



Loudspeakers and Rooms for Multichannel Audio Reproduction

by
Floyd E. Toole
Vice President Acoustical Engineering
Harman International

Part 1 - How many loudspeakers? What kind? Where do we put them?

Here we look at the basic theory of multichannel audio systems, leading us to understand why certain loudspeaker designs and room arrangements work better than others.

In the beginning, there was monophonic – single channel – sound. Compared to nothing, it was impressive, but eventually serious people began to wonder what more might be possible. Bell Labs, one of the world’s greatest research institutions, looked into what was required for accurate directional reproduction, and concluded that, for loudspeaker reproduction, multiple channels were needed. While many channels were desirable, they were not very practical, certainly not at that time, so they looked into a practical minimum number. They came up with three front channels, just to reproduce the soundstage – no ambiance, no sense of spaciousness. For a single listener, they thought that two channels would be sufficient.

So, in the 1950’s we got two channels.

The reason was that there were no practical methods, at the time, to get more than two channels into and out of the groove of an LP record.

We have put up with this limitation for over 50 years, and it is time to move on to better things. The idea that we only have two ears, and therefore need only two channels, applies only to headphone listening. In normal hearing our two ears and brain give us a remarkable three-dimensional sense of direction and space. To reproduce this, we need many channels.

67 years ago, in 1934:

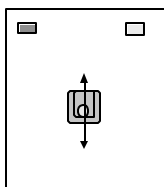
Bell Telephone Laboratories research concluded that there were only two ways to properly reproduce a realistic sense of direction and space:

1. Binaural – dummy head recordings reproduced through headphones. O.K. but not commercial.
2. **Multiple channels** –
 - How many? More are better!
 - A realistic minimum? **Three** across the front to reproduce only the soundstage, not ambiance.

So, how many did we get?

3

Multi-channel Sound - 1st Try TWO CHANNEL STEREO

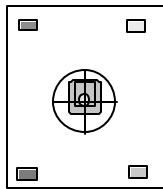


*Better than mono

*Antisocial - sweet “line”

*Poor sense of ambiance or envelopment

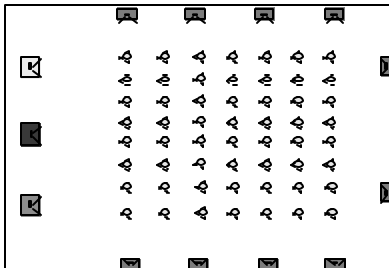
**Multi-channel Sound - 2nd Try
 QUADRAPHONICS**



- *More directional effects are possible
- *Better sense of ambience or envelopment
- *REALLY Antisocial – Sweet SPOT!!

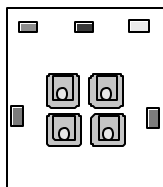
In the seventies, there was an attempt to do better. It failed because of industry disagreements over which of several competing systems should become the standard. Frankly, I am glad it failed, because it was the wrong arrangement of channels. With no center channel, the annoying stereo sweet spot remained. Most of the systems had a lot of crosstalk, or leakage among the channels, so that even the front-back impressions depended on the listener being half way between the front and back speakers. With no side channels, the sense of ambience and spaciousness was less than it could be. A lot of paraphernalia for another antisocial system.

Dolby Stereo for Cinemas



The multichannel matrix technology underlying quadraphonics was quite clever, and Dolby seized on it for Cinema applications. They revamped the active matrix system into four new channels: a left, center and right front array, and a single surround channel that was sent to several speakers distributed down the sides and across the back of a cinema. They included features that allowed the system to function with the imperfections that pervaded optical sound tracks – then the basis of the film industry. One of the compromises was a severe limitation in the high frequency response of the surround channels.

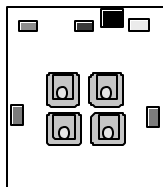
**Multi-channel Sound - 3rd Try
 Dolby ProLogic - for homes**



- *Social ! It can be shared.
- *A real center image
- *Only fair ambience and envelopment (mono surround)
- *Surrounds not broadband
- *Directional information only across the front

Naturally, the system migrated to the home, with the simplification that the surround channel was sent to a pair of speakers located at the sides of the listening area. One of the most common mistakes is to locate the surround speakers behind the listeners, at the back of the room. The perception of spaciousness, or surrounding ambience, is greatest when the sounds at the two ears are uncorrelated (different from each other). This is most effectively achieved when sounds arrive from the sides. This puts you in the hall, not between the band and the hall.

**Multichannel Sound - 3rd Try
 Dolby ProLogic - for homes**

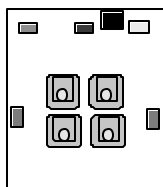


And the common-channel subwoofer arrives on the scene . . . and stays!

Recognizing that customers would react badly to being told that they needed five big full-range speakers, a subwoofer channel (the .1 in 5.1) was added.

However, in the beginning, no provision was made for a proper crossover between the subwoofer and the five “satellites”. As a result, there were many unhappy experiences in trying to make a good sounding acoustical transition between satellites and subwoofers that were not necessarily designed for each other. Because of this, many people thought that subwoofers were inherently less good than full-range systems. They were often right.

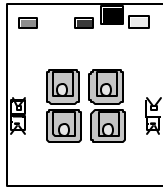
**Embellishments to ProLogic
 Home THX**



- *low-pass and high-pass filters for sub and satellites.
- *decorrelation of surround channel speakers
- *“timbre matching” of surround speakers – a dubious feature!
- *re-equalization (treble attenuation) of sound tracks.

Recognizing that cinemas were not always doing justice to their ambitious sound tracks, Lucasfilm set out to standardize sound quality in cinemas with their THX program. Then, sensing that things were not always right in the consumer world, they created a Home THX program, licensing a number of features and functions to manufacturers of surround processors. The loudspeaker crossover feature was welcomed, as was the electronic decorrelation of the surround channel, making the single channel sound less “monophonic”. The timbre matching of surrounds was inappropriate, and the re-equalization was not always what was needed, but these functions could usually be switched off in the processors.

Embellishments to ProLogic Home THX

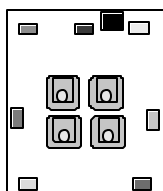


*vertical directivity control of loudspeakers - dubious
 **"dipole" surround speakers -

10

Beyond 5.1:

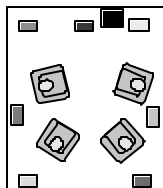
Logic-7 (Lexicon, Harman/Kardon), Dolby ProLogic II



*FIVE or SEVEN Steered channels
 *Directional information in all channels
 *Superb ambience and envelopment
 *Great for MOVIES & MUSIC

Beyond 5.1:

Logic-7 (Lexicon, Harman/Kardon), Dolby ProLogic II



*Sounds good over most of the room. You can look out the window!

12

2 channels in / 5 or 7 channels out

- INPUTS: any stereo source
 - CD's, tapes, LP's
 - Television, VCR, Laserdisc, DVD
 - Stereo radio or satellite/cable audio channels
 - Games
- OUTPUT:
 - 5.1 or 7.1 multichannel audio

13

To add differentiation in loudspeakers, THX promoted the idea of restricted vertical directivity. In my opinion, if one wishes to restrict directivity, it should be done in both vertical and horizontal directions. Directional control is very difficult to achieve with cone and dome drivers, and still retain high sound quality, but it is easily done with horns and waveguides. Some basic performance standards were also a part of the THX program.

To help two monophonic loudspeakers to sound like more, the idea of "dipole"(bi-directional out-of-phase) surrounds was introduced. It helps in many situations. And, so do other multidirectional designs that spray sound in many directions.

As time passed, the limitations of four-channel ProLogic became more evident. It was, after all, designed when optical sound tracks in films were the norm, and several features catered to problems with that signal source. A very successful effort to improve reproduction from film sound tracks was Logic 7, a sophisticated digital active matrix system that translated two channels into five or seven. In addition to all-channel steering, all channels were full bandwidth. Designed by Lexicon with a special sensitivity to the needs of music, Logic 7 has modes that tastefully extract and reproduce ambience from stereo recordings. Some of the modes are extensively user adjustable to accommodate personal tastes or system peculiarities. In my personal experience, the majority of stereo recordings benefit from a well-done multichannel conversion.

Recently, Dolby has introduced an upgraded ProLogic II with some of these features.

The traditional 5.1 channel arrangement evolved from movie theaters, in which everyone is regimented into rows, facing the screen, in the dark. While there are occasions to do this in homes, the reality is that most of our entertainment does not require such restrictions. For more casual video entertainment and for music, we may have some light in the room, open the blinds to see the garden, and face away from the screen. With only two loudspeakers at the sides, the surround illusions suffer and one may be aware of the limited number of channels. With four surround channels, appropriately processed, the sense of space can be remarkably seamless for listeners seated over much of the listening area. And, because there are now four speakers, there is less of a need for them to be multidirectional. In very small rooms, multidirectional speakers may still be less easy to localize, but in larger rooms that problem disappears and we can make all channels absolutely equal in sound quality, something that is important with multichannel music recordings.

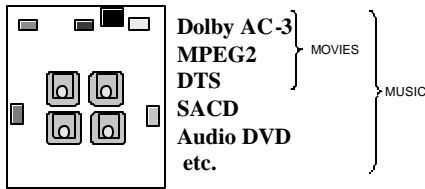
The entertainment business does itself a disservice by over emphasizing the "home theater" theme. We all watch movies, to be sure, but we spend far more time watching TV, listening to FM radio, CD's, satellite/cable music channels, etc.

We need to acknowledge the idea that a multichannel audio system brings a higher level of enjoyment from ALL sources of sound. A high quality two-channel to multichannel conversion system makes this possible.

The often gimmicky and mostly bad sounding "hall", "stadium" and "club" reverberation devices are not what I am talking about. These can be fun, but a tasteful multichannel conversion relies on ambience extraction, digging out the spatial information in the original recording, not adding synthetic reverb that may not be appropriate.

Multichannel Sound - 4th Try

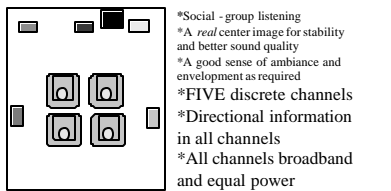
5.1 channel Digital Discrete



Eventually it had to happen, and it has. Technology caught up with our desires to have a fully discrete multichannel system, with all channels equal and independent. Now that it has, because it is digital, and therefore flexible, we have several systems. Not all of them need to survive, but at least all of them sound very good. SACD and DVD Audio, in certain of their modes with very high sampling rates and dynamic ranges, can be better than any human listener needs them to be. These excesses waste bandwidth, but it can certainly be said, with assurance, that the delivery medium is not a restriction to good sound. The recorded music itself is as variable as ever, so, don't shoot the messenger if you don't like the message.

Multichannel Sound - 4th Try

5.1 channel Digital Discrete

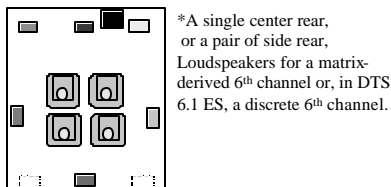


The industry is still learning. The medium is in good shape, it is the messages that are mixed.

Still, if five channels are good, more would be better.

Beyond 5.1 Digital Discrete

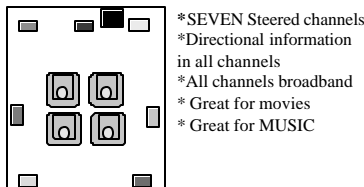
Dolby/THX EX, DTS ES, DTS 6.1 ES



Resurrecting a feature of ProLogic and using it to extract a center rear channel from the surround channels of a Digital Discrete 5.1 mix is a logical embellishment. The channel can be reproduced from a single center speaker or a pair at the rear sides.

Beyond 5.1 Digital Discrete

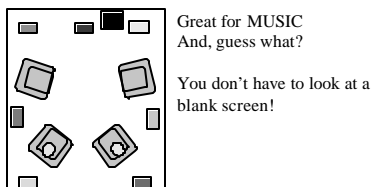
Logic-7 – Lexicon, Harman/Kardon



As always, if one is good, two are better. Logic 7 retains compatibility with the derived center idea, but improves on the sense of surround by adding some separation between the rear channels.

Get a life!

Logic-7 – Lexicon, Harman/Kardon



Again, one can break away from the rigid cinema-seating format, and have a chance to visually share a dramatic or comedic moment with your fellow viewers. When listening to music, one can swivel the "lazy-person" chair around and look at the garden view, without sacrificing the sound illusions.

Always remember –

We are selling *more* than Home Theater.

We are selling ENTERTAINMENT

19

Multichannel Audio Entertainment

- Movies
- Multichannel music recordings
- Stereo music converted to Multichannel
- Television converted to Multichannel
- Games

The challenge is to get people into situations where they can hear good demonstrations of multichannel entertainment, using good equipment. The entry-level in-wall/in-ceiling systems, and systems with inadequate tiny surround speakers can be impressive if one is easily impressed. However, those of us in the business need to show customers that much better sound is possible, and sometimes for only modest cost increases. Good in-wall speakers exist, but they are not inexpensive. Ceiling speakers are for background music systems in stores (I exaggerate, but only slightly). Ceiling speakers should never be used for the front channels, and used for surround channels only in homes that I am never invited to.

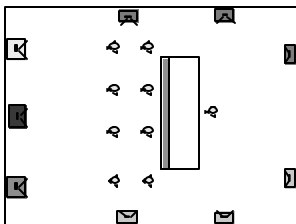
20

But, how were they recorded?

What are we trying to reproduce?

21

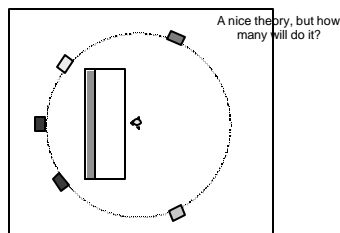
Film Sound Mixing/Dubbing Stage



22

Some folks make a big deal about replicating the cinema experience in the home. For me, I want better than that. First, I want quieter surroundings, better sound quality, my own volume control, the ability to pause the experience, a fridge and a bar for nibbles and drinks, and the ability to choose my company. That said, the rest is easy - no big deal. Buy a popcorn machine. Film sound tracks are put together in a dubbing stage – a scaled down version of a cinema. The rooms are usually larger than we typically have at home, but otherwise there is nothing difficult about imitating the experience. Multiple or multidirectional surround speakers would be appropriate, and they would be located high on the walls.

Music Mixing – the “standard”



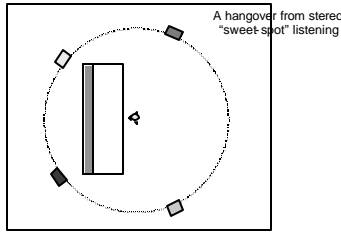
23

For music the rules change.

We are still in the early stages of multichannel music, and the industry is still figuring out what to do. One standard has surfaced, suggesting this arrangement of speakers. It is a reasonable approach.

All five speakers are intended to be identical. Some hard liners insist that all five be full range – not a good idea, as we will see later. They would all be at ear level.

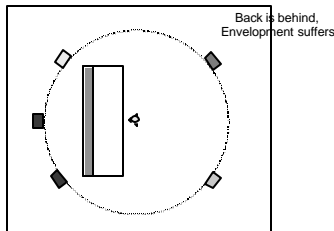
Music Mixing – “retro” surround



24

Old habits die hard, and entrenched stereo music engineers find it difficult to work with a center channel. So several of them simply don't use it, or use it very sparingly. The sweet spot is back. They invent “reasons” like: the customer can turn off all of the other channels and then can hear “the talent” naked, without the backing. Another is that customers might buy small cheap center channel speakers, thus degrading “the talent”. Since 80% or more of what we hear in a movie is from the center channel, it seems to me that film people are the ones who should be concerned. In reality there is little to be concerned about. This is a regrettable practice that, I hope, will cease.

Music Mixing – Quad lives!



25

In looking for material to remix or “repurpose” into a multichannel format, it is natural that old master tapes from the quadraphonic era should find favor. Along with the music have come some old habits, namely placing the surround speakers towards the rear of the room, mirroring the fronts. If this is done for the engineering of the album, customers would have to move their surround speakers to the back of the room in order to hear what was mixed in their specific album. That is not going to happen, and this is a bad idea.

Repurpose the recording engineer!

The only agreement is about the LCR arrangement.

The Surrounds are up for grabs.
 No one solution will work perfectly for all programs!

26

THX introduced the idea of dipole speakers to surround systems, but there are many other ways to spray sound around a room. Actually, the THX speakers are not real dipoles, since the front and rear speakers are separated in space. Consequently they do not produce a sharp null in the direction of the audience, something that probably would be a disadvantage in any event.

Surround Speaker Options

- Conventional forward-facing ‘monopoles’
 - ‘dipoles’
 - ‘Bipoles’
 - ‘Tripoles’
 - ‘Quadrupoles’
- } Multidirectional radiators attempting to spray more sound away from the listeners than at them.
- Multiples of the above (more than one on each side wall, operating in parallel).
 - Any of the above, used with additional derived and steered ‘channels’.

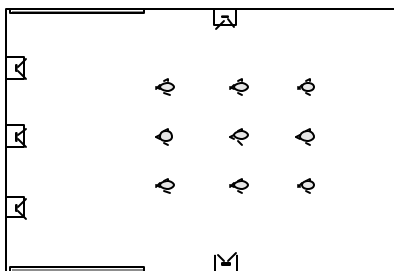
30

Since the THX “dipole” null is a soft one, it means that other multidirectional designs can achieve similar effects. Some of the JBL Synthesis dipoles go further and use horn loaded mid/high drivers to improve on the directional performance by reducing comb filtering in the null region.

With digital discrete and the new generation of active matrix systems, multidirectional speakers are less advantageous, and with seven channel systems, the need is even less.

Music oriented systems should use similar or identical speakers in all channels.

Multichannel Systems: Surrounds-Option 1

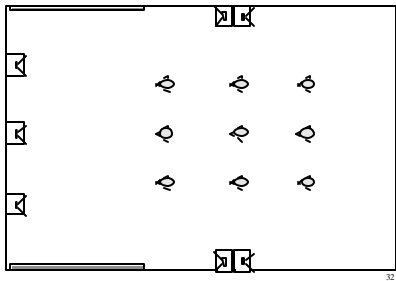


31

Conventional forward-facing loudspeaker systems work well in large rooms but, in small rooms, it may be too easy to localize them. Placing them high on the walls was an answer in the days of Dolby ProLogic, when surrounding sounds were mostly ambient and reverberant sounds and aircraft flyovers. Nowadays, they may need to come down closer to ear level for those occasions when we play multichannel music.

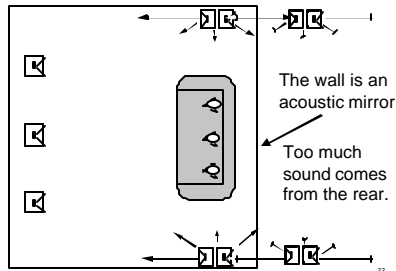
In-wall speakers? These can work, if you choose ones that sound really good (not cheap). Ceiling speakers? Not for me! Be careful, in-wall speakers can also entertain the room next door. Back boxes (enclosures for in-wall speakers) can help.

Multichannel Systems: Surrounds-Option 2



For small rooms, or when the surround speakers need to be close to the listeners, multidirectional speakers can be useful. However, there is a problem that is not much discussed. Most of the sound in the surround channel in Dolby ProLogic encoded films is intended to be ambiguously localized – to come from everywhere and anywhere. Atmospheric music and reverberation were common. However, nowadays, all kinds of sounds are sent to the surround channels. Impulsive sounds, like gunshots and ricochets, are very unlike “atmospheric” sounds. They are usually intended to appear to come from certain directions, and they can be especially well localized by our keen ears and brain.

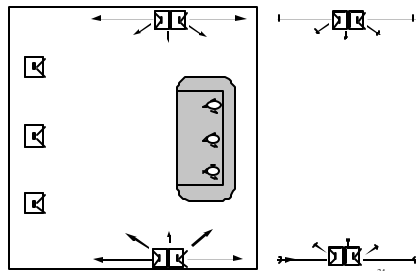
A common Problem



It is annoying when these sounds appear to come from the front (reflected from the screen or front wall) or rear, when they were intended to be at the side.

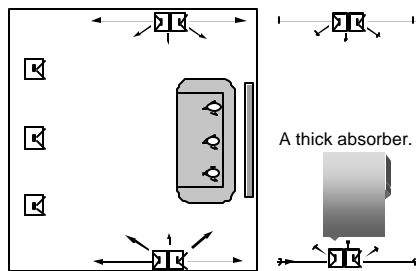
Lots of homes force us to sit with our backs to the wall. This is a problem, because the wall behind the head is an acoustic mirror. This setup often leads to sounds that were intended to be ambiguously localized, or deliberately to one side or the other, being localized behind the listeners. I have heard this in installations where they should have known better.

And a solution:



Moving the speakers forward pushes the mirrored speakers further back, improving the situation. Then be careful about reflections from the front surfaces.

Behind the Listeners:



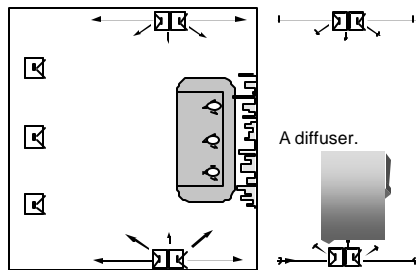
It is sometimes suggested that the solution is to absorb the front and back wall reflections from the dipole surround speakers. Doing this leaves the listener in the direct sound field from the side speakers, which is just what we were trying to avoid by using dipoles. Incidentally, the sound quality to the sides of dipole surround speakers may not be as good as it could be.

Let's focus on the front speakers for a minute. A reflective wall behind the listener is a huge problem, because very shortly after the direct sound from the front arrives at the ears, there is a powerful reflection from the wall. Comb filtering degrades the sound quality, and the temporal confusion degrades the soundstage imaging.

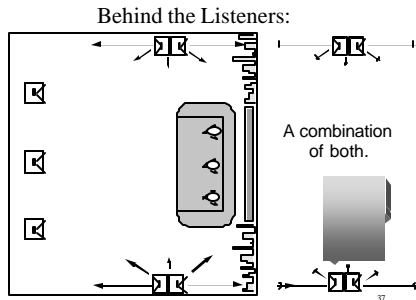
An absorber, like cushions, fiberglass, an acoustic foam panel, or the like, behind the heads brings the front soundstage into sharper focus. How thick an absorber? Not less than 2 inches. Thicker is better.

This is something that really works for stereo, where most of the soundstage is created from “phantom” images. Try it.

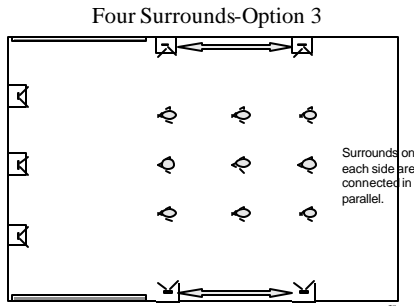
And a solution:



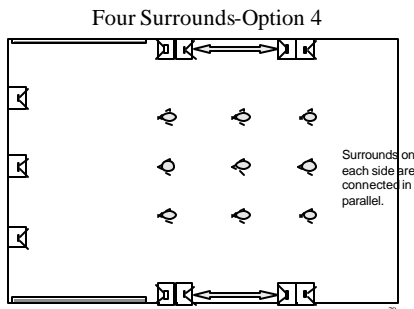
A diffuser behind the heads confuses the imaging even more. Not a good idea. It is well known from scientific research that uncorrelated sound at the ears (what the diffuser creates) delocalizes (makes less clear) auditory images in the front soundstage.



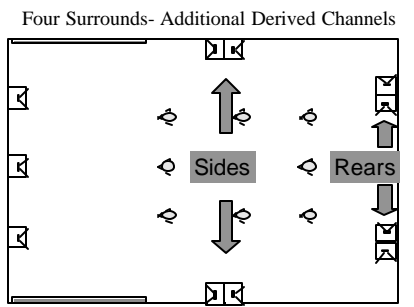
A bit of both can work though, with the absorber maintaining the integrity of the front soundstage, and the diffusers at the sides contributing to an enhanced sense of space.



In a large room, multiple speakers can be useful. Just hook them in parallel, the way they do in cinemas.

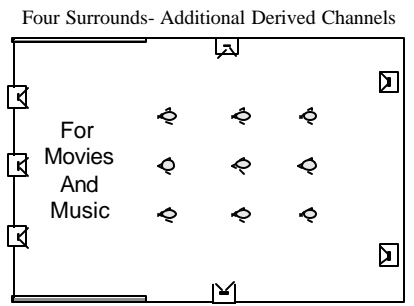


Multidirectional speakers can also be used, but watch out for sounds appearing to come from unusual directions because of reflections.



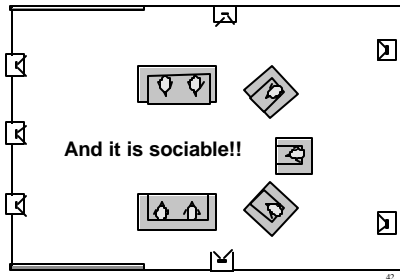
Still better, use a surround processor that creates two new channels with the appropriate delays and spectral processing. The two additional speakers now have their own signals, and the additional benefits are profound.

It works with multidirectional speakers . . .



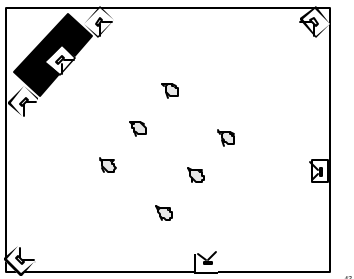
. . . and arguably even better with conventional speakers. In a largish room, this is a superb solution. If the side speakers are very close to listeners, one might use multidirectional speakers on the sides only.

Four Surrounds- Additional Derived Channels



The big bonus, from my perspective, is the liberation of listeners from the rigid theater-seating plan.

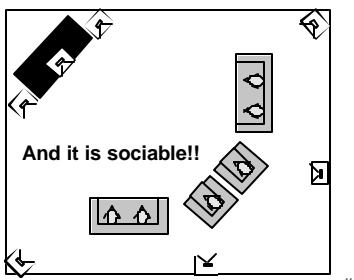
A Solution to a Common Problem: it WORKS!



It amazes me that so few people think to do this. If you are not building a special entertainment room from scratch, the probability is very high that there will be a fireplace, a door, a window, or an opening, precisely where the video display should go. It has happened in my last two houses, in spite of my attempts to avoid it.

So, just go with the flow, and put the system on the room diagonal. Those bothersome side-wall reflections go away, the side channel loudspeakers are a long way from the listeners – if they are in the corners, equalization will be necessary, otherwise move them down the walls a couple of feet or more.

A Solution to a Common Problem: it WORKS!



Having lived with this, I have come to really like it. The space behind the TV can hide a subwoofer, or a rack of equipment, or both. It is excellent for a general-purpose entertainment room. Now, I would not hesitate to deliberately design a room in this configuration.

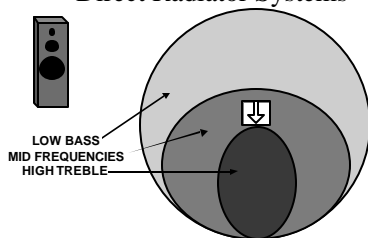
What is the ideal loudspeaker directivity?

Let's look at the options.

Since choosing a surround speaker type and configuration is difficult, one would hope that the choice for the left, center and right fronts should be much easier. It is.

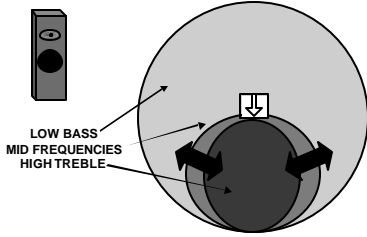
So, what kinds of loudspeakers are best for the purpose? In the stores there are several options vying for our attention, and some are dramatically different in design from others.

Directivity of Forward-Facing Direct Radiator Systems



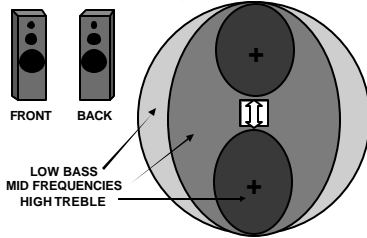
The traditional form of loudspeaker is the forward-firing direct radiator configuration. Woofers handle the low frequencies, tweeters the highs and, in some designs, a midrange fills in the intermediate frequencies. All drivers are arranged on the front face of the enclosure, facing the listeners. Because of their long wavelengths, low frequencies radiate equally well in all directions. As the wavelengths get shorter, in the middle frequencies, the radiated sound begins to favor the forward direction. At the very highest frequencies, the short wavelengths tend to radiate rather specifically in the forward direction. This is by far the most popular of all speaker design configurations.

Directivity of Forward-Facing Systems with Horns or Waveguides



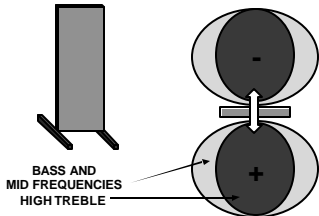
We now know that it is important that speakers exhibit uniform directivity through the middle and high frequencies. Consequently, one increasingly sees systems with horns or waveguides. A true horn, driven by a compression driver, is derived from high power professional systems. Waveguides (really they are horns) on tweeters are becoming more common as designers learn the advantages they offer. No longer need we concern ourselves with the old idea that horns have a “megaphone” kind of sound. Good horn designs do nothing but allow us to control the dispersion of the sound, making it wide or narrow, as we wish, in order to arrive at a superior system design. Designed properly, a horn can improve a system design.

Directivity of Bidirectional In-Phase (Bipole) Speakers



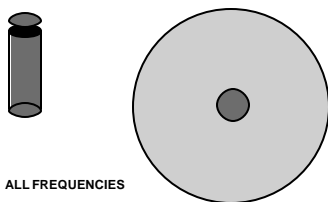
Putting two conventional systems back to back in the same enclosure, and letting them radiate in phase with each other, creates a system that is almost omnidirectional at low and middle frequencies. It generates a lot of reflected sound in a listening room, which, for stereo, is often a very good thing.

Directivity of Bidirectional out-of-phase (dipole) Speakers



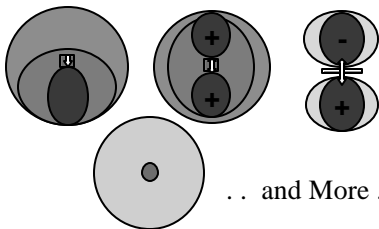
Flat panel loudspeakers of all kinds, electrostatic or electromagnetic, and some systems that use cones and domes, radiate sound equally in both directions, but do so in opposite polarity. This means that, where the sounds from front and rear meet, at the sides, they cancel each other out, creating a null.

Directivity of Omnidirectional Speakers



And finally, there are systems deliberately designed to be as truly omnidirectional as possible.

All of these . . .



. . . and More . . .

. . . evolved during the era of two-channel stereo.

- They sound different from each other.
- Reflected sound from the multidirectional designs enhanced the sense of air, space and depth from stereo recordings.
- What suits one style of recording, may not suit another.
- Only forward-facing radiators are used by the artists and engineers creating the recordings.

8

Multichannel Audio Changes the Rules

- With multichannel sound, impressions of direction, space and envelopment are in the recordings & sound tracks. The artists have more control.
- Customers at home have a higher probability of hearing what was created.
- *Some loudspeakers, designed to embellish stereo, are not appropriate for multichannel audio.*

9



Speaker Mythology

Aren't some speakers better for movies than they are for music?

THIS IS THE WRONG QUESTION.

The real issue is which speakers are appropriate for stereo and which for multichannel reproduction. The same multichannel systems can – indeed they **MUST** - work superbly for both movies and music.

10

And the answer is:

- Forward-facing radiators
 - The overwhelmingly popular choice for stereo reproduction.
 - The only choice for monitor loudspeakers in making music and film sound recordings, both stereo and multichannel.
 - The logical choice for L,C & R in multichannel music and movies, and for surrounds in music.

11

Locating Loudspeakers – some details that can matter a lot.

- Adjacent boundary interactions
- Speakers in bookcases and A/V furniture
- On-wall designs
- In-wall, in-ceiling mounting

1

Those of us who grew up with stereo, remember the numerous devices and techniques that were developed in attempts to create a more convincing illusion of space and envelopment. At the other end of the chain, in the studios, recording engineers experimented with microphone techniques and electronic processing to try to achieve the same end. All of this was trial and error. Among the variables that a consumer could play with was loudspeaker directivity. By spraying sound in more directions it was possible to create a greater sense of space, width and depth. Sometimes, with some recordings, it may be a bit too much. But that is stereo, always a bit of a gamble whether the recording technique and the playback technique match.

Multichannel audio promises more. The existence of more channels is a big step in the right direction, but there are still opportunities to confuse the issue. With more discrete channels, the listening experience should translate from the studio to the home with much less distortion. The effects of the listening room should be less than in stereo, assuming that the loudspeakers don't unnecessarily aggravate the situation. In cinemas listeners are placed in a strong 'direct' sound field through the use of directional horn speakers up front, and acoustically damped rooms. In homes this argues for forward firing, if not horn/waveguide-loaded, speakers for the Left/Center/Right locations.

In music recording, it is assumed that all monitoring will be done with conventional forward firing systems in all five locations. But what of the persistent assertion that some speakers are better for movies than they are for music? The implication often is that we can get away with less 'refined' sound in movies than we can in music. But . . . there is music in movies – sometimes a lot of it. Sometimes, as in a concert video, the music is the entire point of the production. The assertion is silly. Good sound is good sound, whether it is in movies or music-only performances. The only special considerations for film sound are maximum loudness and power handling. In films, things occasionally can get very loud, especially in the low bass.

What about directivity?

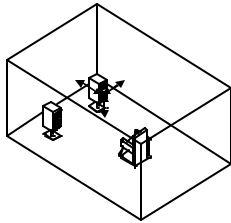
Multidirectional speaker designs tend to alter the spatial aspects of what we hear by adding reflections to the sound field. Is this a good thing for multichannel audio?

The evidence suggests that using anything other than forward facing speakers is a deviation from the principle of recreating the recorded "art" as it was intended.

My vote goes for conventional forward-facing systems.

So, now we know what kind of loudspeaker to use in each channel, and we know, more or less, where to put them. But there is more. The details of placement also matter if truly good sound is desired. Loudspeakers acoustically interact with the floor, and walls that are nearby. Small loudspeakers can be put on shelves with their backs against the wall, or even inside cavities in a cabinet. Doing this changes how they sound, sometimes seriously. There are also on-wall or in-wall speakers that require no visible support, and are visually less obvious. Are these good choices?

**Adjacent Boundaries:
 Optimizing Locations**



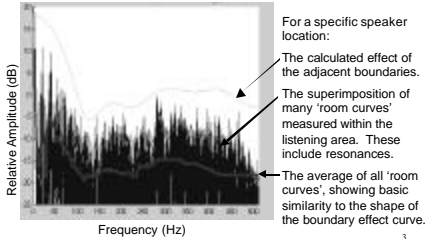
Three dimensions are relevant. Each one is measured from the center of the woofer to one of the adjacent boundaries – floor and walls.

Each of these dimensions is related to a dip in the frequency response of the sound we hear in the room.

To minimize the effect on what we hear, try to make all three dimensions different from each other.

The general exception: woofers and subwoofers operating below about 80Hz. More about this later.

The adjacent boundary effects are in addition to those of the room resonances.



For a specific speaker location:

The calculated effect of the adjacent boundaries.

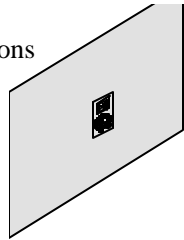
The superimposition of many 'room curves' measured within the listening area. These include resonances.

The average of all 'room curves', showing basic similarity to the shape of the boundary effect curve.

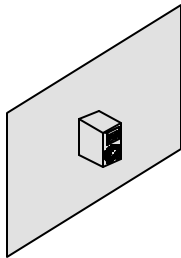
4p and 2p conditions



4p steradians = full free space
 No reflecting surfaces nearby.
 Most freestanding speakers are designed with this in mind.



2p steradians = half space e.g. speaker mounted in a wall.
 Low bass will be boosted compared to 4p conditions, and this is included in the design of in-wall speakers.



An Adjacent Wall

A conventional free-standing speaker used in this manner will exhibit increased low bass and colored upper bass. The speaker has been "redesigned", and needs equalization.

However, speakers designed specifically for on-wall use will be right at home.

For example: Infinity OWS1 (On Wall Speaker)



Freestanding Speakers get Built In



Were these properly measured and equalized after installation?
 I'll bet they weren't!

The location of a full-range or satellite speaker with respect to the adjacent boundaries determines the acoustic "loading" of the woofer. The consequence for listeners is that, at frequencies determined by the distances from the woofer to the reflecting surfaces, there will be variations in the sound radiated by the woofer. This usually shows up as peaks and dips in the frequency response – certain sounds being more or less loud than they should be. These effects cannot be eliminated, but they can be considerably reduced by making the distances to each of the nearby surfaces different from one another. The worst situation is if they are all equal. We will deal with subwoofer locations later in this paper.

In listening rooms there are also resonances or standing waves. We will spend a lot of time on these later in this paper. However, for now it is important to realize that this is an additional effect. In this diagram can be seen a calculated curve showing the ups and downs in frequency response contributed by the adjacent boundaries. Under this can be seen the 'grassy' looking dark area which is the combination of many measurements made at different locations in the listening area of the room. The spiky 'grass' is evidence of variations caused by the room resonances – they are very large. An average of all these curves has been calculated and it can be seen to follow the general shape of the predicted curve. It is a real effect.

When speakers are designed, it has been traditional to evaluate them in what we call the 'free field', a space without any reflections. Technically, this is called a 4π environment, one where the sound from the speaker is free to radiate in all directions. We know this is not how they get used, but it is important to understand how the speaker functions alone, before adding the complications of the room.

If a speaker is flush mounted into a wall, it is said to operate in a 'half space', or a 2π environment. This means that all of the sound that would have radiated to the rear is reflected back towards the front. If you look back a page or so, to the directivity of forward-facing speakers, you will find that the bass is omnidirectional.

The middle and high frequencies have a more forward directional bias. Consequently, mounting such a speaker in a wall causes the bass to be increased, something that must be compensated for in the design of speakers used for this purpose.

If a conventional box speaker is placed adjacent to a wall, the bass will also be increased and, depending on whether this was the intended location, the sound may or may not be correctly balanced. If the speaker is thick or deep, there may also be upper bass/lower midrange coloration due to interference of the direct sound with sound reflected from the wall behind.

Speakers designed for on-wall mounting avoid the problems entirely.

Custom cabinets often put speakers into specially made cavities. In the picture shown here, the speakers are, in effect, 2π mounted. The notes accompanying this photo tell us that the speakers were models that would normally be used in a free-standing manner. This installation substantially changes their performance. Low frequencies would increase in level, and since the cabinets no longer have any front edges or corners, the directional effects of diffraction are absent. To restore them to anything like their original sound quality requires equalization of a kind that is difficult to do in a room. This forces the installer into the role of speaker designer, something both he and the original speaker manufacturer might not be very uncomfortable with!

Some “bookshelf” speakers actually work properly when placed on bookshelves . . .



. . . and have adjustments to allow them to work properly when on stands.

7

Small speakers are sometimes called ‘bookshelf’ speakers because they can fit into a bookshelf – albeit sometimes a rather large one. In actual fact, most such speakers are recommended for use on stands, positioned some distance from the walls.

However, if the speaker is powered, and if it has the appropriate equalization options built into it, the customer has the option of using it in either manner.

These got built in with a wood mesh grill in front. Two problems!



It looks O.K. but good speakers would be seriously corrupted!

8

Good woodworkers like to work wood. Here the craft has been taken too far, because of the coarse wooden grating over the speaker openings at the top of the cabinet. The open area is too small for this to be an acceptable grille.

The second problem is the elevation. Front channel speakers should not be so far above ear level.

Each speaker has its own little resonant cavity. B-a-a-a-d idea!



Manufacturers take care to avoid resonances in speaker drivers and enclosures. Here the empty space around the speakers in the cabinet add numerous unwanted colorations, honks and booms. Done properly, the empty space would be filled with sound absorbing material and a grille cloth would cover the opening.

9

Speakers surrounded by empty space in an overly large cavity will have their sound degraded by the acoustical resonances in the open spaces. To avoid this, fill the empty space with fiberglass wool, or other fibrous material, foam, cloth or even old socks.

Cover the filling, or the entire opening with a porous, open weave, grille cloth. This is available in many colors at specialty shops or at any fabric store as polyester double knit.

Center-Channel Speakers

Can we use regular speakers?
 It depends. Center channel speakers are (or should be) designed to sound good when placed on a television. The television modifies the performance of the speaker.



And some classy ones have adjustments to optimize their performance on different sizes of televisions!



10

Most center speakers find themselves sitting on top of a television set. Such speakers need to be designed with this in mind. Sadly, many are not.

The television set is an acoustical obstacle in the sound field of the speaker, and it modifies the sound of the speaker, mainly at lower frequencies.

Certain speakers can be adjusted to perform properly when used in a free-standing fashion, or sitting on TV screens of different sizes.

In-wall and in-ceiling speakers



11

Speakers intended for in-wall or in-ceiling installation began as relatively inexpensive devices intended for distributed sound applications – music everywhere. As such, sound accuracy was not the first requirement. Many were direct descendants of car audio speakers.

Times have changed, and now we find installations in the main entertainment area of a home that are completely or partially outfitted with these speakers.

The virtues of in-wall speakers

- They are less visible

Out of sight, out of mind, the saying goes. Invisible speakers don't exist, but these come the closest, and as such fill a need for customers who just want the sound, but not the sight, of speakers. Let's put them in the ceiling. We rarely look up, right?

I accept ceiling speakers in airline terminals, and tolerate them in "music everywhere" uses in homes.

I do not endorse ceiling speakers in multichannel music or home theater systems.

Mounting a speaker on a wall may be asking for trouble. Mounting one in a wall is worse. Of course the wall panels will vibrate, and radiate sounds that were never intended, corrupting the sound from the speaker itself. The vibration will occur on the opposite side of the wall as well, radiating sound into the adjacent room. A ceiling speaker will fill the attic with sound, letting it leak into all of the rooms on that floor.

The constraints of building frames and services often restrict where such speakers can go, and customers often ask for them to be put where they are least visible. Many end up in the wrong locations.

The problems with in-wall speakers.

- Many of them don't sound all that good.
- Walls make poor speaker enclosures.
 - They resonate mechanically and acoustically
 - They can buzz and rattle
- Sound leaks through the wall and through ceiling/attic spaces into adjacent rooms.
- Many of them are located in the wrong places for good sound.

Applying the same design criteria to in-walls as get applied to top line free-standing speakers, it is possible to make them into truly hi-fi products. Naturally, the problems of walls are still there, so it is a good idea to get inventive and find ways to mount the speakers so that the vibrations generated by them are not well coupled to the wall. This moves this category of product into the front line, able to compete with conventional speakers for multichannel sound applications. Place the front speakers close to ear level, and the surround speakers slightly higher. Please keep them out of the ceiling.

Hi-Fi in-walls + a difference



These compete with the sound of free-standing speakers, in part because of built-in mechanical isolation to reduce the wall vibrations generated by them.



A good idea?

Only if the customer is not interested in high quality sound.



These poor in-walls are not just too low, but they are built into cavities. The additional touch of sculptures and ornaments that further obscure the sound truly tells us that sound quality was not a priority. Pity.

It looks good though.

Back boxes

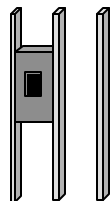
These are special enclosures designed for in-wall speakers create more predictable acoustical environments.

They also can reduce the amount of sound that leaks through the wall.

Do they guarantee good sound? No.

Are speakers without back boxes necessarily less good? No.

Back boxes are an option. Follow the manufacturer's recommendation.



The enclosure is an important part of a conventional free-standing speaker. It seems logical, therefore, to add an enclosure to an in-wall. There are difficulties, because the space is very limited in the space between the studs and wallboard. Adding a substantial enclosure made from thick materials, as is done conventionally, reduces the space further, and shallow enclosures are acoustically not a good thing, as a rule. Small enclosures are also problems if good bass output is required. So, some systems recommend back boxes, and others choose to live with the reality of walls, encouraging builders to add a few more screws and perhaps some glue, and filling the wall cavity with fibrous material. Both, demonstrably, can work.

Coming up in Part 2

What makes a loudspeaker good? Can the same loudspeaker sound good in different rooms? What about "acoustical" treatment of rooms? Can I customize a room to suit my personal tastes?

Loudspeakers and rooms operate as a system. One cannot be separated from the other. Knowing this allows us to design better loudspeakers, ones that are 'friendly' to different rooms. Knowing something about room acoustics allows us to use furnishings and acoustical devices to improve stereo and multichannel reproduction, making the listening experience more pleasurable.