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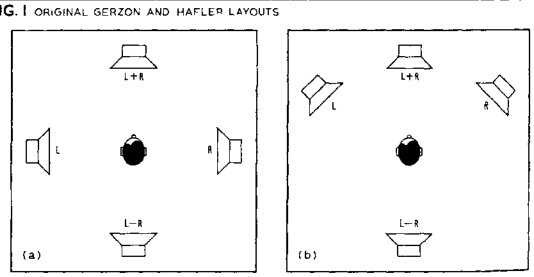
A year of surround-sound

Michael Gerzon describes further experiments and a new idea

A lot of interest was stirred up last August by the publication, in *Hi-Fi News,* of two articles describing how to get 'surround-sound' from 2-channel stereo recordings. Many readers have set up systems, having been assisted also by the excellent practical article by I. J. Kampel (January 1971 HFN/RR). Although some of these arrangements have been acclaimed with enthusiasm, several observers (including the present author) have not been entirely satisfied by what they have heard, and a few have been badly disappointed by the results obtained after considerable effort.

It thus seems a good time to take a second look at the various surround-sound-from-stereo systems, to see what their advantages and limitations are, and how they might be improved. To save a lot of tedious explanations I shall describe the various systems by means of a picture of the loudspeaker layout in which the combination of the left channel signal L and the right channel signal R fed to each speaker is written next to it. The original system that I proposed in August 1970 was that of Fig 1(a), and it was found

FIG. 1 ORIGINAL GERZON AND HAFLER LAYOUTS

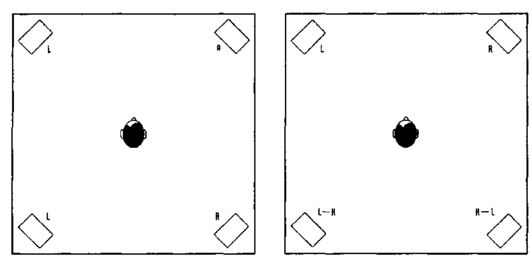


that the best results were obtained by listeners sitting back from the centre, with central listeners obtaining an unpleasant over-ambient effect. In the same issue, David Hafler proposed the practically identical system of Fig 1(b). The main difference in our proposals was that Hafler obtained the signals for the four speakers from a single stereo amplifier fitted with a blend circuit. I did not adopt such a procedure as I felt it desirable to use two stereo amplifiers in order to have complete control over the front and rear levels (which in any case should be (L+R)/√2 and (L—R)/√2 from certain simple considerations) and to avoid interactions between the speaker impedances and the amplifier source impedances, which could upset the frequency and transient response. It is not always realised by those using the Hafler hook-up that a front speaker must be of precisely the same type as the left and right pair, in order to avoid a frequency-dependent stereo width caused by the variation of speaker impedance with frequency.

Although the set-ups of Fig 1 are capable of giving very good results over a fair listening area with specially recorded material – with ideal speaker placements and careful volume adjustments – they are not really very good on commercial recordings and have proved to be rather critically dependent on speaker placement and room furnishings. I had regarded this system as experimental when my article was written, and indeed had not seriously expected it to work at all when I first tried it.

The reason for this initially sceptical attitude was the publication of a proposal in the May 1965 American *High Fidelity* magazine, which described a system of what it called 'spatial stereo', in which one ordinary stereo system was placed in front of the listener and one behind, as in Fig 2(a). As an even

FIG. 2



(a) 'SPATIAL STEREO' (b) 'HAFLER'

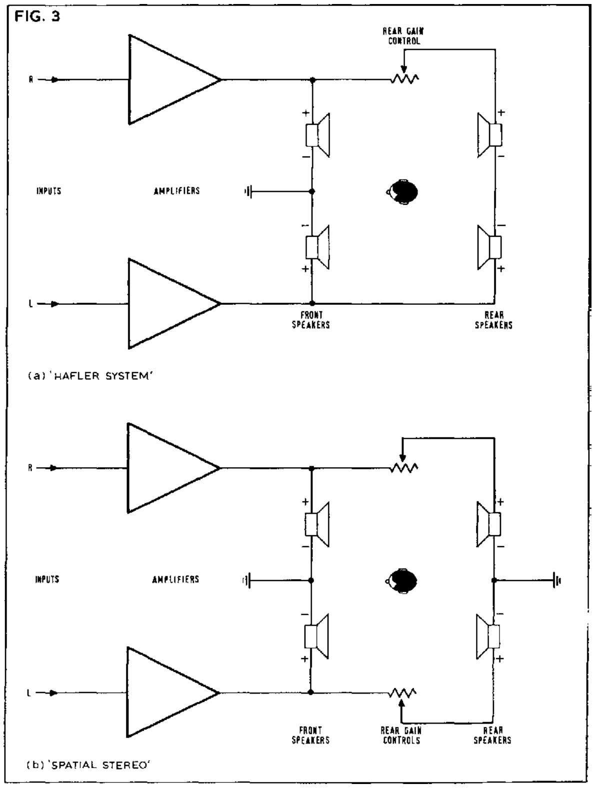
better alternative, it was also suggested that the sum signal L+R could be reproduced through a single speaker placed behind the listener in addition to the usual front stereo pair. The system had evidently given excellent results for Leonard Feldman, who had written that article, but when I tried it results were fine only if one clamped one's head into the confines of the one square inch in which it worked.

Many others must have tried 'spatial stereo' and met with similar disappointments. Speakers producing the difference signal L-R behind the listener would, so it then seemed, produce the same defects, as all non-central sounds would come from both front and behind as in spatial stereo. Despite its simplicity, these discouragements may have been what prevented anyone from trying for several years what has come to be known as the 'Hafler system', which is illustrated in

Fig 2(b), in which ordinary frontal stereo is supplemented by two rear speakers reproducing L-R in antiphase.

As is now well-known, the wiring diagram for the 'Hafler' system is as in Fig 3(a), in which a single stereo amplifier is used to drive all four loudspeakers.

FIG. 3



(a) 'HAFLER SYSTEM'

(b) 'SPATIAL STEREO'

Of course, separate a stereo amplifiers can be used for the front and rear pairs of speakers, so that their volume can be independently adjusted; or alternatively, a variable resistor can be placed in series with the rear speakers to provide volume adjustments, as in Fig 3(a).

There are several troubles arising from the use of a variable series resistor attenuator as a rear volume control:

(i) Some speakers have an impedance varying by as much as 10:1 over the audio-frequency range, and this causes the attenuation to vary a lot with frequency, giving an irregular rear frequency response.

(ii) The attenuation resistor causes a poor damping factor on the rear speakers.

(iii) There is a power loss in the attenuation resistor, although in practice this can be small.

(iv) One cannot turn *up* the volume of the rear speakers.

Inadequate rear volume can arise because the signal reproduced by the rear speakers by the Fig 3(a) circuit, when no attenuation is used, is only ½(L-R) and ½ (R-L)), instead of L-R (and R-L). One can attempt to overcome defect (iv) by wiring the rear speakers in parallel rather than in series, and this would increase the rear volume obtainable, but it also increases the drain on the amplifier's power reserves. One way of overcoming the defect is to use rear speakers of effectively higher efficiency than the front, and this solution is adopted by the author. Problem (i) can be minimised by using a speaker with a uniform impedance curve; but regrettably, many otherwise excellent speakers are poor in this respect.

However, the most severe problems experienced with the Hafler system have other causes. Everyone agrees that the system is capable of an excellent quality of ambience on good recordings, but there have been complaints that it produces a very fatiguing sound, that it gives spurious unwanted sounds from the back, and that it depends critically on where the listener sits. At the same time, other listeners profess themselves to be entirely satisfied. Sometimes the two reactions are produced in different critical listeners hearing the same set-up. Clearly, some listeners are more sensitive or worried by the faults than others, and I admit to being not at all happy with the system myself.

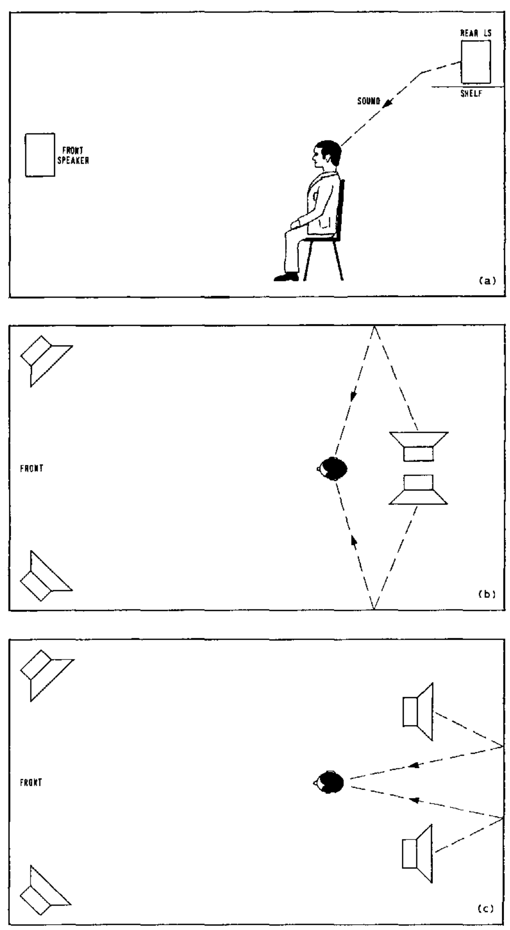
The first mistake often made has been to use rather coloured loudspeakers at the rear. There has been a regrettable tendency to claim that the rear quality doesn't matter much, but I think experience shows that this is simply not true. The reason for this is partly that the Hafler system depends on the front and rear speakers both reproducing the ambient information at comparable signal levels. If this critical front-to-rear balance is upset at some frequencies, by resonances in the rear speakers, then one can hear many direct sounds come from the back, and the stereo definition can become imprecise, with many sounds being heard as coming from two places at the same time. Some of this effect remains even if very uncoloured rear speakers are used, but it is then far less obvious or objectionable. It may not be overstating the case to assert that the rear speakers have to be at least as uncoloured as those at the front, possibly even more so.

It was probably the inferior quality of my rear speakers that caused my early efforts at 'spatial stereo' to fail. This indicates that a system of ambient stereo reproduction cannot be condemned completely unless it has been tested with no compromises in the equipment. I have recently been trying 'spatial stereo' again for reasons that will emerge, and have been surprised at the relative cleanness of the stereo image that it can give with good rear speakers.

Not only do inferior rear speakers give a very poor stereo quality, but they can prove to be very fatiguing generally, and the moral is to make the rear speakers as good as the front ones. This may seem to be a counsel of perfection, but it really does seem to be essential for satisfying Hafler sound.

However, there are ways of 'bodging' poor rear speakers to give a much better Hafler quality than they would normally give. Many people seem quite happy with the results of such artifices, although the author finds plain old un-ambient 2-speaker stereo preferable to these. The first such proposal is to place the rear speakers high up on shelves, or at the back of high cupboards, Fig 4(a), so that the shelf partially obstructs the sound reaching listeners near the back of the room. This prevents the rear speakers becoming over-prominent at the back of the room, and helps attenuate the rear coloration.

FIG. 4 REDUCING REAR SPEAKER PROMINENCE



The second proposal is more of a fiddle, but has produced reasonable ambient stereo in a very tiny room. The arrangement illustrated in Fig 4(b) places the rear speakers immediately behind the listener, but makes them fire sideways at the walls. As long as one prevents much direct sound from the speakers reaching the listener, the longer path travelled by the reflected rear sound causes it to reach the listener later, and this helps to render coloration less objectionable. The reflected sound also becomes more diffuse, which also helps hide its faults. This system allows one to vary the ambient effect by angling the rear speakers slightly forward or backward, and seems to be the only way of getting surround-sound in many small rooms.

In larger rooms, the rear speaker coloration can be tamed to some extent by firing the speakers backwards at the rear wall, as in Fig 4(c). Again one can vary the effect by angling the speakers inwards or outwards for best results. All these ways of getting round poor speaker quality can also tame defects due to poor recordings, such as rear echo. All systems involving wall reflections rely on the acoustics of the listening room, and so cannot recreate the original concert hall properly. They have some of the same deficiencies as conventional stereo systems using omnidirectional loudspeakers, though the ambience is derived from a genuine ambience signal at least.

All this has relatively little to do with reproducing the ambient effect hidden in the stereo record grooves. Doing this properly does require the best equipment all round, but this equipment also has to be used properly. At the present stage of the art, so little is known about what set-up will give the most realistic effect that it seems unwise for the average hi-fi enthusiast to spend a lot of time and money on an ambient system when he runs a large risk of disappointment. There is, as yet, no real body of expert knowledge on how to put bad systems right, and the techniques described in the following paragraphs must be regarded as strictly experimental.

Those with an experimental bent, and who are willing to risk failure, may find some of the following ideas worth trying. This is done with least risk if you can pool your equipment with friends. One must be prepared both to experiment *and* to sit back and just listen to the music. The latter is essential, as listening fatigue can rule out many otherwise promising systems, whereas a particularly untiring quality suggests that the system is on the right lines.

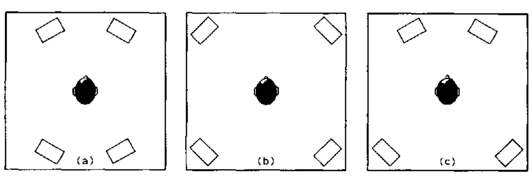
As a system for everyday use, even good Hafler reproduction has its defects. The most obvious is that the Hafler system tends to emphasise all the worst qualities of poor recording techniques. Pop records and (particularly American) classical recordings can sound definitely nasty, and highlighted solo instruments stick out in a most unpleasant manner. Some spaced microphone recordings can have a particularly distracting echo coming from behind.

Another far more subtle drawback is evident on only a few commercial recordings. If one plays a recording with a particularly convincing sense of the distance of each musician, then switching on the rear speakers can actually destroy this sense of distance, although the sound is then much more ambient.

Some types of recording benefit very little from the Hafler system, notably many of those made with coincident cardioid microphones. On other recordings, the ambient effect is fine, but the sound from the rear speakers draws attention to itself at reasonable settings of the ambience. A very general fault is that the ambience seems to have the quality of being in a tunnel running from front to back, rather than being all around one. Something is not quite right.

The first thing wrong is undoubtedly the usual speaker placement, which is a rather longish rectangle looking something like Fig 5(a). This makes most of the sound seem to come from the front or the back (or even both simultaneously), with little from the sides. This reduces the general sense of space.

FIG. 5 VARIOUS SPEAKER PLACEMENTS

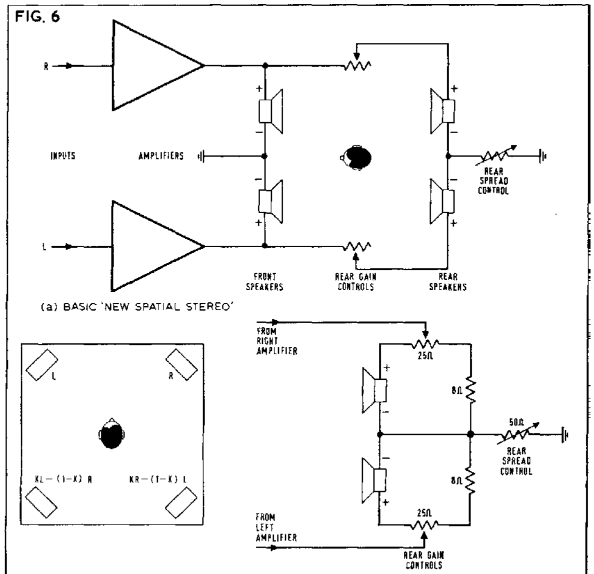


Initial trials indicate that as the rectangle of speakers is widened to approach a square, the sense of space improves, and less of a 'tunnel-effect' is heard. In most cases it is difficult to use a perfectly square speaker layout, especially as a hole-in-the-middle often appears at the front with the square layout of Fig 5(b). However, the front and rear speakers should made as close to a square as possible within these constraints, possibly as in Fig 5(c). One must conduct experiments to find the best layout with good recordings having a good ambient effect. Although improvements do result, there can be little doubt that the ambient effect is still never quite natural. And this is where we return to the long-discredited system of 'spatial stereo'.

The 'spatial stereo' system, with an ordinary stereo pair of speakers both in front and behind, may be reproduced from a single stereo amplifier as in Fig 3(b). It would not be worth printing this rather trivial wiring diagram were it not for the fact that it bears a striking similarity to that of the Hafler system of Fig 3(a). Apart from the rear volume controls, the only difference is that the common point of the rear speakers is earthed in Fig 3(b) and unearthed in Fig 3(a).

As soon as one spots this, a new insight is gained into the Hafler system, and a possible improvement is suggested. Suppose that the common point of the rear speakers were connected to earth via a rather large variable resistor, as in Fig 6(a). Then when the resistor is reduced to zero we have 'spatial stereo', and when it is increased to a very large value we have the Hafler system.

FIG. 6



(a) BASIC 'NEW SPATIAL STEREO'

(b) SIGNAL DISTRIBUTION

(c) IMPROVED METHOD OF CONNECTION

At intermediate positions of this resistor we have a new system, in which the sound from the rear speakers is ordinary stereo with an attenuated sum signal. Perhaps a better way of thinking about the new system is that the rear speakers are reproducing an out-of-phase difference signal as in the Hafler system, but retaining a certain amount of stereo spread. The signals fed to the four speakers are shown in Fig 6(b), where *k* is a quantity between ½ and 1, depending on the setting of the resistor. Fig 6(a) shows this new spatial stereo system with variable resistors in each of the two rear live speaker connections. If these are ganged or varied together, then they act as a rear volume control, with all the usual disadvantages of resistive attenuation listed earlier.

The main advantage of 'new spatial stereo' is that it introduces a degree of directionality to the rear of the listener. For example, a sound that is recorded out-of-phase but slightly stronger on the left channel than on the right will tend to be reproduced from a direction slightly to the left of behind. Because of this effect, the variable resistor connecting the rear speaker common point to earth is called the 'rear spread control'

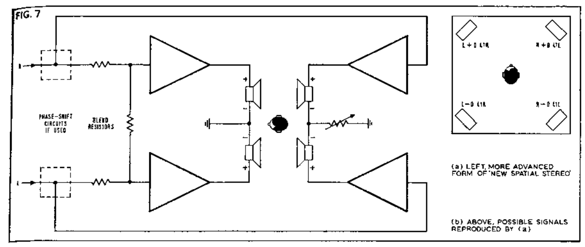
What is the precise effect of the rear spread control? With the few set-ups on which it has so far been tried, as one turns the control away from the pure 'Hafler' system, the sound seems to gain a subtle life and depth that the Hafler system lacks. This effect is very subtle, but as soon as one turns back down to pure Hafler, the sound becomes somehow flat and two-dimensional, although the ambient effect is no less obvious. However, if one turns the rear spread control too far towards 'spatial stereo', the ambient effect diminishes, and the sound takes on a somewhat gimmicky 'all-round' quality, which some may like on popular music. It is difficult to recommend a precise setting for the rear spread control, as a lot depends on the impedance curves of the back speakers. A setting between one and two times the nominal impedance of the rear speakers is likely to be about right. The maximum value of the rear spread control should be at least three times the rear speaker impedance, so as to give reasonable Hafler if required.

A disadvantage of the arrangement of Fig 6(a) is that one needs to readjust the rear spread control whenever the rear gain is adjusted. This is because the effective speaker impedance 'seen' by the rear spread control is that of the rear speaker plus the gain control resistor. The interaction between the rear gain and spread controls can be reduced by connecting up the rear speakers as in Fig 6(c). The resistance values shown are for use with rear speakers of 8-ohm effective impedance; they should be increased or decreased proportionately for other speaker impedances. Alternatively, the rear gain and spread adjustments can be made independent by using a second stereo amplifier for the rear speakers, using that amplifier's volume control to adjust rear gain.

If one uses a reasonably square loudspeaker layout with the new spatial stereo system, then one can get stereo images appearing beyond the left and right speakers. This shows that the system is beginning to approach the ideal of all-round sound, rather than the front-and-back of the Hafler system. Although the effect of new spatial stereo is subtle, I find that it gives less listening fatigue than Hafler, and tends to improve the dramatic effectiveness of stereophonic plays. Central mono sounds are not reproduced from the rear speakers with conventional Hafler, and this makes them 'stick out' and sound somewhat flat. But spatial stereo reintroduces some sum signal into the rear, and fills out mono sounds such as BBC announcers.

There is reason to believe that all this can be improved even further if one examines the out-of-phase signals supposedly emerging from behind the listener, then it will be seen that as much of this arrives from the front speakers as from the back. Just as new spatial stereo increased the front-to-back cross-talk, so do we need a further modification that reduces the amount of back-to-front cross-talk. To diminish the amount of rear sound from the front speakers, it is necessary to diminish the out-of-phase component at the front. This is another way of saying that the stereo width at the front should be reduced, by a blend circuit (see Fig 7). The degree of front

FIG. 7



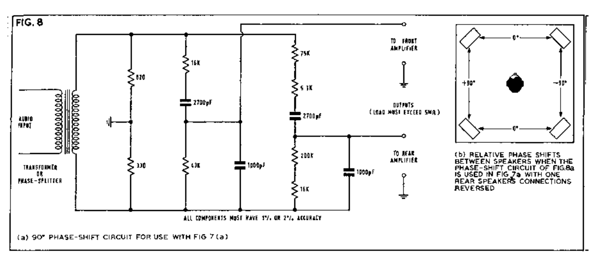
(a) LEFT, MORE ADVANCED FORM OF 'NEW SPATIAL STEREO'

(b) ABOVE, POSSIBLE SIGNALS REPRODUCED BY (a)

blend required is certainly not as great as that used for the Hafler system of Fig 1(b), but it is not obvious exactly how much blend *is* required. One possibility is to reproduce the signals of Fig 7(b), which were first suggested in the June 1970 *Hi-Fi News* (the J.O.K.E. system); these correspond to four directions of modulation in the stereo record groove at 45° to one another. In figure 7(a) the rear speakers are shown as running off a separate stereo amplifier from the front, in order that rear level adjustments can be optimum.

A disadvantage of such a system, as with all Hafler-type systems, is that one pair of speakers (in this case the rear pair) is always mutually out-of-phase. Reversing the connections of one of the rear speakers does no good, as this merely makes one of the side pairs out-of-phase. To get round this problem, one can connect the two rear speakers mutually in-phase, and then introduce a 90° phase-shift circuit into the dotted boxes of Fig 7(a), so as to render the rear speakers 90° out-of-phase relative to the front ones. A suitable 90° phase-shift circuit is illustrated in Fig 8(a), which

FIG. 8



(a) 90° PHASE-SHIFT CIRCUIT FOR USE WITH FIG 7(a)

(b) RELATIVE PHASE SHIFTS BETWEEN SPEAKERS WHEN THE PHASE-SHIFT CIRCUIT OF FIG.8a IS USED IN FIG 7a WITH ONE REAR SPEAKERS CONNECTIONS REVERSED

gives two outputs with a flat frequency response, with one being 90° out-of-phase with respect to the other over most of the audio band. This works well above 100Hz, and as long as one of the rear speaker connections in Fig 7(b) is reversed, it causes the relative phase shifts to be as in Fig 8(b).

This idea has been incorporated by Sansui in their QS1 'Quadphonic Synthesiser' albeit with a much cruder 90° phase-shift circuit. Unfortunately, the QS1 also contains non-linear processing circuitry, namely a phase modulator, and in the author's opinion this cannot be construed as high fidelity, although the effect may be liked by some. The basic operating principle of the QS1 is a matrix similar to that of Fig 7b, and it is likely that many other commercial systems of synthesising four channels from two are nothing more than elaborated versions of such matrix systems. If this is so, then it is likely that most such I systems will prove to be mutually compatible – *ie* will work off the same recordings.

Although the developments of the Hafler system shown in figs 7 and 8 are rather complex, it seems likely that they offer substantial improvements, especially in their ability to reproduce sounds from *all* directions around the listener. It will be seen that there are an enormous number of parameters to play around with, and clearly much patient experiment is required to establish the best such system. The optimum system can only be determined if suitable stereo recordings are available, including reverberant sounds coming from all in-phase and out-of-phase positions. At the present time, recordings made with the simple 90°-angled crossed coincident figure-of-eight microphone technique approximate closest to this ideal. Many of the earliest EMI stereo recordings are reputed to have been made by this technique.

Once this lengthy process of testing is completed, there is no reason to suppose that surround-sound from two channels could not give results as good as from four channels for nearly all types of music. Meanwhile, the experimentally minded can sample the and 'new spatial stereo' systems – but it must never be supposed that these are the ultimate.