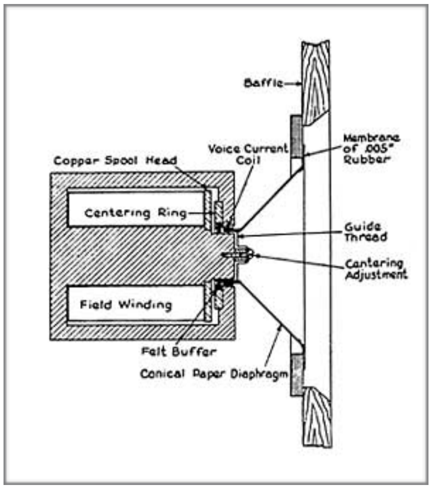
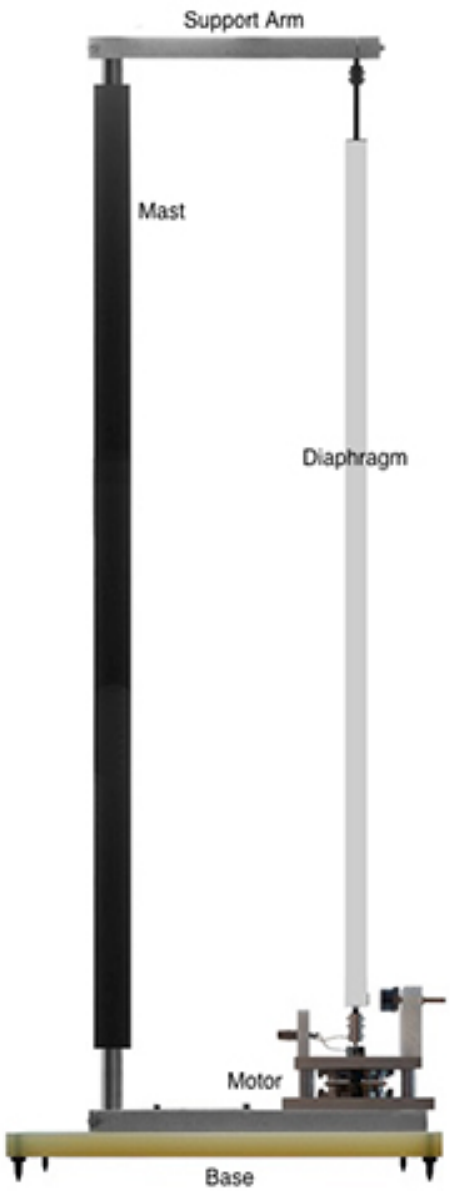


Planot® acoustic transducer design that address all of the short comings of the traditional pistonic acoustic transducer (aka, loudspeaker or speaker).

The design of this new speaker was realized through a process starting with the adoption of the methodology, of abandoning the original biomimicry metaphor of the eardrum and starting the analytical process of deconstructing the Rice & Kellogg design down to the essential functionality that is needed to achieve the goal of reproducing sound.



What were the design goals of the original loudspeaker design of the acoustic (cone/pistonic) transducer?

1) The basic function of an acoustic transducer is to modulate air pressure by means of sound pressure waves propagated by an electromechanically modulated *surface*.
2) Rice & Kellogg (R&K) patented the basic design of the cone speaker in 1925.
3)The form and function of the round diaphragm follows from two analogues; one is natural and one is man made.
The round "ear drum" is functionally a receiver and the round "drum skin" is a sound producer.
4) The need for a surround to (1) facilitate the back and forth movement (pistonic movement) of the diaphragm without undue "nonlinear flexing" of the diaphragm while (2) at the same time centering the diaphragm in the "gap" of the magnetic field and (3) returning the cone to its rest (or home position) when there is no signal present, to assist in (4) dampening extraneous movement and (5) to securely hold the diaphragm/voice coil structure.

Main Structures of R&K Speaker

- Cone Diaphragm
- Surround
- Motor
- Box
- Frame

Cone Diaphragm, Properties of the Form

1) Cone is more rigid than a flat round disc shaped diaphragm (both being) made from the same material, while a flat diaphragm will have a more linear frequency and phase, due to the geometry alone without consideration of other factors.
2) Cone shape allows for affixing the voice coil to the apex of the cone.
3) Round structure of the diaphragm allows for fairly uniform radiation of a broad range of frequencies in the audible spectrum.
4) Cone structure causes sound to "reflect around" within the inner surface of the cone, causing destructive and additive interference, before exiting the cone.
5) Cone's radiation of "frequencies" narrows as the signal goes higher in frequency and this measurement is a speaker's directivity. This fact of limited directivity, will most always lead to the need, for a second additional diaphragm tailored to producing high frequencies; the tweeter. The small diameter of the tweeter (characteristically 1" to 2" in diameter) allows for a broader directivity at higher frequencies. But this additional diaphragm almost always necessitates the addition of a crossover network, which is most often an assembly of resistors and capacitors and coils that shape the frequency response of the two drivers to make a smooth and flat frequency and phase transition between the output of the two diaphragms. But this additional speaker and crossover components introduced into the signal path add significant nonlinearities of their own to the output.
6) To maintain the cone as rigid as possible, the stiffness of the cone material can be increased, but if the added stiffness adds mass then consequently to maintain the cone's centering function of the surround, the stiffness of the *surround* should be increased. As the stiffness of the surround increases the combined greater mass of the cone and stiffness of the surround, decreases linearity of the whole moving system. As a consequence of this solution there is a corresponding decrease in the efficiency of the transducer necessitating either increasing the amplifier power to the coil or increasing the efficiency of the motor.

Components

Surround

- Annular flexible ring attached at the circumference of the large end of the cone allows for the movement of the cone (pistonic movement) while attempting to minimize the nonlinear flexing of cone. Most all modern speakers include a “spider” or flexible circular support at the voice coil end of the cone. (Hereafter when I speak of the surround the presence of the spider is assumed.)

Motor

- Electromagnetic motor composed of a coil and magnet (originally an electromagnet [Field Coil] but later a permanent magnet.)
- Coil fixed to the apex of the cone is centered in the magnetic gap.
- In and out movement of coil in magnetic gap, modulated by electric analogue of sound waves, drives cone back and forth (pistonic movement) generating sound.

Box

- The speaker assembly is mounted to a box to isolate the front wave (sound) from the back wave and therefore avoiding Destructive Phase Interference (DPI). The box may be modified in several ways to enhance the performance of the speaker, but the speaker still requires a box.

Structural-Functional time line …

1) The electrical signal varies in current and frequency and moves the coil back and forth in the magnetic field. This movement is transferred to the speaker cone (diaphragm) at its apex.
2) Because of the surround, nonlinear flexing of the cone during movement is minimized.
3) Because of the surround, as the travel of the cone increases so does the nonlinear flexing of the surround. The surround stretches as it bends further and further from the home position.
4) The surround keeps the cones voice coil in the magnetic “gap” as it travels back and forth but not precisely as the centering is dependent on a linear surround which does not exist in a R&K speaker.
5) When the the signal strength is reduced the elasticity of the cone’s surround begins to dominate the travel of the cone by restricting its movement so that when the signal strength reaches zero it is returned towards its rest or home position.

Shortcomings of the Rice and Kellogg (R&K) design.

1) The cone structure of the diaphragm, while allowing for a more rigid structure than a circular (disc) structure is far from a perfect rigid structure. It is well documented that a cone exhibits significant nonlinearities.

2) The surround is the basis of this particular structural configuration. But the surround is forced to perform several antithetical functions which leads to all of the individual functions being executed marginally.

3) The surround performs the function of managing the travel, centering and homing of the moving structure, while at the same time introducing nonlinearities during its travel; its shape is distorted during the movement of the cone introducing nonlinearities. While these nonlinearities introduced by the surround's motion were acceptable in the beginning because there were no hi-fidelity signal sources, it has since become obvious (decades ago) and easily measured, that the surround introduces distortions. Also take note that as the speaker ages the response of the surround degrades, as the material of the surround "wears." (It was a common service to replace the surround.)

4) The cone's attached voice coil can not move linearly through the magnetic gap if the cone is not moving linearly.

5) Any diaphragm (of any shape) that moves in a pistonic motion is limited by the need to have an enclosure to isolate the front wave from the back wave, to avoid destructive phase interference. When the length of the sound wave exceeds the width of the diaphragm the front waves encounter the back waves and cancel out.

6) While the surround appears as an elegant solution (and it was) to support the cone diaphragm, it comes at the cost of adding its own distortion to the audio signal in a non-equal tradeoff.

7) The physical construction of the cone means that signals of differing frequencies were arriving to the listener at different times. This causes time arrival irregularities in the signal with the result of smeared information and a loss of localization of sound sources within the sound field as well as a general smearing of the signal, like an out of focus image.

8) The Box, while helping to extend the useful frequency response, is also the source of distortion; boxes are not acoustically dead and mounting the speaker on/in a box introduces resonances to the signal inherent in the box's structure. The back waves inside the enclosure will destructively interact with the cone's signal. The speaker signal refracts and reflects off the outside of the box. The box creates costs in researching its optimal construction, in the actual building of the box and in the added costs of shipping.

Goals of New Transducer Design

•Wide dispersion. The extended output off-axis leads to a room filling sound with improved coverage for multiple listening positions.

• Eliminates the need for a cross-over in the critical 1kHz – 3kHz region.

• Maintains source integrity because all the sound is coming from a single source and not multiple transducers.

• Absolute phase coherence with a single acoustic source with no midrange/tweeter comb filtering interference.

•Flat diaphragm eliminates the hollow sound effect produced by cone shaped diaphragms.

•A flat diaphragm surfaces that reduces the volume of the speaker and occupying less space with no enclosure.

Specific Structural Requirements

1) does not have a surround or spider,
2) does not require to be mounted in a box,
3) has the same directivity across the audible spectrum,
4) is omnidirectional,
5) can function as a full range transducer,
6) has flat frequency and phase response,
7) eliminates or significantly reduces phase nonlinearities.

Solution

To achieve these multiple goals in one transducer demands that a radically different approach be taken. First, the biomimicry design principle must be abandoned. The main fundamental principal to be addressed is the avoidance of destructive phase interference (DPI) because to eliminate the surround and the box you have to address this factor; It impacts most all acoustic transducers. (There are a few transducer exceptions which will also not have the DPI issue but fall significantly short of realizing all design goals set forth here.)

1) To eliminate DPI one must abandon the geometry of the pistonic movement of cone and membrane[1] speakers.

2) The surround acts as a bearing for the cone’s forwards and backwards movement along an axis from the center of the voice coil through the center of the wide end of the cone.

3) Diaphragm’s movement must be supported by bearings.

4) Diaphragm must move in a linear motion to maintain a linear audio output.

5) The only alternative linear motion would be circular.

6) How would the diaphragm be “redesigned” to move in a circular motion?

7) The diaphragm could have an axis of motion parallel to its surface and dividing its circular shape into two half circles; rotating in an arc.

8) The circular diaphragm could have an axis of movement that is perpendicular to its center but this would generate little or no audio signal.

9) The circular diaphragm could be “extruded” from a disc into a cylinder but the angle of attack of the surface to the air would be inefficient and generate a small audio signal, but fulfill the other design goals.

1. Membrane Speakers: planar magnetic and electrostatic speakers

10) Instead of a cylinder we could use a square or triangular cross section. The diaphragm would pivot back and forth around its long axis. Now the angle of attack, of the equal faces, to the surround air is much greater and the resultant sound will be high amplitude as well as hi-fidelity.

11) Now we have a diaphragm which, if scaled to the proper dimensions (say, 1” to .75” for each of 3 or 4 short dimension) will give us a uniform radiation pattern across the audible spectrum, if there is no DPI.

Proof of concept Prototype
Prototype 3 had a flat diaphragm, a sandwich of carbon fiber and Rohacell® foam, one inch wide and approximately 36” long. A single voice coil from a hard drive head is affixed to one end, perpendicular to the long axis of the diaphragm and at its base. The voice coil is placed within the magnet structure from the same hard drive. When an audio signal is applied the diaphragm generates an audio signal. While it does generate a simple analogue of original signal the quality is not satisfactory and is not omnidirectional but bipolar. Fearing that the diaphragm is still not stiff enough and that this lack of stiffness is severely limiting its performance, two balsa wood reinforcement strips (.5” X 1”X 36”) are placed on either side of the diaphragm changing its cross section from a thin line to a square cross section. Now when fed an audio signal, the output level is significantly increased, the fidelity is greatly increased and the sound is being generated in an omnidirectional pattern across the audible spectrum.

• My first thought was that this order of magnitude increase in performance could not be the result of a slightly stiffer diaphragm. There had to be a better explanation. Then I realized it was the geometric transition from a two dimensional diagram to a three dimensional diaphragm. Somehow the 3D structure was able to completely sidestep the effects of DPI. The apparent answer to this discovery is that the Planot diaphragm generates planar waves; it is not a point source. The planar waves, from each long face, construct and destruct in the same event resulting in a net zero effect on the waves being propagated. I demonstrated the same effect with a diaphragm of a triangular cross section.

Conclusion

• Significant improvements over other technologies are immediately realized both in my measurements and by an independent testing laboratory as well as hearing tests with sophisticated listeners.

• The slender structure of the diaphragm and its pivoting movement around its long axis generates planar waves that exhibit very accurate phase information to a high order of fidelity. The waves generated are planar waves and as a consequence the waves do not cancel. The signal has omnidirectional directivity which minimizes room modes and creates an extremely broad and all encompassing sound stage allowing for an area of stereo localization that extends beyond the bounds of two speakers and, with a recording of appropriate quality, extends behind and above the listener.

• Since there is no destructive phase interference, there is no need for an enclosing box and all of its negative attributes, are eliminated.

• Planar waves' output decreases from the source at the rate of 3 dB per meter while the traditional cone speaker's output decreases at the rate of 6 dB per meter. Three dB is a halving of sound level.

• Since the diaphragm pivots on bearings and the voice coils are aligned with and perpendicular to the center of rotation of the diaphragm the voice coils are always in perfect alignment within the motor.

• One of the functions of the surround is to hold and support the cone and voice coil structure. In P3 to P4.5 the diaphragm is supported by ball bearings. The bearings not only support and hold fast the diaphragm but also allow for it to pivot freely. Performing functions #1,2 & 5 of the surround. Because of the way these three functions are implemented in the prototype there are no functional conflicts between them as in the R&K speaker.

Functions #3 and 4 of the surround are implemented in the prototype by a new structure, the Magnetic Homing Dampening Device (MHDD). This structure utilizes small Ne magnets on the diaphragm and larger and more powerful magnets mounted on top of the motor. Pairs of magnets are positioned and configured so that they present the same magnetic pole to each other. This balanced repulsive force holds the voice coil in the home or static position. When the diaphragm/voice coil structure moves the MHDD restrains the movement of the structure limiting its movement and dampening spurious vibrations arising from, for example, the abrupt loss of a driving signal following a large impulse. The magnets do not require a “break-in” period as do rubber surrounds and their function does not degrade over time as is the case with surrounds. Note that with this design there are several other options. One would be, to replace the large magnets mounted on the motor with electromagnets that are under the control of a computer control system, which could include feedback signals, to add significantly finer control in managing the movement of the system.

• Since we now have a speaker that does not require a separate tweeter, midrange or woofer but a has single driver there is no need for a crossover.

• This prototype is driven by two coils that attach to the base of the diaphragm. Because this diaphragm is a solid and rigid structure and because it is being driven at its base, there is no flexing as in a cone that introduces nonlinearities to its output.

• Since the prototype diaphragm pivots about its axel the inertial mass decreases from the surface inwards towards the center of rotation the design minimizes the effect of inertial mass on the performance of the diaphragm.

Planot®, Planot, LLC
info@planotspeaker.com
http://www.planotspeaker.com/
U.S. Utility Patent 7860265