INNOVATIVE SOUND SOLUTION

Radically redefining loudspeaker usage in form and function.
"The New Look of Sound."

IT'S NOT A SPEAKER.
IT'S THE SoundPanel

Flat-Panel Technology, a new paradigm in sound technology.

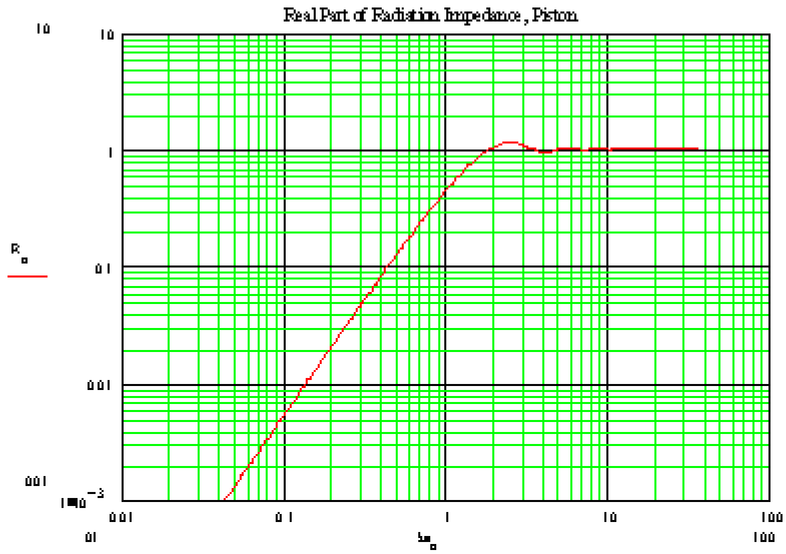
The objective of an audio loudspeaker is simple: to reproduce sound as realistically as possible. It is a technological miracle, only a bit over a century old, that sound can be mechanically reproduced, and even more recently that a speaker system can be made to sound quite realistic. But the fact is, many loudspeakers don't. Loudspeaker technology has remained principally unchanged the past 40 years. Modern loudspeaker design has revolved around improvements upon the basic conventional cone design, improvements in materials and adhesives, and understanding and designing around fundamental limitations inherent in cone speaker technology. These limitations include beaming and frequency range response. As with any mechanical device, physical laws govern its behavior. The more we understand the physical properties associated with acoustics, the better chance we have to produce realistic reproduction of sound.

The first question is: why do we need a new loudspeaker paradigm when so much academic and design effort has been expended on perfecting current technology? To answer that we need go back to the basic principles of how conventional loudspeakers operate and identify the fundamental restrictions on performance they impose.

Cone speakers and their limitations.

Conventional loudspeakers aim at achieving "pistonic" motion of the diaphragm. By pistonic we mean that the diaphragm moves as a rigid whole. As an electric signal is applied to the voice coil, the cone diaphragm moves back and forth with the frequency of the signal, and *viola*, we have the magic of mechanically reproduced sound.

Normal diaphragm movement occurs when the frequency of the applied signal produces a corresponding audio output (the linear response). As frequency rises, the wavelength in air reduces to the point where it becomes comparable to the diaphragm dimensions, and a major change occurs in the speaker's operation. Instead of continuing to rise, the acoustic power reaches a limit and essentially becomes a constant for all higher frequencies. The diaphragm's



acoustic power output now begins to fall at a rate of 12dB per octave. This doesn't mean that the on axis pressure response falls away, what generally happens is that the diaphragm's acoustic output becomes restricted to progressively narrower angles of projection. In other words, it becomes directional; it begins to beam.

Figure 1. Cone speaker response to increase in frequency.

An obvious solution would be to use a diaphragm sufficiently small that the 'knee' in the radiation resistance curve was forced above the audible frequency range. But such a diaphragm would have to undergo enormous, impractical excursions to produce the volume displacements necessary at low frequencies. Consequently, loudspeaker designers are generally forced to compromise and deploy multiple drive units of progressively decreasing diaphragm size. Large diaphragms provide the volume displacement necessary to reproduce low frequencies; smaller diaphragms take over at higher frequencies before the output of the larger units becomes too directional. The use of crossovers to divide up the frequency range to each speaker is necessary. Crossover networks bring with them a host of unwelcome side effects: phase distortion, further disruption of off axis output, more reactive elements in the loudspeaker load, sound quality issues related to capacitor performance and the saturation behavior of inductor cores.

The obvious result is that the effective frequency response of a cone speaker is limited by its size. Subwoofers are large; tweeters are small, by necessity. You simply cannot get high frequency sounds out of a subwoofer accurately with strong volume, and you cannot put a low frequency signal into a tweeter. That is why a crossover network is required to deliver the proper frequency ranges to the proper speakers.

The beam effect.

You have seen flat-screen LCD monitors or TVs before, especially some of the older models, where you tilt the screen or look at it from an angle and the colors are distorted to the point where you can barely make out images. The pixels project colors perfectly when you are directly in front of ("on axis" to) the screen. However, the pixels are not capable of projecting the full spectrum at an angle. Loss of greater parts of the visible spectrum occurs when viewing the display from an angle. This is called "beaming," and results in a distorted image when viewing off axis.

The same phenomenon happens to audio speakers. Even within the effective operating range of a speaker, its directivity varies significantly with frequency. Lower frequencies have a much greater angle of dispersion than higher frequencies. When you move from the front to the sides of a typical loudspeaker, just as the LCD display loses information at an angle, some of the audio signal is lost. Bass frequencies will still be heard, but the higher frequencies will drop off in volume as you approach the sides. This change in dispersion angle with frequency is "beaming" and contributes to the distortions when heard across a venue. Listeners directly in front of a loudspeaker will hear the entire frequency range, while listeners towards the sides will hear less and less of the full range of frequencies. Loss of the upper portions of the frequency range creates a muddy sound common to many loudspeakers, particularly in the vocal range. This results in a loss of intelligibility of speech. This is a shame, as speech is a large portion of audiovisual requirements, and is not something that you want to miss parts of. This is particularly annoying to listeners across a venue straining to clearly hear the speaker. You likely have experienced this once or twice before.

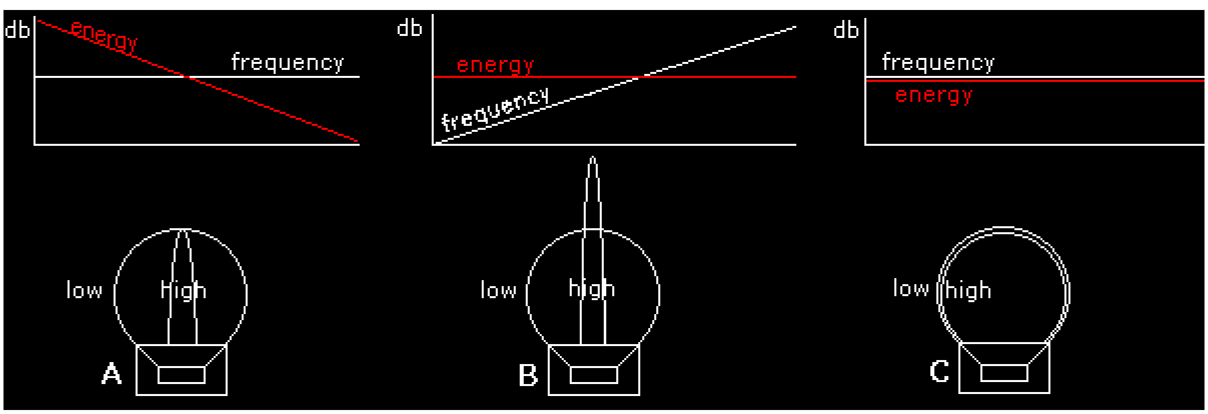


Figure 2. Frequency response of a speaker: the beam effect as frequency increases.

(A) The on axis frequency response appears flat across the frequency range. The high frequency energy is small, but highly directional. The low frequency energy is larger, but spread around the box. Off axis, there is little to no high frequency, and the sound will be muddy.

(B) On axis, the frequency response is trebly. Both high and low frequency energy is equal, but the high frequency energy is highly directional, and the low frequencies are spread around the box.

(C) On axis frequency response is flat. Both high and low frequencies have a similar polar response and their energies are equal. Off axis the sound will remain balanced, and the level will evenly decrease.

How do we overcome these limitations of a cone speaker? To achieve (C), an ideal response across the entire listening range, an ideal sound system would have 4 speakers, each covering 2-3 octaves (12-15 in. for sub-bass, 8-10 in. for lower voice, 4-5 in. for upper voice, 1 in. for the higher harmonics). This allows each speaker to operate in its effective range, producing clear sound in each range.

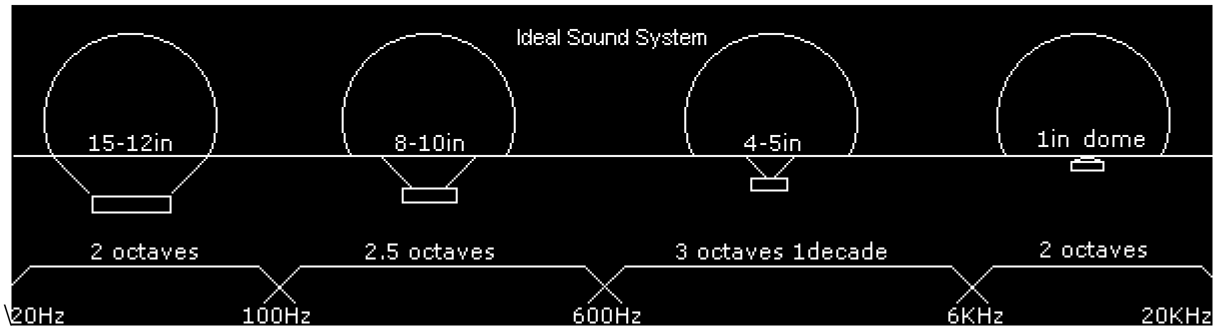


Figure 3. An ideal sound system incorporating different sized speakers for each frequency range.

Inter-modulation, linearity and intelligibility.

When a speaker operates outside its effective range, we get audible distortions. Muddle-ness and inter-cluttering within the music makes it difficult to discern detail. With continued listening, this becomes fatiguing. This is caused by interference within and between speaker components, compounding as the power increases. Primary inter-modulation is where a single speaker is used beyond 3 octaves, or full range.

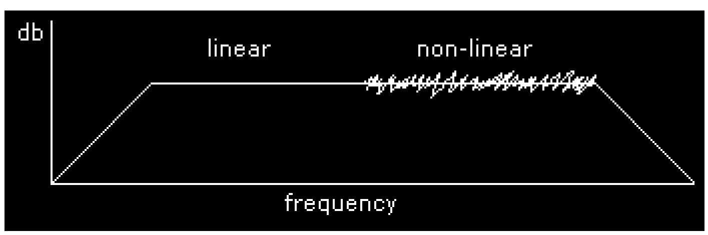


Figure 4. Frequency response of a speaker: muddled response when operating above its efficiency range.

The large cone movement for low-frequencies modulates the middle and higher frequencies, causing them to sound dirty. Distortion is caused by high frequencies creating secondary vibrations and chaotic resonances within the speaker cone, causing it to sound harsh and screechy. You've experienced this in cinema sound that is harsh, or venues and live concerts where not a single word can be understood. We have become so accustomed to this it has become accepted practice.

In summary, there are basic physical limitations of cone speakers such as frequency response, beaming, and related problems that affect clarity of sound across a venue. Modern speakers have improved with modern technological developments. However, these are merely improvements to the basic cone design, and we are still left with compromises and tradeoffs to manage the basic physical limitations inherent in a cone speaker. These limitations must be engineered around, and must be considered when selecting loudspeakers for a particular application. Typical 2-way loudspeakers are great for producing loud music, but are not designed for clarity of speech. Yet, this is the application often used in the audiovisual industry, despite their limitations in the vocal range. The result is a muddy voice that is nearly impossible to correct with equalization; the typical 2-way loudspeaker simply cannot operate effectively across the vocal range. This makes for fatigue for the listening audience, and loss of enjoyment of the event. The beam effect produces "hot" and "cold" spots in a room that must be compensated for, typically by adding more speakers. In practice, this means that sound professionals will "over-design" speaker placement in a venue—not because they need the volume, but because they must account for "hot" and "cold" spots created by the beam effect of typical loudspeakers. Setting up more speakers creates more work for the sound techs. Sound professionals accept this fact and are used to dealing with these typical issues.

The Flat-Panel alternative. It's not a speaker, it's the SoundPanel.

Now, some wonderful things happen if you abandon the concept of pistonic motion and consider instead a diaphragm vibrating randomly across its surface. Instead of moving back and forth as a speaker does, think of it in the way a tuning fork vibrates. You don't wave a tuning fork back and forth (as a cone speaker moves) to produce sound, you strike it and it vibrates freely. This is the essence of flat-panel technology. Each small area of the panel vibrates, in effect, independently of its neighbors, rather than in the fixed, coordinated fashion of a pistonic diaphragm. Think of it as an array of very small drive units, each radiating a different, uncorrelated signal but summing to produce the desired output.

Such a randomly vibrating diaphragm behaves quite differently than a cone speaker because power is delivered to the mechanical resistance of the panel, which is constant with frequency, as opposed to a cone speaker's varied audio responses with frequency changes. Consequently, we now have a consistent audio response from the flat-panel, from 60hz all the way to the top of the audible range. Size no longer constrains audio output: you can make the panel large without directivity or treble response suffering. In fact, frequency response actually improves in performance as size increases because the frequency of the fundamental bending resonance is lowered, which not only extends the bass response, but also increases modal density in the mid and high frequencies.

Nice trick if you can do it.

But how can you make a diaphragm vibrate randomly? Actually you can't, but you can get very close to it by using what we term distributed-mode (DM) operation, on which flat-panel technology is based. The diaphragm of a Distributed-Mode Loudspeaker (DML) vibrates in a complex pattern over its entire surface. The panel vibration is so complex that it approximates random motion. It is impossible, for example, to identify the point(s) of excitation on a snapshot of the panel motion, thereby providing the freedom from directivity related problems described above.

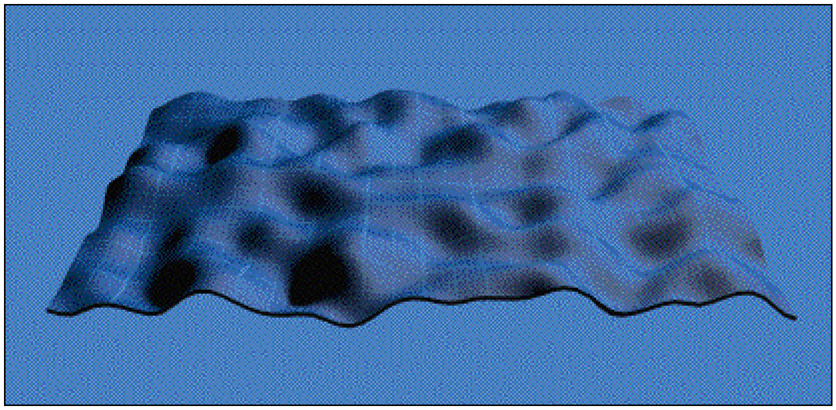


Figure 5. Snapshot of panel motion, shortly after excitation with an impulse.

This is close to the directivity of a true point source, i.e. approaching omnidirectionality, even when the diaphragm is quite large relative to the radiated wavelength (the fundamental constraint of a cone speaker, if you recall).

Distributed Mode operation is therefore ideal for a loudspeaker: it guarantees consistent output level for all frequencies and undistorted projection in all directions. With pistonic diaphragm motion, these characteristics are mutually exclusive. In practice, the flat-panel produces wonderfully clear sound across the entire frequency range, and puts that sound evenly across a venue in a way not possible with conventional loudspeakers.

The panel itself operates wholly in resonance, which is one of the features of flat-panels that most concerns audio people raised to regard resonance as anathema. Doesn't all this resonance in the panel color the sound unacceptably? The surprising answer is no, it doesn't, because of the highly complex nature of the panel's vibration. In fact, the sound quality has extraordinary clarity and transparency confirming the measured flat frequency response.

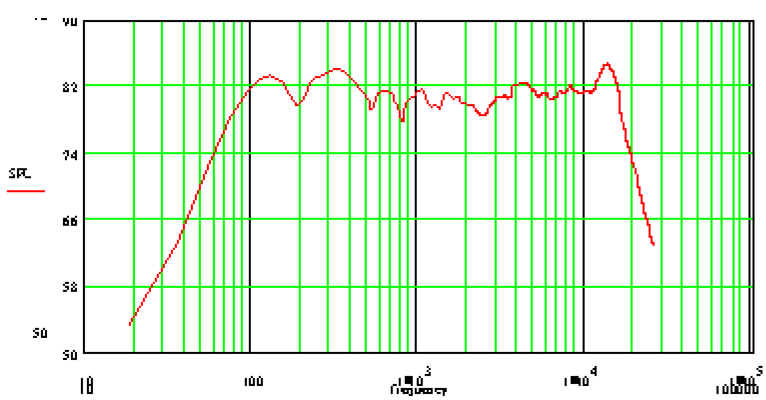


Figure 6. Frequency response of the SoundPanel.

What about distortion? Again, our painstaking research has shown that a flat-panel performs as well or better than conventional alternatives. This is because in the frequency range of interest, panel vibrations are very small in amplitude, putting much reduced demand on the coil excursion, with the panel remaining well within its linear elastic range.

Throw out the beam effect.

As opposed to a cone speaker, diaphragm dimensions of the flat-panel do not restrict directivity. The large surface area (several times larger than a 12-inch subwoofer) of a flat-panel radiates sound without high frequency output becoming confined to a narrow angle about the forward axis. In fact, the dispersion angle of a flat-panel approaches 180 degrees, as opposed to 90 degrees with a typical loudspeaker. Consequently, the beam affect and its associated distortions across a venue are gone! Such diaphragm behavior opens up the possibility of a full-range driver freed from the familiar constraints and compromises of cone speakers, including speaker placement in a venue. Due to the wide dispersion of sound, you can now think more creatively about where to place flat-panels in a venue—no longer are you forced to compensate for the narrow requirements of conventional loudspeakers and their consequent "hot" and "cold" spots.

These essential properties of flat-panel technology allow the audio output of a flat-panel to be constant across nearly the entire audible range. As a result, one flat-panel can take the place of the 4 speakers in the ideal sound system above, and eliminate the problems associated with varied frequency responses. Furthermore, crossover networks are disposed of, and their associated distortions. We have hereby provided an even frequency response and eliminated the muddy voice problem, *without loss due to the beam effect of conventional speakers!* This is truly a revolution in speaker design.

More benefits to come.

There are also numerous spin-off benefits to a DM loudspeaker. As well as being insensitive to diaphragm size, the acoustic behavior is unaffected by diaphragm mass. This gives us a surprising option: you can actually attach graphics, such as a poster or photo, directly to the flat-panel, without noticeably affecting the audio quality. The reason is that attached graphics become part of the moving diaphragm, not muffling the sound as you would if you put a sheet of paper in front of a cone speaker. Using a non-permanent adhesive, such as Duro, the graphics are easily removed and changed

Another major benefit is that the flat-panel's acoustic output from both sides of the flat-panel is useful. In applications where the panel is not required to be baffled, as in high-end free-space loudspeakers, the power radiated from the back face sums up constructively with radiated power from the front face of the panel. This is clearly a very positive aspect of flat-panel loudspeakers as there is not an intrinsic need for containment of the rear radiation through baffling or the use of enclosures, which have their own resonance, colorations, weight, and cost penalties.

In practice, this allows you to place a flat-panel in the middle of a large area, and completely fill it by taking advantage of the sound dispersion from both the front and back sides. The nearly 360 degree dispersion will fill even a greatly "audio-challenged" room with even sound.

Stereo imaging is another common concern. Anyone who has heard conventional wide-dispersion ('omni-directional') loudspeakers will know that they produce a large, blurred stereo image rather than the precise, tightly defined sound stage of more directional designs. Again flat-panels confound expectations here because, while maintaining a wide radiation pattern, their diffusivity helps reduce destructive boundary interactions. Research has shown that stereo imaging, in typical domestic surroundings, is at least as well defined and stable as with conventional directional loudspeakers listened to from the stereo 'sweet spot'. Outside this small area of optimum stereo the flat-panel is much superior because of its better-maintained off axis performance and reduced room interaction. These attributes serve to make flat-panels an exciting proposition in any conventional two-channel music system, but in a multi-channel home theater set-up the benefits are even greater. In addition to their wide listening area and reduced visual impact, flat-panels offer further particular advantages here, where sound image is important. With conventional speakers, you have a very narrow spot in the room where the full sound image is directed. To enhance the listening pleasure of all the viewers, the flat-panel will produce a full sound image across a much wider area of a room that more accurately reproduces what was intended with surround sound production.

With conventional wide-directivity loudspeakers you also tend to hear much more of the room. Standing wave resonances are more pronounced, so the tonal balance varies significantly as you change listening position. Interaction with room boundaries is worsened too, making speaker placement more critical. Flat-panels behave quite differently because of the diffuse nature of their radiation: their sound does not emanate from a fixed, well-defined point in space. As a result the distribution of sound within a room is actually much more even with a flat-panel than with a conventional loudspeaker, and room interaction is reduced.

Flat-panel technology aims to overcome the fundamental challenges to conventional speaker design, and gives us numerous advantages as a bonus. The extended frequency response produces clarity of sound across the entire sound spectrum. It does away with the audible consequences of crossover networks. Its wide, essentially frequency independent directivity removes a pervasive source of coloration. Furthermore, room interaction is reduced and stereo imaging remains sharp over a large listening area. Flat-panels are thin and can either be used in free space or wall-mounted, so their footprint and visual impact are reduced. Their light weight makes them ideal for portable applications. Cabinet resonances are no longer an issue because there is no need for a cabinet. The ability of flat-panels to fill a room with a sound field which alters very little from side to side as well as front to back of the venue is unique among conventional speakers commonly in use today in the audiovisual industry. The remarkable way the flat-panel exhibits a reduced fall-off in sound level with distance is greatly superior to conventional loudspeakers. Graphics can be used on the flat-panel to display as signage or décor. Power consumption is a fraction of conventional loudspeakers; a battery powered amplifier is a viable option.

It is true to say that the design goals for a conventional loudspeaker have to be a compromise. A conventional drive unit design always embodies trade-offs between bandwidth, directivity and smoothness of frequency response. In the finest conventional loudspeakers these engineering compromises are skillfully struck, but they remain compromises. Flat-panels could not represent a greater contrast. As we refine panel material, exciter location, boundary conditions etc., we approach the behavior of an ideal randomly vibrating panel whose power output is largely independent of size. Separating output directivity from the panel dimensions releases us from the traditional compromises loudspeaker designers have faced for more than 70 years. Smooth, dense modal behavior confers on flat-panels predictable, deterministic, scaleable behavior that, until now, has been the loudspeaker designer's unfulfilled dream.

Many thanks to: http://lenardaudio.com/education/05_speakers.html as the source for much of the information and graphics used herein.

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