The Loudspeaker As A Spherical Sound Source

***Winslow N. Burhoe**

It has long been known to physicists and audiophiles that the ideal loudspeaker would radiate sound equally in all directions, at all frequencies without any distortion. The usual visual image which is called to mind is that of a small pulsating sphere, perhaps the size of a tennis ball. As this imaginary ball expands and contracts, it transmits a pressure wave to the air which then expands as a spherical wave of sound. Unlike wave motion in strings or on the surface of water, sound waves are three dimensional.

The term "omnidirectional" applies to the three dimensional spherical wave pattern this ideal sound source would generate. This term has been abused in recent years by being applied to speakers that do not technically qualify as omnidirectional. Some have been omnidirectional only over a very narrow frequency bandwidth and most are not omnidirectional at any frequency. As a consequence, there has been little industry or consumer excitement over speakers which have been introduced and labelled "omnidirectional".

It is essential for true and valid omnidirectionality that two conditions be met: (1) Omnidirectionality at all frequencies, and (2) equal energy radiation in *all* directions—up, down, left, right, forward and backward. Omnidirectionality is NOT a substitute for other high fidelity specifications; it cannot compensate for poor frequency response or high distortion. It is of no advantage unless applied to wide frequency bandwidth. However, when the traditional high fidelity values of flat frequency response, low distortion, and wide bandwidth are embodied in a truly omnidirectional speaker, a major improvement in sound reproduction is achieved; the close approximation of the mythical ideal speaker, a Spherical Sound Source.

Like all other historical advances in the art of high fidelity, true omnidirectionality provides a greater degree of musical realism and increases the aural perception of the listener. The psycho-acoustic effects of a stereo pair of true Spherical Sound Sources requires many hours of acclimatization, but once the listener's ear has accepted the more complicated aural impulses, the result is the most realistic perception of sound reproduction possible.

It has become a well known fact in recent years, even among audio consumers, that a speaker providing the listener with a combination of direct and reverberant sound imparts a greater sense of spaciousness and realism to the listening room. A truly omnidirectional speaker carries this concept many steps further by providing the maximum possible reverberant field effect, ie., the ratio of reflected energy from an omnidirectional speaker arriving at the ear from all directions, milli-seconds after the direct input, imparts an ambience and realism to the reproduced signal unequalled by any direct or partially reflective speaker.

The amount of reverberant field effect of any speaker is determined by the amount of dispersion, especially of mid and high frequency energy, the amount of reflective versus absorbant surfaces in a listening room, and the speaker's position in relation to those reflective surfaces. In order to effectively utilize the maximum effect of reverberant field in an acceptable listening environment, a speaker must be able to accurately supply the listener's ear with two distinctly different and separately perceived aural inputs: the transient information and the tonal information.

The transient wave form provides the brain with bits of purely digital information. The time of first arrival of the transient at each ear is compared and the difference between these two arrival times provides a directional analysis and the greater part of the stereo image. Without proper transient information the stereo image becomes distorted, possibly through exaggeration of the size of the image, possibly through a minimization of the difference between channels.

The tonal information provides the brain with the actual musical overtones. The ear has the ability to act as a Fourier Analyzer and to separate all the complex tonal input into its actual frequency content. Even the most complicated harmonic structures and overtones are individually analyzed and then transmitted separately to the proper information processing sections of the brain, where the listener enjoyment of the reproduced musical signal occurs.

As long as a speaker provides transient information that can be accurately identified by the ear, the presence of a reverberant field effect serves to multiply and enhance the tonal input from the original musical signal allowing the brain a longer period to identify and enjoy the complexities of the musical overtones. Therefore, the greater the reverberant field, the greater the psycho-acoustic pleasure becomes.

*EPI Inc.

The lack of accurate transient response from the speaker, or an unusual listening environment that would provide an extreme saturation of reflected sounds (the opposite of an anechoic chamber) could result in a muddy or blurred sound. The problem of transient information can be overcome with proper speaker design and an unduly high percentage of reflected sound would never be a problem in a normal listening room.

In a closed acoustical environment such as a normal listening room, an additional benefit of a spherical sound source is its ability to produce a field of sound, in much the same way that the earth produces a gravitational field. Because of the reverberant or reflective characteristics of a room and the psycho-acoustic effects of reverberation, the acoustic field produced is equivalent to a uniform field. In other words, there is no apparent source and no apparent change of loudness in different room positions. Because the stereo effect or image is created by the sound of first arrival, or the transient input, there is no degradation of stereo imaging in these uniform sound fields created by the Spherical Sound Source (transients are radiated equally in all directions). An accurate stereo effect is achieved over the entire listening area, provided only that there is a direct line-of-sight path between each spherical sound source and the listener. The psycho-acoustic effects of reverberation described above enable any normal room to closely approximate the effect of a large concert hall more effectively than any other type of transducer. The uniformity of the acoustic fields enables comfortable listening anywhere in the room, even next to one of the Spherical Sound Sources. Listener fatigue is virtually non-existent.

In order to optimize the acoustic field effects, the room should be divided mentally into equal areas with symmetrical reflective characteristics. The Spherical Sound Sources should be located as close to the center of each such area as possible, in order to maximize the amount of reflection and therefore increase the reverberant field effect occurring in the listening environment. The effects on placement are relatively subtle, however, and truly omnidirectional speakers provide an acceptable level of placement flexibility in most listening rooms.

Achieving a Spherical Sound Source

Conventional bookshelf speakers, whether two-way or three-way, which have the speakers mounted on the same surface in the front of a rectangular box, all have similar directional characteristics. Over some portion of the frequency range of a woofer or tweeter, the drivers operate in a linear fashion whose sound radiation characteristic pattern is hemispherical: that is, the sound radiated off axis as far as 90 degrees in any direction, is equal to the sound radiated straight ahead. (It is a common misconception that speaker's radiate sound mostly in the direction they are facing.)

At very low frequencies, the dispersion pattern is even wider: sound is actually radiated backwards from the speaker —this is why speaker placement affects bass response, there being conspicuously more reflected bass when the speaker is in a corner than when it is in the middle of the room or up in the air. At high frequencies, however, all tweeters become directional, that is, the hemispherical radiation pattern narrows to a straight beam whose diameter is the same as that of the tweeter. In a two inch tweeter this transition occurs between 6 kHz and 8 kHz: in a one inch tweeter it occurs above 13 kHz. In general, good dispersion is achieved only if the diameter of the cone is smaller that the wave length of sound concerned.

By taking four conventional bookshelf speakers with acceptable frequency response, linearity, distortion specifications, and hemispherical dispersion over the entire audio bandwidth, and mounting them with a small enough horizontal separation in a four sided cabinet, it is possible to create a speaker that would closely approximate a Spherical Sound Source.

The cost of building a speaker that meets these criteria is high, due to the complexity of the drivers that must be used. I firmly believe however, that the most devoted audiophiles and music lovers would find the enjoyment received from the complex aural and psycho-acoustic effects described above well worth the expense. Until a physicist or acoustic engineer manages to actually build a working model of the mythical "Pulsating Sphere" the hi fi industry and the consumer must settle for the "Spherical Sound Source" available. Anyone who makes the effort to find and listen to a "Spherical Sound Source" long enough to appreciate its benefits will not be disappointed. Æ