Loudspeaker Stereo Techniques

How to combine left and right signals and get the message from the medium

by E. J. Jordan

I think to start with it is pertinent to ask 'why stereo?'. As is often the case in the design of loudspeaker systems the primary aim may appear somewhat cloudy. One advantage of stereo is that two loudspeakers are sold instead of one, which is very much in the interests of many people. But what are the *performance* advantages of stereo reproduction? It may be suggested that lateral location of the various instruments or voices in music becomes possible, but on this point it is worth noting that one of the difficulties associated with concert hall design is to provide a sound stage which *minimizes* lateral spread, and such spacing as there is only comes about due to the problem of having to accommodate possibly 100 or more instruments (and many of them large) on the sound stage. Obviously they should not be too deeply ranked, otherwise the sounds from the front will mask those from the rear and there may also be a time delay problem. On the other hand it would be equally unsatisfactory to stretch an orchestra out in a horizontal line so that sounds came to us from widely different directions. Orchestral layout must aim to bring out the full quality of each individual instrument whilst maintaining a balanced harmonious whole.

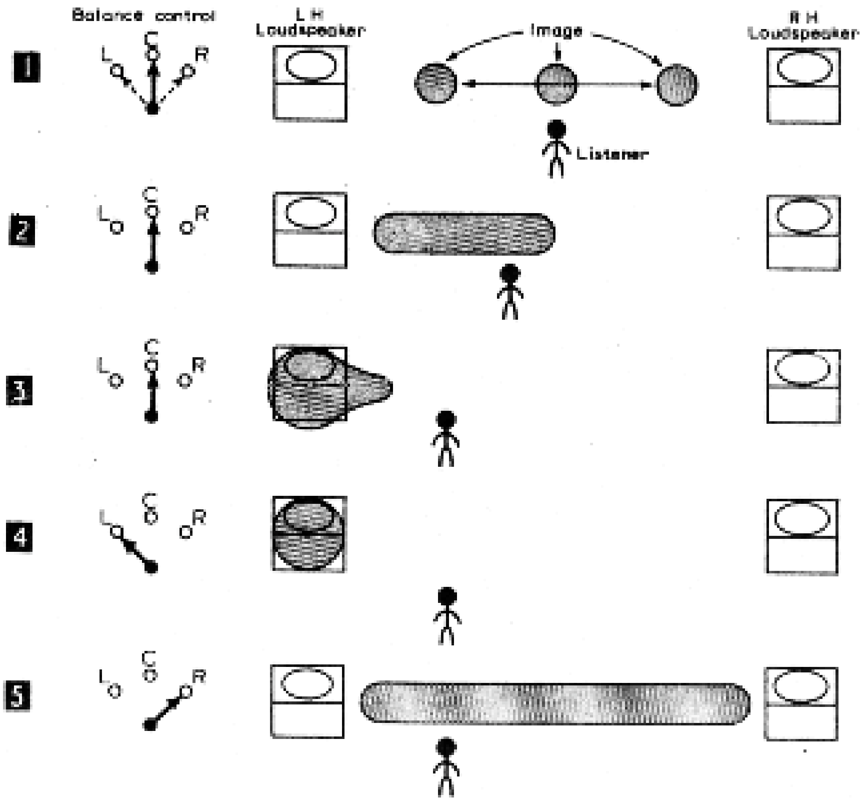
Having said this it is a double paradox that so often in stereo reproduction attempts are made to spread the sound out over the greatest possible width, whilst using conventional loudspeaker arrangements that are intrinsically incapable of doing this. It has become apparent to me that in so many aspects of sound reproduction, considerable time, money and effort are directed towards ends which are neither possible nor even desirable.

Certain types of programme, such as opera, can benefit from a wide sound stage, particularly where movement on the stage is to be portrayed; and this provides us with one advantage of stereo. However, the effective stage width must be appropriate to the programme and to the listening area. I personally do not like to hear a violin solo spread over the same area as the full chorus in *Aida*—or vice versa.

Which leads us to the second and more important performance advantage of stereo, which is to provide an appropriate sound stage: not to squirt sound from the left and right, but to provide a sound area commensurate with the programme. A single loudspeaker can do this adequately for an unaccompanied voice or small instrument provided that there is little reverberation. This situation normally only applies to news bulletins. For all other programme material good stereo provides a considerable enhancement of realism which cannot be secured merely by using two spaced loudspeakers in mono.

The reader will have appreciated by now that the advantages of stereo reproduction are purely subjective; accordingly this article is primarily a description of some of the many experiments that I and my colleagues have conducted over the past few years, and the observations made therefrom.

A third important advantage of stereo reproduction is that it separates the sounds of instruments playing together. Now I am not referring here to apparent physical separation in the sense of spreading apart but to the discrete identity of instruments, even when closely grouped, allowing the individual music lines to be heard more clearly. This is due to the fact that binaural hearing is far more selective than monaural when dealing with a multiplicity of sound sources. The dramatic demonstration of this is to listen to someone speaking in a noisy environment first using both ears normally and then with one ear covered. The immediate impression with one ear covered is that the wanted sound is being masked by the noise whereas the use of both ears results in a far higher degree of separation of the speaking voice and the other sounds, and higher definition.



Figs 1-5. Listening effects produced using two loudspeakers connected to a twin-channel amplifier switched to 'mono'. The positions of listener and balance control are varied.

To sum up then, stereo reproduction can offer the following performance advantages:

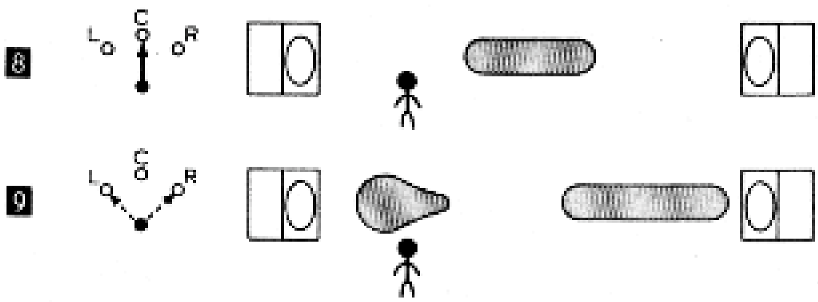
(1) the provision of an appropriate sound stage width;

(2) enhanced separation of sound detail; and

(3) the effect of sound source movement.

These are in what I consider to be their order of importance.

Throughout this article I shall only consider two-channel stereo. First, we are normally equipped with only two ears and can therefore deal with only two bits of audio information at any one instant. Secondly, any advantage of multi-channel stereo can be secured with two channels at less cost by improved loudspeaker techniques which will be discussed later. (The use of four channels to give reverberation effects is another matter entirely and will be dealt with in a subsequent article—the editor permitting.)



Figs. 8 and 9. Images produced by the arrangement of Fig. 7 for an off-centre listener.

Basic arrangement

The simplest and almost universally adopted loudspeaker arrangement for stereo is the use of one loudspeaker for each channel positioned to the left and right of the required sound stage. Such a situation is shown in Figs. 1 to 5.

To study how these and other configurations work, two loudspeakers were connected to the left and right outputs of a stereo amplifier which was switched to the mono position. Each loudspeaker thus received the same signal which could be varied in relative intensity between the loudspeakers by varying the balance control from centre to half right and half left. For these tests the loudspeakers were placed face upwards to eliminate polar effects.

In Fig. 1 with the balance control central and the listener on the centre line facing forward, there is a sharply defined image straight in front of the listener. If the listener, however, swivels his head, the sound image will tend to move in the direction he is facing. (By shaking his head vigorously, he can shake the entire orchestra—rather like the effect with headphones. Returning now to the 'eyes front' condition and swinging the balance control, the image will retain its sharpness and move left or right accordingly. So far so good, we have a working stereo system—just so long as your head is held in a clamp.

Setting the balance control back to centre and moving the listener just off axis, has the effect shown in Fig. 2, where we see the centre image replaced by an extended sound area of indeterminate position between the nearest loudspeaker and the centre.

Moving the listener further off axis with the balance control still central gives the situation in Fig. 3 where most of the sound image is centred around the nearest loudspeaker with just a hint of pull to the centre. This is known as the Haas effect and also explains why two spaced loudspeakers in mono will not give an increase in the size of the sound stage. Keeping the listener in this position and moving the balance control half left (in this case) not surprisingly concentrates the image solidly around his nearest loudspeaker as in Fig. 4.

Moving the control half right, however (Fig. 5), produces a completely indeterminate image extending from one loudspeaker to the other.

It is obvious from these experiments that for any listener position other than forward-facing on centre, the reproduction of a stereo signal by this system is quite unsatisfactory. It is appreciated that by gimmick recording techniques some sounds may emanate from the remote loudspeaker but the image in between the units will remain distorted.

Improved results can be secured by the use of loudspeakers having forward polar lobes. The loudspeakers should not be highly directional and a very suitable characteristic would be to have a difference of about 6dB at 15kHz between the response on axis and 30° off axis. A frequency response curve of the preferred type is shown in Fig. 6. The optimum stereo results are secured when the axis of the polar lobes crosses *in front* of the main listening area (Fig. 7). If we now place our little man back in the centre of the listening area he will experience exactly the same situation as depicted in Fig. 1. In fact, this will be true for any symmetrical arrangement of identical loudspeaker systems. It is when our man moves off centre that the trouble starts, and what we are trying to do is establish a two-channel stereo system which will work for all listening positions.

With the loudspeakers arranged as in Fig. 7 and the balance set centrally, our off-centre man will observe a somewhat extended image but at least it will be situated more or less centrally (Fig. 8). (Compare with Fig. 3.)

If the balance control is swung half left a more sharply defined image will approach the left-hand loudspeaker. If it is swung half right our listener, still to the left, will 'observe' a broad image between centre and the right-hand speaker (Fig. 9). This is still far from ideal but nevertheless it is considerably better than the effects in Figs. 4 and 5.

An additional problem arises in the crossed polar system when broad images occur: there is apparent sound movement within the image which is frequency conscious, but this is usually the least disturbing problem.

A programme source in which there is considerable movement exposes a further drawback of the basic two loudspeaker

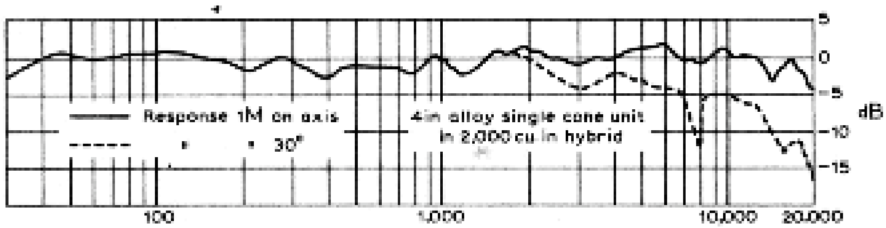


Fig. 6. The type of polar characteristic required for optimum stereo performance.

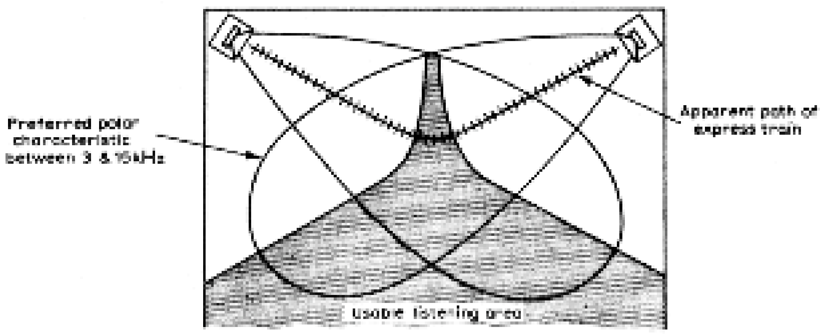


Fig. 7. The optimum stereo condition. The polar lobes cross in front of the main listening area.

arrangement and this can be illustrated by the use of one of the 'passing express train' types of recording. One assumes that the train did in fact go *straight* past the microphones in the first place but all arrangements similar to those described so far give the impression that the train passes on a curved track as indicated in Fig. 7.

It is thus theoretically possible to provide perfectly adequate stereo from two channels. However, the arrangements normally used can provide considerable image distortion. This can be minimized by optimizing the polar characteristics of the loudspeakers. If the loudspeakers tend to be either omni-directional or on the other hand extremely directional, then the image distortion may be so bad as to render the additional cost of stereo over mono quite unjustifiable.

Image distortion is also worsened by trying to achieve too wide a sound stage, i.e. having the loudspeakers too far apart relative to the listening position.

Centre loudspeaker system

I first encountered the use of a centre speaker many years ago demonstrated by Hugh Brittain. He had a large G.E.C. Periphonic system each side of a stage and a small forward facing system in the middle. The middle speaker was fed with a sum signal from each channel attenuated by 20dB and could be switched in or out. Listening in the centre position it was barely possible to tell whether the middle speaker was on or off. Moving to the side with the centre speaker off produced the usual shift of the entire image to the nearest loudspeaker. Switching in the centre loudspeaker expanded the image right across the full width of the stage with good image location.

Fig. 10 illustrates our experiments on these lines. In this case the two side loudspeakers were turned inwards by an angle of about 30°. The centre unit faced upwards and was fed from both channels at full level. This resulted in an effective gentle top roll-off above about 3kHz. With the listener in his usual off-centre position and the balance at centre, an almost perfect central image was secured. With the control set half left or half right, fairly well defined images were secured in the appropriate positions. It was very refreshing to be able to walk across the full sound stage and find that all the images remain stationary and well formed. It was interesting to note that the passing express on this system went *straight*.

A game that two can play

A very entertaining evening can be spent if you get your hi-fi friend to bring his loudspeakers to your house. (Naturally his equipment is not quite up to your standards so he will only have bookshelf units.) Each of these is then connected, via very long leads, in parallel and in phase with your own systems. You can now play for hours with various juxta-positions of all four loudspeakers and the various effects obtained can be quite startling. You can 'do your thing' and get 'high' on a plasma of sound; and at the culmination you can shake your heads vigorously and splatter the sound all over the walls. (Marijuana has nothing on this.) Having settled down, however, the effects of placing the two 'visiting' loudspeakers in the centre back-to-back will bring about a remarkable improvement in the stereo effects. Quite seriously, these experiments are well worth trying.

An arrangement sometimes used on grounds of economy is a large centre speaker handling the bass of both channels with the middle and high frequencies handled by small left and right 'outrigger' units. But if the crossover frequency is too high or the crossover too sharp, the imagery will be distorted as in the case of the basic two-loudspeaker system and the bass will be disembodied.

Reflected stereo system

A variation of the centre loudspeaker technique which possesses certain additional advantages is the reflected system. The arrangement is shown in Fig. 11 where two loudspeaker systems are placed back-to-back facing two reflectors. It is necessary for the polar characteristics of the loudspeakers to be similar to those described for Fig. 7 and it must be stressed that the arrangement is not satisfactory with polar responses markedly different from these. The reflectors should be inclined inwards at an angle of about 60°. The surface of the reflectors should be as hard as possible, glass or Formica covered timber is ideal, and they must be substantially flat. Any attempt to broaden the coverage by curving the reflectors will destroy the stereo effect. The arrangement as described can provide full room coverage in any case. The spacing of the reflectors and their area is not critical. It can be seen from the diagram that due to the positions of the reflected loudspeaker images, the effective sound stage width is nearly double the actual distance between reflectors. A typical spacing between reflector and loudspeaker might be 3 to 4ft in which case the width of the listening area will be 6 to 8ft and the effective stage width 12 to 16ft. As a guide to reflector area, if the spacing is 3ft then the area should not be less than about 3ft² with the smallest dimension not less than 1ft. These figures are taken pro rata for other spacings.

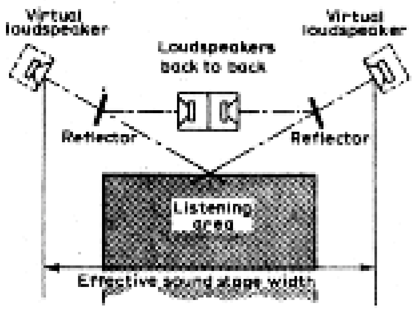


Fig. 11. A reflector system providing a virtual sound stage wider than the spaced reflectors.

The stereo performance of this arrangement is very good, being almost identical with that shown in Fig. 10. It has the additional advantage that only two loudspeakers are required. The cost of the reflectors is low and may be offset by the fact that one double enclosure may be used for the loudspeakers instead of two separate ones. In spite of the fact that all very low frequencies will be coming from the centre, this is not apparent when listening. The reflectors in any case will start to become operative only above about 200Hz. A considerable increase in extreme bass efficiency is provided by the mutual coupling between the units.

All in all this technique provides a neat, practical and economic solution to the problems of stereo reproduction. From the point of view of room décor the reflectors may be made appropriately decorative, fitted on simple stands and put away when not in use. The space between the reflectors and the loudspeakers may be used, provided no large object is placed in line of sight on the loudspeaker axis. A standard lamp, plants, coffee table or a small chair may be accommodated or even a bookcase, provided it does not project into the 'beam' of the system.

An integrated radiogram

Not long ago I conducted an interesting exercise to see if a fully integrated stereo hi-fi radiogram could be successfully made using the reflector technique. The carcass of the system was provided by two back-to-back double loudspeaker systems spaced about four feet apart. The enclosures were of the hybrid type and the tunnel structures extended across the four-foot space and formed 'girders' upon which the equipment was mounted. One of the obvious problems was to prevent feedback from the speakers to the pickup without overloading the excellent bass response. This was achieved by a mechanical filter upon which the entire record player was mounted.

Full delay-line system

A delay line system is costly but nevertheless represents, in my opinion, the most advanced loudspeaker system at present possible both in quality of reproduction and in stereo performance. In view of the degree of the design

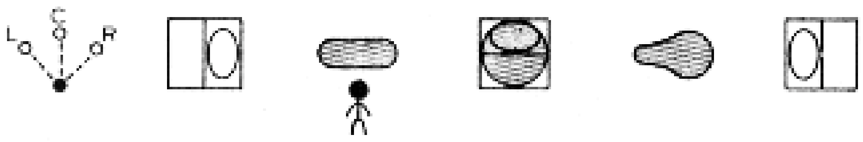


Fig. 10. Adding a centre speaker.

flexibility available, it is very desirable to design these systems individually to match the room in which they are to be used both aesthetically and acoustically. Basically the system comprises a continuous line of loudspeakers extending the full width of the required sound stage and the left and right channels are fed in at each end (Fig. 12). The loudspeakers are interconnected to form a delay line. The simplest arrangement is shown in Fig. 13. In practice, of course, provision has to be made for impedance matching. To make the continuity of the sound source as complete as possible the loudspeaker units should face upwards or downwards so that their axes are at 90° to the listener with the exception of the extreme end units which should face inwards. The effective polar response of these can be controlled by choice of delay components to optimize stereo performance. We naturally wish to avoid the hysteretic distortion normally associated with inductive crossover components and therefore only air cored inductors should be used and resistors if necessary. Development work on purely acoustic delay components is at present under way. Actual component values and the dimensions and layout of these systems are determined by the particular environmental requirements.

The stereo performance of the system is virtually perfect: well-defined images are produced which are precisely located and location remains quite independent of the position of the listener even if he stands at the end looking along the system. (To stand in this position with an express train rushing towards you is frighteningly realistic.) On the score of cost this would be in the region of £400 for a 10ft stage which does not make it the most expensive loudspeaker in the world by any means, especially when it is pointed out that this is only £200 per channel. It is interesting, therefore, to see how this system compares with others in this price bracket. I have already made my stand clear in the first of these articles regarding the advantages of the full frequency range single-cone moving-coil approach over crossover systems, so we will not cover that ground again. We have just qualified the stereo performance as being vastly superior to basic two-speaker system techniques. So if we are going to pay £200 for a conventional loudspeaker, such as a large horn-loaded system, what in fact are we paying for? The answer and remaining consideration is power bandwidth. On this score it is worth noting that a 10ft delay-line system would have a very high efficiency at low frequencies (approaching 20 times that of a single cone unit) and would handle up to 300 watts input power. The available sound power would therefore be extremely high; of the order of one acoustic watt. This is about 500 times higher than the power required to reproduce a full symphony orchestra in a 2000 ft^3 lounge.

A delay-line system need not take up very much space. A convenient configuration might take the form of a 'shelf' approximately 15in. wide and 8in. deep, running along one wall. The top surface of the shelf would be free for use with most of the loudspeaker units mounted on the underside (Fig. 14). As we have already pointed out, the delay-line system allows great flexibility of design.

Reflector delay-line system

As we have seen, the use of reflectors can produce a very wide sound stage—wider than the room if required—and for this reason reflectors may be used in conjunction with a full delay system. Of more interest, perhaps, is the fact that with the use of reflectors the delay line may be shortened with only a small deterioration in stereo performance and a considerable reduction in cost. An arrangement which has been satisfactorily used is shown diagrammatically in Fig. 15. A system like this would cost basically about £180, or £90 per channel. The total power handling capacity would be 120W and the low-frequency efficiency would be well above average. The available low-frequency power would be 64 times that of a single unit or about 0.13 acoustic watts. Using a system like this in the library of a large country house, an effective sound stage of 40ft was readily achieved with good location throughout this area. It was wonderful for listening to grand opera.

Conclusions

I feel that the loudspeaker industry as a whole has shown insufficient regard for the requirement of stereo, whilst on the other hand some of the record companies have messed things up with multi-channel computerized gimickry. The result is a squirt to the left of us and a squirt to the right, with a muddled hubble bubble in the middle. (Tongue twisters please note.) *Given* an optimized polar characteristic and correct placement, the basic two loudspeaker system will work sufficiently well to justify the additional cost. With very little additional effort these may be placed back-to-back in conjunction with reflectors to achieve a very marked improvement. If cost is not a primary consideration, then one of the delay line techniques may be used with or without reflectors to provide an ultimate in sound reproduction by today's standards.

A few times I have used the expression 'available sound-stage width', and to avoid confusion I should point out that there is no disadvantage in making this as wide as possible, provided the image location is good. In this case if the programme requires only a restricted stage, then this should be evident in the signal information and the programme material will restrict itself near to the centre of the available sound stage. Some programme material does benefit from a wide stage, in which case it is nice to have it available and to let the programme (by the grace of the recording engineer) determine its own width.

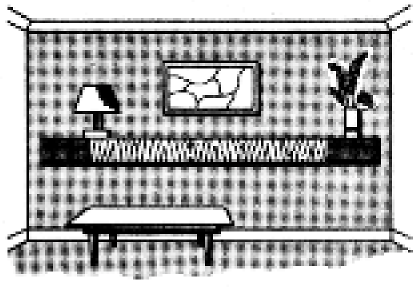


Fig. 14. Impression of how a full delay system might be fitted on a wall.

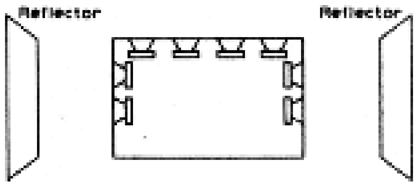


Fig. 15. A shortened delay line system also employing reflectors.

Fig. 12. A continuous line of speakers.

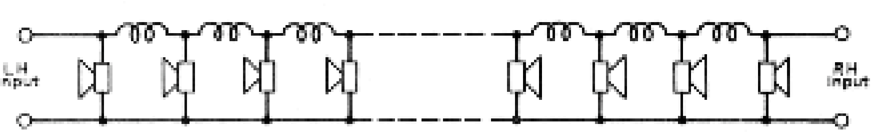


Fig. 13. Introducing delays to blend polar characteristics.

Printed-circuit Boards

Wireless World Colour TV Receiver. We are informed by D-B-S Electronics, The Parade, Cadnam, Hants, that they can supply printed-circuit boards for this receiver. One for part of the colour circuitry measures only $2\frac{3}{4}$ in. by $9\frac{3}{4}$ in. The layout is different from the original, but the board is drilled and the *R* and *C* numbers are marked on it.

Capacitor-discharge Ignition System. D. E. Bolton, of 61 Cuckmere Road, Seaford, Sussex, has produced printed-circuit boards for the capacitor-discharge ignition system designed by R. M. Marston and published in January 1970. Boards are available for both negative and positive earth versions at a cost of 25s (£1.25). This price includes postage, circuit diagrams, a list of components and suppliers, and practical construction tips.