Improving Headphone Fit Using Design Of Cable

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ABSTRACT OF THE DISCLOSURE

Aspects of the disclosure provide for a system that includes an ear hook, a bone conduction transducer (BCT) and a cable. In the system, the ear hook is configured to hook around at least a portion of a user’s ear. Supported by the ear hook is the BCT that is configured to contact the user's head. The cable is attached to the ear hook, the cable extending away from the ear hook at an angle with respect to a direction of a vertical axis. A force of gravity on the cable produces a torque, which presses the ear hook and the BCT against the user’s ear.

BACKGROUND

Headphones producing bone conducting audio cause vibrations in a user’s bone or cartilage. In this way, the bone conduction transducers in the headphones do not generate sound waves travelling through the air to transmit audio to the user's ear. Rather, the transducers vibrate the user's inner ear indirectly via vibrations in the user's skull or other bones or cartilage in the user's head proximate to where the transducers are positioned. Sound is perceived by the user primarily via the cochlea in the user's inner ear while bypassing the user’s ear drum.

BRIEF SUMMARY

Aspects of the disclosure provide for a system. The system includes an ear hook configured to hook around at least a portion of a user’s ear; a bone conduction transducer (BCT) supported by the ear hook and configured to contact the user's head; and a cable attached to the ear hook, the cable extending away from the ear hook at an angle with respect to a direction of a vertical axis such that a force of gravity on the cable produces a torque, the torque pressing the ear hook and the BCT against the user’s ear. In this disclosure, the bone conduction transducer is not limited to transmitting sound through bone, but further includes transmission of sound through cartilage, such as the auricle, or pinna, of the ear of a user, as
well as transmission of sound through a combination of bone and cartilage. However, for ease of discussion, the transducer will continue to be referred to as a BCT.

In one example, the cable has a proximal end attached to the ear hook and a distal end attached to a plug, the plug adapted to electronically couple with an audio output device. In another example, a distal end of the cable is affixed to an audio output device that outputs audio information. In this example, the device that outputs audio information is a pendant weighing between 10 and 20 grams.

In yet another example, the system also includes a second ear hook including a second BCT; and a second cable attached to the second ear hook, the second cable extending away from the second ear hook at the angle with respect to a direction of the vertical axis such that the force of gravity on the second cable produces a torque, the torque pressing the second ear hook and the second BCT against the user’s ear. In this example, the first cable and the second cable join together at a point forming a Y shape. Also in this example, the first cable and the second cable each have a proximal end attached to the first ear hook and the second ear hook, respectively, and a distal end where the first cable and the second cable are joined and attached to a plug, the plug being capable of attaching to a device that outputs audio information.

In another example, the cable extends away from the ear hook at an angle with respect to the coronal plane, sagittal plane, and transverse plane. In a further example, the angle is between 40 and 50 degrees from the direction of the force of gravity. In yet another example, the cable extends straight from the ear hook for a distance of at least 1 centimeter in a direction substantially perpendicular to a surface of the ear hook at a point where the cable is attached.

Other aspects of the disclosure provide for a device for bone conduction. The device includes a first ear hook and a second ear hook at a proximal end of the device; a first bone conduction
transducer (BCT) supported by the first ear hook applying a first contact force against a user’s head and a second BCT attached to the second ear hook configured to apply a second contact force against a user’s head; a first cable attached to the first ear hook, the first cable extending away from the first ear hook at an angle with respect to a direction of a vertical axis such that a force of gravity on the first cable produces a torque, the torque pressing the first ear hook and the first BCT against the user’s ear; a second cable attached to the second ear hook, the second cable extending away from the first ear hook at the angle with respect to the direction of the vertical axis such that the force of gravity on the second cable produces a torque, the torque pressing the second ear hook and the second BCT against the user’s ear; and a pendant connected to the first cable and the second cable at a distal end of the device.

In one example, the pendant outputs audio information. In another example, the first cable and the second cable connects the first BCT and the second BCT to electronic components in the pendant.

In yet another example, the first cable and the second cable join together at a point forming a Y shape. In this example, the point at which the first cable and the second cable join is adjustable.

In a further example, the first cable is attached to a portion of the first ear hook resting on a back of the user’s ear and the second cable is attached to a portion of the second ear hook resting on a back of the user’s ear. In another example, the angle is between 40 and 50 degrees from the direction of the force of gravity. In yet another example, the first cable and the second cable extend straight from the first ear hook and the second ear hook, respectively, for a distance of at least 1 centimeter.
In a further example, the pendant has a weight that provides additional contact force between the first BCT and the user's ear and between the second BCT and the user's ear. In this example, the weight ranges between 10 and 20 grams.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a side view of an example system according to aspects of the disclosure.

FIGURES 2A and 2B are side view illustrations of example systems according to aspects of the disclosure.

FIGURE 3 is an oblique view of an example system according to aspects of the disclosure.

FIGURE 4 is an oblique view of an example wearable open-ear audio device according to aspects of the disclosure.

DETAILED DESCRIPTION

OVERVIEW

The technology relates to a cable configuration in a wearable open-ear audio device. A cable extends from a portion of the ear hook behind the user's ear. At an opposite end of the cable, a plug or weighted pendant may be attached. The positioning of the cable produces a torque which causes a bone conduction transducer (BCT) attached to the ear hook to contact a portion of the user's cartilage, skull, or both with increased contact force. The open-ear audio device may provide bone conducting audio. Bone conducting audio typically requires a decent contact force to the body in order to get good quality audio. The BCT needs to be coupled to the body in order to transmit the necessary vibrations.

In an over-the-ear BCT design, it is difficult to provide an adequate contact force in comfortable and easy to wear way. When worn, an ear hook may naturally rest at the top of a user’s ear. The majority of the force of the ear hook, without more, is downward into the top of the user’s ear. A BCT positioned away from the top of the user’s ear, for example, 45
degrees or 90 degrees from the top, there may not be enough contact force between the BCTs and the user’s head to provide clear audio output to the user.

In some examples, the audio device may include two ear hooks at a proximal end of the audio device, each ear hook shaped to curve around at least a portion of the user's ear. Each ear hook may be configured to support a BCT, and a cable may extend from each BCT. The cables may join together, forming a “Y” shape. The point at which the cables join may be adjustable for the comfort of the user. A plug may be included in the device and attached to an opposite end of the cables at the second end of the device. The plug may be configured to attach to another device to receive audio information for bone conduction.

The cables may be designed to provide a torque to the ear hooks and the BCTs such that the BCTs are pressed firmly against the user’s ears. The cables may protrude from the BCTs or portions of the ear hooks at a particular angle. For example, the cables may extend from the portion of the ear hooks that lay at the backs of the user’s ears. The angle of the cables may be straight down or may stick straight back, about 90 degrees from a straight down position, or may be an angle in between. The strain relief in the cables may cause the cables to extend more or less straight from the ear hooks before curving. The natural pull of gravity on the cable at this angle provides a torque on the ear hooks. The force provided may rotate the ear hooks into the user’s ears, thereby increasing the contact force between the BCTs positioned at the backs of the user’s ears or anywhere else away from the tops of the user’s ears.

The ear hooks of the audio device may be designed to ergonomically fit on a user’s ears. They may be C-shaped and worn such that the ear hook curves along the back of the user’s ears. When worn, the ear hooks rest on the top of the user’s ears and maintain substantially the same positions while worn. The ear hooks may be designed to be detachable from the audio device and interchangeable with ear hooks having different sizes and/or shapes.
Each BCT may be attached through an opening in an ear hook. The BCTs provide audio to the user by vibrating against the user’s cartilage and/or skull. Bone conduction requires an amount of contact force against the user in order for the vibration of the BCTs to reliably cause a same or similar vibration of the user’s cartilage and/or skull and, ultimately, the user’s inner ear, thereby providing clear audio output. The openings may be in the shape of the BCTs and be located where the ear hooks contact the back of the user’s ears or a higher or lower portion of the ears. For example, the openings may be anywhere within a range from the top of a user’s ears to 90 degrees down from the top of the user’s ears.

In the audio device, the BCTs may be enclosed in pods, which may be shaped to fit a user’s ears. A first portion of the pod may be configured to fit through the opening of an ear hook and contact the user’s ears. A second portion of the pod may be configured to house components of a BCT that may generate a vibration in response to received audio information. The vibration may translated to the user’s ear through the contact between the first pod and the user’s ear. The pods may also be sealed off in order to be water-proof or sweat-proof. The second portion of one or both pods may also include sensors, such as accelerometers.

The BCTs may be connected to one or more processors, a circuitry board, a battery, a memory, one or more sensors, a microphone, an amp, and/or other components. These components may be located remotely from the BCTs.

In some examples, a pendant may be attached to the cables at the second end of the audio device. A mass of the pendant may exert a force on the cable, thereby increasing the contact force between the BCTs and the user’s cartilage and/or skull. For example, the pendant may weigh between 10 and 20 grams. The pendant may include components such as one or more processors, a circuitry board, a battery, a memory, one or more sensors, a microphone, and/or
an amp that are connected to the BCTs. Other components may include user input controls, such as volume or play/pause controls, charging input, such input for a USB Type-C connector, and pairing mechanisms. Including these components in the pendant not only allows for a sleeker design, but also provides the mass to the pendant to provide the needed contact force for the BCTs. The components in the pendant may be connected to the BCTs or other components in the pods via wires running through the cables.

When the audio device is worn, the pendant may rest on a user’s chest with the first surface facing forward and the second surface lying against the user’s chest. The cables from the point where they are joined to the pendant may be vertical or nearly vertical, and the pendant may be more or less at the center of the user’s chest. The gravitational pull on the pendant therefore may provide a downward force on the cables, which translates the same force to the ear hooks and the BCTs, thereby pushing the BCTs more firmly onto the user’s cartilage or skill behind the user’s ears. The amount of force provided is enough to provide the contact necessary for clear audio output, but not an amount that would be uncomfortable to the user.

EXAMPLE SYSTEMS

As shown in FIGURE 1, a cable may be designed to provide a torque to an ear hook and a BCT such that the BCT is pressed firmly against the user’s ear. For example, ear hook 110 may include BCT 120. Cable 130 is attached to a portion of ear hook 110 that lies at the back of a user’s ear. The cable may protrude from the BCT or a portion of the ear hook at a particular angle. The angle of the cable may be straight down parallel a vertical axis or may stick straight out at about 90 degrees in relation to the vertical axis, or may be an angle in between. The vertical axis may be an axis running through the top of the user’s head down between the user’s feet, or the intersection of the coronal plane and the sagittal plane. In some examples, the vertical axis may be the direction of the force of gravity. The cable may
be angled with respect to the coronal plane, sagittal plane, and transverse plane of the user. In other words, the angle may extend not only behind the user but also to the side of the user as well. For example, when the ear hook including the BCT is worn by a user, the cable 130 extends from a portion of the BCT in the ear hook behind the user's ear near the mastoid at an angle between approximately 0 and 90 degrees with respect to a vertical axis. Angle 140 represents the angle at which cable 130 extends with respect to a vertical axis. According to one example, the angle 140 is approximately 45 degrees.

The angle of the cable in relation to the direction of gravity may also be based on an angle between the cable and a portion of the ear hook. For example, a portion of the ear hook 110 to which the cable connects may have a surface extending at least partially along a first plane, and the cable 130 may extend along a second plane for a predetermined distance, wherein the second plane is substantially perpendicular to the first plane. For example, the second plane may be within an angular distance of 45 degrees from a perpendicular position in relation to the first plane.

As shown in FIGURE 2A, a portion of the ear hook 110 may extend partially along first plane 210, and the cable 130 may be attached on the portion of the ear hook and may extend along second plane 220. The first plane 210 and the second plane 220 may intersect, the second plane 220 bisecting the first plane 210 to form two angles, lower angle 230 and upper angle 240. Angle 230 may be 60 degrees, or 30 degrees from a perpendicular position.

In FIGURE 2B, a portion of ear hook 110 may extend partially along first plane 250, and the cable 130 may be attached to the portion of the ear hook and may extend along second plane 260. The first plane 250 and the second plane 260 may intersect, the second plane 260 bisecting the first plane 250 to form two angles, lower angle 270 and upper angle 280. Angle 270 may be 80 degrees, or 10 degrees from a perpendicular position. As shown in FIGURES
2A and 2B, the angles of cable 130 in relation to the vertical axis remain between 0 to 90 degrees.

The cables may naturally hang from the angled position and curve based on the force of gravity or a mass of an object attached at the other end of the cable. The strain relief in the cable or additional material in the cable may cause the cable to extend more or less straight for a predetermined distance from the ear hooks before curving. For example, additional material may be a metal coil inside the cable. The predetermined distance may be one centimeter, or more or less, and may be in a direction substantially perpendicular to a surface of the ear hook at the point where the cable is attached. The natural pull of gravity on the cable at this angle provides a torque on the ear hooks. The force provided may rotate the ear hooks into the user’s ears, thereby increasing the contact force between the BCTs positioned at the backs of the user’s ears or anywhere else away from the tops of the user’s ears. It is therefore unnecessary to use adhesive to maintain contact of the BCT and/or the cable to the user or otherwise adhere the BCT and/or the cable to the user’s head. In addition, because of the angled position and curve of the cable, when compressive forces are applied to the cable, it will also prevent the ear hook from becoming unseated on the user’s ear. For example, when the user turns his head or when the pendant is resting on a surface and no longer applying a tensile force on the cable, the cable may return to its resting angled position as opposed to translating the compressive force to the ear hook or BCT.

As shown in FIGURE 3, a torque is produced as the force of gravity in the direction of arrow 310 pulls on cable 130. The torque causes ear hook 110 to be pushed into the user’s ear in a direction of arrow 320. BCT 120 is therefore also pushed against the user’s ear. A pendant or other object may be secured at the end of cable 130 such that an additional force is provided on cable 130 along with the force of gravity.
The ear hook may be designed to ergonomically fit on a user’s ear. As shown in FIGURE 3, ear hook 110 may be C-shaped and may be worn such that the ear hook 110 curves along the back of the user’s ear. The ear hook 110 may have an inner surface configured to rest against the user’s ear and an outer surface opposite the inner surface disposed away from the user’s ear when the ear hook 110 is worn. For example, the inner surface of the ear hook 110 may contact the crease where the auricle, or pinna, of the user’s ear connects to the user’s head. The inner surface may contact at least the user’s zygomatic process and the user’s mastoid process and/or other nearby portions of the temporal bone. The inner surface may also contact the cartilage of the user’s auricle. As mentioned previously, the ear hook rests on the top of the user’s ear and maintains substantially the same position while worn. The ear hook may be designed to be detachable from the BCT and interchangeable with ear hooks having different sizes and/or shapes.

The BCT may be attached through an opening in the ear hook. The opening may pass through the inner and outer surface of the ear hook. When the BCT is fitted in the opening, the BCT may be maintained in a fixed position in contact with the back of a user’s ear. For example, the BCT extending through the ear hook may contact the crease where the auricle, or pinna, of the user’s ear connects to the user’s head. In other examples, the BCT may directly contact the cartilage of the auricle of the user’s ear, or may be secured against the skull of the user.

The BCT may provide audio to the user by vibrating against the user’s cartilage and/or skull. For example, the BCTs may vibrate against the cartilage in the auricle, or pinna, of the user’s ear in order to provide audio to the user. The vibration against the cartilage may be the primary source of audio provided to the user provided from the device. The BCTs may additionally or alternatively vibrate against the mastoid process and other portions of the
temporal bone of the user’s skull to provide the audio. Bone conduction requires an amount of contact force against the user in order for the vibration of the BCT to reliably cause a same or similar vibration of the user’s cartilage and/or skull and, ultimately, the user’s inner ear, thereby providing clear audio output. The opening may be in the shape of the BCT and be located where the ear hook contacts the back of the user’s ears or a higher or lower portion of the ears. For example, the openings may be anywhere within a range from the top of a user’s ears to 90 degrees down from the top of the user’s ears.

The BCT may be enclosed in a pod, which may be shaped to fit against a user’s ear, such as against the crease where the auricle of the user’s ear connects to the user’s head. A first portion of the pod may be configured to fit through the opening of an ear hook such that a surface of the pod may pass through the inner surface of the ear hook and may contact the user’s ears. A second portion of the pod may be configured to house components of a BCT that may generate a vibration in response to received audio information. The vibration may be translated to the user’s ear through the contact between the first pod and the user’s ear. The pod may also be sealed off in order to be water-proof or sweat-proof. The second portion of the pod may also include sensors, such as accelerometers. In some examples, the pod may be generally spherical in shape and may be rotated when inserted in the ear hook similar to a ball and socket.

The cable may be connected to a portion of the ear hook or the BCT. If connected to a portion of the ear hook, the cable may be attached at any portion of the outer surface of the ear hook. For example, the cable may be attached at a top of the ear hook, travel along the curvature of the outer surface of the ear hook for a length, and extend from the ear hook at a lower point of the ear hook. In another example, the cable may be attached at a point of the
ear hook and extend from the attachment point without traveling along the curvature of the ear hook.

If connected to the BCT or the pod enclosing the BCT, the cable may extend from the opening in the ear hook provided for the BCT or the pod. The cable may extend from the BCT or pod in a direction towards the outer surface of the ear hook, or away from the surface of the BCT or pod that contacts the user's head. The BCT may be inserted in and attached to the opening of the ear hook at different angles, thereby varying the angle of the cable as well. According to another example, the cable may be moldable to extend at different angles. For example, a length of the cable at the end attached to the ear hook or BCT may include a malleable metal or other deformable substance, allowing an angle of the cable with respect to the ear hook to be adjusted and readjusted by a user after fabrication.

An audio device may include at least one ear hook, at least one BCT, and at least one cable having the configuration described above. In some examples, as shown in FIGURE 4, audio device 400 may include two ear hooks 110, 410 at a proximal end of audio device 400, each ear hook shaped to curve around at least a portion of the user's ear. Each ear hook may be configured to support a BCT 120, 420, and a cable 130, 430 may extend from each BCT. Cables 130, 430 may join together at a point 440, forming a “Y” shape. The point at which the cables 130, 430 join may be adjustable for the comfort of the user. A plug may be included in the device 400 and attached to an opposite end of cables 130, 430 at the second end of the device 400. The plug may be configured to attach to another device to receive audio information for bone conduction. The audio device 400 may alternatively have only one ear hook and one BCT connected to a pendant via a cable.
The BCTs 120, 420 may be connected to one or more processors, a circuitry board, a battery, a memory, one or more sensors, a microphone, an amp, and/or other components. These components may be located remotely from the BCTs 120, 420.

Alternatively, the cables may connect to a pendant at the second end. As shown in FIGURE 4, Pendant 450 may be attached to cables 130, 430 at the second end of the audio device 400. A mass of pendant 450 may exert an additional force on cables 130, 430, thereby increasing the contact force between the BCTs 120, 420 and the user’s cartilage and/or skull. For example, the pendant may weigh between 10 and 20 grams. The gravitational pull on the pendant may provide the additional downward force on the cables, which translates the same force to the ear hooks and the BCTs, thereby pushing the BCTs more firmly onto the user’s cartilage or skull behind the user’s ears. The amount of force provided is enough to provide the contact necessary for clear audio output, but not an amount that would be uncomfortable to the user. The additional force on cables 130, 430 may be in the direction of arrows 460, 470.

The pendant may include components such as one or more processors, a circuitry board, a battery, a memory, one or more sensors, a microphone, and/or an amp that are connected to the BCTs. Other components may include user input controls, such as volume or play/pause controls, charging input, such input for a USB Type-C connector, and pairing mechanisms. Inclusion of these components in the pendant not only allows for a sleeker design, but also provides the mass to the pendant to provide the needed contact force for the BCTs. The components in the pendant may be connected to the BCTs or other components in the pods via wires running through the cables.

When the audio device is worn, the pendant may rest on a user’s chest. The pendant may have a first surface and a second surface that are substantially parallel to one another. The
first surface 452 of pendant 450 may face forward and the second surface 454 of pendant 450 may lie against the user’s chest. The cables from the point where they are joined to the pendant may be vertical or nearly vertical, and the pendant may be more or less at the center of the user’s chest.

The features described above provide for a bone conduction audio device that may be worn comfortably by a user for long periods of time. The simple hook design of the ear hooks coupled with the angle at which the cables extend from the ear hooks does not require any clipping or clamping as required by other designs, such as those that wrap around and clamps down on a user’s head using a spring force. Unlike, clipping or clamping designs, which may cause discomfort to a user’s head over time, the features of the audio device described above provide the amount force that is needed in the right location to allow the user to hear the audio output clearly. The features also provide an audio device that is adjustable and therefore may be used by different users or adjusted for comfort.

Unless otherwise stated, the foregoing alternative examples are not mutually exclusive, but may be implemented in various combinations to achieve unique advantages. As these and other variations and combinations of the features discussed above can be utilized, the foregoing description of the embodiments should be taken by way of illustration rather than by way of limitation. In addition, the provision of the examples described herein, as well as clauses phrased as “such as,” “for example,” “including” and the like, should not be interpreted as limiting the subject matter to the specific examples; rather, the examples are intended to illustrate only one of many possible embodiments. It is therefore to be understood that numerous modifications may be made to the illustrative embodiments and that other arrangements may be devised without departing from the spirit and scope of the present disclosure.
FIGURE 3
FIGURE 4