DESIGN OF THE AR48-S AND OF S SERIES SYSTEMS FOR THE OPTIMUM ROOM-SPEAKER INTERACTION

BY

TIM HOLL

VICE PRESIDENT, ENGINEERING AND PRODUCT DEVELOPMENT

AND

ALEXANDER P DEKOSTER

CHIEF ENGINEER

INTRODUCTION

With the completion of its new line of bookshelf loudspeakers, every speaker system in the A.R. line is now designed such that the effects actual listening rooms have on the sound of a loudspeaker are taken into account. A.R. began this design work with the AR-9, a system which incorporated several unusual features to enable it to achieve such optimum performance in real listening environments. Later systems, such as the current bookshelf systems, have more conventionally positioned drive units than the AR-9 type of system in that the woofers are mounted on the front panel instead of on each side. However, in terms of speaker-room interface the performance of these later systems is not far removed from that of the AR-9. These systems utilize A.R. developed computerised measurement techniques in their design that ensure that the effects of room boundaries are taken into account. They also incorporate drive units positioned in vertical arrays to ensure that the stereo image is not degraded by assymetrical dispersion patterns, together with sophisticated computer-developed crossover circuitry to give a level of performance not previously available at these price levels. Finally, in the AR-48S, which is the latest of our new bookshelf speakers, we introduce a new 4" midrange unit with a cone manufactured from a completely new material exhibiting extremely well controlled behavior and freedom from unwanted mechanical resonant modes.

THE NEW A.R. 4" MIDRANGE UNIT

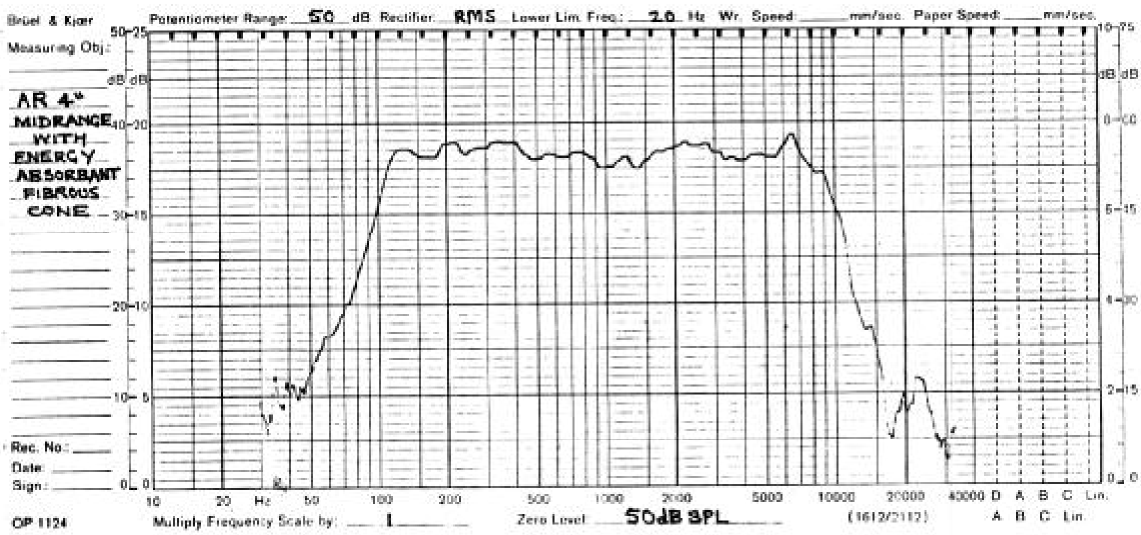
In any loudspeaker system, the midrange area of the frequency band is extremely important in that slight changes in response within those frequencies are very audible. This frequency region is the range of frequencies covered by the human voice, approximately 300 Hz to 3000 Hz, and it is extremely important for natural reproduction. For this reason it was decided to design the new midrange unit to cover substantially this range.

Within the pass-band of any drive unit it is very important that the cone or dome not exhibit any unwanted movements as distortion will then result. One major cause of such unwanted movements is the excitation of mechanical resonant modes within the cone or dome itself, commonly called "break-up" modes. A common approach taken to remove such modes is to make the cone or dome very rigid. Unfortunately such an approach merely moves the unwanted motions to a higher frequency and, when they do occur, they occur with greater severity. We say that they have a higher Q. The result of such resonant modes is peaks and dips in the frequency response, peaks and dips that generally cannot be completely removed by the crossover. This latter is so because, being resonant modes, they can be excited by sub-multiples of the frequency at which they occur.

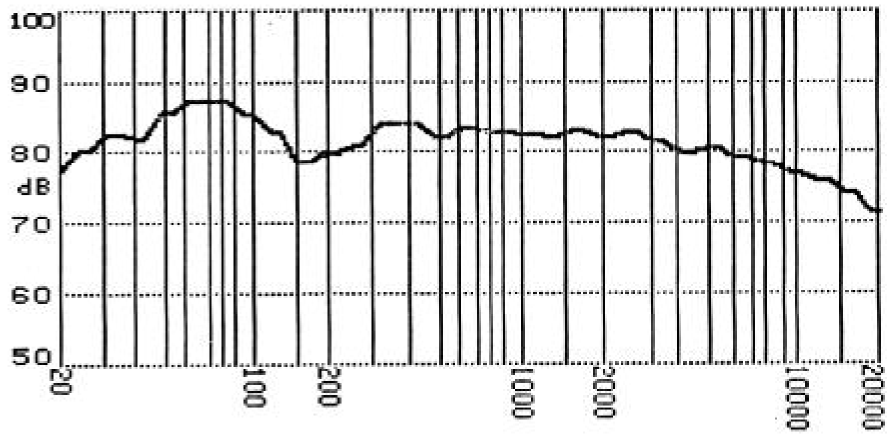
A. R. drive units take a different approach to controlling these undesirable movements. A.R. cones and domes are made to have an extremely low Q so that it is very difficult to excite mechanical modes within the diaphragm--the materials used have a high mechanical loss factor. On our woofers, for example, this is achieved by the use of proprietary treatments which soak right into the pulp of our cones, thus ensuring such energy absorbant properties through all parts of the material. This, incidentally, explains our continuing use of paper-pulp cones, as surface treatments on non-porous materials could not achieve the same results throughout the material.

In the cone of the new 4" midrange unit we have used a new technique. The cone is fabricated from a new fibrous material which is in itself highly energy-absorbant throughout its thickness. The result is a cone with much more consistent properties than could be achieved by adding treatments to a cone of such small size. The results can be seen by looking at the curve shown overleaf of a typical 4" conventional paper cone unit.

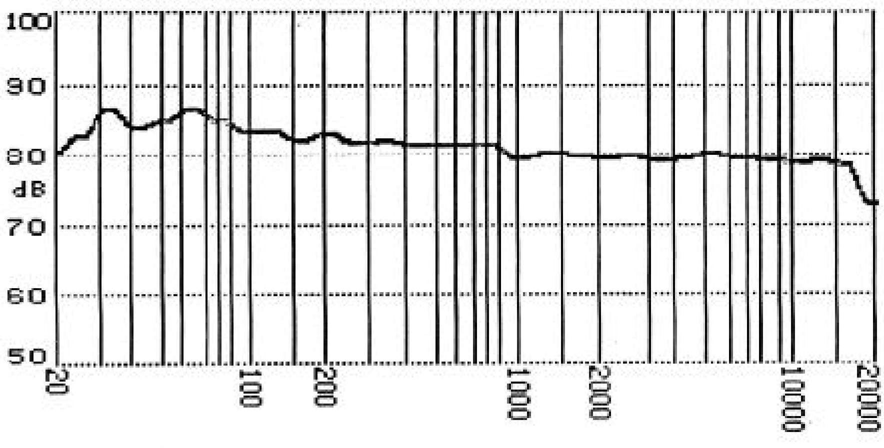
If we now look at a similar curve of the new A.R. unit, we see a much smoother high frequency performance.



The response does not look too bad and is in fact quite smooth. If however we place the speaker on its stand near a rear wall in a real listening room, a very different picture emerges. The next response curve was taken using the A.R. listening room measurement equipment. This takes a response curve on a third octave basis that is averaged both in time and space, the space averaging covering the normal listening area.

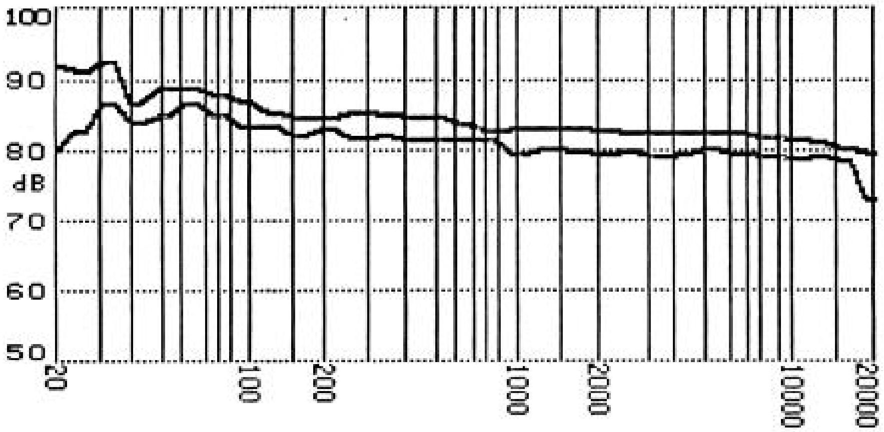


We can see on this new curve two frequency ranges that are very different to the anechoic curve. The high frequencies roll off much faster. This is because the anechoic curve is extremely sensitive to microphone position in this frequency region and the curve shown is only one of many, depending on precise microphone placement (this is particularly true in the crossover region between midrange unit and tweeter). The room curve, however, is averaged for the listening area and shows the true audible response. The second and most significant change is the broad dip in response that occurs between 100 Hz and 300 Hz. This is caused by reflected sound waves from adjacent wall and floor surfaces. System dimensions are such that when the cabinet is back against a wall, then these reflections are out of phase with the directly radiated sound waves in this range and a cancellation of output occurs. The obvious answer was to design a system with specially placed drive units so that the dimensions could not cause such cancellations, as in the AR-9 shown in the following curve:

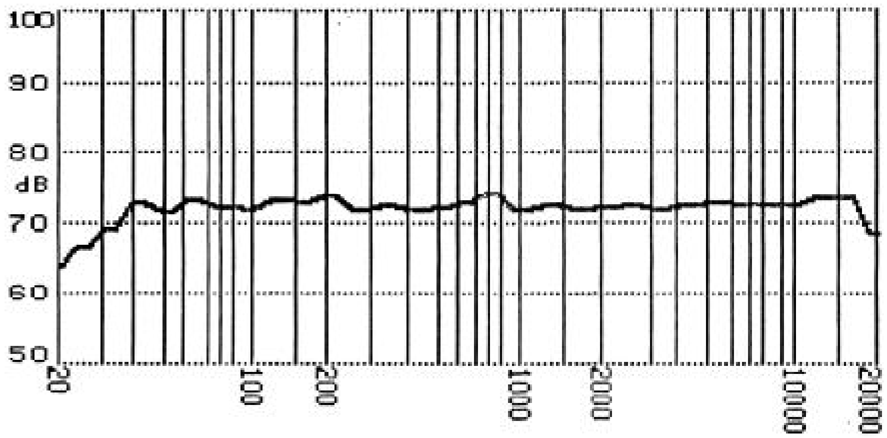


We can see on the previous curve that the AR-9 did indeed remove the cancellation at lower midrange frequencies caused by sound waves reflected from wall and floor. We can see that the frequency response is not "flat", however, does this mean that the system has a lack of high frequencies? It does not. In fact, what we are seeing is the natural high frequency roll off of the room itself, a characteristic that will vary from room to room with such factors as room furnishings, carpets, wall surfaces and so on. This roll off in high frequencies would be superimposed upon any sound source in the room, whether that source be a loudspeaker, a live piano, or someone's voice, for example. The speaker should not attempt to modify that inherent room characteristic as this could only work in the specialized case of a single room. The speaker should neither add to nor take away from that characteristic.

This room characteristic, or "room response", can be measured by measuring reverberation times. We see the room response for the room used to measure the AR-9 on the same plot as the AR-9 in the curve overleaf.

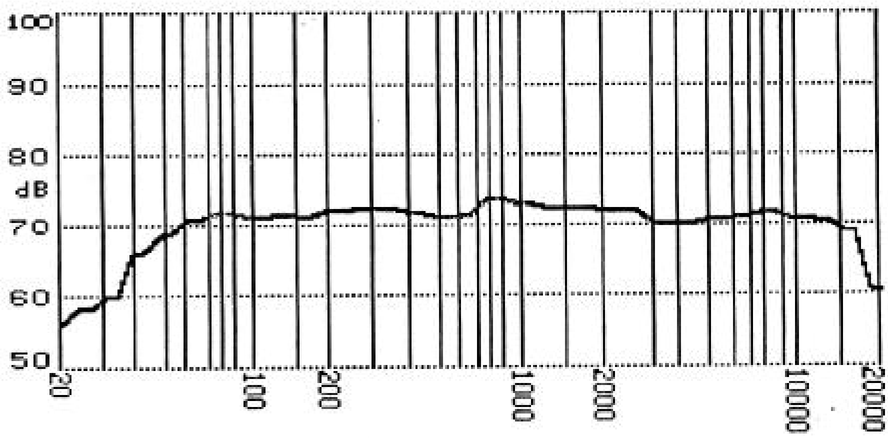


It can be seen that the shapes are very similar. Using our computer, we can then subtract the room response from the combined speaker-room response.

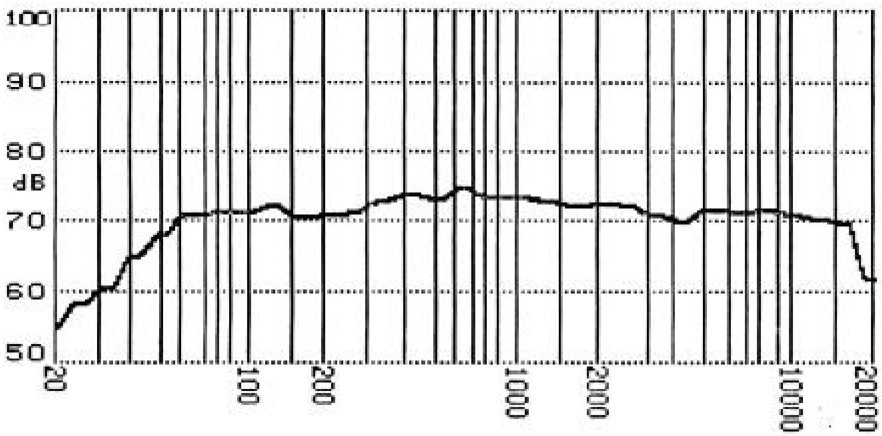


We can see two things in the resultant curve. First we see whether room surfaces close to the speaker will adversely affect the frequency response. Secondly we see whether the speaker itself adds to or takes away from the natural room response. In the case of the AR-9, we see a flat curve which shows that it combines very well with the room. All the rest of the curves shown will have had the room removed in this fashion.

So far we have spoken about a system with specially positioned drive units. What is the situation with conventional systems such as the current A.R. bookshelf systems, systems with all units on the front of conventional cabinets? By using the type of measurements discussed when designing all systems, we can take account of the effects that will be encountered in various speaker placements. We cannot remove the wall and floor reflections, but we can be aware of them and design the drive units and crossover for a given system such that the overall response averages out to a smooth curve. The results can be seen on the next curve which shows an AR-48S on the floor against a rear wall (room response subtracted out).



The results are as smooth when the system is placed on a bookshelf as shown below. In this case the center of the cabinet was approximately at ear level.



It should be borne in mind that smooth response in a real room with any speaker depends on the relative distance to reflective surfaces and whether these are such as to cause out of phase reflections which would thus cause cancellations. This can occur, for example, if speakers are the wrong distance from wall or floor. In the case of the A.R. systems, they should either be back against a rear wall or several feet away, but not at about 1 to 2 feet distance. The bookshelf systems should be on the floor or with the center of the cabinet about at ear level, but not in a position only raised slightly above the floor. If such guidelines are heeded, then the performance in actual listening rooms can be predicted to a high level of accuracy.

CROSSOVER DESIGN

The design of a crossover is one of the most important things affecting the sound of a loudspeaker system. Moreover, it is possible to achieve a given performance with several different types of circuitry. Using A.R. developed computer programs for the design of crossovers, we have been able to achieve systems which exhibit the desired frequency response together with excellent impedance characteristics. We have also taken computer aided design one stage further. The networks for the bookshelf systems have been designed such that component count and component size have been reduced compared to conventional networks which would yield similar performance. If conventional parallel networks had been used for the 400 Hz crossover in the AR-48S, then we would have had to use two 3.8mH chokes, one 120µF and one 100µF capacitor. By using the type of series network shown below, we end up using one 2.3mH choke and two 120µF capacitors. We use only air cored chokes for low distortion and so the difference in the amount of copper for the two versions is significant. The circuitry developed by A.R. enables a performance level to be obtained that is not otherwise available at such a price point.