweeter units are small compared with the wavelengths of all signals within their frequency spans, and mounted one directly above the other (**fig. 6(a)**). Such a system will tend to have equal radiation in all lateral directions out to an angle of 180° represented by the cabinet front (**b**). Now erect a reflector close to one side of the drive units, angled so that energy that would otherwise have been 'lost' out to the side is added back in a more forward direction (**c**). When all possible reflections are drawn in, a pattern emerges roughly in line with classical stereo requirements, while suitable curvature of the reflector might improve matters further. There are, of course, various path-lengths, but the changes are minute compared with the large time differential between left and right speakers for typical off-centre listeners, while a fully random phase pattern is reached only at high frequencies, where intensity overrules phase in stereo perception.

This sort of scheme seems to have been used some years ago in J. B. Lansing's complete stereo speaker known as the 'Paragon', and no doubt plays a part in the effectiveness of a curved stereo panel supplied for positioning between stereo speakers by A. Davies, the cabinet people.* A complete solid wall curved to join the two speakers would seem to be the ideal arrangement (**fig. 7**), while a logical corollary would be to fit absorbent acoustic panels along the listening room's side walls to prevent the inverse (but so common!) effect of greater sound concentration from the *nearer* speaker. Anyway, the idea is thrown out for general consumption, while in the meantime my more modest panels do indeed have a worthwhile stabilising effect on the stereo image—very noticeably in the back half of the room.

Turning now to other aspects of performance, final tests and adjustments of frequency balance were concluded in comparison with four other systems: the unmodified commercial IMF (set with its mid and top controls at maximum, which I judge to be 'best'), Rogers-BBC Monitor, Spendor Studio BC–1 (reviewed in this issue by Ralph West), and Acoustic Research type LST (with contour switch at position No. 2, corresponding to a flat overall acoustic response); all as heard on-axis, mounted as specified by their designers, and as nearly as possible the same distance from the listener as one or other of my own assemblies. All these speakers have been calibrated 'objectively' under controlled conditions, and while I fully concur with Ralph West's distrust of anechoic sinewave measurements[5], there is some consolation in the fact that such superb speakers as these do sound very similar in terms of general tonal balance, if not in coloration.

As finally set, and considered in terms of tonal balance only, the complete system sounds somewhat brighter than the IMF in the 2–4 kHz region, has a trifle more 'bite' than the BBC Monitor in the 5–10 kHz range, is practically indistinguishable from the AR LST, and is just a little less incisive than the Spendor BC–1 in the region where this is brighter than the BBC. Thus it represents an average balance amongst a group of tip-top assemblies, all of which are in any case tonally very similar as loudspeakers go. In comparison with all four, and with any others that have been in my house, the built-in system has a fuller and firmer deep bass below 50 Hz—which is just as well considering the mass of work, material and inconvenience involved in building the original horns!

But this is not the only gain, as colorations of all sorts now seem minimal to the point of vanishing. Using a splendid little battery operated white-noise generator shortly to be manufactured by Rogers Developments—and of course a mass of musical material of all sorts—I have searched for curiosities by means of A–B comparisons between my speakers and the various other models mentioned. Every speaker system has its own sonic personality, of course, a fact particularly evident when using white or pink noise; but apart from some full-wavelength room eigentones around 44 Hz which interact with the horns as detailed in the 1967 articles, the effect of switching from system to system is always to reveal a more open sound on mine, corresponding to less 'character' on musical items and a less 'pitched' quality on white-noise.

The complete exercise has therefore been well worth while despite a four-year gap stretching, as it were, between bass and treble. However, I would warn would-be emulators on two points: (i) the system has been adjusted for optimum performance (and a similar tonal balance to that from standard monitor speakers) *in my particular room*, and unless the reader is fully acquainted with crossover circuits and their manipulation it would be wise not to get involved; (ii) experience with correspondence arising from my Mk I horn system described in HFN in 1961–62 forces me to say that I positively will not work out alternative horn designs for different shapes or sizes of rooms. I must have spent several weeks on this sort of task during the last few years, but I fear that other pressures are now too great. Nevertheless, I hope these notes will be of interest to all readers intrigued by the problems of building domestic speakers to professional standards. They should certainly keep me happy for at least another four years!

Finally, my particular thanks to the following helpful and friendly people: John Wright (IMF) for making the whole mid-top project feasible; likewise Ted Howlett (Rola-Celestion) for various units and much information; Jim Rogers (Rogers Developments) for loan of BBC Monitors and test gear; Malcolm Jones (KEF) for useful information and various components; Don Thompson and Frank Jones for helpful discussions and listening tests; and Dennis Wratten (AR) and Spencer Hughes (Spendor) for loan of various speakers.

SPECIFICATION

Drive Units
Bass: KEF B139 (8 ohms)
Mid-range: KEF B110 (8 ohms) (specially doped)
Tweeter: Rola-Celestion HF1300/II (T1512, 4–6 ohms)
Super-tweeter: Rola-Celestion HF2000 (T1637, 4–6 ohms)

Acoustic Loading
Bass (B139): Concrete exponential horn: flare cut-off frequency, 25 Hz; axial length, 11·4 ft.; throat area, 45 sq. ins.; mouth area, 7·6 sq. ft. Mouth in room corner at floor level.
Middle (B110): Irregular sealed enclosure made of braced chipboard and concrete; internal volume, 1·8 cu. ft.; filled with BAF wadding.
Treble (HF1300 and HF2000): Sealed units mounted flush in plain baffle.

Main System Resonance
Horn pushes this down to 21·5 Hz.

Crossover Frequencies
Bass/mid: 235 Hz. Mid/treble: 3·5 kHz. Treble/super-treble: 12 kHz.

Load impedance (electrical)
Nominally 8 ohms. Between 6·7 ohms and 10·7 ohms at all frequencies between 20 Hz and 20 kHz.

* *A. Davies & Co., 56 Wellesley Road, London, N.W.5.*

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