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Egg Shaped Speaker System

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ABSTRACT

This is a report on our challenge and achievement of creating unique performance specifications and sound quality through adoption of smooth curved surface for overall dynamic speaker system design. Enclosure is shaped like an egg and speaker diaphragm is curved to match the overall enclosure form. In order to achieve smooth and even sound radiation without any disturbance, speaker edge surround and frame are not visible from outside and there is no speaker grill. As a result, we were able to develop a speaker system with very high S/N ratio across wide frequency range, allowing reproduction of subtle nuances, and with ability to create superb sound stage. Furthermore, a large number of favorable attributes, in addition to wide dispersion and smooth sound radiation, could be observed.

1. FORWARD

There was still room for improvement in dynamic speaker system design, after not seeing any significant change over the last few decades. Our solution may not be entirely new, but we kept taking an approach of an Egg of Columbus.

Recently, there is increased number of speaker systems employing curved surface for enclosure design. This is an effort to decrease diffraction and also to control enclosure resonance. However, although the idea is sound and there are some improvements along the way, we felt as if the promise has not been completely fulfilled. In order to pursue the idea to its limits, we have decided to make diaphragm to match curvature of the enclosure surface. As a result, we were faced with

major challenge of developing a transducer unit from scratch, which has convex diaphragm with broad curvature in addition to having an elliptical outline



Figure 1: Egg shaped speaker system

2. MAJOR 3 AREAS OF IMPROVEMENT

Following is a summary of 3 target areas of improvement we strived to achieve by the speaker system.

- 1) Decrease in diffraction effect and cavity effect
- 2) Decrease in enclosure resonance
- 3) Wide dispersion and smooth even sound radiation pattern

As a result of achieving these 3 targets, we were able to create a speaker system with a 4th characteristic of having stable sound stage creation.

In order to minimize diffraction effect, all cabinet edges have been rounded.

In order to reduce cavity effect, driver unit is convex shaped.

3. ENCLOSURE

The enclosure was designed using continuous curvature in order to minimize resonance, and as a result, light weight but yet rigid enclosure was achieved. Through the effort of satisfying all of the target criteria, the resultant enclosure has taken an egg shape.

Such shape is most suitable in achieving smooth radiation of sound, not only in horizontal direction but also in vertical direction as well. In order to make visually pleasing egg shaped enclosure, measurements were taken of actual chicken eggs but with inconsistent results. Instead, in order to determine the form, we decided to adopt the Golden ratio in combination with bio-mimetics, which were derived by nature over a long period of time. The final egg shape is created through proper application of 1:0.618:0.382 ratio. (Figure 2)

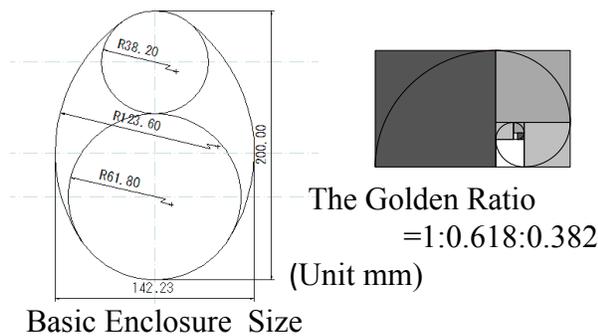


Figure2: The Golden ratio and basic enclosure size

These efforts were made with the conviction that ideal egg shape will be ideal enclosure shape as well.

As a result of taking vibration accelerometer measurements of the enclosure, following positive traits were found. (Figure 3, 4)

- 1) Higher lowest resonant frequency (small number of modes of resonance)
- 2) Low Q for resonance (quick resonance decay)
- 3) Resonance is decreased as frequency is increased (in comparison to flat plate)

It is traditionally established that natural events that are pleasing to human beings are characterized by 1/f behavior. Pleasing sound is achieved when energy decreases in inverse proportion to frequency. Musical instrument builders have been paying attention and have been studying this effect.

Egg shaped enclosure not only has low level of resonance, but also the resonance decreases in proportion to 1/f. Furthermore, the sound is radiated evenly in all directions, and it sounds very natural.

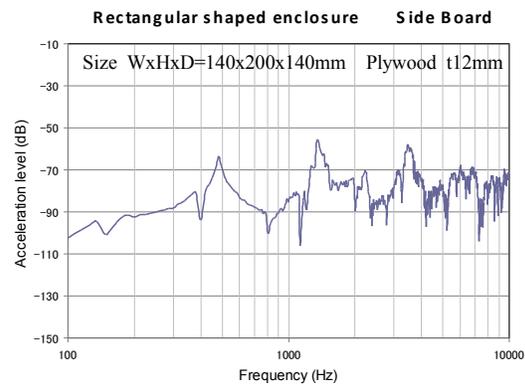


Figure 3: Acceleration level of enclosure

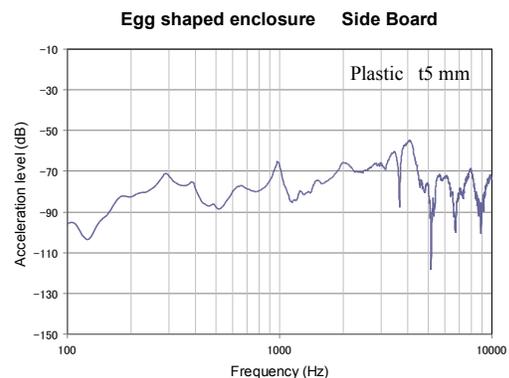


Figure 4: Acceleration level of enclosure

4. DRIVER UNIT

In order to have diaphragm that matches the form of enclosure, we needed to develop a driver unit with subtle convex diaphragm. We encountered many obstacles in designing such convex driver unit with good specifications and we almost gave up more than once. Traditional paper and plastic cone materials are not rigid enough to provide accurate driving capabilities. As of this moment, we are using unique light rigid material to create a thick diaphragm, which is then used in a driver unit by employing a method to determine best driving points. However, we feel there is still room for improvement in this area.

In order to realize smooth sound radiation and wide dispersion, convex diaphragm and egg shaped cabinet were quite effective. Speaker unit using diaphragm with the same rate of curvature as the enclosure surface does not suffer from cavity effect (resonance due to cone shape of diaphragm).

By measuring direction and intensity of radiated sound energy towards the front of the speaker system using Sound Intensity Method and displaying them as vectors, it becomes very clear that sound energy is being radiated quite evenly. On the other hand, when traditional cone speakers mounted on rectangular box type enclosure is measured, the resultant response shows disturbances in the radiated sound energy due to effects of cavity and sharp edges. (Figure 5)

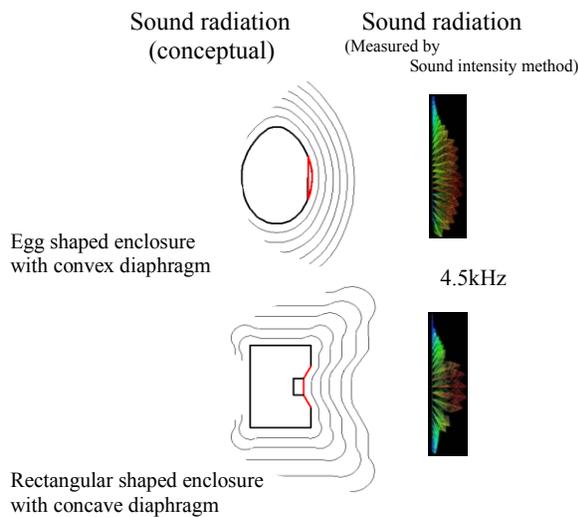


Figure 5: Sound radiation pattern

Significant traits can be observed in the dispersion characteristics. With traditional cone type speakers, improvements can only be implemented over range of ± 60 degrees. Since standard cone shape has apex angle of 120 degrees, sonic shadow forms outside of the ± 60 degrees range.

The convex diaphragm in use provides a wide ± 120 degrees dispersion.

One can imagine that the secret is in the diaphragm, which is clearly visible when speaker system is observed from the sides. (Figure 6)

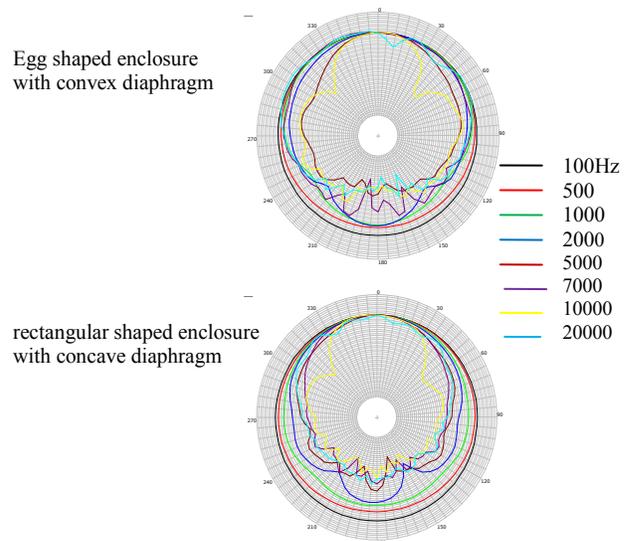


Figure 6: Polar pattern

5. DIFFRACTION EFFECT AND CAVITY EFFECT

It is often assumed that diffraction effect can be ignored without serious problem, since disturbance in frequency response is minimal within 30 degrees off axis, where listening usually takes place with speakers facing straight forward. (Figure 7)

Furthermore, it is commonly accepted that cavity effect caused by speaker cone can be ignored without serious problem as long as on axis response is flat. (Figure 8)

However, these effects are essentially acoustic resonances, where time delays are introduced and with their own frequency response, and can be considered as unwanted extraneous sound. (Figure 9)

We can conclude that this unwanted extraneous sound, which is not a part of the original sound, can be heard as noise and distortion.

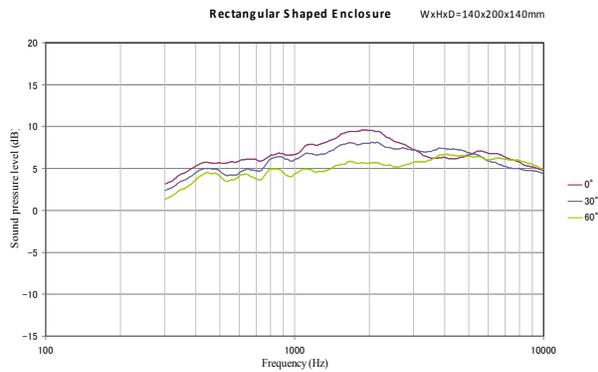


Figure 7: Diffraction effect

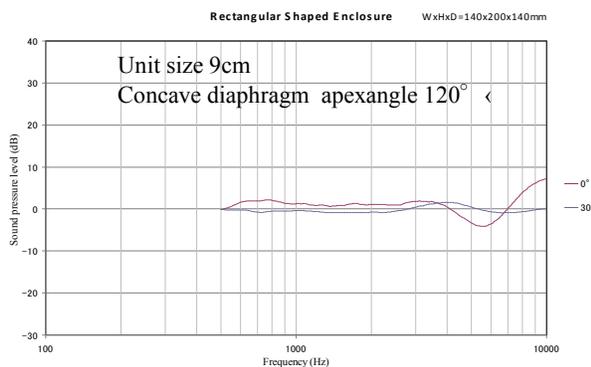


Figure 8: Cavity effect

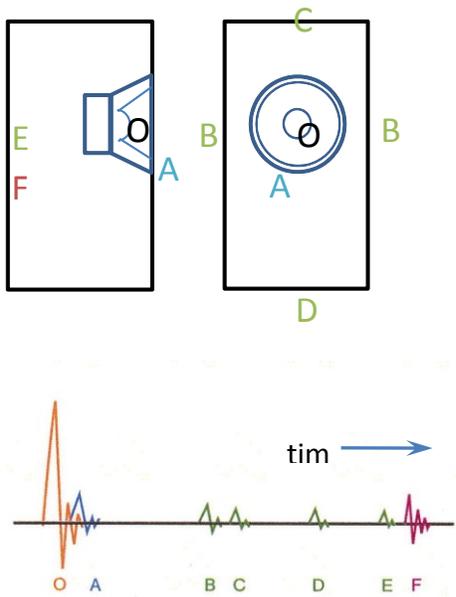


Figure 9: Conceptual diagram for extraneous sound

In most cases, subtle nuances, instantaneous sound peaks, and sound stage, are all disturbed by the extraneous sound, and will decrease the overall reproduction capability.

Furthermore, additional sound generated by enclosure also dilutes the sound, introducing additional sound character and resulting in decreased reality.

6. NEAR HOLOGRAPHIC SOUND STAGE

Reducing unnecessary extraneous sound and providing even wide dispersion without disturbance are the reasons behind creation of unprecedented stable sound stage.

That sound stage is not only superior in terms of side-to-side extension, but also excels in reproduction of both depth and height. Such expansive sound stage was previously only possible with high end audio equipment. The egg shape results in smooth radiation response and dispersion capabilities in all directions. As a result, listening position is not critical.

As an example, listening from behind the speakers gives an interesting experience, where sound stage is created around the speakers. Granted that there is loss of high frequency energy, but it is at a level still allowing full enjoyment of music.

This speaker system can create stable sound stage regardless of the quality of source material. However, with source material with large amounts of spatial information, such as SACD, one can enjoy extreme level of stable sound stage, which can be described as holographic.

7. SUMMARY

We feel our initial instincts were well served, with what started out as a simple egg of Columbus idea providing so many desirable sonic and aesthetic attributes, as a result of hours of hard work and contributions from a number of people.

The main characteristics of this speaker system can be summarized as follows:

- 1) Superb sound stage creation capability
- 2) Highly capable of recreating difficult-to-reproduce source material, such as piano with sharp transient
- 3) Superior in delineating subtle nuances
- 4) Superior in recreating echo elements
- 5) High resolution in low frequencies as a result of rigid speaker diaphragm
- 6) Superior mid-low frequency reproduction due to minimum enclosure resonance

- 7) Superior vocal reproduction, since the enclosure form is very similar to human head
- 8) Can be enjoyed over a wide range of listening positions around the speakers. Therefore, listening position is not critical.

Summarizing the valuable lessons from this experience of development:

- 1) Functional Beauty: Speaker system must be in a form most suitable for sound reproduction
- 2) Temporal Accuracy: There should not be any cavities and sharp edges which can add unwanted extraneous sound to sound radiated by speaker units
- 3) Sound Stage Reproduction: Undisturbed even sound radiation and wide dispersion can reproduce sound stage over wide range of listening positions

Egg of Columbus has turned into an egg the size of a dinosaur egg.

Although most dinosaur eggs are about this size, there were eggs measuring over 30 centimeters, which could be suitable for multi-way and woofer type applications. (Figure 10)

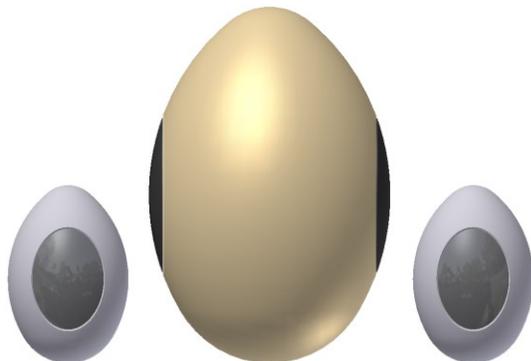


Figure 10 : 2.1ch speaker system

Looking into the future, there are multiple number of possibilities from chicken egg size design to larger size design, and by applying the same basic principle

As long as the design provides smooth sound radiation and with good resonance characteristics, there is no need to adhere to egg shape.

Previously, expansive sound stage reproduction was the envy of many, only achievable in true high-end audio systems.

With this speaker, such expansive sound stage is now a reality at much affordable price and with relative ease.

This speaker system consists of a full range speaker unit, an enclosure, and small amount of sound absorption material

It is light weight, simple, inexpensive, and the design has universal appeal.

Egg shape has been around for many years and will exist for some time to come without any change. Therefore, it can continue to be used over time, regardless of fashion trends. By being able to use for a long time, it also becomes environmentally friendly.

Lastly, I must confess that efficiency is relatively low, and with enclosure volume being less than expected, low frequency extension is somewhat limited.

However, there are many positive attributes which overcome these few shortcomings.

It looks as if delicious egg plate can be served from this Egg of Columbus after all. In fact, it is a plate that can satisfy a large number of people, although not in quantity but in quality.

8. ACKNOWLEDGEMENTS

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