Modeling Directional Response of Slim Height Channel Speakers

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Background:

Modern multichannel audio content can include height channels for audio sources that are meant to be above a listener. Dolby Atmos® enabled speakers [1] use angled upward firing speakers to radiate majority of the acoustic energy towards the ceiling. Effective perceived location of sound origination is the point of reflection in the ceiling and not the physical speaker location.

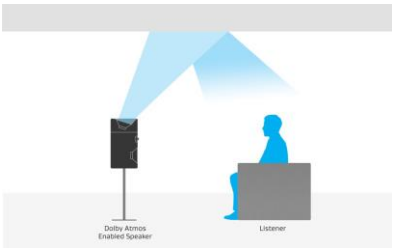


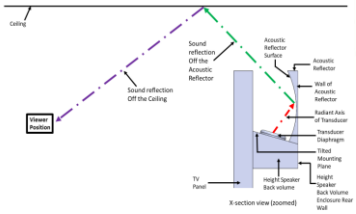
Figure 1. Product concept sketch of a conventional (large form factor) height channel speaker

Slim Height Channel Speakers - Key Challenges:

Dolby Atmos® enabled speaker technology is expanding into new markets, for example: TVs. Slim form factor TV design constraints pose significant challenge on the slim height speaker vertical plane directional response, leading to narrow sweet spot coverage area in the listener direction.

Reflector Waveguide – A Directivity Control Solution:

A reflector waveguide [2] is coupled to rear titled slim height channel speakers to radiate and focus majority of the sound energy forward and towards the ceiling to improve sweet spot coverage area.



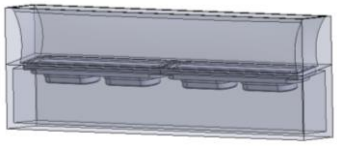


Figure 2. Product concept sketch of a slim height speaker with integrated reflector waveguide; with ~1" overall thickness and dual 90mmx15mm slim transducers

Acoustic FEM Study – Estimating Directional Response:

3D model using ACPR physics (PML + far field calculation node) is developed to evaluate the vertical plane directivity improvements of the slim height speaker with integrated acoustic reflectors. Narrow radiation characteristics is desired, to sufficiently attenuate direct sound (0 degrees to -90 degrees) compared with ceiling reflection sound (0 degrees to 90 degrees), to overcome Haas effect [3].

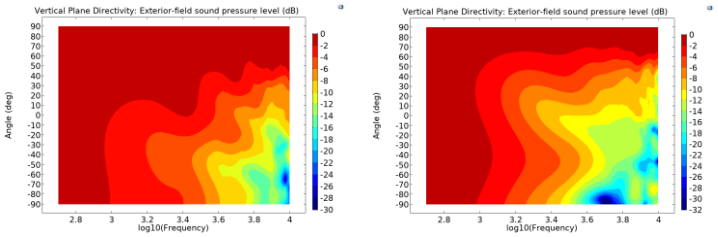


Figure 3. Simulated vertical plane directivity comparison – slim height speaker with integrated reflector (left) has wider directivity for ceiling reflection sound than the conventional slim height speaker without reflector waveguide (right)

BEM Study - Estimating Height Speaker SPL at Listener:

To numerically assess the directional response benefits of the acoustic reflector considering ceiling reflections prior to building physical prototypes, 3D model using PABE physics is developed to estimate the averaged amplitude response at different on-axis distances from TV center around typical listener position.

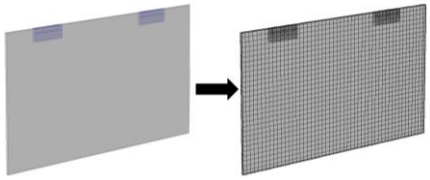


Figure 4(a) . CAD model of 65" TV panel with structurally occluded slim Left Height/Right Height modules and corresponding boundary mesh @2kHz

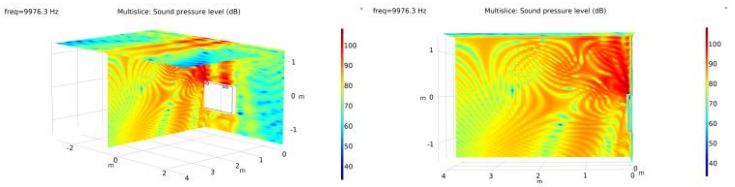


Figure 4(b). Simulated sound pressure distribution along ceiling surface and from speaker towards listener direction at ~10kHz

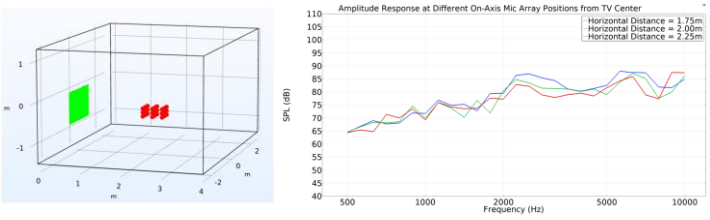


Figure 4(c). Simulated amplitude response showing minimal variation at different horizontal distances (mic array) from TV center around typical listener position

Experimental Testing and Model Validation – Module Level:

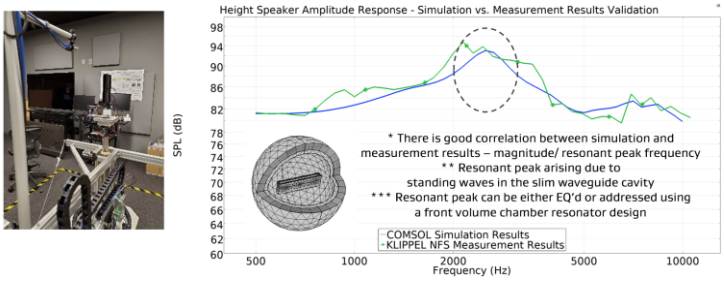


Figure 5. Amplitude response (without EQ) comparison showing good correlation between acoustic FEM results (blue curve) and 4pi anechoic measurement results using KLIPPEL NFS (green curve)

Conclusion:

It has been shown that acoustic reflector can efficiently improve the directional response of slim height speaker by redistributing acoustic energy from the slim transducer towards the listener position considering ceiling reflections.

References:

1. "Dolby Atmos® Enabled Speaker Technology", 2016
2. Tipparaju, L., "Acoustic Reflector for Height Channel Speaker", WIPO Application No 2020/176421, Published Sept 3rd, 2020
3. Gardner, M.B., "Historical background of the Haas and/or precedence effect", J. Acoust. Soc. Am., 43, 1243 (1968)