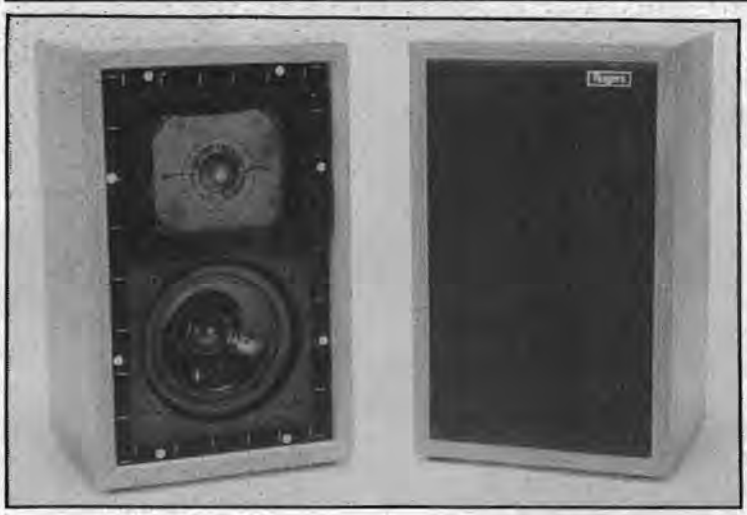
BBC's home service

Just what does the BBC use to monitor the output of its many studios? David Prakel takes a look at BBC speaker design in the particular and the abstract



Typical BBC control room with LS/1 enclosures either side of the TV monitors and swivel stand mounted LS3/5 playing a conventional winger position

The LS3/5A loudspeaker dressed and with the grille removed to show KEF B110 and T27 drivers; note the felt strips around the tweeter

'Good evening, this is the BBC...' — an announcement which reassures the listener of the high technical quality of the following broadcast. The British Broadcasting Corporation is probably the single most influential body in shaping a public's awareness and expectations of high fidelity sound. There is a strong parallel here between the public acceptance of the quality of BBC broadcast sound and the now synonymous Queen's or BBC English. Perhaps the biggest element in this acceptance is the design of what could justly be called 'the BBC loudspeaker'.

All radio and TV sound broadcast is monitored on BBC designed or related design loudspeakers and their 'voice' will be portrayed in the final sound balance put out from studios be they in BBC Local Radio in N. Scotland, Television Centre or BBC Manchester. More directly influential on the hi-fi buyer is the number of BBC designs or related designs available on the commercial market, many of which represent the sound of the 'British speaker' to the overseas buyer.

The balance of work between the BBC Research and the Designs Departments is changing as the technology of speaker development alters but broadly speaking a design will progress from Research through Designs to Engineering Production. This obviously relates to designs researched and built in-house but in terms of the arithmetics of the exercise in manpower, material, facilities and time it is obviously better if the BBC can license its designs to outside producers for a nominal royalty and then buy back the product. Such producers can sell the speaker on the open market too.

The best instance of this arrangement is the diminutive 'monitoring loudspeaker type LS3/5A'. (Incidentally, we meet a shorthand description and it may be useful to distinguish here between the BBC LS3 loudspeaker series intended for outside broadcast use and the LS5 series intended for studio monitoring.)

Originally designed as a $\frac{1}{4}$ scale monitor loudspeaker for acoustics experiments in model auditoria, a use was soon seen for this loudspeaker — monitoring in cramped conditions where headphones were unsuitable. The experimental speaker used for acoustic scaling was found to have a fair performance down to 100Hz despite being designed for a 400Hz to 20kHz required bandwidth only; with music programme the speaker was found to be surprisingly good. This design was put into production as the LS3/5 and saw use in mobile TV control rooms for producers to monitor the mixing desk output at levels below that required for the mix itself. It is commonly wall mounted, angled in and upside down to put the tweeter closer to the producer's ear.

When the drivers were eventually modified and improved by the manufacturer (for this speaker used KEF drivers), the design was rethought which resulted in the present LS3/5A. Not only do the BBC Equipment Department have the ability to produce this design but Audiomaster, Chartwell and Rogers are commercial licencees for its production. Other companies have applied for licences to be turned down by the BBC Engineering Secretariat for inadequate facilities.

Mythology

Part of the myth surrounding the LS3/5A in commercial production is that owning a licence is tantamount to owning a licence to print money as 'all the hard work's already been done'. The other myth, more prevalent among the buying public, is that the LS3/5A from one specific manufacturer is best because 'they were the first' or 'they know more about what they are doing'. This has led to the common belief that there are marked differences between an LS3/5A from Chartwell and say one from Audiomaster.

Both ideas are quite wrong as the production of the LS3/5A is so closely specified, and the tolerances so tight, that there is a high rejection rate. In a speaker containing the finest, most expensive ingredients and representing an investment of hours of skilled labour it can be seen that this is not an operation to make you a millionaire overnight.

As to differences between speakers from different firms, there may have been some differences in the past when Rogers bought-in their chokes and Chartwell wound their own; perhaps causing the speakers from one manufacturer to lie consistently at the top limit and the speakers from the other towards the

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bottom limit. With Rogers and the production side of what was Chartwell Electro Acoustic Ltd under the wing of Swisstone Electronics, both these speakers are now produced on the same line. Audiomaster are working to the same closely specified design and turn out a product equal in every sense to those from Rogers and Chartwell. Price difference between the models is often quoted as evidence for the superority of one model over another but the biggest difference of just under £5 most probably relates to the acceptability of reduced profit margins as there is a fixed cost to the materials between manufacturers.

Just what does go into an LS3/5A? The cabinet measures 31 x 19 x 16cm and is made of 12mm birch plywood braced on *every* joint with beech wood battens. How many speakers 10 times the volume of the LS3/5A have bracing on every joint? — not a lot. The birch ply and beech wood has been closely specified as other hard woods (specifically Pirana Pine in the BBC's tests) showed up a clearly audible colouration due to interaction with a resonance of the bass driver chassis. Cabinet walls are damped with one layer of Bostik sound deadening panel and a layer of 16mm anechoic grade foam on the sides and two layers of deadening pads and a layer of 25mm thick foam.

Drivers are the KEF B110, specially selected to a BBC specification, and the KEF T27 tweeter which is fitted with a perforated metal grille which the BBC suggest 'has a small effect on the frequency response which is wholly beneficial as it raises the output somewhat at high frequencies'. The diaphragm of the T27 radiates almost omnidirectionally and to reduce colouration, and image instability, from secondary wavefronts reflected by the cabinet edges, the tweeter is surrounded by strips of thick felt.

Crossover is designed to allow matching between treble and bass drivers of different sensitivities by the incorporation of seven tap positions on an autotransformer. This idea is incorporated in the LS3/6 and LS5/8 (and other) BBC designs as it enables a blown tweeter to be replaced and its sensitivity allowed for by a service engineer. The crossover design of the 5A was first used in the LS5/1 and has proved its usefulness. The large 18-element board is mounted behind the tweeter on the front baffle and is prevented from rattling by means of a thick felt pad. Audiomaster ensure that each component is pulled down tight onto the board to prevent component rattles while I believe Rogers adopt the opposite principle of giving the components long enough legs to keep them away from the board.

Referenced

Each licensee keeps as a reference one of a pair of LS3/5As of which the other is deposited with the BBC Research Department at Kingswood Warren. The official production test schedule states that a production loudspeaker should be compared with the standard LS3/5A using high quality tape recordings using a wide range of material.

Eighteen element crossover board for the LS3/5A enclosure, the seven position tap can be seen in front of the autotransformer at the back left of the board.

On the left the Spendor BC1 in its improved version, on the right the Swisstone Rogers Export Monitor. Spot the differences between these cousins of the BBC LS3/6.

It should be pointed out that the design is of a loudspeaker as an integrated unit and indeed the grille cloth is as closely specified as the cabinet materials and it should be in contact with the felt strips surrounding the T27, or a glich will occur at 5.5kHz preceded by a peak at 4.5kHz. Without the grilles, a deep trough opens at 4kHz with a plateau from 6kHz upwards. (The moral here is don't use LS3/5As without their grilles as they are an integral part of the design; make certain they are located properly. Removing the grilles can make a difference — but that's not an improvement!)

The acceptance manual for the B110 bass driver runs to five pages and covers its mechanical inspection, electrical and acoustic testing, labelling, packing and storage. Detail enough to prove the close tolerance of the design.

Apart from licensing agreements, to which only the LS3/5A is subject at the present, the BBC, from its position of 'privileged neutrality', can develop designs that are put into commercial production after close liaison between the Corporation and manufacturers.

The original LS3/6 was a two-way design, flat to about 14kHz, which is all very well if you are monitoring stereo broadcasts which have no information above 14kHz but can be a problem in a TV studio if you are listening for a line whistle at 15.625kHz. The LS3/6 is now obsolete but the cabinet design lives on in the Rogers Export Monitor and the Spendor BC1 and BC2 designs. The original port was square section but both the Rogers and Spendor use a port of circular cross section and Rogers a short tunnel.

Other detail changes in the commercial models include the change from paper coil formers to Nomex which enables the bass unit to handle 50 watts instead of the previous 11 watts with paper. The bextrene bass driver in the Rogers Export is an exclusive model made by Dalesford to Rogers' specifications. So much of the final quality of a speaker is determined by details like the cone profile and the temperature effects of the adhesives used.

Taxation

But there was another factor influencing the design and that, believe it or not, was Purchase Tax. It was of course known that the Celestion HF1300 in the LS3/6 had a natural roll-off above 14kHz and the addition of a third driver to the design would not only improve the measured frequency response but also make the speaker exempt from Purchase Tax (as all three unit speakers were at the time). Rogers Loudspeakers (the Jim Rogers — Rogers Loudspeakers Co.) added a Celestion HF2000 to the design without altering the existing cross over but exploiting the natural roll-off of the HF1300 and adding a simple filter for the HF2000 unit. Referenced against a standard LS3/6 there were mutterings about phase anomalies but the public preferred a response to 20kHz. I have recently heard of American and Japanese audiophiles turning the clock back and wiring the super tweeter out of circuit or removing it entirely.

Swisstone Rogers have improved the three unit design by substituting a KEF T27 for the HF2000. Other detail changes are to make the speaker more suitable for domestic use and the auto transformer mentioned earlier has been replaced with a resistive attenuator. Air cored coils are now used instead of the iron cored inductors of the BBC design.

Spendor have put their own signature to the LS3/6 design — Spencer Hughes their MD is an ex-BBC man (one who holds the unique distinction of being able to lift a BBC LS5/5 by himself). The latest BC1 incorporates a longer throw bass driver with the HF1300 common to the Rogers and Spendor design rolling off into a Coles 4001G super tweeter. The reflex port has a foam ring to reduce turbulence around the edge of the port and therefore promotes a cleaner bass. The BC2 is simply a higher power handling version of the BC1. Spendor also produce an AB version of this speaker with built-in Quad power amplifiers.

Designs

What of the future? The early LS3/1 design, which was a large box with 15inch Goodmans paper bass driver crossed over to a Rola Celestion tweeter, was replaced by the LS3/7 design which, built and developed in-house, was never produced commercially. This speaker was a departure for the BBC as it was their first electronic crossover design. The active LS3/7 design incorporates a 12inch bextrene driver crossed over to a soft-

dome tweeter and represents a design philosophy based on two-way speakers due entirely to improvements in tweeter technology which have enabled mid range drivers to be ditched.

The LS5/1 was a pre-stereo design and appears to have been strongly disliked. This was replaced by the LS5/5 which was a passive design incorporating three units, both mid and bass drivers being fitted with a BBC slot to improve dispersion, more of which later. This speaker is now near the end of its 15-year life, but at its inception incorporated a crossover which represented £100 of components. The mid-range driver was isolated from the bass enclosure in its own box. The LS5/5 was described to me as mellow and plummy but has of late been replaced by the LS3/7 in studios due to the delay in the official LS5/8 replacement.

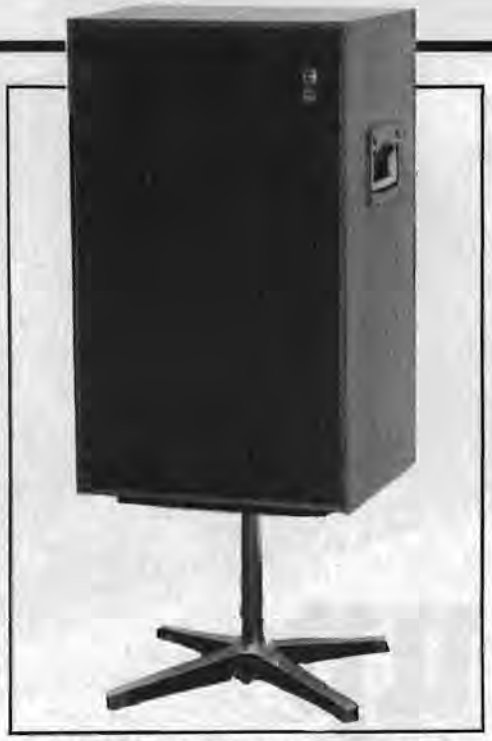
The LS5/8, and its close commercial relatives the Chartwell PM450 Electronic and Passive, was designed primarily for high level monitoring and prototypes have measured out at a maximum sound pressure level of 114dB at 1 metre which is equivalent to 97dB at 1 metre for 1 watt input. Low frequency efficiency is important for a flat response and the LS5/8 is flat to 50Hz (by comparison the LS3/5A is respectably flat to 70Hz). The LS5/8 is an efficient two-way design with a large diameter soft dome tweeter crossing over to a 12 inch bass driver which will work up to 2kHz. This driver is made not of bextrene but of polypropylene. This material's application was pioneered by Dudley Harwood during his long stay at the BBC and has the edge on bextrene in more than a few ways.

One of the biggest advantages using polypropylene copolymer is its consistency from batch to batch as it is a simpler polymeric substance and does not contain the plasticisers which often affect bextrene's properties; additionally polypropylene avoids additional doping, often applied to bextrene to reduce its 'quack' colouration, by its high self-damping; this makes for greater consistency as doping is usually hand applied. Polypropylene is therefore a lightweight, low colouration material which enables a drive unit to be built that is both efficient and clean.

Indeed the LS5/8 design appears not only to have the high level SPL capability required for rock monitoring but is also uncoloured and suitable for speech and classical music. This is a big advantage where previously the BBC have used two pairs of loudspeakers on turntables when a studio is to be used for rock and classical broadcasts — one pair is turned to face the rock producer and when the studio is required for classical music the tables are turned to give voice to the other speaker pair suited for classical music monitoring.

The LS5/8 incorporates the BBC slot which, despite rumours to the contrary, is designed to improve dispersion of low frequencies and reduce directionality in the horizontal plane. The slot is wide and only encroaches on the driver area by 3 to 4 cm at each side of the circle.

Cabinets for the 5/8 conform with Dudley Harwood's advocated light, easily damped material and consist of 12mm ply with an equivalent thickness of damping pads and foam. Air damping is provided in the cabinet by rock wool which was chosen to reduce the fire risk with other materials in safety conscious studios. The cabinets have been 'listened' to with a figure-8 microphone and acclererometer tested to investigate their colouration resonances or indeed the lack of them which were found to increase linearly with cone amplitude. Production agreements for the LS5/8 are at present under discussion between Swisstone Chartwell and the BBC.



Chartwell PM450P, a polypropylene drivered, high efficiency enclosure related to the LS5/8. The electronic version contains an active crossover and a Quad 405 power amplifier feeding a full 100 watts to the 12 inch bass driver and an attenuated 12 watts to the large diameter soft-dome tweeter.

Polypropylene cone material was pioneered by Dudley Harwood and is seen here in his Harbeth HL Monitor.

Assessors

So much for practical loudspeaker design, but what does the BBC look for in its loudspeakers and how does it assess a design once it has been produced? It is said that Dudley Harwood would always take the first opportunity to butt into a technical discussion about some development and say 'Yes but what does it sound like?' And this could well be the maxim which determines the performance of a BBC design.

The Corporation looks for two main defects in speaker sound: colouration and non-flat frequency response. The latter changes the presence of a speaker — which in BBC jargon is a literal description of altered perspectives in imagery due to a change in the frequency balance of a loudspeaker. For instance, if a speaker is more efficient around 1kHz then violins will sound forward in the orchestra, whereas horns, bassoons, trombones (and the instruments with lower ranges) will sound recessed. A peaky response will be averaged by the ear and its effects not heard as a frequency aberration.

Colouration is not shown in steady state frequency tests and, though colourations can be measured, there exists no standardisation for their measurement and so the Corporation relies on assessment of colouration by trained ears. Digital tapedecks are used to feed the speakers, commonly in rooms with a reverberation time of 0.35 to 0.4 seconds (which corresponds closely to a domestic room), with a range of materials, but the favourites seem to be male voice (revealing of chesty colouration, and similarly revealing is trombone in a multi-mic recording of dance band music). No form of noise reduction is used. BBC announcers, known personally to the listeners are recorded under carefully controlled conditions to provide material for these tests.

There is a feeling that trained listeners are far better at colouration assessment than an untrained ear, as untrained ears often make random choices. The ultimate critic of a loudspeaker design is the person who is going to use it as only they can say if a fault in this loudspeaker would cause them to make a balance adjustment in the sound from their studio that would otherwise not have been made. Most tests are carried out under blind conditions.

Subjective testing must be done by the specialists as they know what they are listening for; speech is the most discriminatory material due to its familiarity — rather like colour TV where colour sets are set for the best reproduction of skin tones. One interesting finding has been that for a speaker equalised for a flat response in a dead room there is subjectively too much HF energy in a control room setting.

Stereo imagery is assessed with great finesse by trained listeners marking the boundaries of a central speech image with a movable white chord. Accuracy of the LS3/5A is quoted as an average image width for five listeners of 6 degrees with a standard error of 1.3 degrees for a centrally-placed full bandwith male speech recording, which is very accurate. Furthermore the sound supervisor/studio manager and producer both want stereo so the off-axis response has to be good.

The continued quality of BBC and related designs seems ensured because of the accuracy of their subjective assessment which is due no doubt to the ever present reference of live music. And there's a lesson for us all.