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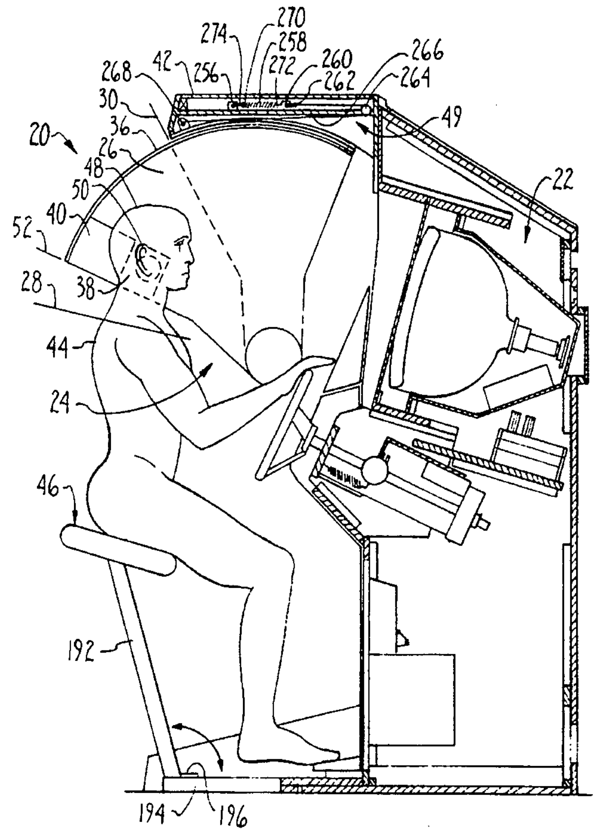
(54) Title: NON-CONTACT AUDIO DELIVERY SYSTEM FOR A THREE-DIMENSIONAL SOUND PRESENTATION

(57) Abstract

A non-contact audio delivery system (20) which delivers a three-dimensional sound presentation to a listener. The non-contact audio delivery system comprises a support structure such as a hood (26) with speakers (38) mounted in the support structure. In the embodiment using the hood (20), the hood (26) surrounds a portion of the head of the listener (44) to block out external audio and visual distractions from the listener (44). The support structure is also designed to focus the listener's attention in a preferred forward looking position which ensures the placement of the audio delivery speakers (38) proximate the ears (50) of the listener (44). The delivery system (20) also includes an ambient noise measurement system which automatically adjusts the volume level of the presentation depending on a measured level of external ambient noise. Additional improvements to a typical three-dimensional sound presentation include the scaling of the three-dimensional sound effects based on the determination of an approximate head size of the listener (44). Finally, a method of reducing the required amount of data that is stored in order to implement a three-dimensional sound presentation is disclosed.



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NON-CONTACT AUDIO DELIVERY SYSTEM FOR A THREE-DIMENSIONAL SOUND PRESENTATION

Background of the Invention

The present invention relates generally to sound systems and, more particularly, to an improved audio delivery environment to produce a three-dimensional sound presentation.

There is an increasing interest in several industries in developing more realistic audio systems to correspond with the improved quality of highly realistic video systems. One area of realistic audio systems that has been explored is the area of "three-dimensional sound". Three-dimensional sound is a term used to describe the ability to incorporate a location or position element with a sound element to produce a more realistic sound. In a three-dimensional sound environment, the listener will actually be able to hear the "location" of the sound source within an audio environment.

The basic concepts behind the production of a three-dimensional sound system are disclosed in an article entitled "Localization in Virtual Acoustic Displays" by Elizabeth Wenzel published in PRESENCE: Teleoperators and Virtual Environments, Vol. 1, No. 1, March 1992, which is hereby incorporated by reference. The article discloses the concept that when a sound source emits a sound each of a listener's ears will hear the sound at a different time depending on the position of the source of the sound. The time difference in the receipt of the sound at each ear is caused by the difference in the distance of the source of the sound from each of the listener's ears. Thus, the ear which is the farthest distance away from the sound will hear the sound last. The time difference between the receipt of the sound by the two ears may not be a large difference, but it is a difference which is detectable by the human brain. In addition to a time difference, the receipt of a sound at each ear also has a frequency difference depending on the location of the sound source. The shape of a person's head and the outer potion of the listener's ear, or pinnae, acts as a filter which modifies the frequencies recorded at the ears. Therefore, the ear which is closer to the sound will hear a higher set of frequencies, while the ear which is the farthest distance away from the sound will receive a more dominant lower range of frequencies, as the higher frequencies have been attenuated. Therefore, in order to accurately reproduce a three-dimensional sound both the time difference, the amplitude difference and frequency difference for each ear must be taken into consideration.

The simulation of the three-dimensional sound effects created by a sound source located at a specific position requires that both time and frequency modifications be made to the sound delivered to each ear of the listener. These time and frequency modifications are made to the sound delivered to each ear to simulate the three-dimensional sound effect. A head-related transfer function (HRTF) defines how the sound is to be modified to simulate the three-dimensional sound effect. By delivering a sound to each of the listener's ears which has been separately modified according to the HRTF, the listener is deceived into thinking that the source of the sound is at the simulated location.

Currently, the time and frequency modifications which are made to a sound to simulate the three-dimensional effect are only known for specific sound source locations which have been previously measured for a specific head size and shape. If the location of the sound source occurs between any of the measured locations, the simulated three-dimensional sound effect is determined by linear interpolation between the locations at which the three-dimensional effect has been measured. Most commonly, a four way interpolation is performed on the information measured at four known surrounding locations to determine the three-dimensional effect on the simulated sound source.

A conventional three-dimensional sound system is implemented by playing the modified sound back to the listener via headphones. The headphones enable the modified sounds to be delivered directly to the corresponding ear of the listener without encountering any external distortion. The external distortion may come from other external sound sources, cross-talk between speakers, sound reflections within the audio environment, etc. The use of headphones to simulate the three-dimensional sound effect helps eliminate some of these external interferences. Further, the use of headphones provides the modified sound directly to the ears of the listener without causing a real three-dimensional sound effect to interfere with the simulated effect.

The ability to provide a three-dimensional sound presentation in many applications is severely limited by the necessity of providing headphones to achieve this type of sound. For example, if the headphones are shared by a number of listeners, the chance of contamination of the headphones by listeners and transmission of contagious diseases to others is greatly increased. Also in multi-listener environments, such as simulators or arcade games, the chance of damage to the headphones or theft of these rather expensive components is greatly increased. Accordingly, it is apparent that the sharing of headphones is an undesirable requirement for three-dimensional sound delivery.

Therefore, there exists a need for an improved sound environment which will deliver a realistic three-dimensional sound effect to the listener, but does not require the listener to come into physical contact with the sound delivery device.

Summary of the Invention

A sound system for broadcasting a three-dimensional sound presentation to a listener comprises a housing, a hood secured to the housing such that at least a portion of the hood is moveable and a pair of speakers mounted on the moveable portion of the hood such that movement of the hood with respect to the listener positions the pair of speakers in proximity to the ears of the listener, thereby delivering a three-dimensional sound presentation directly to the ears of the listener. In one embodiment, substantially all of an internal surface of the hood is covered with at least one layer of sound absorptive material. The hood preferably reflects a portion of external ambient sound such that the external ambient sound is prevented from entering the internal audio environment. In addition, the hood directs the head of the listener in a preferred forward looking direction. In one embodiment, the three-dimensional sound system further comprises an external microphone to measure the level of ambient noise external to said sound system.

One embodiment of the sound system for broadcasting a three-dimensional sound presentation to a listener further comprises a sound source for providing sound signals representative of selected sounds, a transfer function and a controller, responsive to the sound signals and the transfer function and connected to the pair of speakers for delivering a three-dimensional sound presentation through the speakers to the ears of the listener. The transfer function preferably defines the amount of modifications that are to be made to the sound signals to provide sound through the speakers which define to the user a selected location of the sound source. In another embodiment, the sound system for broadcasting a three-dimensional sound presentation to a listener further comprises detecting means mounted on said hood to measure a volume of noise external to said hood, and scaling means for scaling the sound signals to provide sound through the speakers to deliver a three-dimensional sound presentation based upon the volume level of the noise external to the hood. One embodiment of the sound system further comprises means for determining an approximate size of the head of the listener. Preferably, the transfer function relates to the size of the head of the listener.

As discussed above, the modified sounds incorporating the three-dimensional sound effect preferably are delivered directly to the desired ear of a listener to eliminate any distortion of the effect. Preferably, in the non-contact audio system, the hood is designed to focus the attention of the listener toward the internal environment created by the hood and away from the external surrounding environment. More preferably, the attention of the listener is focused in a preferred forward direction to align the ears of the listener with the speakers mounted in the hood. Preferably, the moveable hood is counter balanced to enable the hood to remain stationary in any desired position. By counter balancing the hood, the listener is able to position the hood in any position that will place the speakers proximal to the listener's ears to provide the listener with an enhanced audio experience. Further, the hood is preferably designed to prevent the listener from turning his head from the preferred forward position to an alternate position to deliver the correct sound "position" to the listener. If the listener's head is turned from the forward position, the sound "position" will appear to be shifted by the amount that the user has turned his head. In addition, the forward position of the listener's head is preferred to prevent the listener from paying attention to external distractions.

Since the effects of the three-dimensional sound experience depend on such elements as the shape of the listener's head and the distance that the sound must travel, the size and shape of a person's head will affect how a sound should be modified to provide the correct three-dimensional sound effect. A preferred embodiment of a method of delivering a three-dimensional sound presentation to a listener, comprises storing a set of head-related transfer function data related to the position of one of the ears of the listener with respect to at least one sound source position and determining the position of a sound source relative to the location of the one of the ears of the listener. Additionally, the method comprises selecting from the set of head-related transfer function data, the head-related transfer function data most closely associated with the sound source location relative to the one of the ears of the listener. Also, the method comprises determining the position of the sound source relative to the other of the ears of the listener; and determining a position of the sound source relative to the one of the ears of the listener which is equivalent to the position of the sound source relative to the other of the ears of the listener. The method further comprises selecting from the set of head-related transfer function data, the head-related transfer function data most closely associated with the equivalent sound source location relative to the one of the ears of the listener; and delivering a three-dimensional sound presentation to each of the ear's of the listener, wherein the three-dimensional sound presentation is based on the selected head related transfer data.

Brief Description of the Drawings

Figure 1 is a side elevational view of a preferred embodiment of the non-contact audio environment illustrating a moveable hood in both an extended and a retracted position.

Figure 2 is a side elevational view of a preferred embodiment of the non-contact audio environment and further illustrating a moveable hood in an extended position wherein the position of a set of speakers is proximate to the listener's ears.

Figure 3 is a perspective view of an alternate embodiment of the non-contact audio environment illustrating a moveable hood in an extended position.

Figure 4 is a perspective view of the alternate embodiment of the non-contact audio environment of Figure 3 illustrating the moveable hood in a retracted position.

Figure 5 is a perspective view of an alternate embodiment of the non-contact audio environment illustrating a moveable hood in an extended position.

Figure 6 is a perspective view of an alternate embodiment of the non-contact audio environment illustrating an accordion style moveable hood in an extended position.

Figure 7 is a perspective view of an alternate embodiment of the non-contact audio environment illustrating a rotating seat and a stationary hood embodiment with the rotating seat in a closed position.

Figure 8 is a top plan view of the alternate embodiment of the non-contact audio environment as shown in Figure 7, illustrating the rotating seat in a closed position.

Figure 9 is a top plan view of the alternate embodiment of the non-contact audio environment as shown in Figure 7, further illustrating the rotating seat in an open position.

Figure 10 is a perspective view of another alternate embodiment of the non-contact audio environment illustrating a counterbalanced vertically moveable seat with a stationary hood.

Figure 11 is a perspective view of another alternate embodiment of the non-contact audio environment illustrating a horizontally moveable and rotatable seat with a stationary hood.

Figure 12 is a block diagram of a preferred embodiment of the audio circuitry of the audio system in communication with a video system.

Figure 13 is a perspective view of a typical environment in which a three-dimensional sound system would be located.

Figure 14 is a schematic diagram of one presently preferred embodiment of the sound measuring and volume scaling circuit.

Figure 15 is a schematic block diagram of a preferred strain-gage measurement circuit in communication with the audio processor.

Figure 16 is a flow chart illustrating one presently preferred embodiment of a head size determination software initialization program.

Figure 17 is a top view of a sound source positioned relative to a first ear.

Figure 18 is a top view of the sound source of Figure 18 reflected to an equivalent position relative to a second ear.

Detailed Description of the Preferred Embodiments

A preferred embodiment of an improved non-contact sound system for broad casting a three-dimensional audio presentation to a listener is illustrated in Figures 1-2. As shown in Figure 1, an audio or sound system generally indicated at 20 is preferably used in combination with a video system generally indicated at 22. Preferably, the audio system 20 comprises an internal audio environment generally indicated at 24, related audio circuitry (Figure 12) and a three-dimensional sound software program which is attached hereto in the above referenced Microfiche Appendix. The internal audio environment preferably comprises a moveable hood 26 which is moveable from a maximum retracted position 30 to a maximum extended position 28. Preferably, the hood 26 is non-transmissive to external audio and visual interference. In addition, the hood 26 preferably reflects external audio sounds to provide a listener with an internal three-dimensional sound environment 24 substantially free from external distractions.

Preferably, the hood 26 comprises a first side panel 32 and a second side panel (not shown), a top panel 36. The first side panel 32 and the second side panel of the hood 26 are designed to limit distractions to the user caused by other external devices positioned along the sides of the audio system 20. The first side panel 32 and the second side panel of the hood 26 are in communication with a first stationary side panel 34 and a second stationary side panel (not shown), respectively, which cover the video system 22 of the illustrated embodiment. Preferably, a first speaker 38 is mounted on the first side panel 32 and a second speaker (not shown) is mounted in a corresponding position on the second side panel of the hood 26. Each speaker 38 and its associated wiring are preferably enclosed in a speaker containment box 40. The speaker containment box 40, also referred to as a speaker enclosure, is used to provide a non-detracting containment area for the speaker 38 such that a listener in the internal audio environment 24 is not distracted by the placement of the speakers 38. A top panel 36 of the hood 26 is designed to block any external noise which may approach the audio environment 24 from above and eliminate distractions which may occur behind a listener from drawing the attention of the listener away from the internal audio environment 24. Further, a stationary top panel 42 which covers the video system 22 of the illustrated embodiment is in communication with the top panel 36 of the hood 26. One aspect of the preferred hood design cloaks the head of a listener to eliminate any audio or visual distractions from entering the internal audio environment 24. By maintaining the communication between the first side 34, second side (not shown) and top 42 stationary panels with the first side 32, second side (not shown) and top 36 panels of the hood 26 there is no space for the external sound to penetrate the internal audio environment 24.

Further, the preferred embodiment of the moveable hood 26 enables the compact storage of the hood 26 within the video system 22. As illustrated in Figure 1, when the hood 26 is in the maximum retracted position 30, a large portion of the moveable hood 26 is housed within the video system 22. As the hood 26 is pulled down by a listener into the maximum extended position 28, portions of the hood 26 exit the video system 22 to cloak the head of the listener. The internal storage of the moveable hood 26 within the video system 22 enables the moveable hood 26 to be stored in an unobtrusive location when the hood 26 is not in use.

If it is desirous to enable outsiders to view the activities which are occurring inside the internal environment 24, a plastic or glass plate (not shown) can be installed in the top panel 36 of the hood 26 to enable outsiders to view the internal environment 24 within the hood 26. Preferably, the plastic or glass plate is tinted a dark color to reduce any external light or other visual distraction from interfering with the internal environment 24 of the hood 26.

The hood 26 is preferably made from a non-transmissive, reflective material such as plywood or other suitable material known to one of skill in the art. Preferably, plywood at least 1/2 inch thick is used to form all of the panels of the hood 26. More preferably, plywood at least 3/4 inch thick is used to form the panels of the hood 26.

The internal surfaces of the first side panel 32, the second side panel and top panel 36 of the hood 26, as well as the first stationary side panel 34, the second stationary side panel and the stationary top panel 42 are preferably covered with at least one layer of sound absorptive material. The sound absorptive material helps block a large percentage of external noises from entering the internal environment 24. In addition, the absorptive material helps absorb the internal sound reflections from the speakers 38, thus minimizing their interference with the three-dimensional effect. Preferably, the sound absorbing material is designed to eliminate a broad band of frequencies from interfering with the delivery of the three-dimensional sound presentation. In one preferred embodiment, at least 75% of the internal surface of the audio environment 24 is covered by at least one layer of sound absorptive material.

With at least 75% of the internal surfaces of the audio environment 24 covered, about 80% of the undesired sound may be absorbed.

In the presently preferred embodiment, the layers of sound absorptive material comprise an external perforated portion and an interior foam portion. The perforated portion is provided to protect the interior foam portion from abuse and damage. The perforations on the external portion cause the external material to be completely sound-transparent. The foam is preferably at least 1/2 inch thick to provide a minimum level of sound absorption. Preferably, the foam is at most 6 inches thick to achieve a 99% absorption of the sound incident on the material. If the thickness of the foam layer that is used were based solely on sound absorption, the 6 inch material would be most preferred. However, six inches of foam on all of the internal surfaces of the hood 26 and video system 22 would take up an excessive amount of space. Accordingly, in the preferred embodiment, the foam is between 1/2 inch and 2 inches thick to achieve a reasonable level of sound absorption without using extensive space. The perforated external portion can be made from a number of materials such as vinyl, metal, fabric, etc. The type of perforated material is chosen based on the harshness of the environment in which the material will be used. Preferably, metal is used as it can stand up well in any type of environment in which such a system would typically be expected to be used. In addition, metal can be easily cleaned without damaging the sound absorptive properties of the interior foam material. Further, metal has an inherent structural strength compared to other fabrics or coatings. Metal can be formed into complex curved shapes and the metal sheet can support itself, i.e., stand alone, in these shapes, if necessary. Lastly, metal is the most resistive to abuse and damage. However, for cosmetic or economic reasons, other materials such as vinyl or fabric may be preferred.

Broad band sound absorbing materials such as those described above are available from the SOUNDCOAT® Company in Santa Anna, California. One such type of material that is available from the SOUNDCOAT® Company is called Soundfoam. SOUNDCOAT® also provides Soundfoam with an external layer of perforated vinyl or fabric facings. The perforated vinyl layer is preferred over the fabric facing layer as the perforations on the vinyl surface enable the vinyl layer to be completely sound transparent while the fabric facing may reflect a portion of the sound. The vinyl acts as a protective layer as well as providing a cosmetically appealing surface. If the environment is harsh enough that a perforated metal layer is preferred as the exterior layer, an acoustic foam such as Soundfoam is used as the interior sound absorptive layer without the external vinyl or fabric layer.

Figure 2 further illustrates the preferred audio system 20 in communication with a listener 44. In the preferred embodiment, the listener 44 is seated on a seat 46 to assist in placing the listener in a stationary position within the internal audio environment 24. The hood 26 is designed to focus the head 48 of the listener 44 in a preferred forward looking position, as illustrated in Figure 2. The preferred forward looking position of the listener's head illustrates the alignment of the speakers 38 with the ears 50 of the listener 44 to provide the listener with an accurate three-dimensional presentation. If the head of the listener is turned from the preferred forward looking position, the sound "location" that is heard by the listener in the three-dimensional presentation will appear to be shifted by the amount that the listener's head is turned. This shift in the sound "location" would be undesirable. Therefore, the hood 26 is preferably designed to align the ears of the listener with the speakers 38 by positioning the listener's head in the preferred centered forward position illustrated in Figure 2.

The moveable hood 26 is preferably counter balanced using a cable system 49 to enable the hood 26 to remain stationary at any position along its moveable path. The line 28 near the shoulder of the listener 44 illustrates the maximum extended position 28 of the hood 26. In use, the hood 26 is pulled down from its maximum retracted position 30 to a preferred extended position 52 wherein the speakers 38 are proximate to the ears 50 of the listener 44. When the listener 44 has concluded his use of the audio system 20, the listener 44 moves the hood 26 back into the retracted position 30, thereby permitting him to exit the audio sound environment 24. The cable system 49 used to counter balance the hood 26 will be described in more detail hereinafter. In another embodiment, gas shocks are be used to replace the cable system 49. In the gas shock embodiment, one end of the shock is attached to the bottom portion of each of the first side panel 32 and second side panel of the hood 26 near the pivot location and the other end of the gas shock is attached to the first stationary side panel 34 and second stationary side panel, respectively, of the video system 22.

Figure 3 illustrates an alternate embodiment 54 of the moveable hood design with the moveable hood 56 shown in an extended position. Figure 4 illustrates the alternate embodiment of the moveable hood design illustrated in Figure 3 with the moveable hood 56 in a retracted position. The alternate moveable hood 56 is similar to the design of Figures 1 and 2 except that when the hood 56 illustrated in Figure 3 retracts a large portion of the hood 56 remains external to the video system 22. The moveable hood 56 is moveable about a pivoting point 57. The pivoting point 57 enables the hood to rotate in such a manner as to maintain a large portion of the hood external to the video environment. The hood 56 rotates about the pivot point 57 until it comes into contact with a top panel 55 of the video system 22 which is the extended position of the hood 56. The extended position of the hood 56 is used when the user wishes to enter and exit the audio environment 24. When the user is ready to begin play, the user reaches up and pulls the hood 56 down to the retracted position which is illustrated in Figure 3. The hood 56 rotates about the pivot point 57 until it reaches the desired retracted location. The embodiment of Figures 3-4 is preferred when it is not desirable to provide space within the video system 22 for the moveable hood 26 illustrated in Figure 1. By using the moveable hood 56 illustrated in Figures 3-4 a minimum amount of integration is required to combine the moveable hood 56 to the video system 22.

Figure 5 illustrates a further embodiment of a moveable hood 58. This embodiment comprises a stationary hood portion 60 and a moveable hood portion 62 and is shown with the moveable hood portion 62 in an extended position. Preferably the stationary portion 60 of the hood 58 remains in place and external to the video system 22 to provide a housing for the storage of the moveable portion 62 of the hood 58. When the moveable portion 62 of the hood 58 is retracted, the stationary portion 60 stores substantially the entire moveable portion 62 within the stationary portion 60. The speakers of the audio system are mounted on the moveable portion 62 of the hood 58 and remain external to the stationary portion 60 when the hood 58 is in the retracted position. This embodiment is preferred when it is desirous to partially store the hood 58 within an enclosure, i.e., the stationary portion 60 of the hood, without requiring the use of the video system 22 for storage.

Figure 6 illustrates another alternate embodiment of the moveable hood which utilizes an accordion style hood 64. The accordion style hood 64 preferably can be positioned in an extended and a retracted position. Figure 6 illustrates the accordion style hood 64 configured in the extended position. Preferably, the accordion style hood 64 comprises a first shingle 66, a second shingle 68, a last shingle 70 and a plurality of shingles 72 in between the second shingle 68 and the last shingle 70. Preferably, speakers (not shown) are mounted onto the first shingle 66, such that when the hood 64 is retracted the speakers do not interfere with the retraction of the hood 64. When the hood 64 is moved from the extended position to the retracted position, the first shingle 66 is retracted into the second shingle 68. The second shingle 68 is retracted into its next adjacent shingle 72 and so on until all of the shingles 66, 68 and 72 are retracted into the last shingle 70. Thus, the speakers which are mounted on the first shingle 66 are on the most interior portion of the audio environment 24 and do not interfere with the retraction of the accordion style hood 64. When the hood 64 is extended, the first shingle 66 is extended which in turn extends the second shingle 68 which extends the plurality of shingles 72 in between the second 68 and last shingle 70 one at a time. Finally, the last shingle 70 is extended. To adjust the placement of the speakers proximal to the ear 50 of the listener 44, the plurality of shingles 72 in between the second shingle 68 and the last shingle 70 and the last shingle 70 itself do not necessarily have to be extended. The listener 44 only pulls down the hood 64 until the speakers align with his ears 50 as in all other vertically adjustable designs. Therefore, the position of the speakers can be adjusted by one shingle length at a time as the hood 64 is extended to enable the preferred placement of the speakers proximal to the ears 50 of the listener 44.

Figures 7-9 illustrate another alternate embodiment of the hood design. Preferably, the alternate embodiment of the hood design 74 illustrated in Figures 7-9 comprises a rotatable hood portion 76 which is attached to a rotatable seat 78 of the listener 44 and a stationary hood portion 80 which is attached to the video system 22. The stationary hood portion 80 of the alternate hood embodiment 74 comprises a stationary top panel 80, a first stationary side panel 82 and a second stationary side panel 84 which are mounted to the video system 22. The rotatable hood portion 76 comprises a third side panel 86, a fourth side panel 88 and a back panel 90 which are connected to the rotatable seat 78. The speakers 90 of the system are mounted to the third and fourth side panels 86, 88, respectively, of the rotatable portion 76 proximal to the location of the ears 50 of the listener 44. The rotatable seat 78 is mounted on a turntable 94 on a platform 96. The turntable 94 enables the rotatable seat to move in a circular direction relative to the platform 96. The rotatable seat 78 rotates in a clockwise direction from an open position where the listener may enter the system environment to a closed position where the listener's attention is focused in a forward direction. The rotatable seat 78 rotates in a counter-clockwise direction from a closed position where the listener's attention is focused in a forward direction to an open position where the listener may enter the system environment. Figures 7 and 8 illustrate the rotatable seat 78 and rotatable portion 76 of the hood 74 in a first closed position which focuses the listener's attention in the forward direction. Figure 9 illustrates the rotatable seat 78 and rotatable portion 76 of the hood 74 in an open position which enables the listener 44 to enter and exit the audio system environment 24.

In another embodiment of the system illustrated in Figures 7-9, the rotatable seat 78 is replaced with a stationary seat. In the stationary seat embodiment, the size of the stationary top panel 81, a first stationary side panel 82 and a second stationary side panel 84 which are mounted to the video system 22 are significantly reduced to enable the listener 44 to enter and exit the audio environment 24 without requiring the seat to rotate. By reducing the size of the stationary top panel 81, a first stationary side panel 82 and a second stationary side panel 84, the amount of ambient noise that enters the audio environment may significantly increase.

Figure 10 illustrates another embodiment of the audio system, generally indicated at 96. The embodiment 96 comprises a stationary hood member and a seat which is slidable in a horizontal direction. In the embodiment of Figure 10, the listener's ears 50 are positioned in proximity to the speakers 38 by moving the listener's ears 50 toward the stationary speakers 38, rather than moving the speakers 38 toward the listener's ears 50. Preferably, the seat is located in an initial extended position 97 to enable a listener to enter and exit the audio environment 24. The seat is rotatable about a pivot 99 to enable the listener to rotate the seat 46 to enable easy entry and exit from the audio environment. The seat 46 moves in a horizontal direction from the extended position 97 to a preferred speaker alignment position 98. Preferably, the seat 46 moves until the user aligns his ears 50 with the speakers 38 and the seat will retain the preferred positioning. Upon completion of the usage of the system, the seat 46 will be released and the user can move the seat back to the extended position 97 to exit the audio environment. One example of a horizontally moveable seat within a hooded environment is shown in U.S. Patent No. 4,960,117 entitled REAR ENTRY BOOTH AND SEAT FOR A SIT-DOWN VIDEO GAME which is assigned to the assignee of the present application and is hereby incorporated by reference.

Figure 11 illustrates another embodiment 100 of the audio system, generally designated at 100. This embodiment 100 comprises a stationary hood member and a seat which is moveable in a vertical direction. In the embodiment of Figure 11, the listener's ears 50 are positioned in proximity to the speakers 38 by moving the listener's ears 50 toward the stationary speakers 38, rather than moving the speaker's 38 toward the listener's ears 50. Preferably, the seat 46 is located in an initial extended position wherein the ears 50 of an extremely small listener would be positioned in proximity to the speakers 38. The seat 46 moves in a vertical direction from an extended position 102 to a preferred speaker alignment position 104. In this embodiment, the seat 46 is automatically moved in a vertical direction against a counter weight mechanism 106 depending on the weight of the listener. When the listener sits on the seat 46, the weight of the listener acts against the counter weight mechanism 106 to position the seat 46 in a preferred speaker alignment position 104. Preferably, the magnitude of the counter weight 106 is determined such that the weight of the listener will act against the counter weight 106 to position the seat 46 such that the ears 50 of the listener are in proximity to the speakers 38 of the audio system in the preferred aligned position 104. In another embodiment, a gas shock is used to mount the seat 46 to the base of the system instead of a seat post to enable a vertically adjustable seat 46. This gas shock embodiment is used to replace the counter weight mechanism 106 to enable the vertical movement of the seat to a desirably location to position the user close to the speakers 38 of the system.

Figure 12 is a block diagram of audio circuitry 108 of the preferred embodiment of the audio system 20 illustrated in Figures 1 and 2 in communication with system logic circuitry 110. The system logic circuitry 110 comprises a system logic processor 112, such as a Motorolla 68010, in two way communication with a Random Access Memory (RAM) storage area 114, for storing such information as current video object position, speed of the video object, etc, so that data may be transferred from the RAM 114 to the system logic processor 112, or visa-versa. The system logic processor 112 runs its own software program which controls the operation of the overall system functions. A ROM storage area 116 is in one-way communication with the system logic processor 112 for down-loading portions of the stored data into the system logic processor and to the RAM storage area 114 where the data may be temporarily altered. The system logic 110 further comprises communications hardware 118, such as TTL LS244 and LS245 integrated circuits, to enable communication via an external bus 128 to the audio circuitry 108. The operation of the system processor and associated logic is similar to the system disclosed in U.S. Patent No. 5,005,148 entitled DRIVING SIMULATOR WITH MOVING PAINTED DASHBOARD which is assigned to the assignee of the present application and is hereby incorporated by reference. Significant improvements have been made to the audio circuitry disclosed in U.S. Patent No. 5,005,148, these improvements are the subject of the current application. The improved portions of the audio circuitry are described hereafter.

The audio circuitry 108 comprises communications hardware 118 which is similar to the communications hardware 118 located in the system logic circuitry 110 to enable communication from the audio circuitry 108 to the system logic circuitry 110. The audio circuitry 108 further comprises an audio processor 120, such as an Analog Devices ADSP2101, a Random Access Memory (RAM) storage area 127, a Read Only Memory (ROM) storage area 129, an audio volume sensing and control circuit 122 (Figure 14) and audio output circuitry 126, such as bridged TDA 2030 integrated circuits, to drive the speakers 38 (Figure 1). The audio processor 120 is in two-way communication with the RAM storage area 127. The RAM storage area 127 stores data such as a preferred set of head-related transfer function data which was downloaded from the ROM 116 in the system logic circuitry 110. The ROM storage area 129 supplies the audio processor 120 with an audio software program, such as the program disclosed in attached Appendix A. The output signals 123 from the audio processor 120 are a digital representation of the audio sounds. The output signals 123 are delivered to the Audio Analog-to-Digital Converter 124 which converts the digital signals 123 to a scaled audio output sound 125. The audio circuity 108 is also in communication with the audio volume sensing and control circuit 122. The audio volume sensing and control circuitry 122 scales the output volume level of the three-dimensional audio presentation and all other audio output signals based on a measured external ambient noise level which is described in more detail below. The output of the audio volume sensing and control circuit 122 is delivered to a multiplying input of an Audio Digital to Analog Converter (D/A) 124 which scales the audio output signal 125. The scaled audio output signal 125 is delivered to the audio output circuitry 126 to drive the audio transducers, speakers 38 and their enclosures 40 (Figure 1) of the preferred audio system 20.

Figure 13 illustrates a typical external environment 130 in which a three-dimensional sound system 20 may be located. The external environment 130 comprises a plurality of typical audio/video systems 132, such as arcade games or simulator systems of the prior art, positioned in proximity to the three-dimensional sound system 20. As these typical audio/video systems 132 do not have any sound absorbing properties or internal audio environments, their sound presentation is broadcast to the entire external environment 130. Each of the audio/visual systems 132 produce an array of sounds as illustrated by the broken lines 134. As illustrated in Figure 13, if a plurality of audio/video systems 132 broadcast an audio presentation, audio sounds 134 from each system 132 overlap each other and often confuse the listener of one system into thinking that the sounds he is hearing from other systems are coming from his system.

Figure 13 illustrates the ability of the hood 26 of the preferred embodiment of the audio system 20 to reflect a large portion of the external ambient noise. The volume level of the sounds produced by the audio/visual system 132 typically range from a low threshold of 20 dBa to a high threshold of 110 dBa (these sound levels are measured at a typical player position in front of the respective audio/visual system 132).

Many of the sounds 134 which are incident upon the hood 26 are reflected by the hood 26 and are prevented from entering the audio environment 24 of the sound system 20. However, a certain percentage of the external ambient sounds, as indicated by the broken lines 134, may penetrate into the audio environment 24.

In such external environments 130 when many of the other audio/video systems 132 are producing sounds with volumes up to 110 dBa (measured as previously indicated), the overall ambient noise level can be very high. If all of the systems 132 are producing sounds with volumes up to 110 dBa, the ambient noise level can be so high that some of the lower level noises of the audio system 20 can be drowned out by this external ambient noise. However, if only a few systems 132 are in use, the sound produced by the audio system 20, which would typically be configured to compensate for a high level of ambient noise, may be too loud so as to be unpleasant for the listener. Therefore, a preferred embodiment of the audio system 20 includes a microphone 136 positioned on an external surface of the audio system 20 to measure the level of ambient noise in the external environment 130.

The microphone 136 is typically positioned on the hood 26 of the audio system 20. The measured level of ambient noise is used to scale the volume of the audio system 20. A typical external noise level is approximately 85-90 dBa. When the external noise level is at the typical level, the volume of the three-dimensional audio system 20 remains at a typical volume level, i.e., with sounds ranging approximately from 70 dBa to 110 dBa as perceived by the listener 44. If the external measured noise level is measured above the typical level, i.e., approximately 90-110 dBa, the volume level of the three-dimensional audio system 20 is increased to insure that the relatively low level portion of the three-dimensional audio cues can be heard above the ambient noise level. Preferably, the volume of the audio system 20 is increased in direct proportion to the increase in the volume of the ambient noise level above the typical threshold. If the external ambient noise level is measured below the typical level, approximately 75-80 dBa, the volume level of the three-dimensional audio system 20 is decreased so as to prevent delivering a sound presentation which is unpleasantly loud relative to the ambient environment for the listener 44. The preferred decrease in the volume of the audio sound system is directly proportional to the level of decrease in the ambient noise level below the typical threshold. Noise levels below 70 dBa can be expected at times. However, it would be rare to find ambient noise levels measured below 40 dBa in a typical environment 130 in which an audio/visual system of the prior art 132 would be located.

Figure 14 illustrates an exemplary embodiment of an audio volume sensing and control circuitry 122 and a conventional manual volume control circuit. A manual volume control circuit comprises a manual volume control knob 174 which is connected to a multiplexing analog to digital converter (A/D) 154 via a line 176. The manual volume control knob 174 is set by a system operator to command the desired output volume level of the three-dimensional audio system 20. In this embodiment, the potentiometer acts as a voltage divider as is well known to those of skill in the art. The multiplexing A/D converter 154 generates a digital signal on a line 156 in response to a request by system logic processor 112 which indicates which of the input lines to the A/D are to be converted to a digital signal on the line 156. In one case, the digital signal on the line 156 is representative of the input analog signal 176 from the manual volume control knob 174 which indicates the desired volume level of the output sounds to be delivered to the listener. The manual volume control portion of the circuit can be used alone, i.e., a system operator determines via the manual control knob 174 the level of the output sounds, or in combination with an audio volume sensing and control circuit 122. When the audio volume sensing and control circuit 112 is used in combination with the manual control portion, the volume sensing portion of the circuit determines the level of ambient sound in the external environment 130 and the manual control knob 174 is used by the system operator to indicate the volume level above the ambient noise level at which the system operator wishes the audio presentation to be output.

In the audio volume sensing and control circuitry 122, a microphone 136 (also shown in Figure 13) measures the volume of the external environment 130 (Figure 13) and emits a signal on the line 140 which represents the external sound. The signal from the microphone 136 is delivered on a line 140 to an input 142 of a first scaling and rectification portion 144 of the circuit 122. The scaling and rectification portion 144 scales the measured signal to a useful level of voltage ranges representative of the external volume level. Preferably, an operational amplifier is used in the scaling and rectification portion 144 of the circuit. The scaled and rectified signal is delivered on a line 146 to an input 148 of an integrator 150 in an averaging portion of the circuit 122 which averages the signal over time to diminish the effect of the transient nature of the ambient noise from incorrectly representing the overall noise level of the external environment 130 and produces an integrated audio signal. The integrated audio signal is sent on the line 152 to the multiplexing analog-to-digital (A/D) converter 154.

The multiplexing A/D converter 154 is in communication with the system logic processor 112. The system logic processor 112 indicates which of the input lines, i.e., the audio volume control signal on the line 152, the manual volume control signal on the line 176, the string potentiometer control signal 278 or other control signals, are to be converted to a digital signal on the lines 156 by the A/D converter 154. In one case, the system logic processor 112 selects the automatic volume control signal on the line 152 as the input to the A/D converter 154, thus the output digital signal of the A/D converter 154 on the lines 156 is representative of the integrated audio signal on the line 152. The digital signal on the lines 156 is sent to the system logic processor 112. The system logic processor 112 determines the relative amplitude of the integrated audio signal on the line 152 compared to the expected typical value and produces an ambient noise value. The ambient noise value is thus a measure of the level of ambient noise in the external environment 130. As noted above, the manual control knob 174 is used to indicate the volume level above the ambient noise level at which the system operator wishes the audio presentation to be output. The system logic processor 112 commands the A/D converter 154 to convert the voltage from the manual volume control knob 174 on the line 176 to its digital representation. The system logic processor 112 then determines the relative amount above the ambient noise that the system operator has selected for the audio presentation. Using the ambient noise value and the relative amount above the ambient noise as indicated by the system operator that the presentation is to be output, the system logic processor 112 calculates the system volume level. The system logic processor then converts the system volume level to the appropriate digital volume scaling signal that will yield the actual measured system volume level at the location of the listener's head. The output of the system logic processor 112 on the lines 158 is sent to the digital-to-analog converter 160 to convert the digital signal on the lines 158 to an analog volume scaling signal on a line 162. The second scaling portion of the circuit 122 converts the analog volume scaling signal on the line 162 to a volume control voltage on the line 172 which is connected to and is also appropriate for use at the multiplying input of the Audio Digital-to-Analog converter 124 of Figure 12. The final modified output sound level on the line 125 is delivered from the Audio Digital to Analog converter 124 of Figure 12 to the audio output circuitry 126 of Figure 12 to be output to the speakers 38 and their enclosures 40 (Figure 1). If the manual volume sensing circuit is used alone, the signal on the line 176 is selected as the input to the A/D converter 154. The digital signal on the line 156 provides the system operator's desired volume level which is passed on by the system logic processor 112 to the D/A 160 on lines 158. In the audio volume sensing and control circuitry, the system logic processor may further time average the digital input signal 156 and calculate a proportional volume scaling factor.

Preferably, all of the sounds produced by the audio system 20, even those which are not converted into three dimensional sounds are scaled to accommodate the level of ambient noise and therefore benefit from the audio volume sensing and control circuitry 122.

Besides scaling the volume to compensate for ambient noise levels, the three-dimensional sound presentation can be modified to accommodate the different head sizes of the individual listeners. The shape and size of a listener's head cause different coefficients to be recorded in the HRTF for different people when a similar sound source is positioned at the same location. In order to provide a more realistic three-dimensional sound presentation, it is preferred to estimate the head size of the listener and to provide a preferred set of HRTF data for the listener depending on this estimated head size using a software initialization program which will discussed in more detail below.

One preferred embodiment of an initialization portion of the software program comprises measuring different aspects of the listener's body size to approximate the size and shape of a listener's head. For example, the listener's head size can be approximated by determining the player's weight and the approximate position of the player's ears. Once the player's weight and ear location are determined, the approximate size and shape of the listener's head can be determined, as described in more detail below.

In order to determine the weight of the player, the audio delivery system 20 includes weight detection circuitry, as illustrated in Figure 15, which communicates with the moveable seat 46. Referring back to Figure 2, the path traversed by the moveable seat 46 has both a horizontal and vertical component. The weight detection mechanism measures the horizontal component of the seat movement which is proportional to the weight of the listener. The seat 46 is mounted on a moveable post 192 which is in turn mounted to a stationary horizontal member 194. The seat post 192 will deflect or bend from an initial position relative to the horizontal member when the listener is not seated on the seat 46 to a second position relative to the horizontal member when the listener is seated on the seat 46. A strain gauge 196 is mounted to the stationary horizontal member or vertical member near the point of maximum moment, thus maximum strain, near the point 194 to measure the strain caused by the seat post 192 and the weight of the listener. As the horizontal member does not move a long distance due to the weight of the player being applied to the seat, the amount of change in the strain gauge output is very low.

Because the resistance of the strain gauge changes so little during strain of the horizontal member 194 or the vertical member 192, a bridge and strain gauge interface circuit 198, as illustrated in Figure 15, is used to detect the sight changes. The bridge interface circuit 198 also includes interface circuitry to convert the analog bridge output signal to a digital format suitable for use by the system logic processor 112. The output of the bride interface circuitry is read by the system logic processor 112 on the line 200.

One of the difficulties of using strain gauges is that they have temperature drift characteristics. Silicon strain gauges have one hundred times the sensitivity of metal strain gauges, but they also have a much higher temperature drift than metal strain gauges. Because it is desired to have low temperature drift characteristics, metal strain gauges are used in the preferred embodiment of the invention. For the strain gauge circuitry to work properly, it is necessary that the bridge 198 be kept balanced even if the strain gauge characteristics change with changing temperature. Normally, a bridge has two nodes which have voltages that are close together when the bridge is balanced. When the bridge becomes unbalanced by virtue of a change in one of the components making up the bridge, the voltages between these two nodes shifts. As indicated above, it is desirable in the quiescent state when no listener strain is being experienced that the bridge be balanced. However, in mass production techniques, and with changing ambient conditions, it is impossible to obtain circuit component tolerances and temperature characteristics such that the bridge will always remain balanced.

In order to ensure that the bridge remains properly balanced during operation of the vehicle simulator or game embodying the system of the invention, the system logic processor 112 is programmed to sense the balanced state of the bridge and to correct this state if the bridge is unbalanced. This correction is done through a digital-to-analog converter 202 and an AUTOBALANCE signal on a line 204. The system logic processor 112 balances the bridge 198 by periodically sampling the voltage at the output node of the bridge. This voltage is converted to a digital number by analog-to-digital circuitry in the bridge/interface 198 and output on a line 200 to the system logic processor 112. The system logic processor 112 compares this voltage to a desired range of voltages and then loads an AUTOBALANCE signal on the line 204 into digital-to-analog converter 202. The AUTOBALANCE signal on the line 204 is an error correction signal which when converted to an along signal will be summed with the voltage at the output node of the bridge to bring the bridge back into balance. The digital-to-analog converter 202 converts the AUTOBALANCE signal received from the system logic processor 112 to an analog BALANCE signal on line 206. The analog BALANCE signal is applied to the bridge at an appropriate location that will tend to balance the bridge. This process of sampling the bridge output, comparing the bridge output to a desired range of voltages, loading a digital number into the digital-to-analog converter, and applying the resulting analog voltage to an appropriate location of the bridge continues until the bridge is forced back into balance. One type of a strain gage interface circuitry which can be used to implement the above weight determining circuitry is disclosed in U.S. Patent No. 5,197,003 entitled Gearshift Having a Solenoid for a Vehicle Simulator which is assigned to the assignee of the present invention. The strain gage interface circuitry that is disclosed is adapted for a gearshift circuit, however, the same circuit can be used to determine the player's weight in association with the strain gage 196.

Preferably, in addition to the listener's weight the position of the hood 26 is measured from which the position of the speakers 38 can be calculated. Based on the calculated position of the speakers 38, the approximate location of the ears 50 of the listener 44 can be determined. As illustrated in Figure 2, a string potentiometer 256 is placed on the hood 26 to determine how far the listener 44 pulls the hood 26 down from a maximum retracted position 30 to a preferred extended position 52 where the speakers 38 are positioned proximal to the ears 50 of the listener 44. The string potentiometer 256 is mounted in a fixed location on the stationary top panel and measures the movement of the cable system 49. The cable system 49 comprises a spring 258, a mounting member 260, a first pulley 262, a second pulley 264, a cable 266 and a cable mounting member 268. A first end 270 of the spring 258 is mounted to the stationary top panel 42. A second end 272 of the spring 258 is mounted to the mounting member 260 and is able to move freely with the spring 258. The first pulley 262 is connected to the mounting member 260. The cable 266 is mounted on the right end of the stationary top panel 42 arranged over the first pulley 262 and the second pulley 264 which is mounted to the right end of the stationary top panel 42 as the first cable end, and finally terminates on the cable mounting member 268 on the hood 26. When the hood 26 moves to a preferred position 50, the cable 266 moves through the first and second pulleys 262, 264 which extends the spring 258 to balance out the weight of the hood 26. A string 274 of the string potentiometer 256 is attached to a second moving end 272 of the spring 258. The amount of movement of the string 274 in the string potentiometer 256 is converted into a resistance measurement representative of the amount of string 254 which has been let out of the string potentiometer 256.

An initial resistance value from the string potentiometer 256 is sent to the system logic processor 112 which is representative of the amount of string 274 which is let out of the string potentiometer 256 when the spring 258 is in an initialized position and the hood 26 is in the maximum retracted position 30. After the listener has positioned the hood 26 in preferred hood position 52, the spring 258 is in an elongated position and additional string 274 has been let out of the string potentiometer 256. The resistance of the string potentiometer 256 which is representative of the initial position and the additional distance that the spring 258 has moved is sent to an analog-to-digital conversion circuit 154 on the line 278, as illustrated in Figure 14. The analog-to-digital circuit 154 converts the analog signal on the line 278 to a suitable format for receipt by the system logic processor 112. The system signal is then sent to the system logic processor 112 on the line 156 time multiplexed with other signals. The amount that the spring 258 moves is in proportion to the distance that the hood 26 has rotated. Therefore with the resistance data from the string potentiometer 256, the system logic processor 112 is able to detect the position of the hood 26. From the position of the hood, the position of the listener's ears can be inferred, as described in more detail below.

Figure 16 illustrates the flow chart 282 of a preferred software initialization program 190 to implement the head size determination and to select or control calculated modification of the HRTF using preferred HRTF determination coefficients. One preferred embodiment of the software initialization program 282 comprises approximating the listener's head size by determining the player's weight and the approximate position of the player's ears and thus the distance between the listener's seat and their ears using the circuitry described above to provide input to the software initialization program. Initially, the system logic processor 112 performs the typical system initialization procedures as illustrated in transfer block 284, then performs the head size determination portion of the initialization program, blocks 286-292, as described in more detail below. In particular, as indicated in action block 286 of the flow chart 282, the amount of strain caused by the listener sitting on the seat 46 as determined by the strain gauge 196 and associated weight determining circuitry is input to the system logic processor 112. The system then moves to block 288 wherein the listener's weight is estimated and then calculated by the system logic processor, based on the amount of seat strain. In action block 290, the position of the hood 26 is relayed to the system logic processor 112, based on the position of the string potentiometer 196, as described above. In action block 292, the system logic processor 112 determines the approximate position of the listener's ears 50 based on the position of the hood 26. In action block 294, the listener's weight and the location of the speakers 38 are combined to determine an approximate size of the head 48 of the listener 44.

Once the approximate size of the head 48 of the listener 44 is determined, the system moves to block 296, wherein a number of stored head sizes are compared to the approximate head size of the listener 44. The best match of the stored head sizes to the listener's head size is chosen as indicated in decision block 298. Another method for improving the HRTF for matching the appropriate head size of the listener 44 is to modify the HRTF coefficients of a known weight and size person. Because the HRTF coefficients are based on physical properties (sizes and shapes) of a known person's head and ears as well as physical properties of the transmission of sound through air, it is possible to modify the coefficients of the HRTF for listeners of relatively larger and relatively smaller heads. The preferred HRTF data for the best matching head size is selected from a ROM storage area 116 of the system logic processor 112 from a number of sets of HRTF data (Figure 12). In action block 300, the preferred set of head-related transfer function data is down-loaded into the RAM storage area 127 of the audio processor 120. The system then moves to block 302, and returns to the main sound program. The preferred set of HRTF data stored in the RAM storage area 127 is then used by the audio processor 120 of the three-dimensional sound circuitry 108 to simulate the three-dimensional sound effect for the listener in the main program. The data stored in the RAM 127 is operated on by the audio processor 120 of the three-dimensional audio circuitry 108 in the same manner no mater which set of HRTF data is stored in the RAM storage area 127. Thus, the scaling of the three-dimensional effect for a different head size is basically transparent to the main portion of the three-dimensional sound program.

The amount of storage which is required to store each set of HRTF data for a specific head size can be substantial. In order to decrease the amount of RAM storage and ROM storage that is required, instead of storing a set of HRTF data for both the right and left ears of the listener, the system stores a single set of HRTF data for one ear and the HRTF data for the other ear is calculated by the audio processor 120. In order to calculate the HRTF data for the other ear, a first assumption is made that the

HRTF data for the other ear can be approximated by reflecting the position of the sound relative to the other ear to an equivalent position relative to the one ear which has the stored HRTF data.

Figure 17 illustrates the distance 304 and the horizontal and vertical angles from a sound 306 at a source position N relative to a first ear 308 which does not have a stored HRTF. Figure 18 illustrates the equivalent position of the sound 306 at a location M which has the same relative distances 310 and horizontal and vertical angle from the sound location M to a second ear 312 with a relative stored HRTF as the distance and horizontal and vertical angle from the sound location N to the first ear 308 without a stored HRTF. The equivalent position M is determined by equidistant and normally transmitting the sound position N through the symmetry plane S. The plane S is constructed normal to and bisecting a line between the first ear 308 and the second ear 312. In the current system the line between the speakers is equivalent. If the user's head is not in the centered forward position, the determination of the equivalent position M will be incorrect. The HRTF data for the equivalent position M relative to the second ear 312 is retrieved and is substituted for the HRTF data for the position N relative to the first ear 308. With the exception of the improvements described above, the remainder of the three-dimensional audio software program acts as a typical three-dimensional sound program of the prior art.

One advantage of only storing a set of HRTF data for a single ear and calculating the equivalent HRTF for the other ear is the amount of RAM storage 127 that is required to implement a three-dimensional audio circuitry 108 is significantly decreased. By decreasing the amount of RAM storage 127 that is required, the size of the audio system 20 can be decreased which decreases the cost of three dimensional sound presentations. In addition, if the required amount of HRTF data for a single size of listener is decreased, then the number of permanently stored HRTF data sets for different head sizes can be increased for the adapting HRTF embodiment discussed above. By increasing the number of sets of HRTF data for different head sizes, the listener is able to receive a more realistic three-dimensional sound reproduction which is closely tailored to suit the listener's head size.

The audio processor 120 additionally processes the head-related transfer function for the current sound location. The system logic processor 112 downloads the current sound location to the audio processor 120. The audio processor 120 retrieves the four closest stored HRTF data points for the second ear 312. The audio processor 120 additionally runs routines to interpolate between the four proximate stored HRTF data points to determine the HRTF data for the current sound location. In addition, the audio processor 120 runs routines for determining the equivalent position relative to the second ear 312 for the first ear 308. The same interpolation routine is used to calculate HRTF data for the current sound location relative to the first ear 308. The HRTF data for the first ear 308 and the second ear 312 are used to processes the sound 306 to add the desired three-dimensional spacial attributes and then are presented to the listener through the speakers 38.

The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

IN THE CLAIMS:

1. A sound system for broadcasting a three-dimensional sound presentation to a listener, comprising:

a housing;

a hood secured to said housing such that at least a portion of said hood is moveable; and

a pair of speakers mounted on said moveable portion of said hood such that movement of said hood with respect to the listener positions said pair of speakers in proximity to the ears of the listener, thereby delivering a three-dimensional sound presentation directly to the ears of the listener.

2. A three-dimensional sound system as defined in Claim 1 wherein substantially all of an internal surface of said hood is covered with at least one layer of sound absorptive material.

3. A three-dimensional sound system as defined in Claim 1 wherein said hood reflects a portion of external ambient sound such that the external ambient sound is prevented from entering said internal audio environment.

4. A three-dimensional sound system as defined in Claim 1 wherein said hood directs the head of said listener in a preferred forward looking direction.

5. A three-dimensional sound system as defined in Claim 1, further comprising an external microphone to measure the level of ambient noise external to said sound system.

6. A three-dimensional sound system as defined in Claim 1, further comprising:

a sound source for providing sound signals representative of selected sounds;

a transfer function; and

a controller, responsive to the sound signals and the transfer function and connected to the pair of speakers for delivering a three-dimensional sound presentation through the speakers to the ears of the listener.

7. A sound system as defined in Claim 6 wherein said transfer function defines the amount of modifications that are to be made to the sound signals to provide

sound through the speakers which define to the user a selected location of the sound source.

8. A sound system as defined in Claim 6 further comprising:

detecting means mounted on said hood to measure a volume of noise external to said hood; and

scaling means for scaling the sound signals to provide sound through the speakers to deliver a three-dimensional sound presentation based upon the volume level of the noise external to the hood.

9. A sound system as defined in Claim 6 further comprising means for determining an approximate size of the head of the listener.

10. A sound system as defined in Claim 9 wherein said transfer function relates to the size of the head of the listener.

11. A method of delivering a three-dimensional sound presentation to a listener, comprising:

storing a set of head-related transfer function data related to the position of one of the ears of the listener with respect to at least one sound source position;

determining the position of a sound source relative to the location of said one of the ears of the listener;

selecting from said set of head-related transfer function data, head-related transfer function data most closely associated with the sound source location relative to said one of the ears of the listener;

determining the position of the sound source relative to the other of the ears of the listener;

determining a position of the sound source relative to said one of the ears of the listener which is equivalent to the position of the sound source relative to the other of the ears of the listener;

selecting from said set of head-related transfer function data, head-related transfer function data most closely associated with the equivalent sound source location relative to said one of the ears of the listener; and

delivering a three-dimensional sound presentation to each of the ear's of the listener, wherein said three-dimensional sound presentation is based on the selected head related transfer data.

AMENDED CLAIMS
[received by the International Bureau on 05 September 1994 (05.09.94); original claims 1-11 replaced by amended claims 1-17 (4 pages)]

1. A sound system for broadcasting a three-dimensional sound presentation to a listener, comprising:

a support member being configured with respect to the head of the listener so as to encourage said head to remain in a desired position; and

a pair of speakers connected to said support member such that each speaker is positioned in proximity to an ear of the listener, thereby delivering the three-dimensional sound presentation directly to the ears of the listener.

2. A three-dimensional sound system as defined in Claim 1, further comprising a hood secured to said support member such that at least a portion of said hood is moveable, and wherein the speakers are mounted on said movable portion of said hood.

3. A three-dimensional sound system as defined in Claim 2 wherein movement of said hood with respect to the listener positions the speakers with respect to the listener.

4. A three-dimensional sound system as defined in Claim 2 wherein substantially all of an internal surface of said hood is covered with at least one layer of sound absorptive material.

5. A three-dimensional sound system as defined in Claim 2 wherein said hood reflects a portion of external ambient sound such that the external ambient sound is prevented from entering an audio environment internal to the sound system.

6. A three-dimensional sound system as defined in Claim 2 wherein said hood directs the head of said listener in a preferred forward looking direction.

7. A three-dimensional sound system as defined in Claim 2, further comprising:

a sound source for providing sound signals representative of selected sounds;

a transfer function; and

a controller, responsive to the sound signals and the transfer function and connected to the pair of speakers for delivering a three-dimensional sound presentation through the speakers to the ears of the listener.

8. A sound system as defined in Claim 7 wherein said transfer function defines the amount of modifications that are to be made to the sound signals to provide sound through the speakers which defines to the user a selected location of the sound source.

9. A sound system as defined in Claim 7 further comprising:

detecting means mounted on said hood to measure a volume of noise external to said hood; and

scaling means responsive to the detecting means for scaling the sound signals provided to the speakers so as to deliver a three-dimensional sound presentation, wherein the sound signals are adjusted in accordance with the volume level of the noise external to the hood.

10. A sound system as defined in Claim 7 further comprising means for determining an approximate size of the head of the listener.

11. A sound system as defined in Claim 10 wherein said transfer function relates to the size of the head of the listener.

12. A three-dimensional sound system as defined in Claim 1, further comprising an external microphone to measure the level of ambient noise external to said sound system.

13. A three-dimensional sound system as defined in Claim 12, further comprising a controller responsive to a signal from the microphone for controlling the volume of the speaker.

14. A method of delivering a three-dimensional sound presentation to a listener, comprising:

storing a set of head-related transfer function data related to the position of one of the ears of the listener with respect to at least one sound source position;

determining the position of a sound source relative to the location of said one of the ears of the listener;

selecting from said set of head-related transfer function data, that head-related transfer function data most closely associated with the sound source location relative to said one of the ears of the listener;

determining the position of the sound source relative to the other of the ears of the listener;

determining a position of the sound source relative to said one of the ears of the listener which is equivalent to the position of the sound source relative to the other of the ears of the listener;

selecting from said set of head-related transfer function data, that head-related transfer function data most closely associated with the equivalent sound source location relative to said one of the ears of the listener; and

delivering a three-dimensional sound presentation to each of the ears of the listener, wherein said three-dimensional sound presentation is based on the selected head related transfer data.

15. A method of delivering a three-dimensional sound presentation as defined in Claim 14 wherein the step of delivering a three-dimensional sound presentation includes a step of scaling the three-dimensional sound presentation to accommodate the head size of the listener.

16. A method of delivering a three-dimensional sound presentation as defined in Claim 15 wherein the step of scaling includes the steps of:

determining the approximate weight of the listener;

determining the approximate position of the ears of the listener;

calculating the approximate size of the head of the listener based on the approximate weight of the listener and the approximate location of the ears of the listener;

comparing the approximate size of the head of the listener to a number of stored head sizes; and

selecting a preferred head size which is closest to one of the stored head sizes.

17. A method of delivering a three-dimensional sound presentation as defined in Claim 16 wherein the step of delivering a three-dimensional sound presentation additionally includes the steps of:

providing sound data for generation of selected sounds; and

modifying the sound data in response to the selected preferred head size.

STATEMENT UNDER ARTICLE 19

Claims 1-11 were pending in the original PCT application. Claims 1, 3, 7, 8, and 11 are replaced, respectively, by amended Claims 1, 5, 8, 9, and 14; two new claims are added as Claims 2 and 3; previous claim 5 has been renumbered as Claim 12; the previous Claims 2, 4, 6, 9 and 10 are renumbered accordingly and the claim number they depend on is also changed; four additional new claims, Claims 13 and 15 to 17 are also added. The set of claims presented to the International Bureau is thus Claims 1-17, and this complete set, which contains the alterations enumerated above, is enclosed herewith.

The Applicant respectfully submits that the foregoing amendments, as discussed hereinafter, place the subject patent application in compliance with Article 19(1) and (2), PCT.

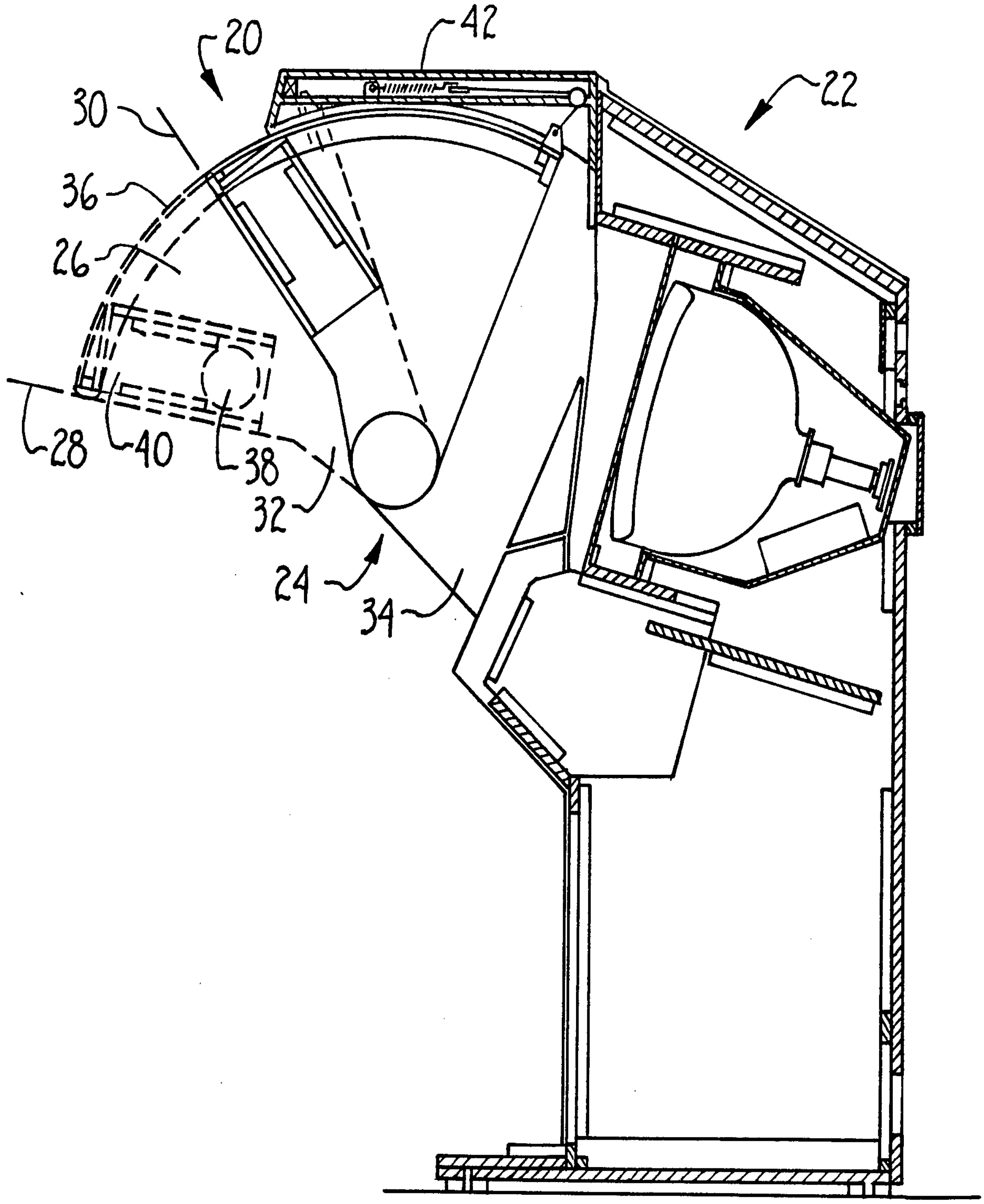

Figure 1

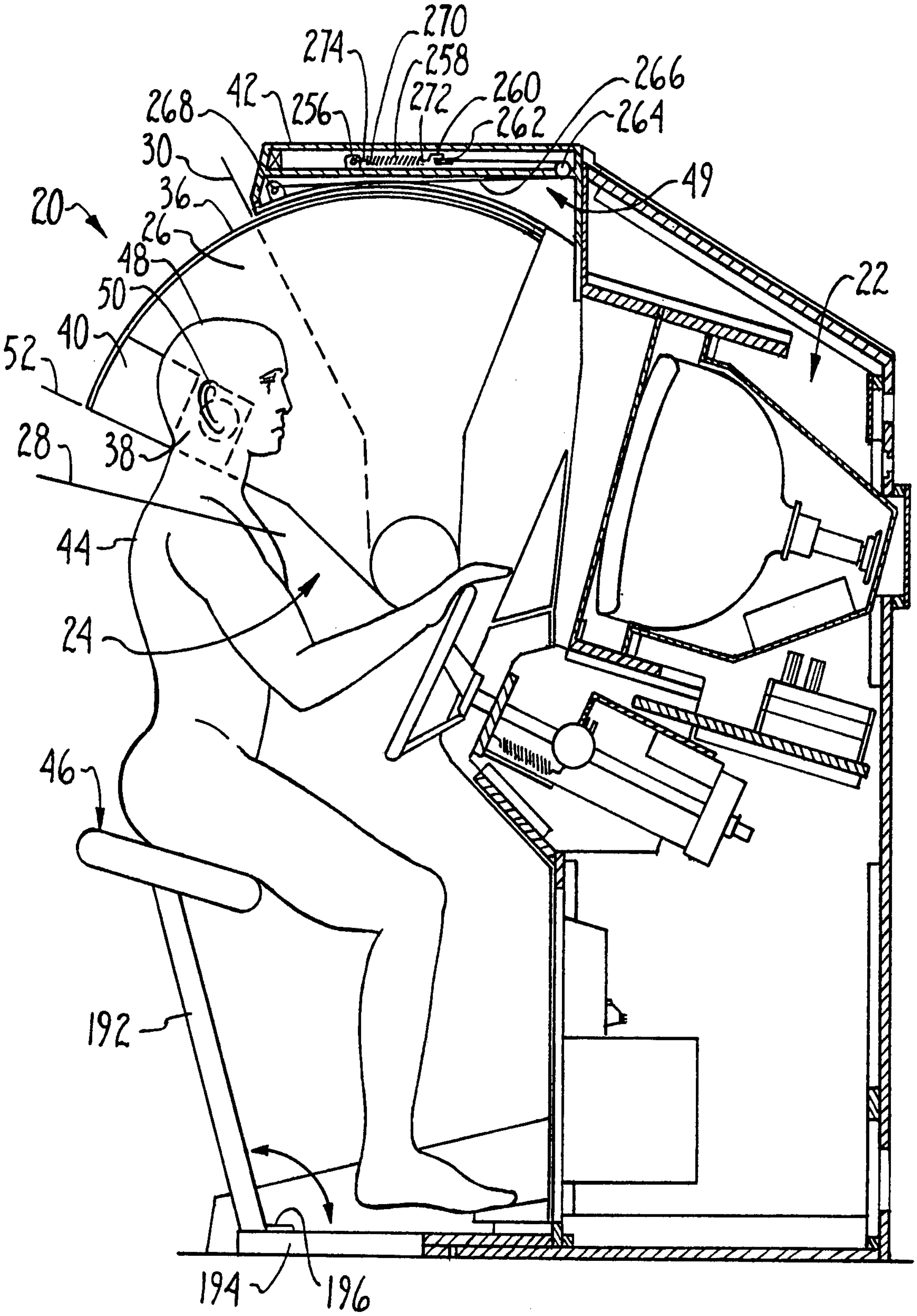
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Figure 2

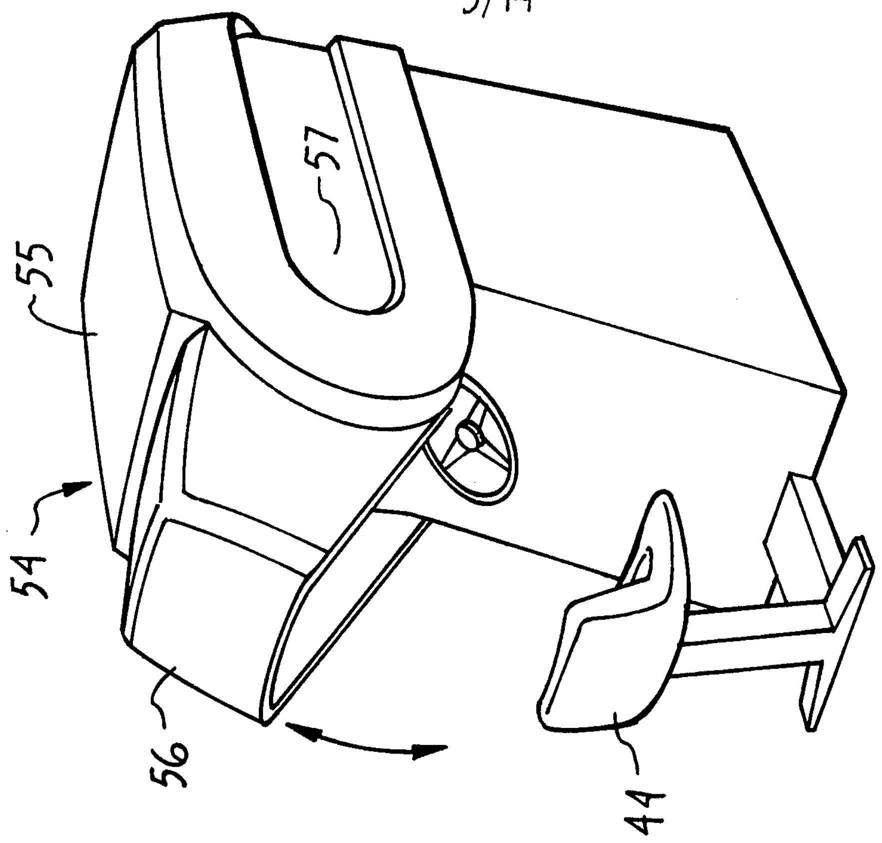


Figure 4

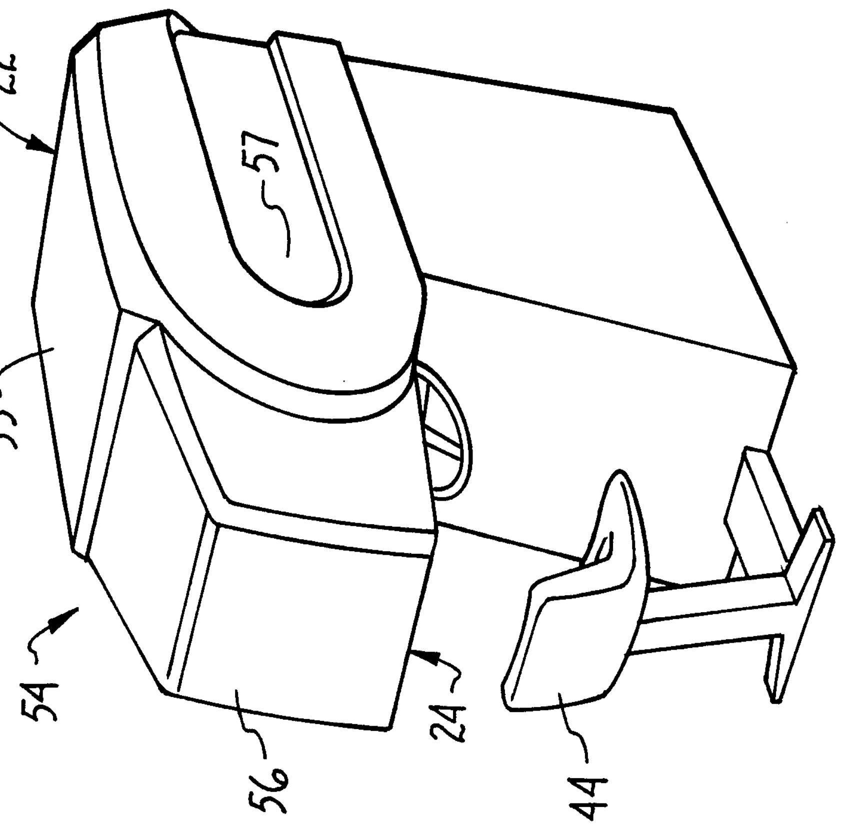
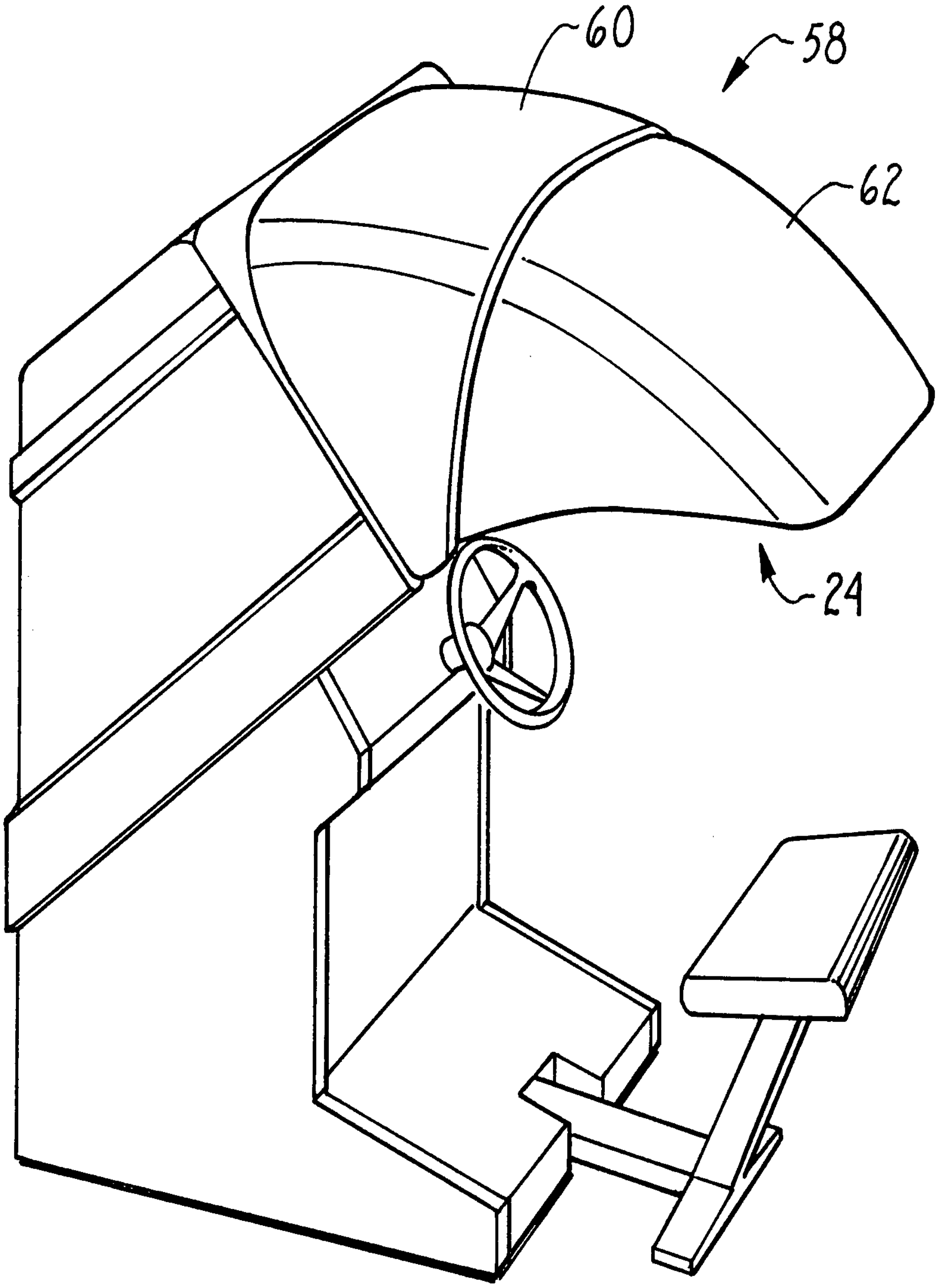


Figure 3



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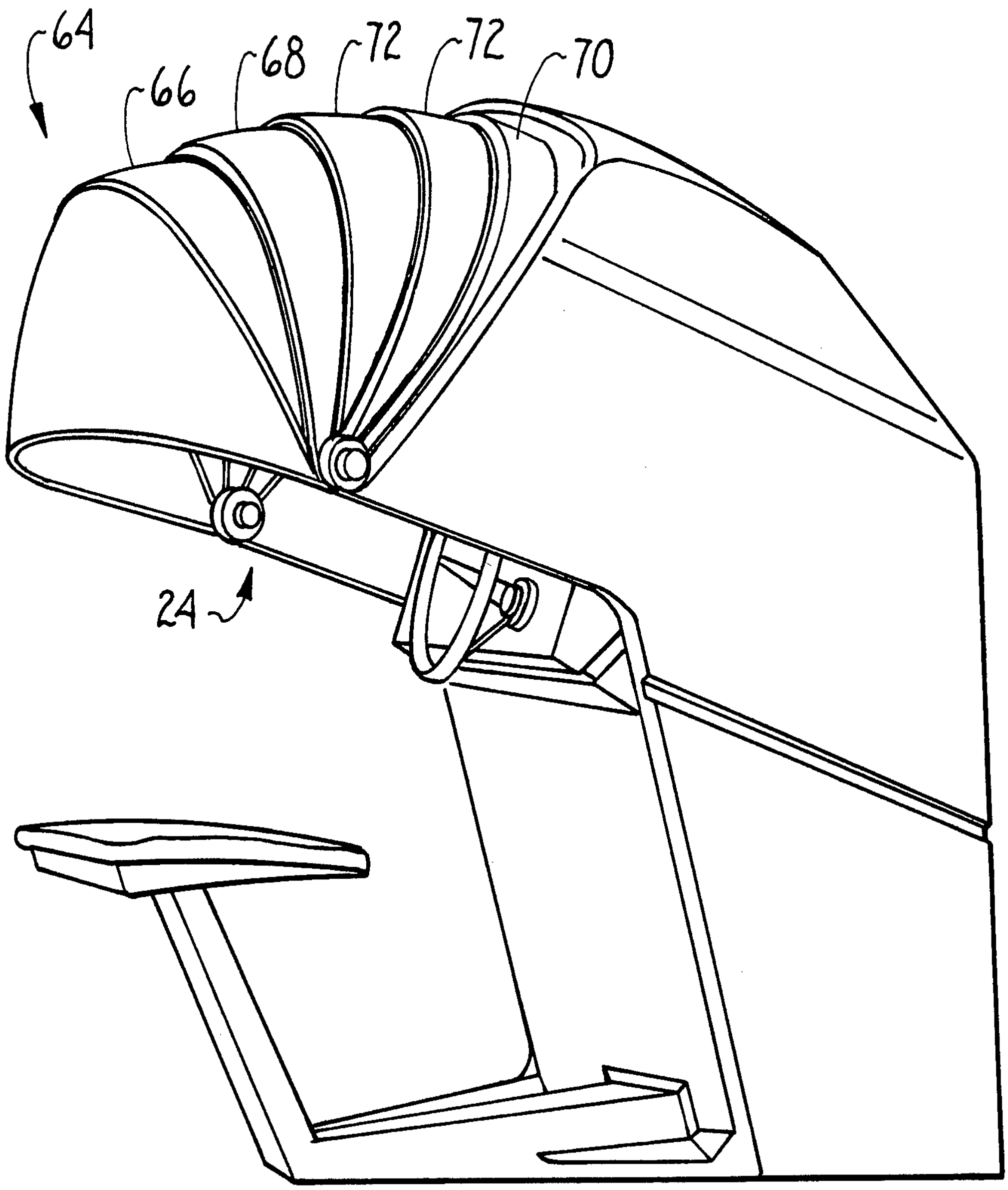

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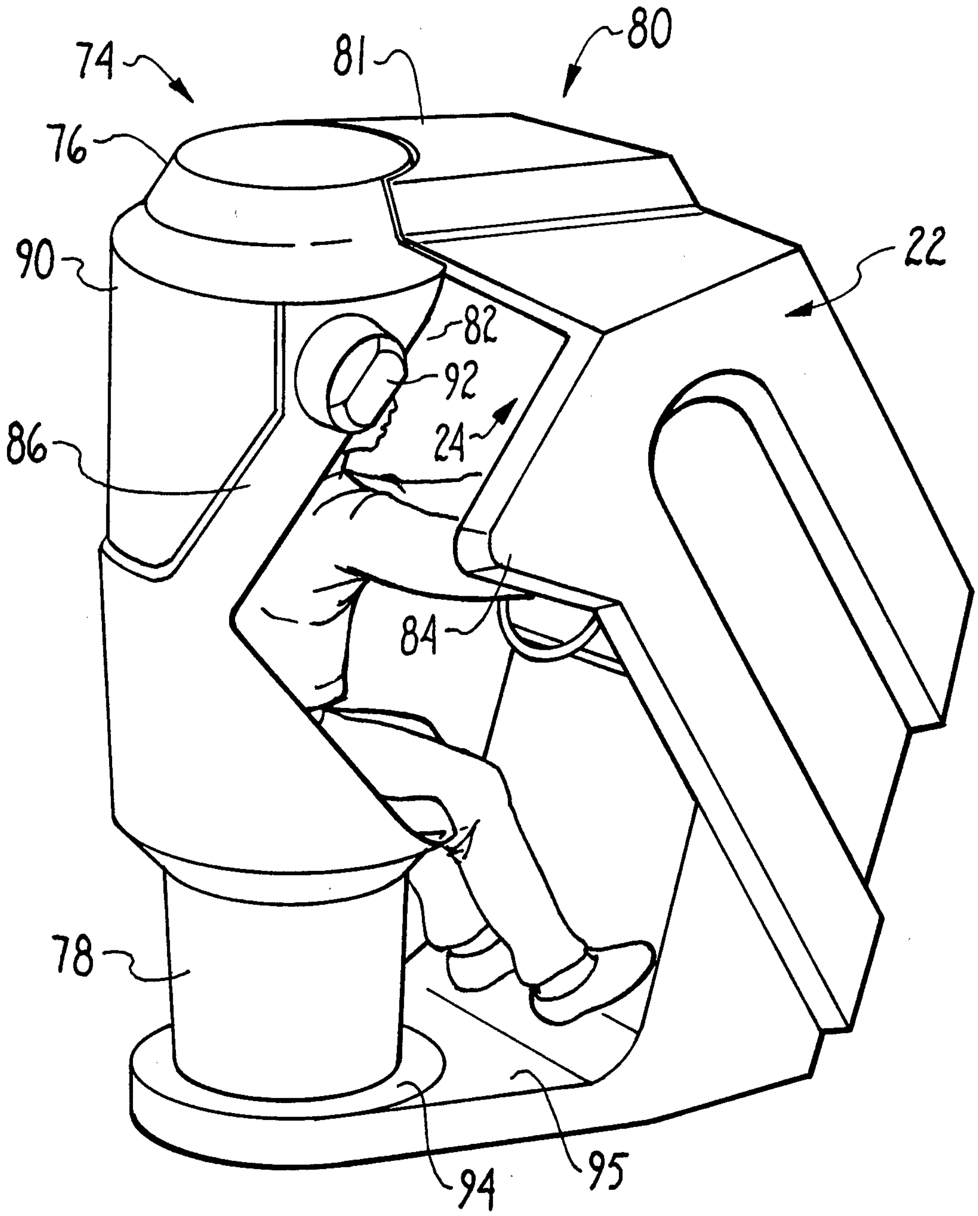


Figure 7

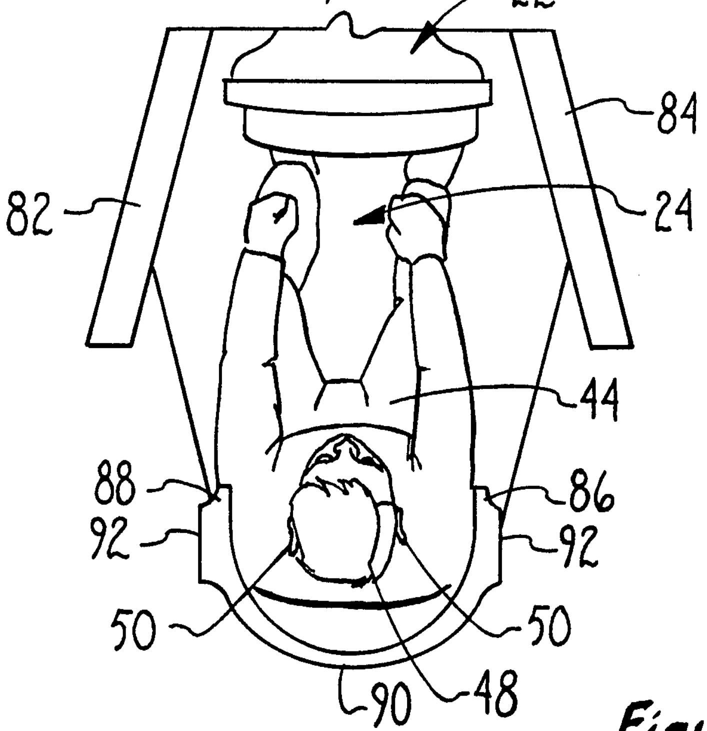
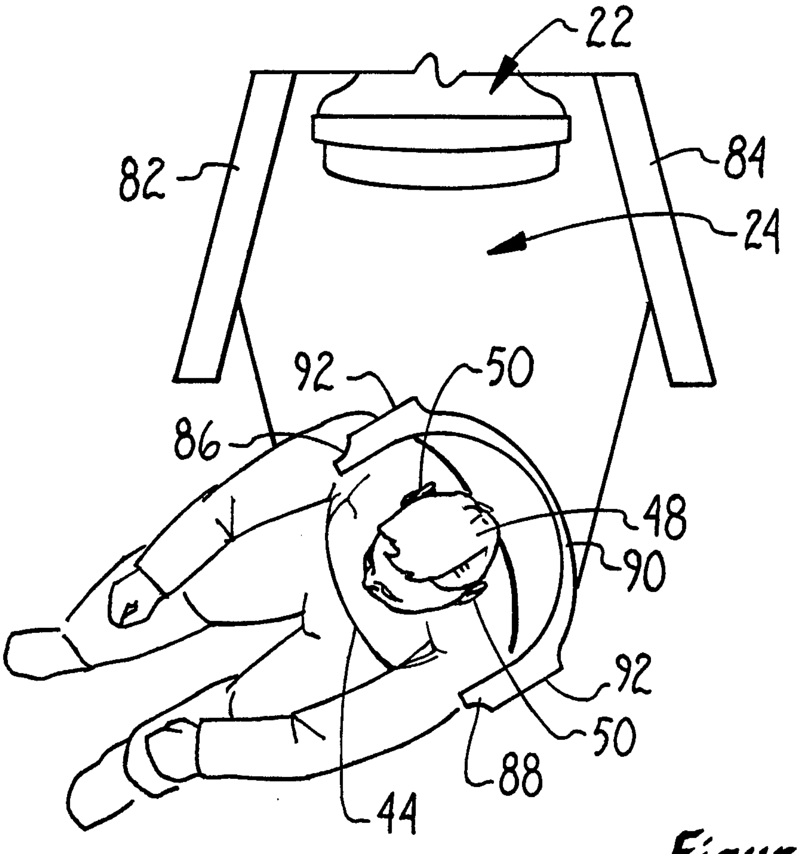


Figure 8



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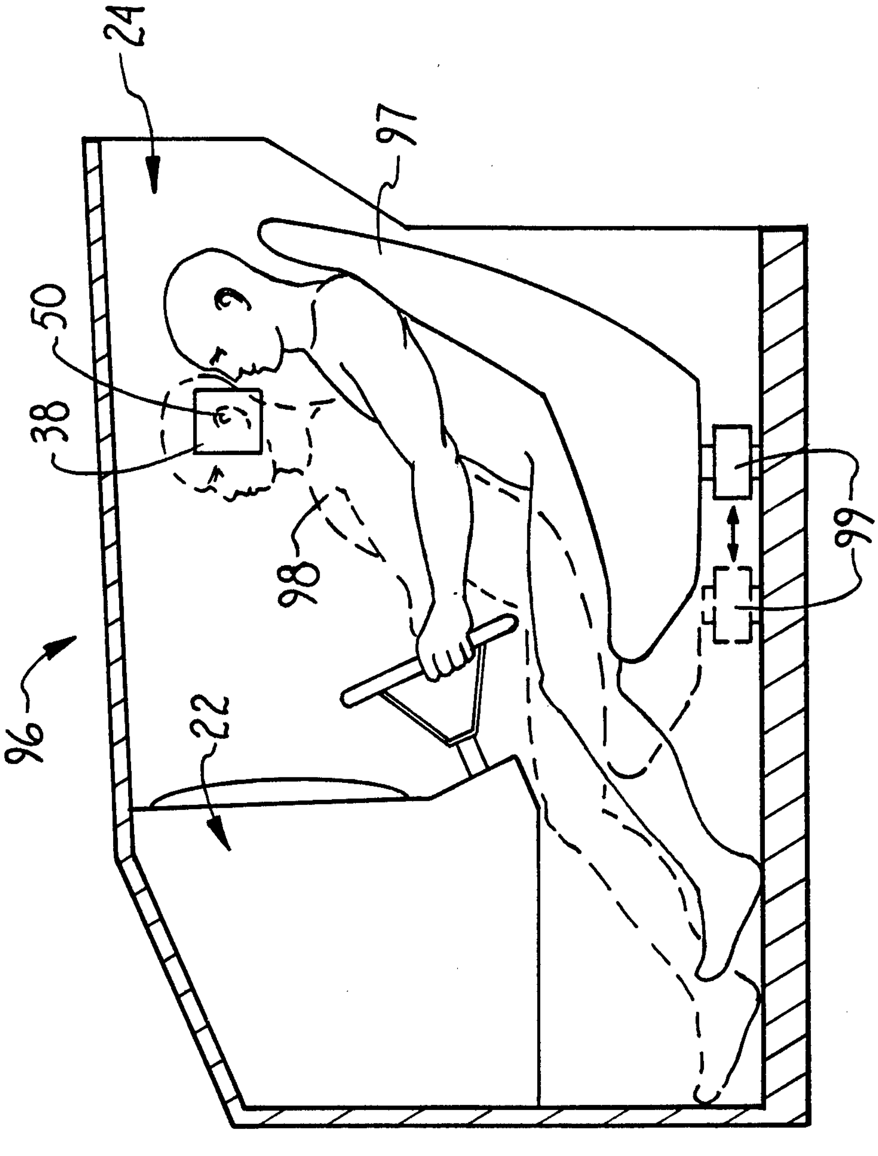
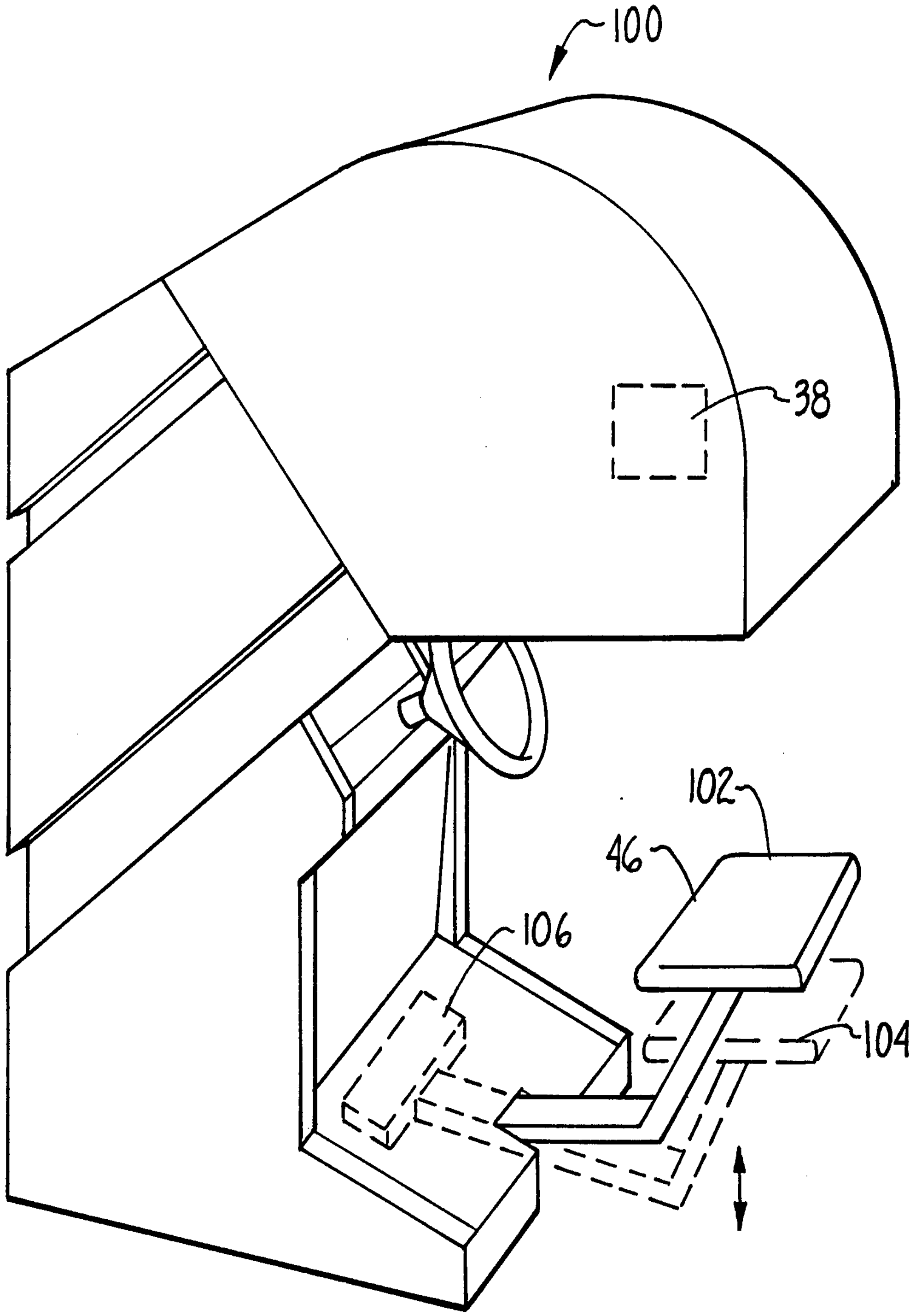


Figure 10



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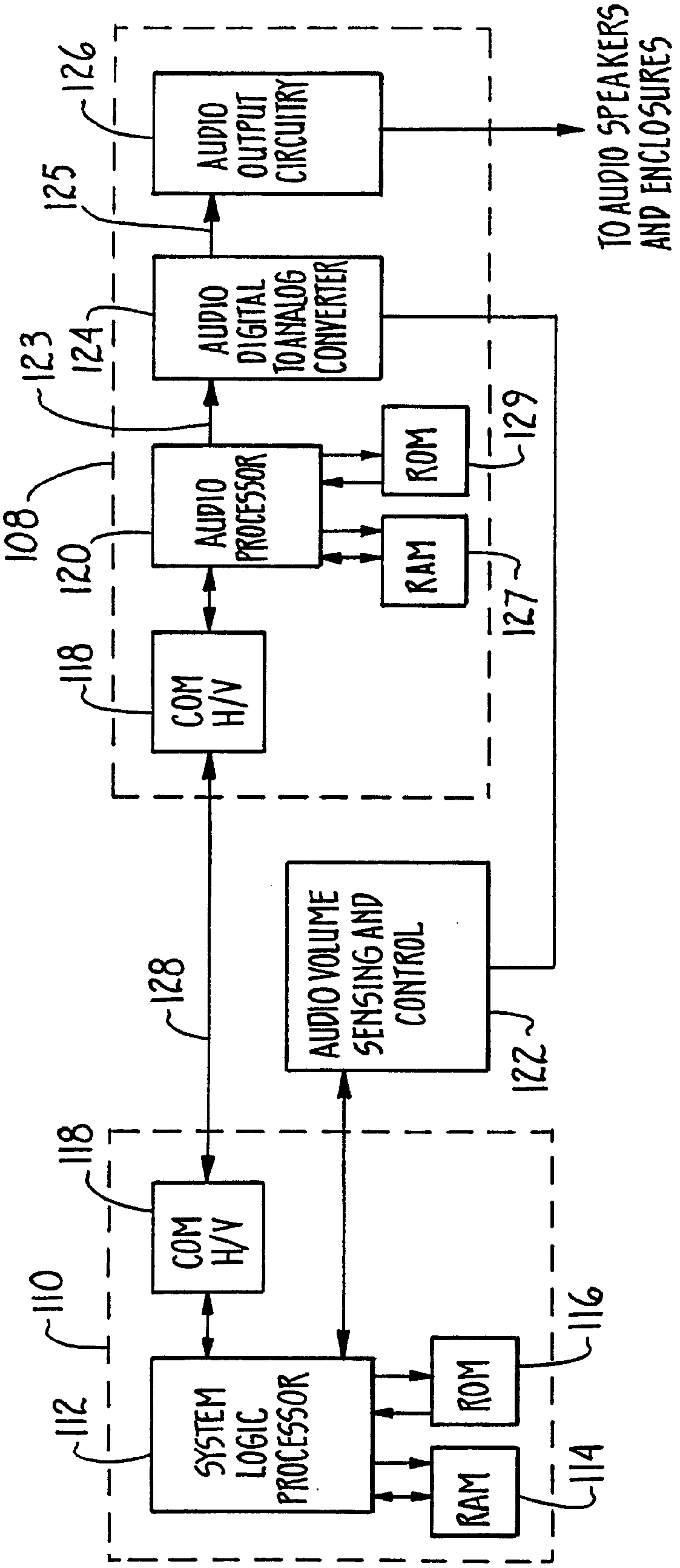
AUDIO OUTPUT CIRCUITRY
126
125
AUDIO DIGITAL TO ANALOG CONVERTER
123
124
TO AUDIO SPEAKERS AND ENCLOSURES
108
AUDIO PROCESSOR
120
ROM
129
RAM
127
COM H/V
118
128
AUDIO VOLUME SENSING AND CONTROL
122
COM H/V
118
110
SYSTEM LOGIC PROCESSOR
112
ROM
116
RAM
114

Figure 12

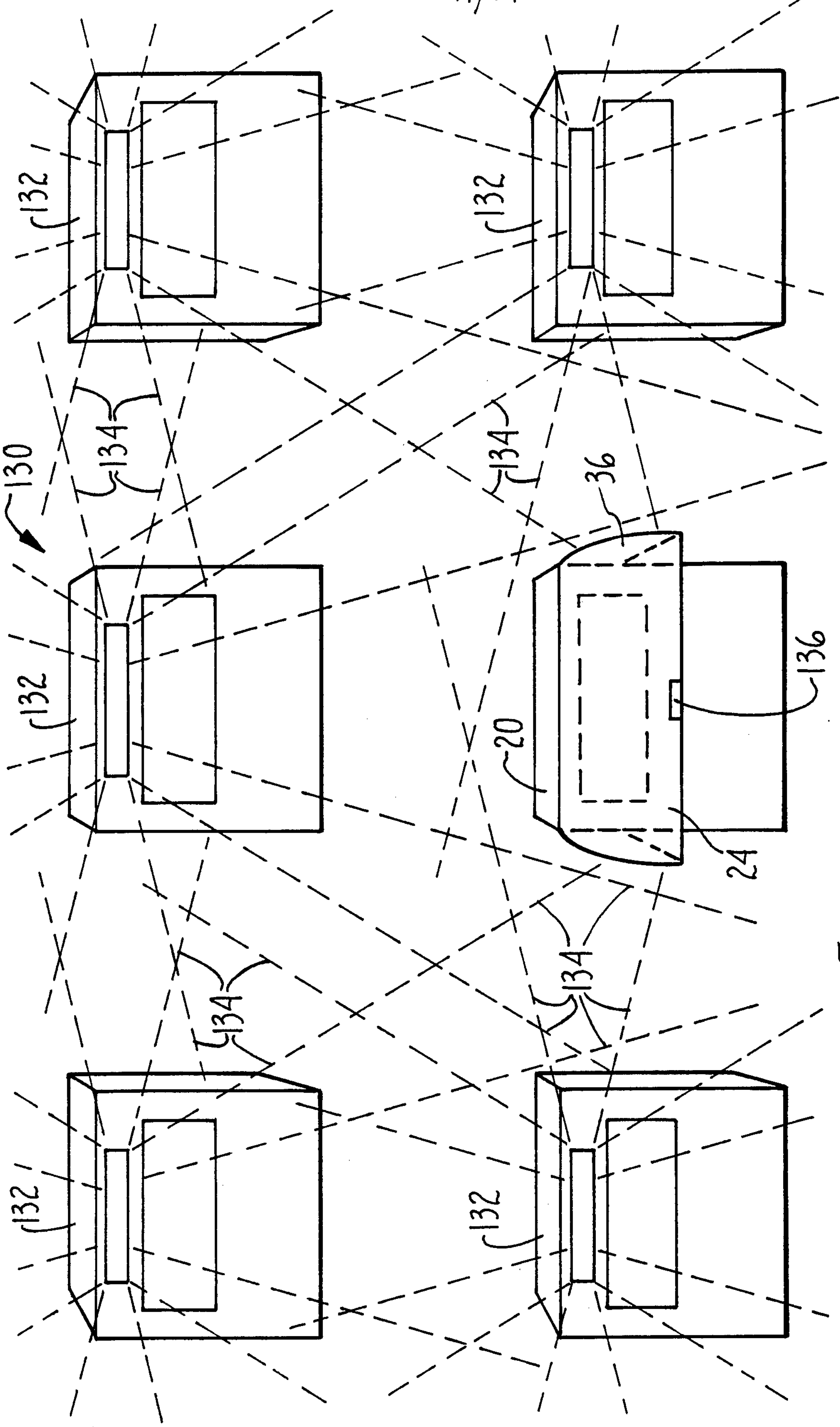

Figure 13

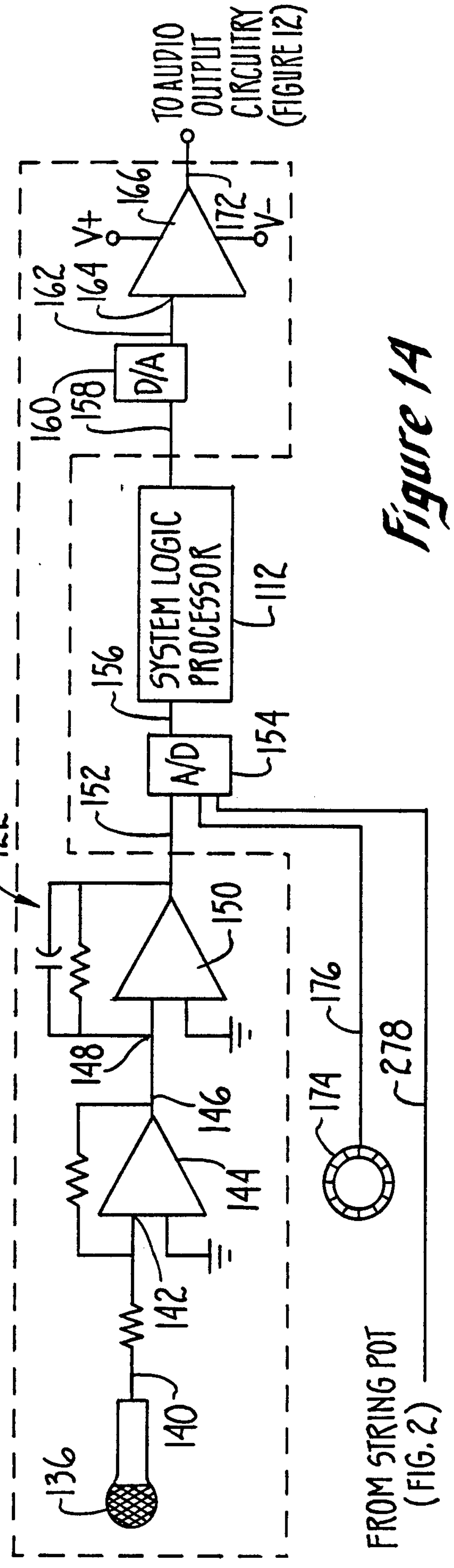

Figure 14

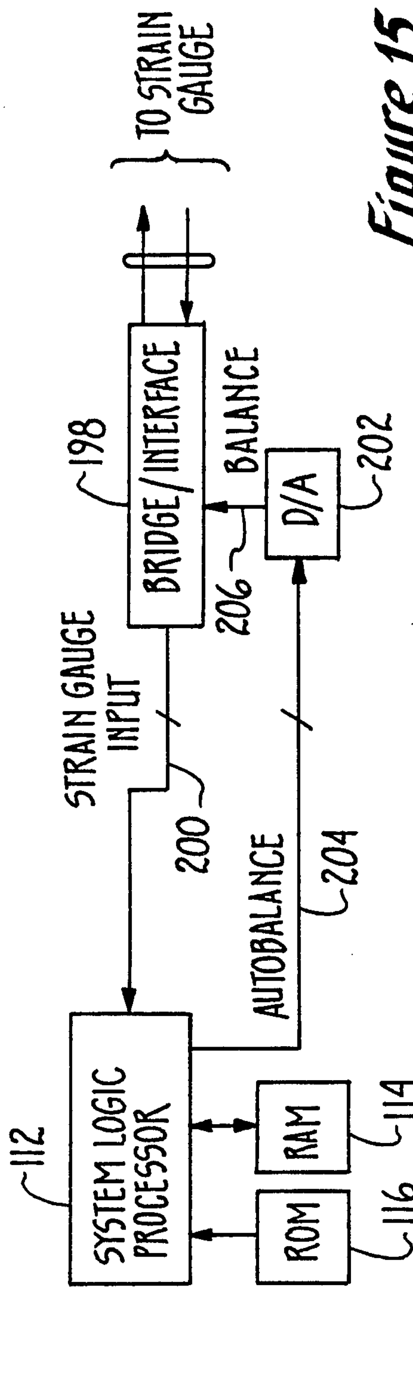

Figure 15

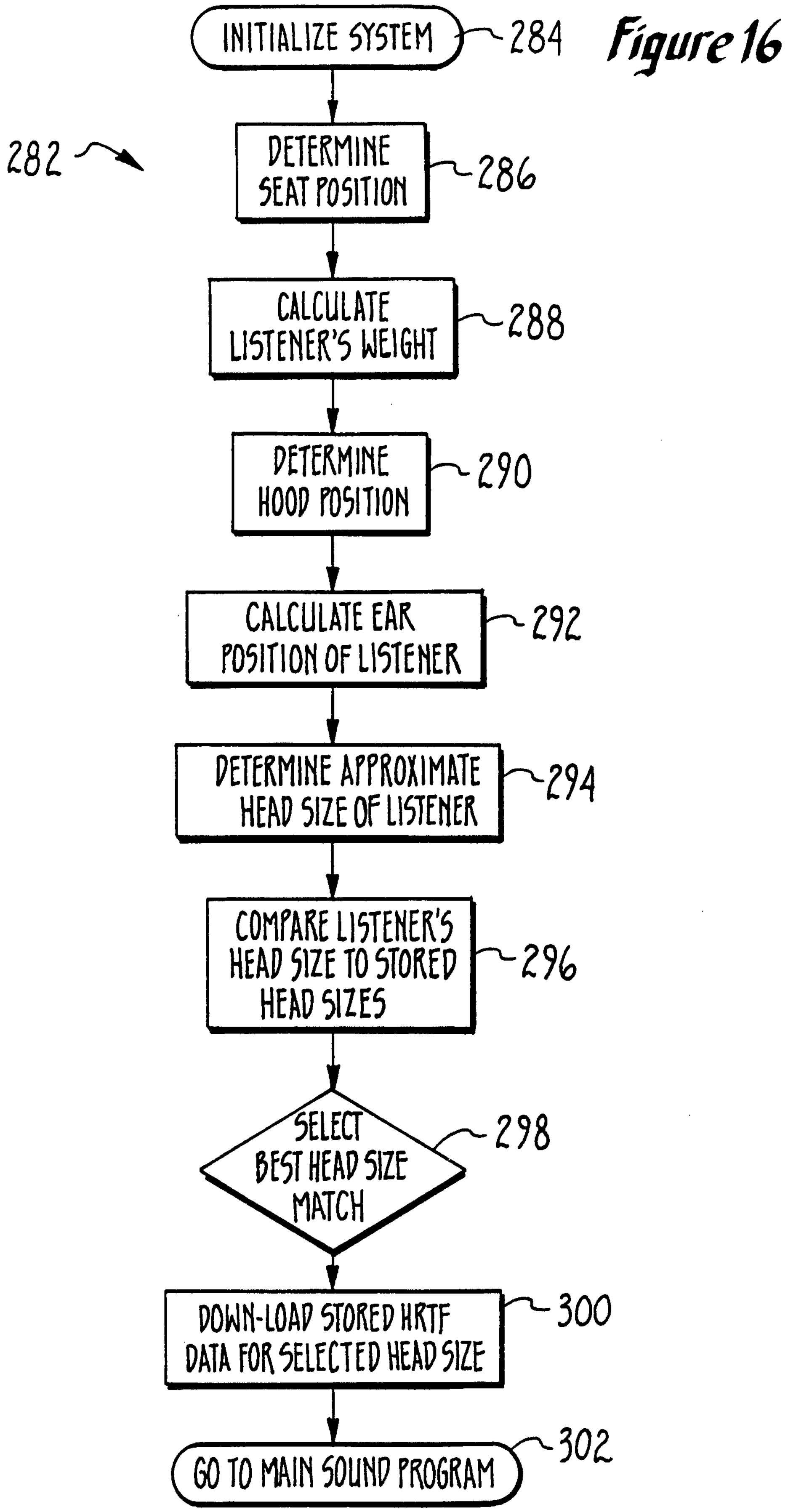
Figure 16
INITIALIZE SYSTEM
284
282
DETERMINE SEAT POSITION
286
CALCULATE LISTENER'S WEIGHT
288
DETERMINE HOOD POSITION
290
CALCULATE EAR POSITION OF LISTENER
292
DETERMINE APPROXIMATE HEAD SIZE OF LISTENER
294
COMPARE LISTENER'S HEAD SIZE TO STORED HEAD SIZES
296
SELECT BEST HEAD SIZE MATCH
298
DOWN-LOAD STORED HRTF DATA FOR SELECTED HEAD SIZE
300
GO TO MAIN SOUND PROGRAM
302

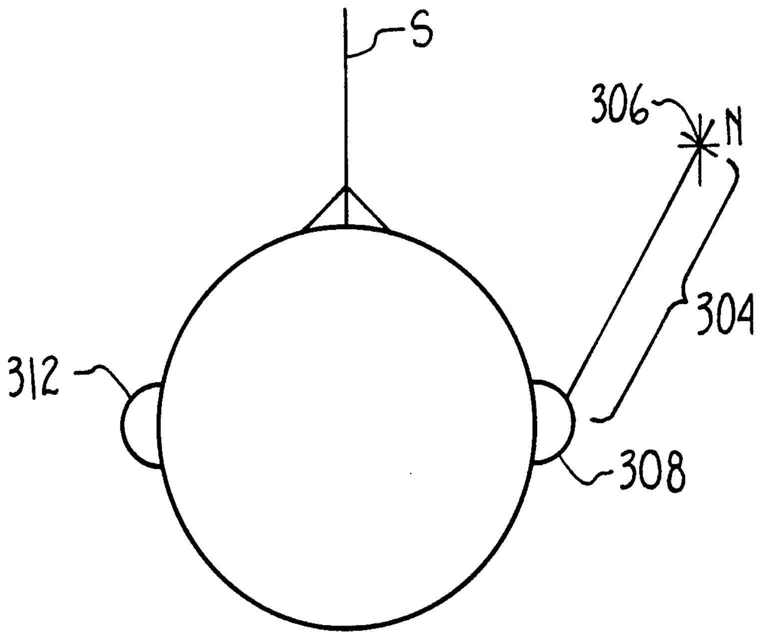

Figure 17

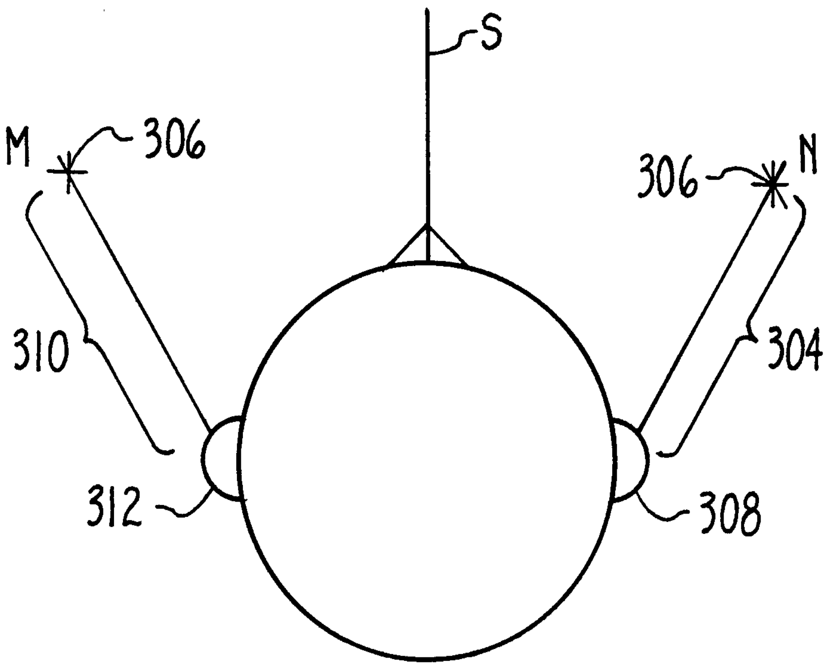

Figure 18

INTERNATIONAL SEARCH REPORT

Interr al Application No
PCT/US 94/03572

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 G09B9/05 H04S5/00 H04R5/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 G09B H04S H04R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 479 604 (TEXAS INSTRUMENTS INC.) 8 April 1992 see the whole document ---	1,6,7,11
A	'ieee 1990 national aerospace and electronics conference naecon 1990' 21 May 1990 , DAYTON SECTION OF THE IEEE , DAYTON Volume 2, VALENCIA,GERMAN et al.: "A Comparaison of Localization Performance with Two Auditory Cue Synthesizers" pages 749-754 see page 749, column 2, paragraph 3 - page 750, column 2, paragraph 1; figures 1,2 --- -/--	1,6,7,11

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

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"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

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Date of the actual completion of the international search	Date of mailing of the international search report
27 June 1994	06.07.94

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Gorun, M

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 94/03572

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO,A,92 09984 (VPL RESEARCH,INC) 11 June 1992 see page 4, line 23 - page 6, line 17 see page 7, line 20 - page 7, line 28 see page 9, line 3 - page 9, line 12; claim 1; figures 1-3C ---	1,4,6
A	US,A,5 173 944 (BEGAULT,DURAND R.;US) 22 December 1992 see column 3, line 49 - column 6, line 63; claims 1,5,7 ---	1,6,7,11
A	WO,A,92 09921 (VPL RESEARCH,INC) 11 June 1992 see the whole document ---	1,6,7,11
E	EP,A,0 593 228 (MATSUSHITA ELECTRIC INDUSTRIAL CO.,LTD.) 20 April 1994 see the whole document -----	1,6,7,11

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 94/03572

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-0479604	08-04-92	JP-A- 4249500	04-09-92
WO-A-9209984	11-06-92	EP-A- 0575332	29-12-93
US-A-5173944	22-12-92	EP-A- 0554031	04-08-93
WO-A-9209921	11-06-92	NONE	
EP-A-0593228	20-04-94	NONE	