## CLAIMS

1. A speaker driver for rendering sound for reflection off of an upper surface of a listening environment, comprising:

a driver cone;

a cone dust cap affixed to a central portion of the driver cone; and

a frame securing the cone for mounting within a speaker cabinet, wherein at least one of the driver cone, dust cap, and frame are configured to apply a height filter having a frequency response curve that is configured to at least partially remove directional cues from a speaker location, and at least partially insert the directional cues from a reflected speaker location, the frequency response curve based on

a first frequency response of a filter modeling sound travelling directly from the reflected speaker location to the ears of a listener at a listening position, for said inserting of directional cues from the reflected speaker location, and

a second filter frequency response of a filter modeling sound travelling directly from the speaker location to the ears of the listener at the listening position, for removing of directional cues for audio travelling along a path directly from the speaker location to the listener.

2. The speaker driver of claim 1, wherein the frequency response curve is a universal height filter frequency response curve that represents an average of a plurality of individual height filter frequency responses, where each of the individual height filter frequency responses corresponds to a different combination of reflected speaker location, listening position, and physical speaker location.

3. The speaker driver of claim 2, wherein the height filter response exhibits a peak located at about 7 kHz and a notch at about 12 kHz.

4. A system for rendering sound using reflected sound elements, comprising:

a speaker placed at a speaker location and comprising a housing enclosing an upward-firing driver oriented at an inclination angle relative to the ground plane and configured to

reflect sound off an upper surface of a listening environment to produce a reflected speaker location; and

a virtual height filter applying a frequency response curve to an audio signal transmitted to the upward-firing driver, wherein the virtual height filter at least partially removes directional cues from the speaker location and at least partially inserts the directional cues from the reflected speaker location, the frequency response curve based on

a first frequency response of a filter modeling sound travelling directly from the reflected speaker location to the ears of a listener at a listening position, for said inserting of directional cues from the reflected speaker location, and

a second filter frequency response of a filter modeling sound travelling directly from the speaker location to the ears of the listener at the listening position, for removing of directional cues for audio travelling along a path directly from the speaker location to the listener.

5. The system of claim 4, wherein the frequency response curve is a universal height filter frequency response curve that represents an average of a plurality of individual height filter frequency responses, where each of the individual height filter frequency responses corresponds to a different combination of reflected speaker location, listening position, and physical speaker location.

6. The system of claim 5, wherein the height filter response exhibits a peak located at about 7kHz and a notch at about 12 kHz.

7. The system of claim 4, wherein the inclination angle is variable, the system further comprising:

a location component configured to determine an optimum listening position within the listening environment;

a communication component configured to communicate the optimum listening position to the speaker; and

a control component configured to alter the inclination angle to reflect the sound waves off of the upper surface to the optimum listening position.

8. The system of claim 4, further comprising:

a detection component configured to detect the presence of the virtual height filter in the listening environment

or

a bypass switch to bypass the virtual height filter during a calibration process that prepares audio playback equipment to transmit the sound waves to the listening environment.

9. The system of claim 4, further comprising a room correction component either:

performing a pre-emphasis filtering operation on the sound waves transmitted to the listening environment to compensate for the virtual height filtering applied to the signal transmitted to the upward-firing driver

or generating a target response of the listening environment by use of a probe signal and adding a default virtual height filter response to a target response of the listening environment.

10. The system of claim 4, wherein the virtual height filter

implements an algorithm using a scaling factor to compensate for height cues present in sound waves transmitted directly through the listening environment in favor of the height cues present in the sound reflected off the upper surface of the listening environment, and, optionally,

wherein the virtual height filter represents a unique frequency response curve, and wherein one or more characteristics of the frequency response curve are changed based on the value of the inclination angle.

11. The system of claim 4, wherein the housing further encloses a front-firing driver configured to transmit sound waves along an axis proximately corresponding to the ground plane.

12. The system of claim 11, wherein the speaker comprises two input terminals, wherein the first input terminal is configured to receive signals corresponding to the sound to be reflected off the upper surface of the listening environment, and the second input terminal is configured to receive signals corresponding to the sound waves to be transmitted along the axis proximately corresponding to the ground plane.

13. The system of claim 11, wherein the system further comprises a crossover filter, the crossover filter having a low-pass section configured to transmit low frequency signals below a threshold frequency to the front-firing driver, and a high-pass section configured to transmit high frequency signals above the threshold frequency to the upward-firing driver.

14. A speaker for transmitting sound waves to be reflected off an upper surface of a listening environment, comprising:

a housing;

an upward-firing driver within the housing and oriented at an inclination angle relative to a ground plane and configured to reflect sound off a reflection point on the upper surface of the listening environment; and

a virtual height filter applying a frequency response curve to a signal transmitted to the upward-firing driver, the frequency response curve based on

a first frequency response of a filter modeling sound travelling directly from a reflected speaker location to the ears of a listener at a listening position, for inserting of directional cues from the reflected speaker location, and

a second filter frequency response of a filter modeling sound travelling directly from a speaker location to the ears of the listener at the listening position, for removing of directional cues for audio travelling along a path directly from a speaker location to the listener.

15. The speaker of claim 14, wherein the frequency response curve is a universal height filter frequency response curve that represents an average of a plurality of individual height filter frequency responses, where each of the individual height filter frequency responses corresponds to a different combination of reflected speaker location, listening position, and physical speaker location.

16. The speaker of claim 15, wherein the height filter response exhibits a peak located at about 7 kHz and a notch at about 12 kHz.

D12202WO01 PCT/US2014/010466 Amended Claims Clean

## CLAIMS

1. A system for rendering sound using reflected sound elements, comprising:

a renderer generating upper signal components of an audio signal intended to be reflected off of an upper surface of a listening environment, and direct signal components of the audio signal intended to be transmitted directly into the listening environment;

at least one speaker for playing the audio signal, and having at least one direct firing driver for transmission of the direct signal components and at least one upward firing driver for transmission of the upper signal components; and

a height filter configured to at least partially remove directional cues from the at least one speaker location, and at least partially insert the directional cues from a reflected speaker location, the height filter having a height filter frequency response which is based on

a first frequency response of a filter modeling sound travelling directly from the reflected speaker location to the ears of a listener at a listening position, for said inserting of directional cues from the reflected speaker location, and

a second filter frequency response of a filter modeling sound travelling directly from the speaker location to the ears of the listener at the listening position, for removing of directional cues for audio travelling along a path directly from the at least one speaker location to the listener.

2. The system of claim 1, wherein the height filter frequency response is a universal height filter frequency response that represents an average of a plurality of individual height filter frequency responses, where each of the individual height filter frequency responses corresponds to a different combination of reflected speaker location, listening position, and physical speaker location.

3. The system of claim 2, wherein the height filter response exhibits a peak located at about 7kHz and a notch at about 12 kHz.

4. The system of claim 1 wherein the at least one speaker comprises a unitary cabinet containing both the upward firing driver and the direct firing driver, and wherein the upward firing driver is disposed at an inclination angle of between 10 degrees and 30 degrees relative to a horizontal angle defined by the direct firing driver.


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5. The system of claim 4 wherein the upward firing driver is coupled to the speaker cabinet through a movable apparatus, and wherein the inclination angle is manually or automatically variable around a nominal angle of approximately 20 degrees.

6. The system of claim 1 wherein the height filter comprises a circuit embodied in one of: a component disposed between the renderer and the at least one speaker, a component provided as part of the renderer, and a component built into the at least one speaker.

7. The system of claim 1 wherein the audio signal comprises a full bandwidth signal, the system further comprising a crossover circuit configured to transmit high frequency components above a cutoff frequency to the upward firing driver and low frequency components below the cutoff frequency to the direct firing driver.

8. The system of claim 7 wherein the upward firing driver comprises two or more transducer elements.

9. A speaker driver for rendering sound for reflection off of an upper surface of a listening environment, comprising:

a driver cone;

a cone dust cap affixed to a central portion of the driver cone; and

a frame securing the cone for mounting within a speaker cabinet, wherein at least one of the driver cone, dust cap, and frame are configured to apply a height filter having a frequency response curve that is configured to at least partially remove directional cues from a speaker location, and at least partially insert the directional cues from a reflected speaker location, the frequency response curve based on

a first frequency response of a filter modeling sound travelling directly from the reflected speaker location to the ears of a listener at a listening position, for said inserting of directional cues from the reflected speaker location, and

a second filter frequency response of a filter modeling sound travelling directly from the speaker location to the ears of the listener at the listening position, for removing of directional cues for audio travelling along a path directly from the speaker location to the listener.



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10. The speaker driver of claim 9, wherein the frequency response curve is a universal height filter frequency response curve that represents an average of a plurality of individual height filter frequency responses, where each of the individual height filter frequency responses corresponds to a different combination of reflected speaker location, listening position, and physical speaker location.

11. The speaker driver of claim 10, wherein the height filter response exhibits a peak located at about 7kHz and a notch at about 12 kHz.

12. The speaker driver of claim 9 wherein the speaker cabinet including the driver comprises an upward firing element containing the driver cone, dust cap, and frame, and a direct firing driver configured to transmit direct signal components of the rendered sound directly into the listening environment.

13. The speaker driver of claim 9 wherein the rendered sound is generated by a renderer separately generating the direct signal components and the upper signal components.

14. A system for rendering sound using reflected sound elements, comprising:

a speaker placed at a speaker location and comprising a housing enclosing a plurality of drivers, wherein a first driver of the plurality of drivers is a front-firing driver configured to transmit sound waves along a first axis proximately corresponding to the ground plane, and a second driver of the plurality of drivers is an upward-firing driver oriented at an inclination angle relative to the ground plane and configured to reflect sound off an upper surface of a listening environment to produce a reflected speaker location; and

a virtual height filter applying a frequency response curve to an audio signal transmitted to the upward-firing driver, wherein the virtual height filter at least partially removes directional cues from the speaker location and at least partially inserts the directional cues from the reflected speaker location, the frequency response curve based on

a first frequency response of a filter modeling sound travelling directly from the reflected speaker location to the ears of a listener at a listening position, for said inserting of directional cues from the reflected speaker location, and


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a second filter frequency response of a filter modeling sound travelling directly from the speaker location to the ears of the listener at the listening position, for removing of directional cues for audio travelling along a path directly from the speaker location to the listener.

15. The system of claim 14, wherein the frequency response curve is a universal height filter frequency response curve that represents an average of a plurality of individual height filter frequency responses, where each of the individual height filter frequency responses corresponds to a different combination of reflected speaker location, listening position, and physical speaker location.

16. The system of claim 15, wherein the height filter response exhibits a peak located at about 7kHz and a notch at about 12 kHz.

17. The system of claim 14 wherein the audio signal comprises a full bandwidth signal, the system further comprising a crossover coupled to the speaker, the crossover having a low-pass section configured to transmit low frequency signals below a threshold frequency to the front-firing driver, and a high-pass section configured to transmit high frequency signals above the threshold frequency to the upward firing driver.

18. The system of claim 14 wherein the virtual height filter is integrated with the crossover as part of an integrated crossover/filter circuit.

19. The system of claim 18 wherein the crossover/filter circuit is one of: a digital component implemented as a digital signal processor (DSP) device or a logic gate circuit, and an analog circuit, and wherein the crossover/filter circuit is one of a: passive device network and an active device network.

20. The system of claim 14 wherein the inclination angle is variable, the system further comprising:

a location component configured to determine an optimum listening position within the listening environment;


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a communication component configured to communicate the optimum listening position to the speaker; and

a control component configured to alter the inclination angle to reflect the sound waves off of the upper surface to the optimum listening position.

21. The system of claim 14 further comprising a detection component configured to detect the presence of the virtual height filter in the listening environment.

22. The system of claim 14 further comprising a bypass switch to bypass the virtual height filter during a calibration process that prepares audio playback equipment to transmit the sound waves to the listening environment.

23. The system of claim 14 further comprising a room correction component performing a pre-emphasis filtering operation on the sound waves transmitted to the listening environment to compensate for the virtual height filtering applied to the signal transmitted to the upward-firing driver.

24. The system of claim 23 wherein the speaker has a default virtual height filter and wherein the room correction component uses the speaker location to modify the default virtual height filter curve based on a frequency response curve optimized for the speaker location.

25. The system of claim 14 further comprising a room correction component generating a target response of the listening environment by use of a probe signal and adding a default virtual height filter response to a target response of the listening environment.

26. The system of claim 14 further comprising an array of audio speakers including respective upward-firing drivers for distribution around a listening environment, and wherein each respective upward firing driver is oriented at a unique inclination angle relative to the ground plane.

27. The system of claim 14 wherein the virtual height filter implements an algorithm using a scaling factor to compensate for height cues present in sound waves transmitted


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directly through the listening environment in favor of the height cues present in the sound reflected off the upper surface of the listening environment.

28. The system of claim 27 wherein the virtual height filter represents a unique frequency response curve, and wherein one or more characteristics of the frequency response curve are changed based on the value of the inclination angle.

29. A speaker for transmitting sound waves to be reflected off an upper surface of a listening environment, comprising:

a housing;

an upward-firing driver within the housing and oriented at an inclination angle relative to a ground plane and configured to reflect sound off a reflection point on the upper surface of the listening environment; and

a virtual height filter applying a frequency response curve to a signal transmitted to the upward-firing driver, the frequency response curve based on

a first frequency response of a filter modeling sound travelling directly from a reflected speaker location to the ears of a listener at a listening position, for inserting of directional cues from the reflected speaker location, and

a second filter frequency response of a filter modeling sound travelling directly from a speaker location to the ears of the listener at the listening position, for removing of directional cues for audio travelling along a path directly from a speaker location to the listener.

30. The speaker of claim 29, wherein the frequency response curve is a universal height filter frequency response curve that represents an average of a plurality of individual height filter frequency responses, where each of the individual height filter frequency responses corresponds to a different combination of reflected speaker location, listening position, and physical speaker location.

31. The speaker of claim 30, wherein the height filter response exhibits a peak located at about 7 kHz and a notch at about 12 kHz.

32. The speaker of claim 30 further comprising a physical interface allowing the housing to be installed on a front-firing driver cabinet that is configured to transmit sound waves along an axis proximately corresponding to the ground plane.

33. The speaker of claim 30, wherein the virtual height filter compensates for height cues present in sound waves transmitted directly through the listening environment in favor of height cues present in the sound reflected off the upper surface of the listening environment.

34. The speaker of claim 33 further comprising a crossover circuit integrated with the virtual height filter, the crossover having a low-pass section configured to transmit low frequency signals below a threshold frequency to a front-firing driver in the front-firing driver cabinet, and a high-pass section configured to transmit high frequency signals above the threshold frequency to the upward-firing driver.

35. The speaker of claim 29, further comprising a direct-firing driver within the housing configured to transmit sound waves along an axis proximately corresponding to the ground plane.

36. The speaker of claim 35, further comprising two input terminals, wherein the first input terminal is configured to receive signals corresponding to the sound waves to be reflected off the upper surface of the listening environment, and the second input terminal is configured to receive signals corresponding to the sound waves to be transmitted along the axis proximately corresponding to the ground plane.

37. A circuit comprising:

a crossover having a low-pass section configured to transmit low frequency signals to a front-firing driver and a high-pass section configured to transmit high frequency signals above to an upward-firing driver, wherein the upward-firing driver is oriented at an inclination angle relative to a ground plane and configured to reflect sound off a reflection point on an upper surface of a listening environment; and

a virtual height filter coupled to the crossover and applying a frequency response curve to a signal transmitted to the upward-firing driver, the frequency response curve based on



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a first frequency response of a filter modeling sound travelling directly from a reflected speaker location to the ears of a listener at a listening position, for inserting of directional cues from the reflected speaker location, and

a second filter frequency response of a filter modeling sound travelling directly from a speaker location to the ears of the listener at the listening position, for removing of directional cues for audio travelling along a path directly from a speaker location to the listener.

38. The circuit of claim 37, wherein the frequency response curve is a universal height filter frequency response curve that represents an average of a plurality of individual height filter frequency responses, where each of the individual height filter frequency responses corresponds to a different combination of reflected speaker location, listening position, and physical speaker location.

39. The circuit of claim 38, wherein the height filter response exhibits a peak located at about 7kHz and a notch at about 12 kHz.

40. The circuit of claim 37 wherein the upward-firing driver is enclosed in a first speaker cabinet and the front-firing driver is enclosed in a second speaker cabinet.

41. The circuit of claim 37 wherein the upward-firing driver and the front-firing driver are enclosed in a unitary speaker cabinet.

42. The circuit of claim 41 wherein the virtual height filter is integrated with the high-pass section of the crossover, and wherein the integrated virtual height filter and crossover are provided as an integrated circuit enclosed in a housing with the upward-firing driver.



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