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(54) **Active and passive directional acoustic radiating**

Aktive und passive akustische Richtstrahlung

Rayonnement acoustique directionnel actif et passif

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Description

BACKGROUND

[0001] This specification describes an audio system for a television employing directional audio devices.

[0002] EP1921890 discloses a sound beam loud-speaker system. WO2009134591 discloses passive directional acoustic radiating. None of those documents anticipates or suggests all the features of the present invention.

SUMMARY

[0003] The present invention proposes an audio system and a method for operating an audio system as recited in the appended set of claims.

[0004] In one aspect an audio system is defined according to claim 1. The audio system may include a second directional array and a second passive directional device, according to claim 2. The first directional array, the second directional array, the first passive directional device and the second passive directional device may be mounted in a common enclosure. The common enclosure may be a television cabinet. The first directional array and the second directional array may include at least one common driver. The audio system may further include a third directional array for radiating acoustic energy, comprising signal processing circuitry and more than one acoustic driver for radiating acoustic energy corresponding to the midrange content of the center channel so that more acoustic energy corresponding to the center channel signal is radiated in a direction substantially orthogonal to the direction of greater radiation of the first directional array and the direction of greater radiation of the second directional array. The audio system may further include a non-directional high frequency acoustical device for radiating the high frequency content of the center channel. The non-directional high frequency device and the third directional array may be positioned in a television on vertically opposite sides of a television screen. At least two of the first directional array, the second directional array, and the third directional array may include at least one acoustic driver in common. The direction substantially orthogonal to the direction of greater radiation of the first directional array and the direction of greater radiation of the second directional array is substantially upward. The direction substantially orthogonal to the direction of greater radiation of the first directional array and the direction of greater radiation of the second directional array may be substantially toward an intended listening area. The omnidirectional device may include a waveguide. The waveguide may be mounted in a television cabinet. At least two of the first directional array, the second directional array, and the third directional array include more than one acoustic driver in common. The first directional array, the second directional array, and the third directional array may include more than one

acoustic driver in common. The audio system may be mounted in a television cabinet. The omnidirectional acoustical device, the first directional array, the second directional array, the third directional array, the first passive directional device, and the second passive directional device each have an exit through which acoustic energy is radiated to the environment, and none of the exits may be in a front face of the television cabinet. The first passive directional device may include a slotted pipe type passive directional acoustic device comprising an acoustic driver, acoustically coupled to a pipe to radiate acoustic energy into the pipe. The pipe may include an elongated opening along at least a portion of the length of the pipe; and acoustically resistive material in the opening through which pressure waves are radiated to the environment. The pressure waves characterized by a volume velocity. The pipe, the opening, and the acoustically resistive material may be configured so that the volume velocity is substantially constant along the length of the pipe.

[0005] In another aspect, a method for operating an audio system according to claim 15 is defined.

[0006] The method may further include radiating non-directionally the high frequency content of the center channel. Radiating non-directionally the high frequency content of the center channel may include radiating from a vertically opposite side of a television screen from the radiating directionally of the midrange content of the center channel. The radiating omnidirectionally acoustic energy corresponding to the low frequency content of the combined left channel, right channel, and center channel may include radiating from a waveguide. 2.2.1. The radiating omnidirectionally may include radiating from a waveguide is mounted in a television cabinet. The directionally radiating in a direction substantially orthogonal to the direction of greater radiation of the first directional array and the direction of greater radiation of the second directional array may include radiating substantially upward. The directionally radiating in a direction substantially orthogonal to the direction of greater radiation of the first directional array and the direction of greater radiation of the second directional array may include radiating substantially toward an intended listening area. The radiating directionally from a first directional array, the radiating directionally from a second directional array, the radiating directionally from a third directional array, the radiating directionally from a first passive directional device and the radiating directionally from a second passive directional device may include radiating from a television cabinet. The radiating directionally from a first directional array, the radiating directionally from a second directional array, the radiating directionally from a third directional array, the radiating directionally from a first passive directional device and the radiating directionally from a second passive directional device may include radiating from one of a side, a bottom, or a top of a television cabinet.

[0007] In another aspect, an audio system for a televi-

sion may include a television cabinet; a slotted pipe type passive directional acoustic device that includes an acoustic driver, acoustically coupled to a pipe to radiate acoustic energy into the pipe. The pipe may include an elongated opening along at least a portion of the length of the pipe; and acoustically resistive material in the opening through which pressure waves are radiated to the environment. The the pressure waves may be characterized by a volume velocity. The pipe, the opening, and the acoustically resistive material may be configured so that the volume velocity is substantially constant along the length of the pipe. The passive directional acoustic device may be mounted in the television cabinet to directionally radiate sound waves laterally from the television cabinet. the pipe may be at least one of bent or curved. The opening may be at least one of bent or curved along its length. The opening may be in a face that is bent or curved. The television cabinet may be tapered backwardly, and the passive directional acoustic device may be mounted so that a curved or bent wall of the slotted pipe type passive directional acoustic device is substantially parallel to the back and a side wall of the television cabinet. The opening may include two sections, a first section in a top face of the pipe and a second section in a side face of the pipe. The audio system for a television of claim 10.0, wherein the acoustic apparatus may be for radiating the high frequency content of a left channel or a right channel laterally from the television. The passive directional acoustic device may be for radiating the left channel or right channel content above 2kHz. The audio system may further include a directional array for radiating midrange frequency content of the left channel or right channel laterally from the television. The audio system may further include a waveguide structure for radiating bass frequency content of the left channel or right channel; the other of the left channel or right channel; and a center channel. The cross sectional area of the pipe may decrease along the length of the pipe.

[0008] Other features, objects, and advantages will become apparent from the following detailed description, when read in connection with the following drawing, in which:

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0009]

Figs. 1A, 1C, and 1E are top diagrammatic views of an audio module mounted in a television;

Figs. 1B and 1D are front diagrammatic views of the audio module mounted in a television;

Fig. 2 is a front diagrammatic view of the audio module, showing the location of the center channel speakers;

Fig. 3A is a block diagram of an audio system;

Fig. 3B is a block diagram showing an alternate configuration of some of the elements of the audio system of Fig. 3A;

Fig. 4A is a diagrammatic view of a low frequency device of the audio system;

Fig. 4B is an isometric drawing of an actual implementation of the audio system;

Fig. 5 is a diagrammatic view of the audio module;

Figs. 6A - 6D are diagrammatic views of the elements of the audio module used as directional arrays;

Figs. 7A and 7B are diagrammatic views of a passive directional acoustic device;

Fig. 7C is an isometric view of an actual implementation of the passive directional device of Figs. 7A and 7B; and

Fig. 8 is a diagrammatic view of a passive directional audio device, mounted in a television.

DETAILED DESCRIPTION

[0010] Though the elements of several views of the drawing may be shown and described as discrete elements in a block diagram and may be referred to as "circuitry", unless otherwise indicated, the elements may be implemented as one of, or a combination of, analog circuitry, digital circuitry, or one or more microprocessors executing software instructions. The software instructions may include digital signal processing (DSP) instructions. Operations may be performed by analog circuitry or by a microprocessor executing software that performs the mathematical or logical equivalent to the analog operation. Unless otherwise indicated, signal lines may be implemented as discrete analog or digital signal lines, as a single discrete digital signal line with appropriate signal processing to process separate streams of audio signals, or as elements of a wireless communication system. Some of the processes may be described in block diagrams. The activities that are performed in each block may be performed by one element or by a plurality of elements, and may be separated in time. The elements that perform the activities of a block may be physically separated. One element may perform the activities of more than one block. Unless otherwise indicated, audio signals or video signals or both may be encoded and transmitted in either digital or analog form; conventional digital-to-analog or analog-to-digital converters may not be shown in the figures. For simplicity of wording "radiating acoustic energy corresponding to the audio signals in channel x" will be referred to as "radiating channel x."

"Directional arrays", as used herein, refers to arrays that use a combination of signal processing and geometry, placement, and configuration of more than one acoustic driver to cause the radiation to be greater in some directions than in other directions. Directional arrays include interference arrays, such as described in U.S. Pat. 5,870,484 and U.S. Pat. 5,809,153. "Passive directional device", as used herein, refers to devices that do not use any signal processing, but rather use only mechanical or physical arrangements or devices to cause the radiation of wavelengths that are large (for example 2x) relative to the diameter of the radiating elements to be greater in some directions than in others. Passive directional devices could include acoustic lenses, horns, dipole radiators, or slotted pipe type directional devices shown below and in Figs. 7A - 7C and described in the corresponding portions of the specification.

[0011] Fig. 1A shows a diagrammatic view of an audio module 10. The audio module 10 may be associated with, or built into, a television 12. The audio module radiates acoustic signals of some frequency ranges corresponding to a audio system including at least a left channel, a right channel, and a center channel.

[0012] The left channel midrange (LM) frequency sound is radiated by a directional array so that more acoustic energy is radiated laterally leftward relative to a listening area than in other directions as indicated. The right channel midrange (RM) frequency sound is radiated by a directional array so that more acoustic energy is radiated laterally rightward than in other directions as indicated.

[0013] The left channel high (LH) frequency sound is radiated by a passive directional device so that more acoustic energy is radiated laterally leftward than in other directions as indicated. The right channel high (RH) frequency sound is radiated by a passive directional device so that more acoustic energy is radiated laterally rightward than in other directions as indicated.

[0014] Radiating the left and right channels directionally laterally causes more of radiation experienced by the listener to be indirect radiation than direct radiation or radiation of the left and right channels toward the listening area. Causing more of the radiation to be indirect radiation results in a more spacious acoustic image and permits the radiation of the left and right channels from a device in the lateral middle of the listening area.

[0015] Figs. 1B - 1E show different implementations of the radiation pattern of the center channel.

[0016] In Figs. 1B and 1C, the center channel midrange (CM) frequency sound is radiated by a directional array so that more energy is radiated in a direction substantially orthogonal to the directions of maximum radiation of the left and right channel midrange frequency sound than is radiated in other directions. The center channel high (CH) frequency sound is radiated directionally by a passive directional device so that more energy is radiated in a direction substantially orthogonal to the directions of maximum radiation of the left and right channel midrange

frequency sound than is radiated in other directions. In Fig. 1B, the direction of maximum radiation of the center channel midrange frequency sound and the high frequency sound is upward relative to the listening area. In Fig. 1C, the direction of maximum radiation the center channel midrange frequency sound and the high frequency sound is toward the listening area. In other implementations, the direction of maximum radiation of the center channel midrange frequency and the high frequency could be substantially downward. The direction of maximum radiation of the center channel midrange frequency sound and the direction of maximum radiation of the center channel high frequency sound do not need to be the same direction; for example, the center channel midrange frequency sound could be radiated substantially upwardly, and the center channel high frequency sound could be radiated substantially toward the listening area. The low frequency device, which will be described below, may be mounted in a television cabinet 46.

[0017] In Figs. 1D and 1E, the center channel midrange frequency sound is radiated by a directional array so that more energy is radiated in a direction substantially orthogonal to the directions of maximum radiation of the left and right channel midrange frequency sound than is radiated in other directions. The center channel high frequency sound is radiated substantially omnidirectionally. In Fig. 1D, the direction of maximum radiation the center channel midrange frequency is upward relative to the listening area. In Fig. 1E, the direction of maximum radiation the center channel midrange frequency sound is toward the listening area.

[0018] When implemented in a television, the center channel high frequency acoustical device may be vertically on the opposite side of the television screen from the center channel directional array to cause the acoustic image to be vertically centered on the television screen. For example, as shown in Fig. 2, if the center channel directional array 44 is above the television screen 52, the center channel high frequency acoustical device 45 may be positioned below the television screen.

[0019] Fig. 3A is a block diagram showing some signal processing elements of the audio module 10 of Figs. 1A - 1E. The signal processing elements of Fig. 3A are parts of a three-way crossover system that separates the input channel into three frequency bands (hereinafter referred to as a bass frequency band, a midrange frequency band, and a high frequency band), none of which are substantially encompassed by any of the other frequency bands. The signal processing elements of Fig. 3A processes and radiates the three frequency bands differently.

[0020] The left channel signal L, the right channel signal R, and the center channel signal C are combined at signal summer 29 and low pass filtered by low pass filter 24 to provide a combined low frequency signal. The combined low frequency signal is radiated by a low frequency radiation device 26, such as a woofer or another acoustic device including low frequency augmentation elements such as ports, waveguides, or passive radiators. Alter-

natively, the left channel signal, the right channel signal, and the center channel signal may be low pass filtered, then combined before being radiated by the low frequency radiation device, as shown in Fig. 3B.

[0021] In Fig. 3A, the left channel signal is band pass filtered by band pass filter 28 and radiated directionally by left channel array 30. The left channel signal is high pass filtered by high pass filter 32 and radiated directionally (as indicated by the arrow extending from element 34) by passive directional device 34.

[0022] The right channel signal is band pass filtered by band pass filter 28 and radiated directionally by right channel array 38 as shown in Figs. 1A - 1E. The right channel signal is high pass filtered by high pass filter 32 and radiated directionally by passive directional device 42.

[0023] The center channel signal is band pass filtered by band pass filter 28 and radiated directionally by center channel array 44 as shown in Figs. 1B - 1E. The center channel signal is high pass filtered by high pass filter 32 and radiated directionally by a high frequency acoustical device 45 (which, as stated above may be directional or omnidirectional, as indicated by the dotted line arrow extending from element 45).

[0024] In one implementation, the break frequency of low pass filter 24 is 250 Hz, the pass band for band pass filter 28 is 250 Hz to 2.5 k Hz, and the break frequency for high pass filter 32 is 2 kHz.

[0025] In one implementation, the low frequency device 26 of Fig. 3A includes a waveguide structure as described in U.S. Published Pat. App. 2009-0214066 A1. The waveguide structure is shown diagrammatically in Fig. 4A. An actual implementation of the low frequency device of Fig. 4A is shown in Fig. 4B. Reference numbers in Fig. 4B correspond to like numbered elements of Fig. 4A. The low frequency device may include a waveguide 412 driven by six 2.25 inch acoustic drivers 410A - 410D mounted near the closed end 411 of the waveguide. There are acoustic volumes 422A and 422B acoustically coupled to the waveguide at the locations 434A and 434B along the waveguide. The cross sectional area of the waveguide increases at the open end 418. The implementation of Fig. 4B has one dimension that is small relative to the other two dimensions and can be conveniently enclosed in a flat panel wide screen television cabinet, such as the cabinet 46 of the television 12.

[0026] Directional arrays 30, 38, and 44 are shown diagrammatically in Fig. 3A as having two acoustic drivers. In actual implementations, they may have more than two acoustic drivers and may share common acoustic drivers. In one implementation, the left directional array 30, the right directional array 38, and the center directional array 44 are implemented as a multi-element directional array such as is described in U.S. Pat. App. 12/716,309 filed March 3, 2010 by Berardi, et al.

[0027] Fig. 5 shows an acoustic module that is suitable for the left channel array 30, the right channel array 38 of Fig. 3A, and the center channel array 44 (all shown in

Fig. 3A). An audio module 212 includes a plurality, in this embodiment seven, of acoustic drivers 218-1 - 218-7. One of the acoustic drivers 218-4 is positioned near the lateral center of the module, near the top of the audio module. Three acoustic drivers 218-1 - 218-3 are positioned near the left extremity 220 of the audio module and are closely and non-uniformly spaced, so that distance $l1 \neq l2$, $l2 \neq l3$, $l1 \neq l3$. Additionally, the spacing may be arranged so that $\neq 1 < l2 < l3$. Similarly, distance $l6 \neq l5$, $l5 \neq l4$, $l6 \neq l4$. Additionally, the spacing may be arranged so that $l6 < l5 < l4$. In one implementation, $l1 = l6 = 55\text{mm}$, $l2 = l5 = 110\text{mm}$, and $l3 = l4 = 255\text{mm}$. The left channel array 30, the right channel array 38, and the center channel array 44 of Fig. 3A each include subsets of the seven acoustic drivers 218-1 - 218-7.

[0028] The directional radiation patterns of the mid-range frequency bands of Figs. 1A - 1E are accomplished by interference type directional arrays consisting of subsets of the acoustic drivers 218-1 - 218-7. Interference type directional arrays are discussed in U.S. Pat. 5,870,484 and U.S. Pat. 5,809,153. At frequencies at which the individual acoustic drivers radiate substantially omnidirectionally (for example frequencies with corresponding wavelengths that are more than twice the diameter of the radiating surface of the acoustic drivers), radiation from each of the acoustic drivers interferes destructively or non-destructively with radiation from each of the other acoustic drivers. The combined effect of the destructive and non-destructive interference is that the radiation in some directions is significantly less, for example, -14 dB, relative to the maximum radiation in any direction. The directions at which the radiation is significantly less than the maximum radiation in any direction may be referred to as "null directions". Causing more radiation experienced by a listener to be indirect radiation is accomplished by causing the direction between the audio module and the listener to be a null direction and so that more radiation is directed laterally relative to the listener.

[0029] Fig. 6A shows a diagrammatic view of audio module 212, showing the configuration of directional arrays of the audio module. The audio module is used to radiate the channels of a multi-channel audio signal source 222. Typically, a multi-channel audio signal source for use with a television has at least a left (L), right (R), and Center (C) channel. In Fig. 6A, the left channel array 30 includes acoustic drivers 218-1, 218-2, 218-3, 218-4, and 218-5. The acoustic drivers 218-1 - 218-5 are coupled to the left channel signal source 238 by signal processing circuitry 224-1 - 224-5, respectively that apply signal processing represented by transfer function $H1L(z)$ - $H5L(z)$, respectively. The effect of the transfer functions $H1L(z)$ - $H5L(z)$ on the left channel audio signal may include one or more of phase shift, time delay, polarity inversion, and others. Transfer functions $H1L(z)$ - $H5L(z)$ are typically implemented as digital filters, but may be implemented with equivalent analog devices.

[0030] In operation, the left channel signal L, as mod-

ified by the transfer functions $H1 L(z)$ - $H5L(z)$ is transduced to acoustic energy by the acoustic drivers 218-1 - 218-5. The radiation from the acoustic drivers interferes destructively and non-destructively to result in a desired directional radiation pattern. To achieve a spacious stereo image, the left array 232 directs radiation laterally toward the left boundary of the room as indicated by arrow 213 and cancels radiation toward the listener. The use of digital filters to apply transfer functions to create directional interference arrays is described, for example, in Boone, et al., Design of a Highly Directional Endfire Loudspeaker Array, J. Audio Eng. Soc., Vol 57. The concept is also discussed with regard to microphones van der Wal et al., Design of Logarithmically Spaced Constant Directivity-Directivity Transducer Arrays, J. Audio Eng. Soc., Vol. 44, No. 6, June 1996 (also discussed with regard to loudspeakers), and in Ward, et al., Theory and design of broadband sensor arrays with frequency invariant far-field beam patterns, J. Acoust. Soc. Am. 97 (2), February 1995. Mathematically, directional microphone array concepts may generally be applied to loudspeakers.

[0031] Similarly, in Fig. 6B, the right channel array 38 includes acoustic drivers 218-3, 218-4, 218-5, 218-6, and 218-7. The acoustic drivers 218-3 - 218-7 are coupled to the right channel signal source 240 and to signal processing circuitry 224-3 - 224-7, respectively that apply signal processing represented by transfer function $H3R(z)$ - $H7R(z)$, respectively. The effect of the transfer functions $H3R(z)$ - $H7R(z)$ may include one or more of phase shift, time delay, polarity inversion, and others. Transfer functions $H3R(z)$ - $H7R(z)$ are typically implemented as digital filters, but may be implemented with equivalent analog devices.

[0032] In operation, the right channel signal R, as modified by the transfer functions $H3R(z)$ - $H7R(z)$ is transduced to acoustic energy by the acoustic drivers 218-3 - 218-7. The radiation from the acoustic drivers interferes destructively and non-destructively to result in a desired directional radiation pattern. To achieve a spacious stereo image, the right array 234 directs radiation laterally toward the right boundary of the room as indicated by arrow 215 and cancels radiation toward the listener.

[0033] In Fig. 6C, the center channel array 44 includes acoustic drivers 218-2, 218-3, 218-4, 218-5, and 218-6. The acoustic drivers 218-2 - 218-6 are coupled to the center channel signal source 242 by signal processing circuitry 224-2 - 224-6, respectively that apply signal processing represented by transfer function $H2C(z)$ - $H6C(z)$, respectively. The effect of the transfer functions $H2C(z)$ - $H6C(z)$ may include one or more of phase shift, time delay, polarity inversion, and others. Transfer functions $H2C(z)$ - $H6C(z)$ are typically implemented as digital filters, but may be implemented with equivalent analog devices.

[0034] In operation, the center channel signal C, as modified by the transfer functions $H2C(z)$ - $H6C(z)$ is transduced to acoustic energy by the acoustic drivers

218-2 - 218-6. The radiation from the acoustic drivers interferes destructively and non-destructively to result in a desired directional radiation pattern.

[0035] An alternative configuration for the center channel array 44 is shown in Fig. 6D, in which the center channel array 44 includes acoustic drivers 218-1, 218-3, 218-4, 218-5, and 218-7. The acoustic drivers 218-1, 218-3 - 218-5, and 218-7 are coupled to the center channel signal source 242 by signal processing circuitry 224-1, 224-3 - 224-5, and 224-7, respectively that apply signal processing represented by transfer function $H1 C(z)$, $H3C(z)$ - $H5C(z)$, and $H7C(z)$, respectively. The effect of the transfer functions $H1 C(z)$, $H3C(z)$ - $H5C(z)$, and $H7C(z)$, may include one or more of phase shift, time delay, polarity inversion, and others. Transfer functions $H1 C(z)$, $H3C(z)$ - $H5C(z)$, and $H7C(z)$ are typically implemented as digital filters, but may be implemented with equivalent analog devices.

[0036] In operation, the center channel signal C, as modified by the transfer functions $H1 C(z)$, $H3C(z)$ - $H5C(z)$, and $H7C(z)$ is transduced to acoustic energy by the acoustic drivers 218-1, 218-3 - 218-5, and 218-7. The radiation from the acoustic drivers interferes destructively and non-destructively to result in a desired directional radiation pattern.

[0037] The center channel array 44 of Figs. 6C and 6D may direct radiation upward, as indicated by arrow 217 and in some implementations slightly backward and cancels radiation toward the listener, or in other implementations may direct radiation toward the listening area.

[0038] Other types of directional array are appropriate for use as directional arrays 30, 38, and 44. For example, each of the arrays may have as few as two acoustic drivers, without any acoustic drivers shared by arrays.

[0039] In one implementation, the left passive directional device 34 and the right passive directional device 42 of Fig. 3A are implemented as shown diagrammatically in Figs. 7A and 7B with an actual example (without the acoustic driver) in Fig 7C. The passive directional devices of Figs. 7A and 7B operate according to the principles described in U.S. Published Pat. App. 2009-0274329 A1.

[0040] The passive directional device 310 of Fig. 7A - 7C includes a rectangular pipe 316 with an acoustic driver 314 mounted in one end. The pipe tapers from the end in which the acoustic driver 314 is mounted to the other end so that the cross-sectional area at the other end is substantially zero. A lengthwise slot 318 that runs substantially the length of the pipe is covered with acoustically resistive material 320, such as unsintered stainless steel wire cloth, 165x800 plain twill Dutch weave. The dimensions and characteristics of the pipe, the slot, and the acoustically resistive material are set so that the volume velocity is substantially constant along the length of the pipe.

[0041] In the actual implementation of Fig. 7C, one lengthwise section 354 of the rectangular pipe is bent at a 45 degree angle to a second section 352. The slot 318

of Fig. 7A is divided into two sections, one section 318A of the slot in the side face 356 of first section 354 of the pipe and a second section of the slot 318B in the top face 358 in the second section 352 of the pipe.

[0042] The implementation of the slotted pipe type directional loudspeaker of Fig. 7B is particularly advantageous in some situations. Fig. 8 shows a curved or bent slotted pipe type directional radiator 110 in a television cabinet 112. The dotted lines represent the side and back of the television cabinet 112, viewed from the top. For cosmetic or other reasons, the back of the cabinet is tapered inwardly, so that the back of the cabinet is narrower than the front. A slotted pipe type directional radiator is positioned in the cabinet so that the curve or bend generally follows the tapering of the cabinet, or in other words so that the curved or slanted wall of the slotted pipe type directional radiator is substantially parallel with the back and side of the television cabinet. The directional radiator may radiate through an opening in the side of the cabinet, which may, for example, be a louvered opening. The direction of strongest radiation of the directional loudspeaker is generally sideward and slightly forward as indicated by arrow 62, which is desirable for use as passive directional devices such as devices 32 and 42 of Fig. 3A.

[0043] Other types of passive directional devices may be appropriate for passive directional devices 32 and 42, for example, horns, lenses or the like.

[0044] Using passive directional devices for high frequencies is advantageous because it provides desired directionality without requiring directional arrays. Designing directional arrays that work effectively at the short wavelengths corresponding to high frequencies is difficult. At frequencies with corresponding wavelengths that approach the diameter of the radiating elements, the radiating elements themselves may become directional.

[0045] Numerous uses of and departures from the specific apparatus and techniques disclosed herein may be made without departing from the inventive concepts. Consequently, the invention is to be construed as embracing each and every novel feature and novel combination of features disclosed herein and limited only the appended claims.

Claims

1. An audio system (10) comprising:

a crossover network for separating a left channel, a right channel, and a center channel into low frequency content, midrange frequency content, and high frequency content;
an omnidirectional acoustical device (26) for radiating acoustic energy corresponding to the low frequency content of a combination of the left channel, right channel, and center channel;
a first directional array (30,38), comprising signal processing circuitry and more than one

acoustic driver, for radiating acoustic energy corresponding to the midrange content of one of the left channel and right channel signal so that more acoustic energy corresponding to the midrange content of one of the left channel signal and the right channel signal is radiated laterally relative to a listening area than in other directions; and

a first passive directional device (34,42) for radiating acoustic energy corresponding to the high frequency content of the one of the left channel and right channel signal so that more acoustic energy corresponding to the high frequency content of the one of the left channel signal and the right channel signal is radiated laterally relative to the listening area than in other directions, a passive directional device being a device that does not use any signal processing, but uses only mechanical or physical arrangements or devices to cause the radiation of wavelengths that are large relative to the diameter of radiating elements to be greater in some directions than in others.

2. The audio system (10) of claim 1, further comprising:

a second directional array (30,38) for radiating acoustic energy, comprising signal processing circuitry and more than one acoustic driver for radiating acoustic energy corresponding to the midrange content of the other of the left channel and right channel so that more acoustic energy corresponding to high frequency content of the other of the left channel and right channel signal is radiated laterally relative to the listening area than in other directions; and

a second passive directional device (34,42) for radiating acoustic energy corresponding to the high frequency content of the other of the left channel and right channel so that more acoustic energy corresponding to high frequency content of the other of the left channel and right channel signal is radiated laterally relative to the listening area than in other directions.

3. The audio system (10) of claim 2, wherein the first directional array (30,38), the second directional array (30,38), the first passive directional device (34,42) and the second passive directional device (34,42) are mounted in a common enclosure.

4. The audio system (10) of claim 2, wherein the first directional array (30,38) and the second directional array (30,38) comprise at least one common acoustic driver.

5. The audio system (10) of claim 1, further comprising a third directional array (44) for radiating acoustic

energy, comprising signal processing circuitry and more than one acoustic driver for radiating acoustic energy corresponding to the midrange content of the center channel so that more acoustic energy corresponding to the center channel signal is radiated in a direction substantially orthogonal to the direction of greater radiation of the first directional array and the direction of greater radiation of the second directional array.

6. The audio system (10) of claim 5, further comprising a non-directional high frequency acoustical device (45) for radiating the high frequency content of the center channel.
7. The audio system (10) of claim 5, wherein at least two of the first directional array (30,38), the second directional array (30,38), and the third directional array (44) comprise at least one acoustic driver in common.
8. The audio system (10) of claim 1, wherein the omnidirectional device (26) comprises a waveguide (412).
9. The audio system (10) of claim 8, wherein the waveguide (412) is mounted in a television cabinet (46).
10. The audio system (10) of claim 8, wherein at least two of the first directional array (30,38), the second directional array (30,38), and the third directional array (44) comprise more than one acoustic driver in common.
11. The audio system (10) of claim 10, wherein the first directional array (30,38), the second directional array (30,38), and the third directional array (44) comprise more than one acoustic driver in common.
12. The audio system (10) of claim 1, mounted in a television cabinet (46).
13. The audio system (10) of claim 12, wherein the omnidirectional acoustical device (26), the first directional array (30,38), the second directional array (30,38), the third directional array (44), the first passive directional device (34,42), and the second passive directional device (34,42) each have an exit through which acoustic energy is radiated to the environment, wherein none of the exits is in a front face of the television cabinet (46).
14. The audio system (10) of claim 1, wherein the first passive directional device (34,42) comprises:
 - a slotted pipe type passive directional acoustic device comprising an acoustic driver (314)

acoustically coupled to a pipe (316) to radiate acoustic energy into the pipe, the pipe comprising an elongated opening (318) along at least a portion of the length of the pipe; and acoustically resistive material (320) in the opening through which pressure waves are radiated to the environment, the pressure waves **characterized by** a volume velocity, the pipe, the opening, and the acoustically resistive material configured so that the volume velocity is substantially constant along the length of the pipe.

15. A method for operating an audio system (10), the method comprising:

radiating omnidirectionally acoustic energy corresponding to the low frequency content of a combination of a left channel, a right channel, and a center channel;
 radiating directionally, from a first directional array (30) comprising signal processing circuitry and more than one acoustic driver, acoustic energy corresponding to the midrange content of the left channel so that more acoustic energy corresponding to the left channel signal is radiated leftwardly relative to a listening area than in other directions;
 radiating directionally, from a second directional array (38) comprising signal processing circuitry and more than one acoustic driver, acoustic energy corresponding to the midrange content of the right channel so that more acoustic energy corresponding to the right channel signal is radiated rightwardly relative to the listening area than in other directions;
 radiating directionally, from a third directional array (44) comprising signal processing circuitry and more than one acoustic driver, acoustic energy corresponding to the midrange content of the center channel so that more acoustic energy corresponding to the center channel signal is radiated in a direction substantially orthogonal to the direction of greater radiation of the first directional array and the direction of greater radiation of the second directional array;
 radiating directionally, from a first passive directional device (34), acoustic energy corresponding to the high frequency content of the left channel so that more acoustic energy is radiated leftwardly relative to the listening area than other directions; and
 radiating directionally, from a second passive directional device (42), acoustic energy corresponding to the high frequency content of the right channel so that more acoustic energy is radiated rightwardly relative to the listening area

than other directions,
wherein a passive directional device is a device
that does not use any signal processing, but us-
es only mechanical or physical arrangements or
devices to cause the radiation of wavelengths
that are large relative to the diameter of radiating
elements to be greater in some directions than
in others.

Patentansprüche

1. Audiosystem (10), umfassend:

eine Frequenzweiche zum Trennen eines linken
Kanals, eines rechten Kanals und eines zentral-
len Kanals in einen niederfrequenten Inhalt, ei-
nen mittelfrequenten Inhalt und einen hochfre-
quenten Inhalt;
eine omnidirektionale akustische Vorrichtung
(26), um akustische Energie abzustrahlen, die
dem niederfrequenten Inhalt einer Kombination
aus dem linken Kanal, dem rechten Kanal und
dem zentralen Kanal entspricht,
einen ersten gerichteten Bereich (30, 38), um-
fassend eine Signalverarbeitungsschaltung und
mehr als einen akustischen Treiber, um akusti-
sche Energie abzustrahlen, die dem mittelfre-
quenten Inhalt eines des linken Kanals und des
rechten Kanals entspricht, so dass mehr akus-
tische Energie, die dem mittelfrequenten Inhalt
eines des linken Kanalsignals und des rechten
Kanalsignals entspricht, seitlich mit Bezug auf
einen Hörbereich als in andere Richtungen ab-
gestrahlt wird; und
eine erste passive gerichtete Vorrichtung (34,
42), um akustische Energie abzustrahlen, die
dem hochfrequenten Inhalt eines des linken Ka-
nals und des rechten Kanalsignals entspricht,
so dass mehr akustische Energie, die dem hoch-
frequenten Inhalt eines des linken Kanalsignals
und des rechten Kanalsignals entspricht, seitlich
mit Bezug auf den Hörbereich als in andere
Richtungen abgestrahlt wird, wobei ein passive
gerichtete Vorrichtung eine Vorrichtung ist, die
keine Signalverarbeitung verwendet, sondern
nur mechanische oder physische Anordnungen
oder Vorrichtungen verwendet, um die Abstrah-
lung von Wellenlängen zu verursachen, die groß
mit Bezug auf den Durchmesser von Strah-
lungselementen sind, um in einigen Richtungen
größer als in anderen zu sein.

2. Audiosystem (10) nach Anspruch 1, weiter umfas- send einen zweiten gerichteten Bereich (30, 38), um akus- tische Energie abzustrahlen, umfassend eine Sig- nalverarbeitungsschaltung und mehr als einen akus-

tischen Treiber, um akustische Energie abzustrah-
len, die dem mittelfrequenten Inhalt des anderen des
linken Kanals und des rechten Kanals entspricht, so
dass mehr akustische Energie, die dem hochfre-
quenten Inhalt des anderen des linken Kanals und
des rechten Kanalsignals entspricht, seitlich mit Be-
zug auf den Hörbereich als in andere Richtungen
abgestrahlt wird; und
eine zweite passive gerichtete Vorrichtung (34, 42),
um akustische Energie abzustrahlen, die dem hoch-
frequenten Inhalt des anderen des linken Kanals und
des rechten Kanals entspricht, so dass mehr akus-
tische Energie, die dem hochfrequenten Inhalt des
anderen des linken Kanals und des rechten Kanals
entspricht, seitlich mit Bezug auf den Hörbereich als
in andere Richtungen abgestrahlt wird.

3. Audiosystem (10) nach Anspruch 2, wobei der erste gerichtete Bereich (30, 38), der zweite gerichtete Be- reich (30, 38), die erste passive gerichtete Vorrich- tung (34, 42) und die zweite passive gerichtete Vor- richtung (34, 42) in ein gemeinsames Gehäuse mon- tiert sind.

4. Audiosystem (10) nach Anspruch 2, wobei der erste gerichtete Bereich (30, 38) und der zweite gerichtete Bereich (30, 38) mindestens einen gemeinsamen akustischen Treiber umfassen.

5. Audiosystem (10) nach Anspruch 1, weiter umfas- send einen dritten gerichteten Bereich (44), um akustische Energie abzustrahlen, umfassend eine Signalverarbeitungsschaltung und mehr als einen akustischen Treiber, um akustische Energie abzu- strahlen, die dem mittelfrequenten Inhalt des zentral- len Kanals entspricht, so dass mehr akustische En- ergie, die dem zentralen Kanalsignal entspricht, in eine Richtung abgestrahlt wird, die im Wesentlichen orthogonal zur Richtung der größeren Abstrahlung des ersten gerichteten Bereichs und der Richtung der größeren Abstrahlung des zweiten gerichteten Bereichs ist.

6. Audiosystem (10) nach Anspruch 5, weiter umfas- send eine nicht gerichtete hochfrequente akustische Vorrichtung (45), um den hochfrequenten Inhalt des zentralen Kanals abzustrahlen.

7. Audiosystem (10) nach Anspruch 5, wobei mindes- tens zwei des ersten gerichteten Bereichs (30, 38), des zweiten gerichteten Bereichs (30, 38) und des dritten gerichteten Bereichs (44) mindestens einen gemeinsamen akustischen Treiber umfassen.

8. Audiosystem (10) nach Anspruch 1, wobei die om- nidirektionale Vorrichtung (26) einen Wellenleiter (412) umfasst.

9. Audiosystem (10) nach Anspruch 8, wobei der Wellenleiter (412) in ein Fernsehgehäuse (46) montiert ist.
10. Audiosystem (10) nach Anspruch 8, wobei mindestens zwei des ersten gerichteten Bereichs (30, 38), des zweiten gerichteten Bereichs (30, 38) und des dritten gerichteten Bereichs (44) mehr als einen gemeinsamen akustischen Treiber umfassen. 5
11. Audiosystem (10) nach Anspruch 10, wobei der erste gerichtete Bereich (30, 38), der zweite gerichtete Bereich (30, 38) und der dritte gerichtete Bereich (44) mehr als einen gemeinsamen akustischen Treiber umfassen. 10
12. Audiosystem (10) nach Anspruch 1, das in ein Fernsehgehäuse (46) montiert ist. 15
13. Audiosystem (10) nach Anspruch 12, wobei die omnidirektionale akustische Vorrichtung (26), der erste gerichtete Bereich (30, 38), der zweite gerichtete Bereich (30, 38), der dritte gerichtete Bereich (44), die erste passive gerichtete Vorrichtung (34, 42) und die zweite passive gerichtete Vorrichtung (34, 42) jeweils einen Ausgang aufweisen, durch den akustische Energie an die Umgebung abgestrahlt wird, wobei sich keiner der Ausgänge auf einer vorderen Seite des Fernsehgehäuses (46) befindet. 20
14. Audiosystem (10) nach Anspruch 1, wobei die erste passive gerichtete Vorrichtung (34, 42) Folgendes umfasst: 25
- eine passive gerichtete akustische Vorrichtung vom Typ eines geschlitzten Rohrs, umfassend einen akustischen Treiber (314), der akustisch mit einem Rohr (316) gekoppelt ist, um akustische Energie in das Rohr abzustrahlen, wobei das Rohr Folgendes umfasst: 30
- eine verlängerte Öffnung (318) entlang mindestens einem Abschnitt der Länge des Rohrs; und 35
- akustisch widerstandsfähiges Material (320) in der Öffnung, durch die Druckwellen an die Umgebung abgestrahlt werden, wobei die Druckwellen durch eine Volumengeschwindigkeit gekennzeichnet sind, wobei das Rohr, die Öffnung und das akustisch widerstandsfähige Material so konfiguriert sind, dass die Volumengeschwindigkeit im Wesentlichen auf der Länge des Rohrs konstant ist. 40
15. Verfahren zum Betrieb eines Audiosystems (10), wobei das Verfahren Folgendes umfasst: 45
- 50
- 55

omnidirektionales Abstrahlen von akustischer Energie, die dem niederfrequenten Inhalt einer Kombination aus einem linken Kanal, einem rechten Kanal und einem zentralen Kanal entspricht;

gerichtetes Abstrahlen, aus einem ersten gerichteten Bereich (30), umfassend eine Signalverarbeitungsschaltung und mehr als einen akustischen Treiber, von akustischer Energie, die dem mittelfrequenten Inhalt des linken Kanals entspricht, so dass mehr akustische Energie, die dem linken Kanalsignal entspricht, nach links mit Bezug auf einen Hörbereich als in andere Richtungen abgestrahlt wird;

gerichtetes Abstrahlen, aus einem zweiten gerichteten Bereich (38), umfassend eine Signalverarbeitungsschaltung und mehr als einen akustischen Treiber, von akustischer Energie, die dem mittelfrequenten Inhalt des rechten Kanals entspricht, so dass mehr akustische Energie, die dem rechten Kanalsignal entspricht, nach rechts mit Bezug auf den Hörbereich als in andere Richtungen abgestrahlt wird;

gerichtetes Abstrahlen, aus einem dritten gerichteten Bereich (44), umfassend eine Signalverarbeitungsschaltung und mehr als einen akustischen Treiber, von akustischer Energie, die dem mittelfrequenten Inhalt des zentralen Kanals entspricht, so dass mehr akustische Energie, die dem zentralen Kanalsignal entspricht, in eine Richtung abgestrahlt wird, die im Wesentlichen orthogonal zur Richtung der größeren Abstrahlung des ersten gerichteten Bereichs und der Richtung der größeren Abstrahlung des zweiten gerichteten Bereichs ist;

gerichtetes Abstrahlen, aus einer ersten passiven gerichteten Vorrichtung (34), von akustischer Energie, die dem hochfrequenten Inhalt des linken Kanals entspricht, so dass mehr akustische Energie nach links mit Bezug auf den Hörbereich als in andere Richtungen abgestrahlt wird; und

gerichtetes Abstrahlen, aus einer zweiten passiven gerichteten Vorrichtung (42), von akustischer Energie, die dem hochfrequenten Inhalt des rechten Kanals entspricht, so dass mehr akustische Energie nach rechts mit Bezug auf den Hörbereich als in andere Richtungen abgestrahlt wird,

wobei eine passive gerichtete Vorrichtung eine Vorrichtung ist, die keine Signalverarbeitung verwendet, sondern nur mechanische oder physische Anordnungen oder Vorrichtungen verwendet, um die Abstrahlung von Wellenlängen zu verursachen, die groß mit Bezug auf den Durchmesser von Strahlungselementen sind, um in einigen Richtungen größer als in anderen zu sein.

Revendications

1. Système audio (10) comprenant :

un filtre d'aiguillage pour séparer un canal gauche, un canal droit et un canal central en contenu basse fréquence, en contenu moyenne fréquence et en contenu haute fréquence ;
 un dispositif acoustique omnidirectionnel (26) pour rayonner une énergie acoustique correspondant au contenu basse fréquence d'une combinaison du canal gauche, du canal droit et du canal central ;
 un réseau directionnel (30, 38), comprenant un ensemble de circuits de traitement de signaux et plusieurs pilotes acoustiques, pour rayonner l'énergie acoustique correspondant au contenu moyenne fréquence de l'un du signal de canal gauche et du signal de canal droit de telle sorte que davantage d'énergie acoustique correspondant au contenu moyenne fréquence de l'un du signal de canal gauche et du signal de canal droit soit rayonnée de manière latérale par rapport à une zone d'écoute que dans d'autres directions ; et
 un premier dispositif directionnel passif (34, 42) pour rayonner l'énergie acoustique correspondant au contenu haute fréquence de l'un du signal de canal gauche et du signal de canal droit de telle sorte que davantage d'énergie acoustique correspondant au contenu haute fréquence de l'un du signal de canal gauche et du signal de canal droit soit rayonnée de manière latérale par rapport à la zone d'écoute que dans d'autres directions, un dispositif directionnel passif étant un dispositif qui n'utilise pas de traitement de signaux, mais utilise uniquement des équipements ou dispositifs mécaniques ou physiques pour amener le rayonnement de longueurs d'ondes qui sont grandes par rapport au diamètre des éléments rayonnants à être supérieur dans certaines directions que dans d'autres.

2. Système audio (10) selon la revendication 1, comprenant en outre :

un deuxième réseau directionnel (30, 38) pour rayonner de l'énergie acoustique, comprenant un ensemble de circuits de traitement de signaux et plusieurs pilotes acoustiques pour rayonner une énergie acoustique correspondant au contenu moyenne fréquence de l'autre du canal gauche et du canal droit de telle sorte que davantage d'énergie acoustique correspondant au contenu haute fréquence de l'autre du signal de canal gauche et du signal de canal droit soit rayonnée de manière latérale par rapport à la zone d'écoute que dans d'autres

directions , et

un second dispositif directionnel passif (34, 42) pour rayonner l'énergie acoustique correspondant au contenu haute fréquence de l'autre du canal gauche et du canal droit de telle sorte que davantage d'énergie acoustique correspondant au contenu haute fréquence de l'autre du signal de canal gauche et du signal de canal droit soit rayonnée de manière latérale par rapport à la zone d'écoute que dans d'autres directions.

3. Système audio (10) selon la revendication 2, dans lequel le premier réseau directionnel (30, 38), le deuxième réseau directionnel (30, 38), le premier dispositif directionnel passif (34, 42) et le second dispositif directionnel passif (34, 42) sont montés dans une enceinte commune.

4. Système audio (10) selon la revendication 2, dans lequel le premier réseau directionnel (30, 38) et le deuxième réseau directionnel (30, 38), comprennent au moins un pilote acoustique commun.

5. Système audio (10) selon la revendication 1, comprenant en outre un troisième réseau directionnel (44) pour rayonner de l'énergie acoustique, comprenant un ensemble de circuits de traitement de signaux et plusieurs pilotes acoustiques pour rayonner de l'énergie acoustique correspondant au contenu moyenne fréquence du canal central de telle sorte que davantage d'énergie acoustique correspondant au signal de canal central soit rayonnée dans une direction sensiblement orthogonale à la direction de rayonnement supérieur du premier réseau directionnel et à la direction de rayonnement supérieur du deuxième réseau directionnel.

6. Système audio (10) selon la revendication 5, comprenant en outre un dispositif acoustique haute fréquence non directionnel (45) pour rayonner le contenu haute fréquence du canal central.

7. Système audio (10) selon la revendication 5, dans lequel au moins deux du premier réseau directionnel (30, 38), du deuxième réseau directionnel (30, 38) et du troisième réseau directionnel (44) comprennent au moins un pilote acoustique en commun.

8. Système audio (10) selon la revendication 1, dans lequel le dispositif omnidirectionnel (26) comprend un guide d'ondes (412).

9. Système audio (10) selon la revendication 8, dans lequel le guide d'ondes (412) est monté dans un meuble pour téléviseur (46).

10. Système audio (10) selon la revendication 8, dans lequel au moins deux du premier réseau directionnel

(30, 38), du deuxième réseau directionnel (30, 38) et du troisième réseau directionnel (44) comprennent plus d'un pilote acoustique en commun.

11. Système audio (10) selon la revendication 10, dans lequel le premier réseau directionnel (30, 38), le deuxième réseau directionnel (30, 38) et le troisième réseau directionnel (44) comprennent plus d'un pilote acoustique en commun. 5
12. Système audio (10) selon la revendication 1, monté dans un meuble pour téléviseur (46). 10
13. Système audio (10) selon la revendication 12, dans lequel le dispositif acoustique omnidirectionnel (26), le premier réseau directionnel (30, 38), le deuxième réseau directionnel (30, 38), le troisième réseau directionnel (44), le premier dispositif directionnel passif (34, 42) et le second dispositif directionnel passif (34, 42) ont chacun une sortie à travers laquelle de l'énergie acoustique est rayonnée vers l'environnement, dans lequel aucune des sorties ne se trouve sur une face frontale du meuble pour téléviseur (46). 15 20
14. Système audio (10) selon la revendication 1, dans lequel le premier dispositif directionnel passif (34, 42) comprend : 25
 - un dispositif acoustique directionnel passif de type tube à fentes comprenant un pilote acoustique (314) couplé acoustiquement à un tube (316) pour rayonner de l'énergie acoustique dans le tube, 30
 - le tube comprenant
 - une ouverture allongée (318) le long d'au moins une partie de la longueur du tube ; et 35
 - un matériau acoustiquement résistif (320) dans l'ouverture à travers laquelle des ondes de pression sont rayonnées vers l'environnement, les ondes de pression étant **caractérisées par** une vitesse volumique, le tube, l'ouverture et le matériau acoustiquement résistif étant configurés de telle sorte que la vitesse volumique soit sensiblement constante le long de la longueur du tube. 40 45
15. Procédé de fonctionnement d'un système audio (10), le procédé comprenant : 50
 - le rayonnement omnidirectionnel d'énergie acoustique correspondant au contenu basse fréquence d'une combinaison d'un canal gauche, d'un canal droit et d'un canal central ;
 - le rayonnement directionnel, depuis un premier réseau directionnel (30) comprenant un ensemble de circuits de traitement de signaux et plusieurs pilotes acoustiques, d'énergie acoustique correspondant au contenu moyenne fré-

quence du canal gauche de telle sorte que davantage d'énergie acoustique correspondant au signal de canal gauche soit rayonnée vers la gauche par rapport à une zone d'écoute que dans d'autres directions ;

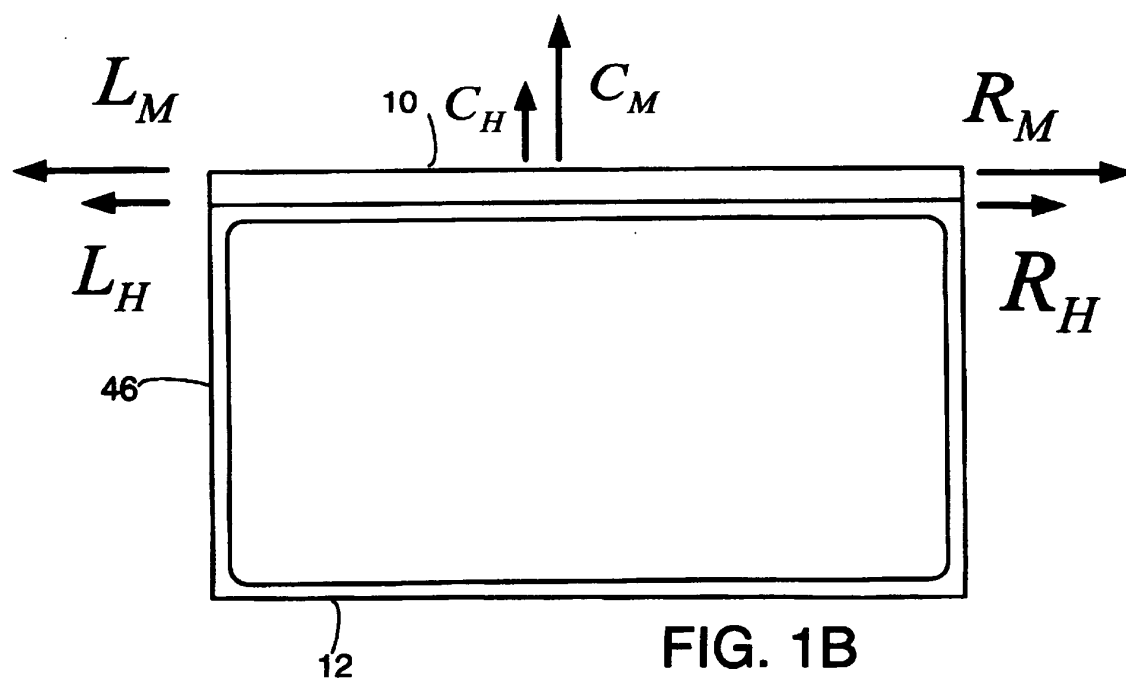
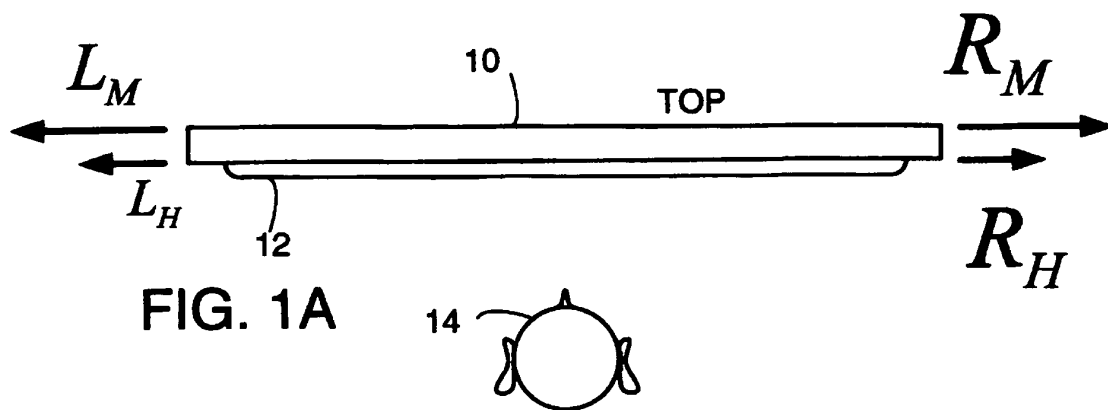
le rayonnement directionnel, depuis un deuxième réseau directionnel (38) comprenant un ensemble de circuits de traitement de signaux et plusieurs pilotes acoustiques, d'énergie acoustique correspondant au contenu moyenne fréquence du canal droit de telle sorte que davantage d'énergie acoustique correspondant au signal de canal droit soit rayonnée vers la droite par rapport à la zone d'écoute que dans d'autres directions ;

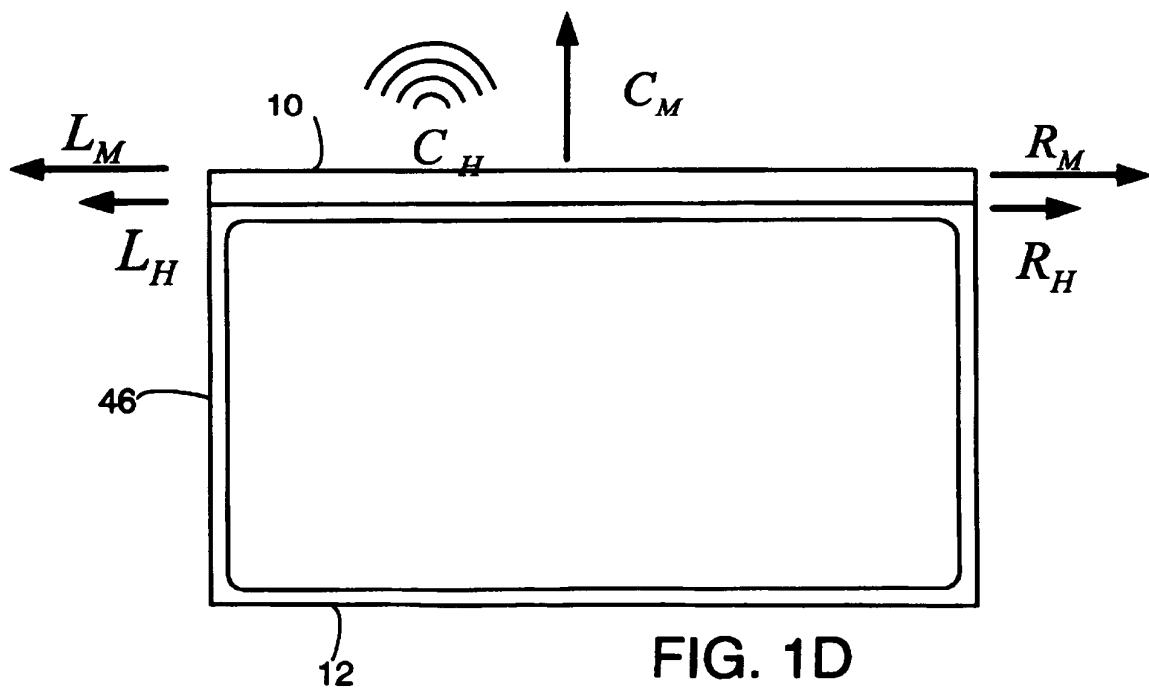
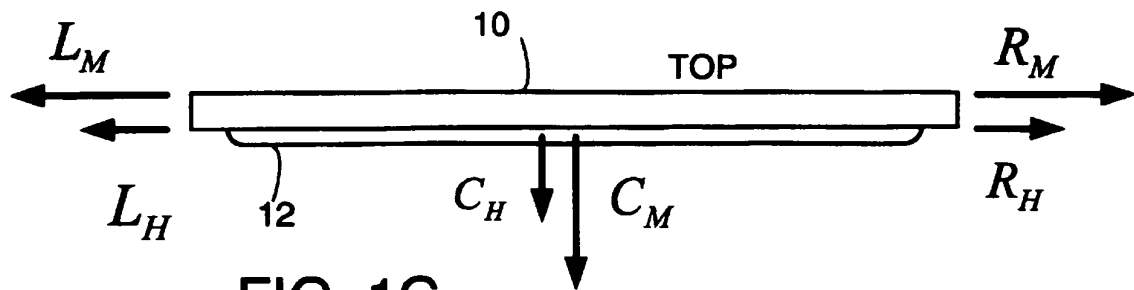
le rayonnement directionnel, depuis un troisième réseau directionnel (44) comprenant un ensemble de circuits de traitement de signaux et plusieurs pilotes acoustiques, d'énergie acoustique correspondant au contenu moyenne fréquence du canal central de telle sorte que davantage d'énergie acoustique correspondant au signal de canal central soit rayonnée dans une direction sensiblement orthogonale à la direction de rayonnement supérieur du premier réseau directionnel et à la direction de rayonnement supérieur du deuxième réseau directionnel ;

le rayonnement directionnel, depuis un premier dispositif directionnel passif (34), d'énergie acoustique correspondant au contenu haute fréquence du canal gauche de telle sorte que davantage d'énergie acoustique soit rayonnée vers la gauche par rapport à la zone d'écoute que dans d'autres directions ; et

Le rayonnement directionnel, depuis un second dispositif directionnel passif (42), d'énergie acoustique correspondant au contenu haute fréquence du canal droit de telle sorte que davantage d'énergie acoustique soit rayonnée vers la droite par rapport à la zone d'écoute que dans d'autres directions,

dans lequel un dispositif directionnel passif est un dispositif qui n'utilise pas de traitement de signaux, mais utilise uniquement des équipements ou dispositifs mécaniques ou physiques pour amener le rayonnement de longueurs d'ondes qui sont grandes par rapport au diamètre des éléments rayonnants à être supérieur dans certaines directions que dans d'autres.





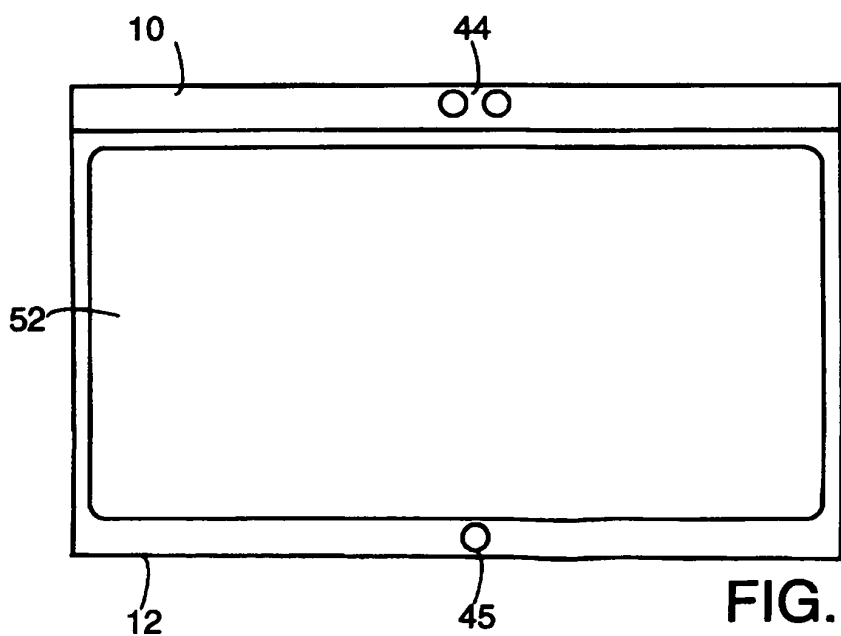
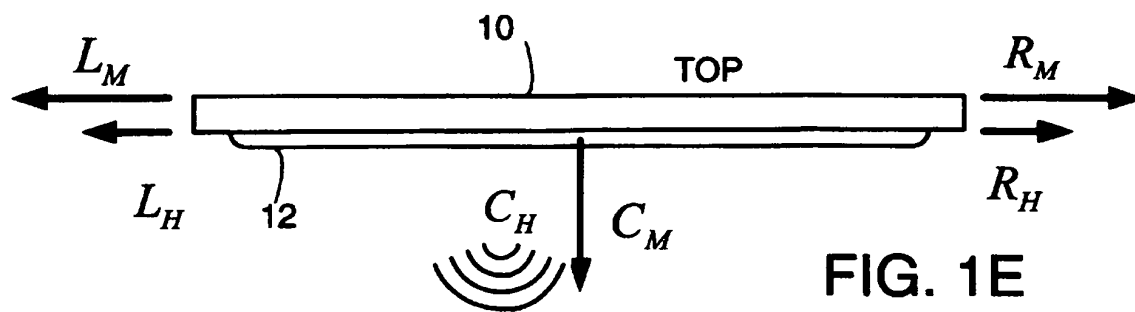
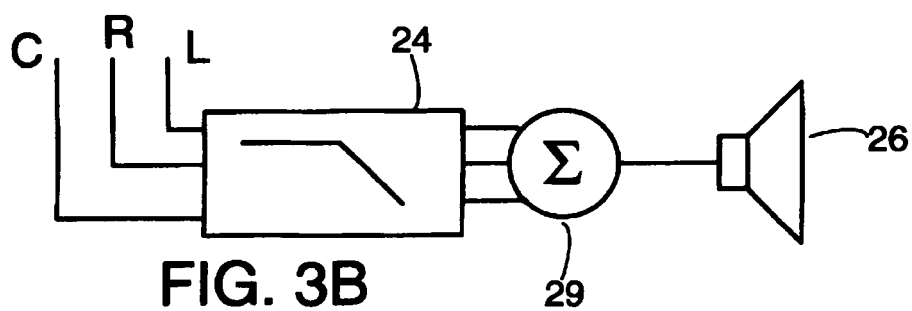
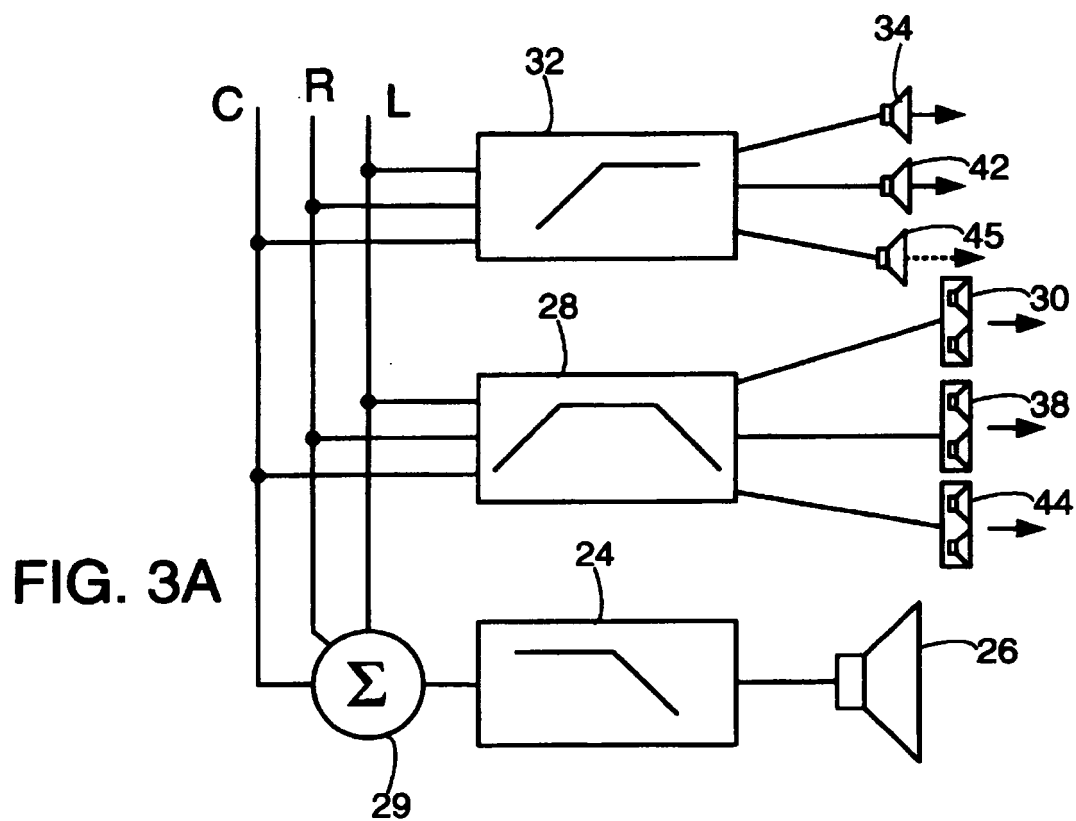
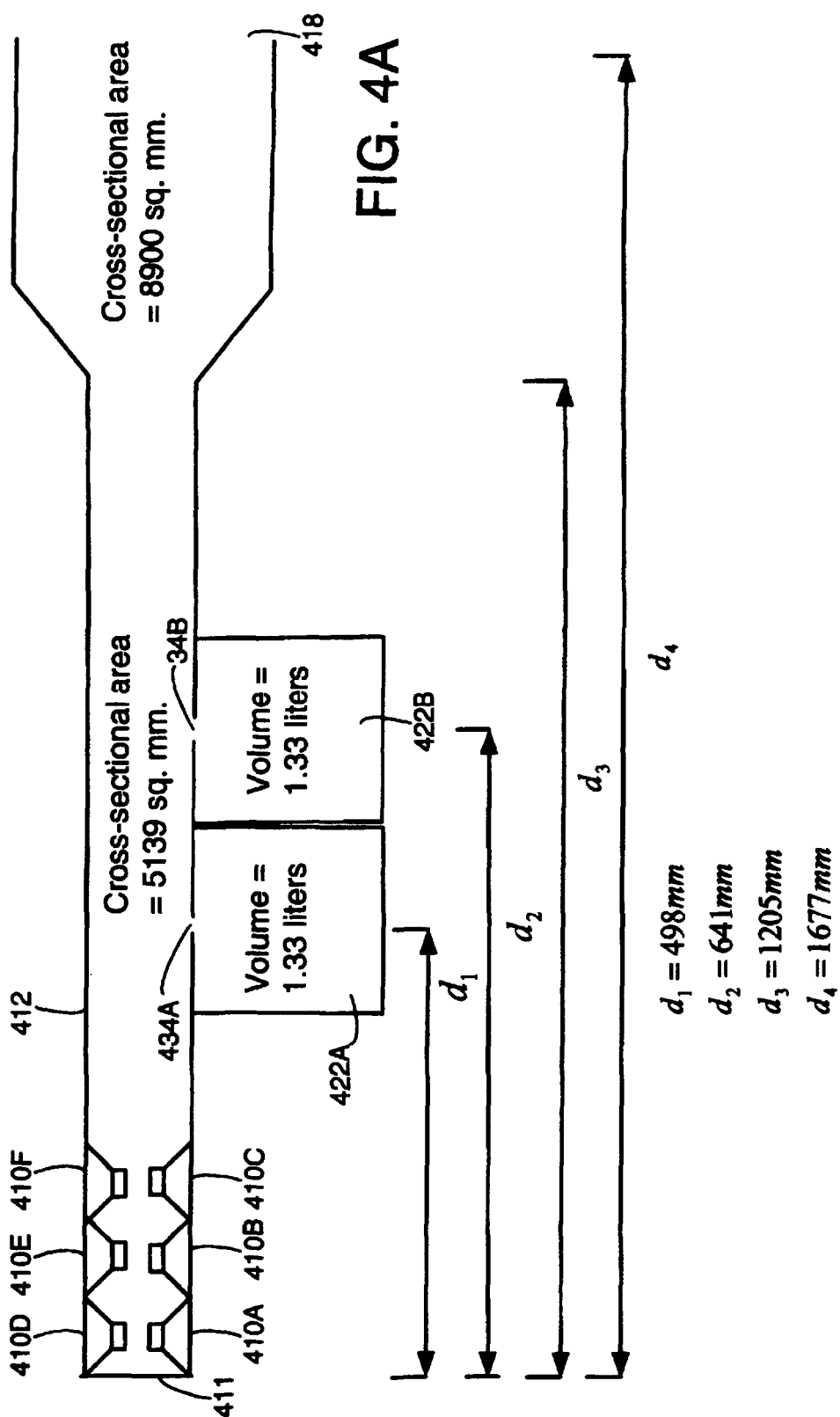


FIG. 2





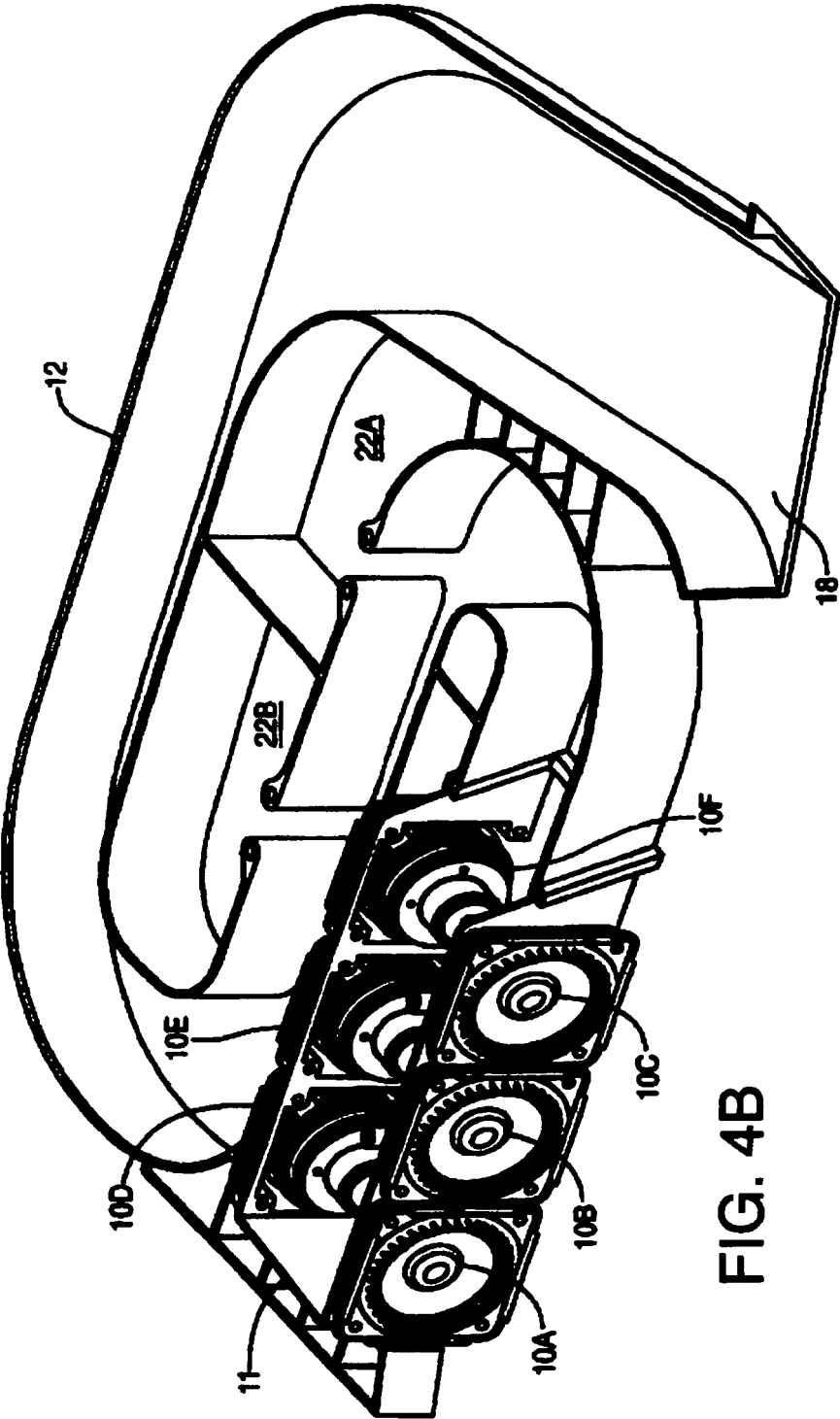


FIG. 4B

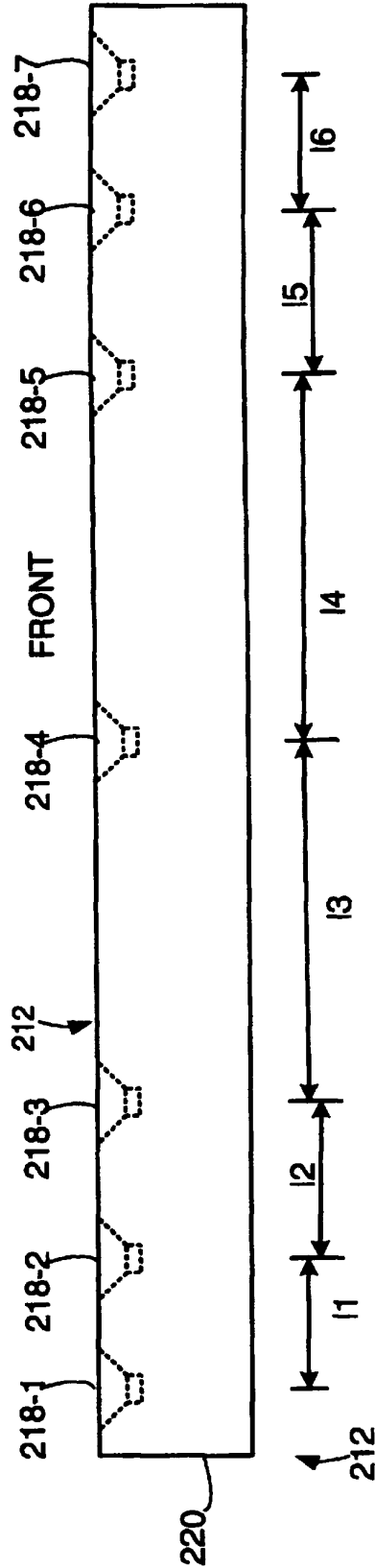
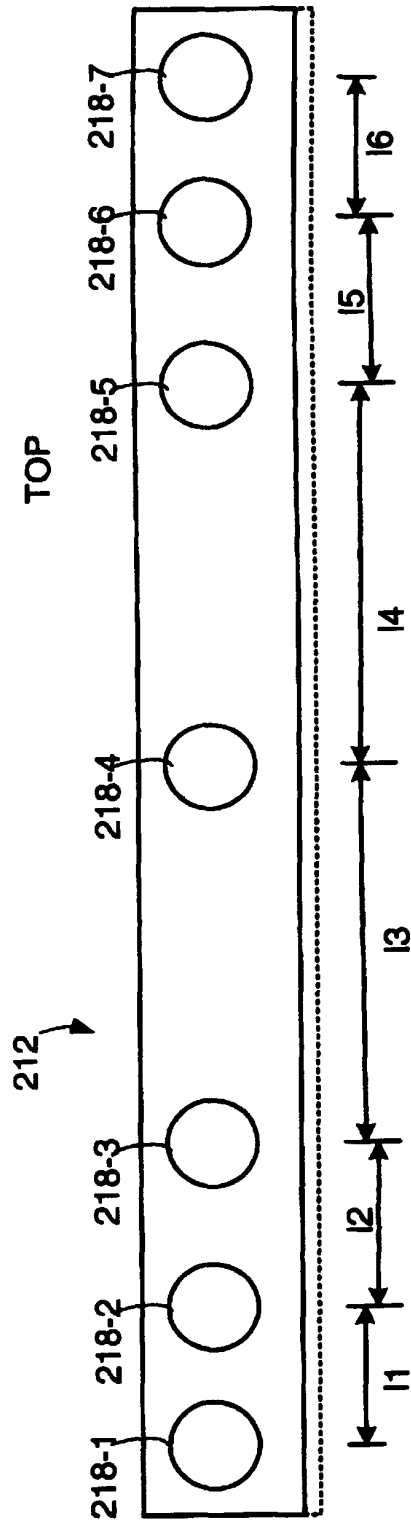
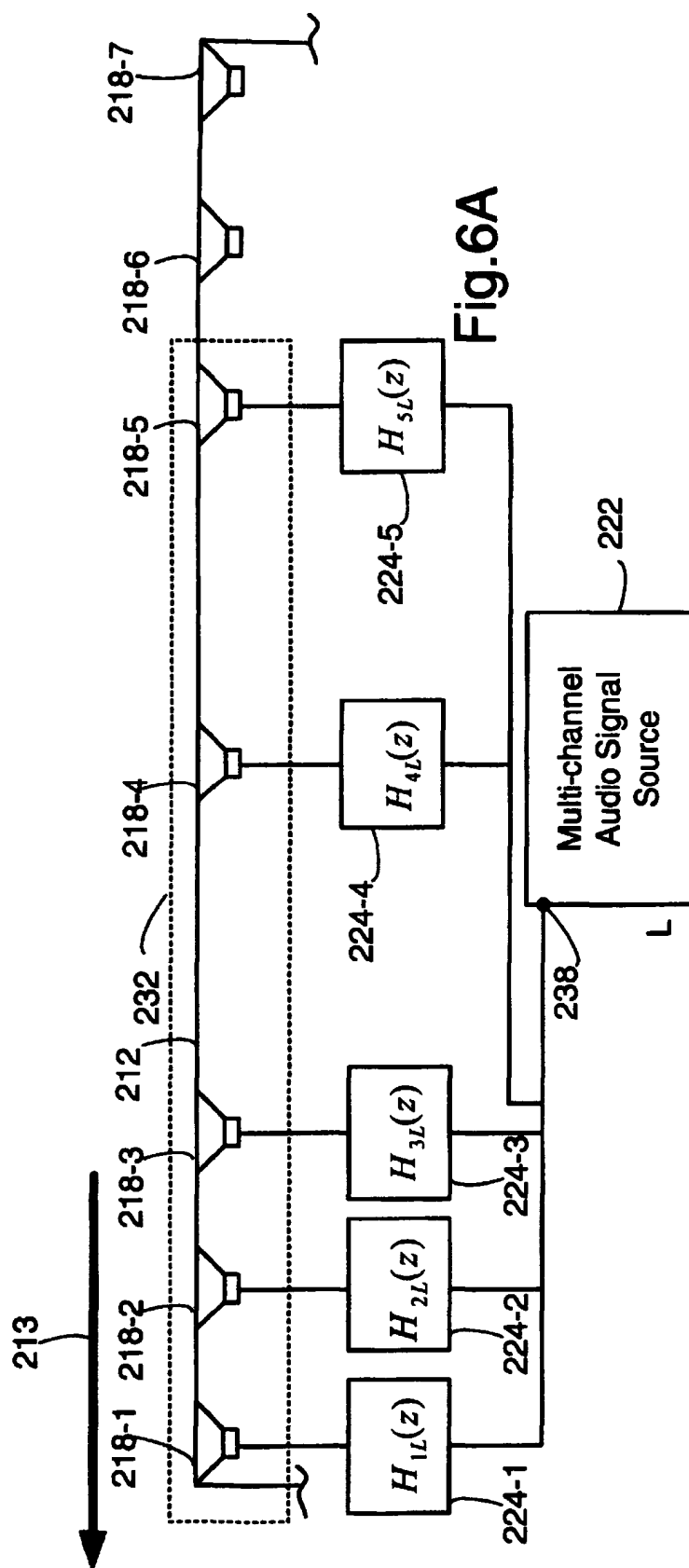


Fig. 5





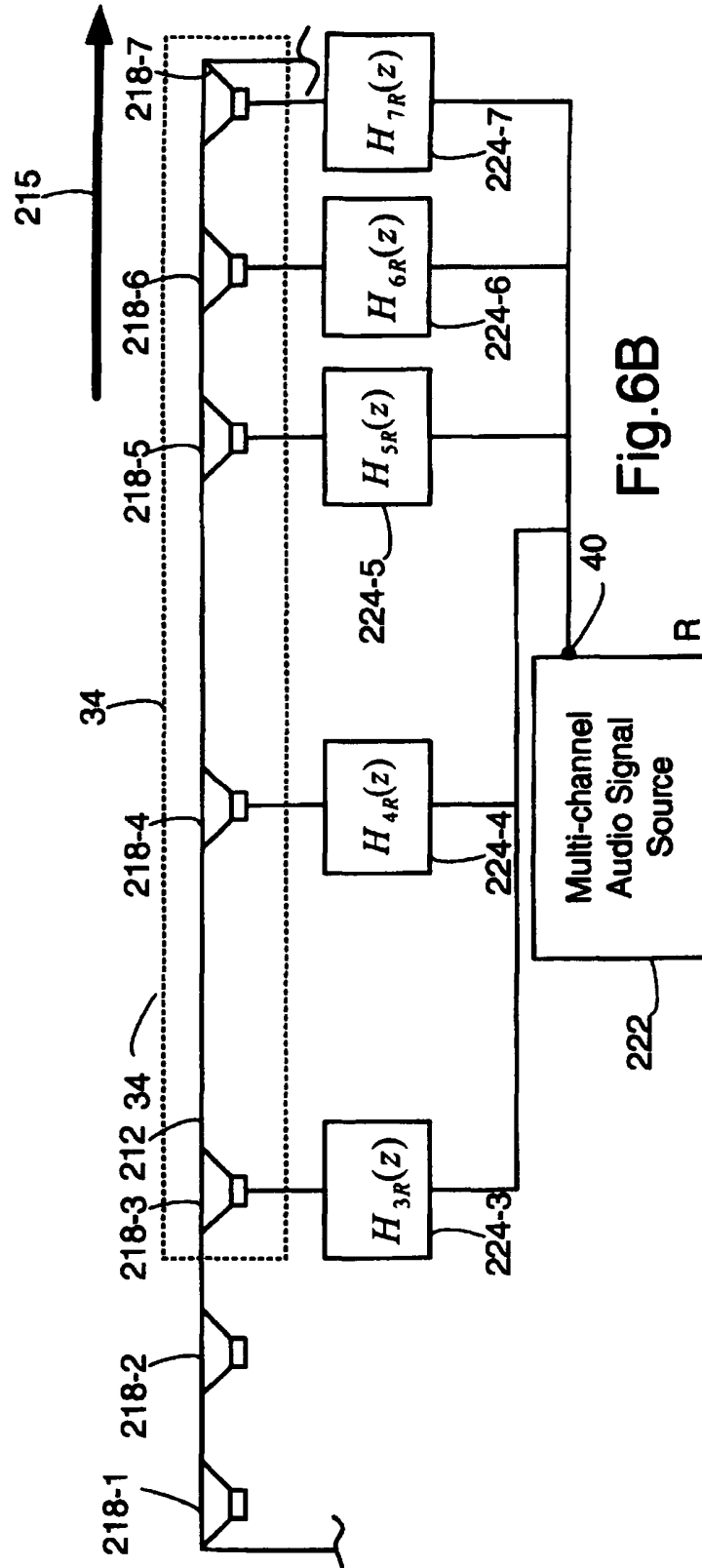
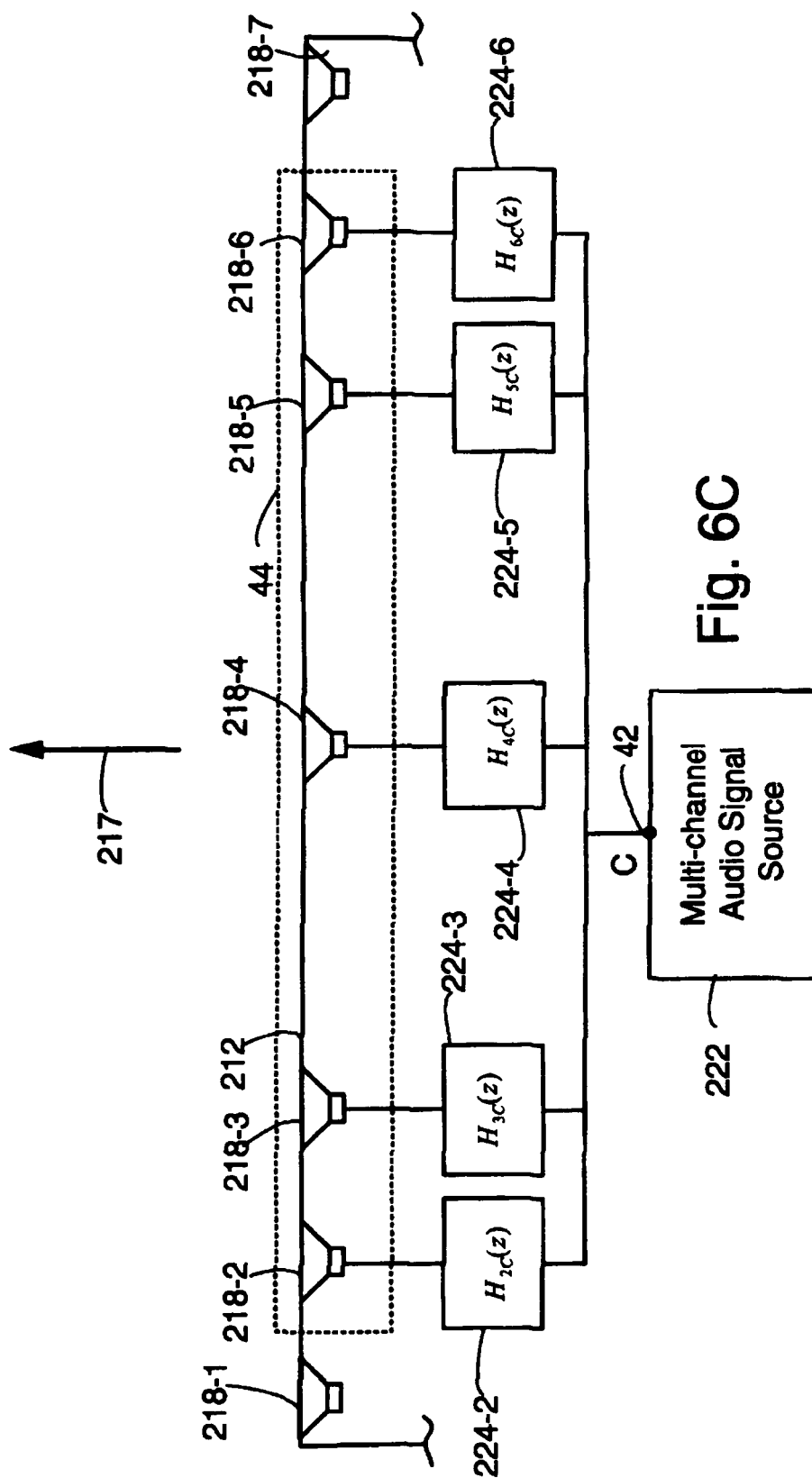


Fig. 6B



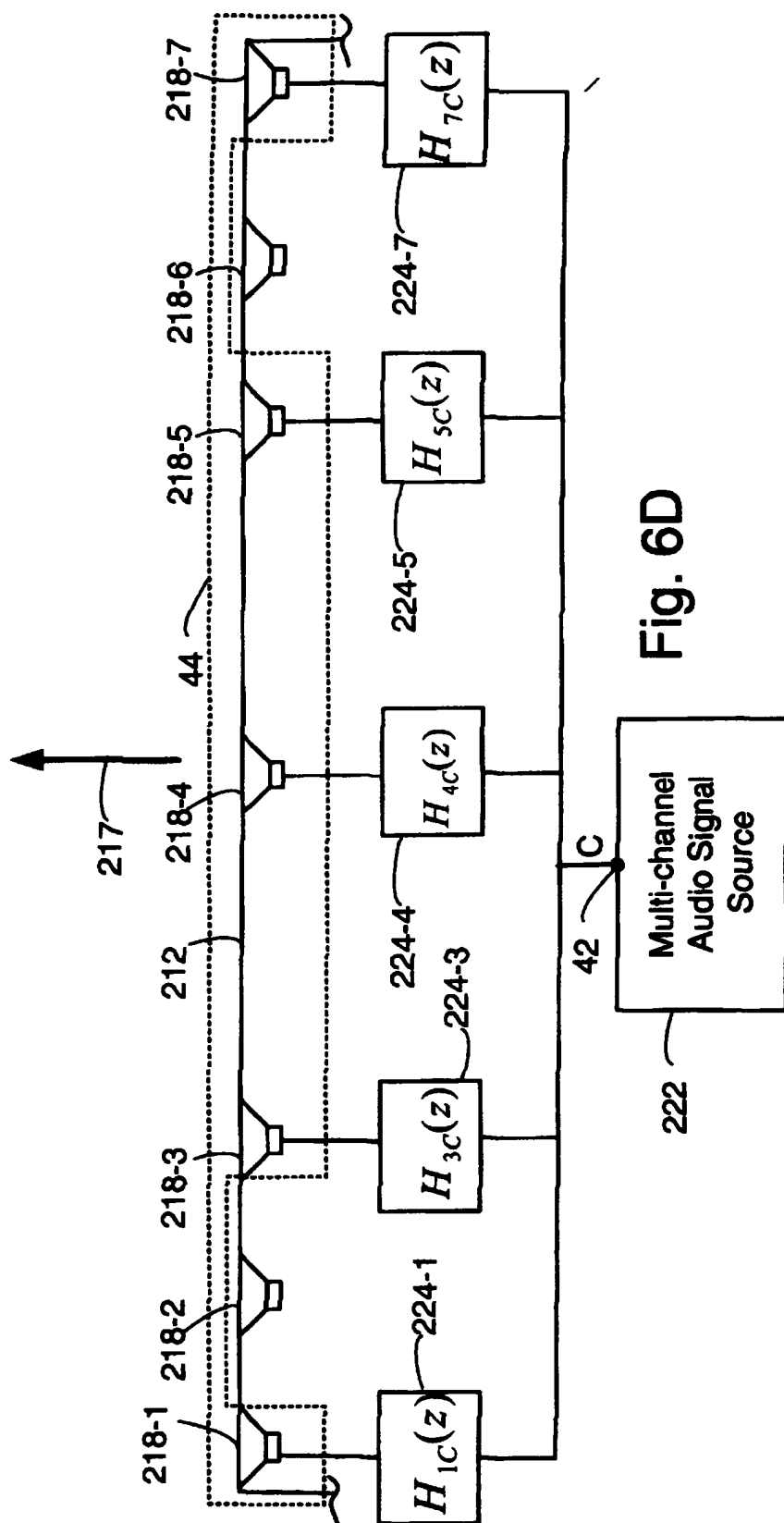
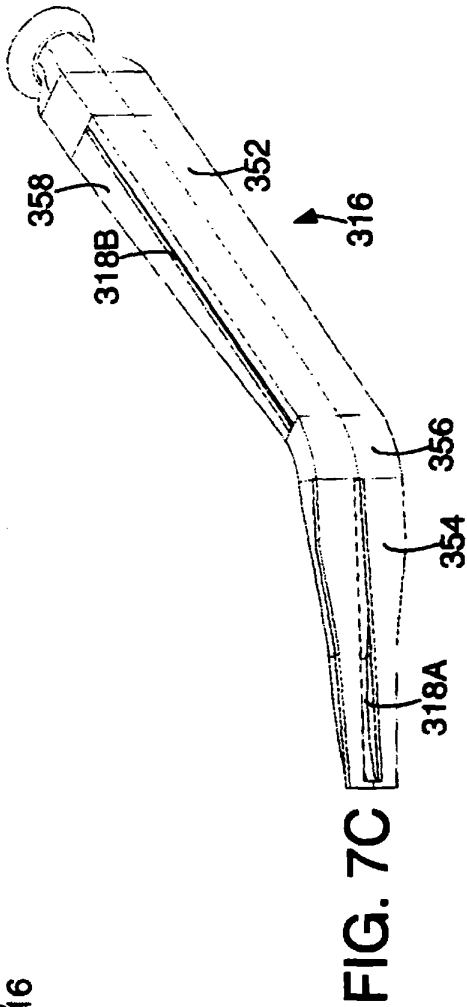
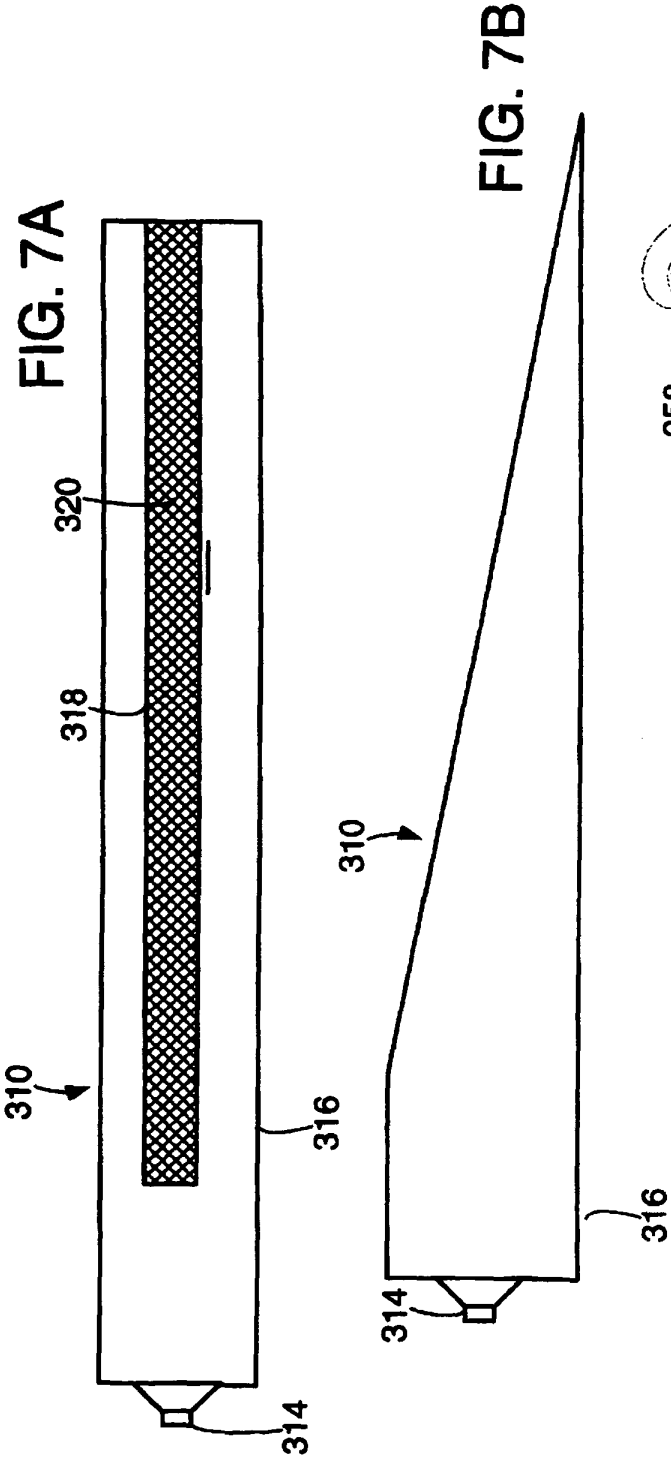
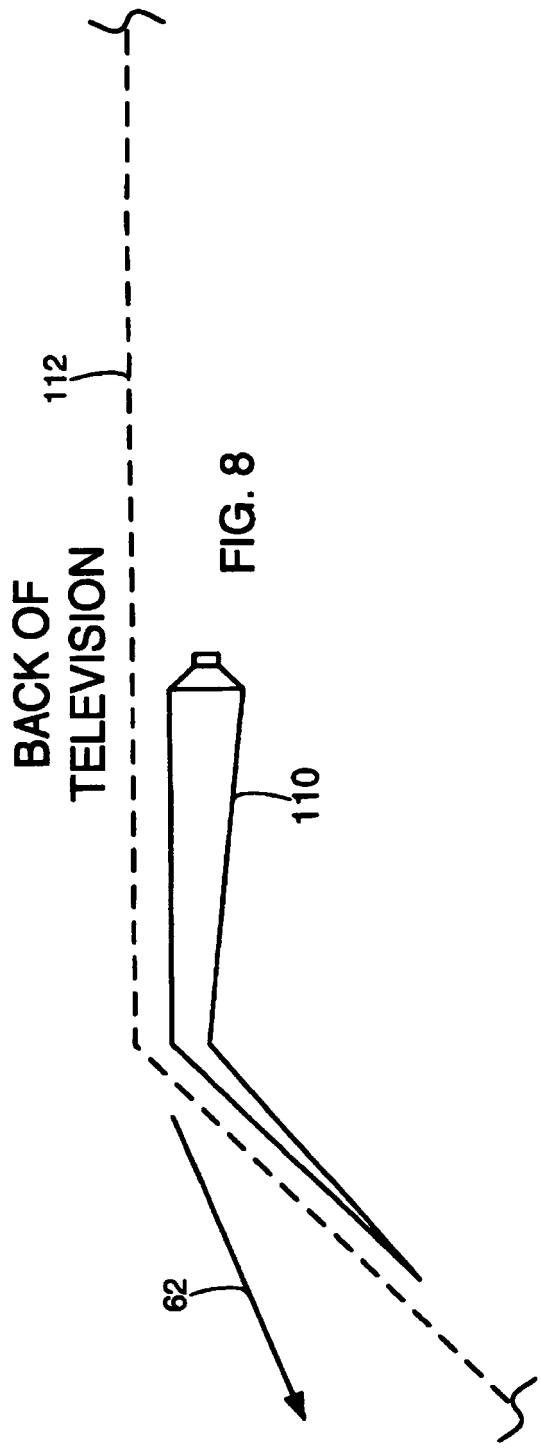


Fig. 6D





REFERENCES CITED IN THE DESCRIPTION

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