

Transducer Apparatus for High Speech Intelligibility in Noisy Environments

Background of the Invention

1. Field of the Invention

Embodiments of the invention generally relate to a transducer apparatus embodying a vibration-sensing transducer placed on the non-boney part of the user's head, including the bucca (cheek) and under-chin, to improve speech intelligibility.

2. Description of the Related Art

Communications via acoustical microphones in noisy (low acoustical signal-to-noise ratio) environments are challenging. A vibration-sensing transducer, such as an accelerometer, also known as a bone conduction microphone or vibration-sensing microphone, is often used. It potentially offers high speech- intelligibility as it does not sense the environmental acoustical sounds but senses the vibrations of the surface where it is placed on.

Accelerometer manufacturers, e.g. Knowles Electronics, recommend that the accelerometer be placed "on the throat, or touching a boney part of the head". The prior-art placement of the accelerometer is always on either the boney or the cartilaginous parts of the user's head, i.e.,

- (a) On the throat, e.g., Ingalls's invention in US 4607383A;
- (b) On top of the skull, e.g., Santori's invention in US787641A;
- (c) On the mastoid or temple, e.g. Nakajima, et al.'s invention in US20050244020 A1 and Kimura's invention in US20100172519A1; and
- (d) In the concha and/or ear canal, e.g., Konomi's invention in EPO 005009851 A1, and Dusan et al.'s invention in US93635996.

In short, the prior-art placement of vibration-sensing transducers is strictly either on the boney (skull, mastoid or temple) or cartilaginous (throat, concha or ear canal) parts of the head. The speech intelligibility of the vibration-sensing transducer sensing vibrations from a

user's voice from these prior-art placements is unsatisfactory for two reasons. First, voiced sounds (vowels) are strongly sensed (strong vibrations) and the unvoiced sounds (fricatives) are weakly sensed (weak vibrations). Second, the transients of the sensed sounds are distorted, often resulting in poorly enunciated speech, often described as :slurred speech~, :mumbled speech~, :dysarthia~, etc.

Put simply, a high speech-intelligibility vibration-sensing transducer apparatus for noisy environments remains unavailable.

SUMMARY OF THE INVENTION

Generally, the invention relates to providing high speech-intelligibility preferably from a vibration-sensing transducer (e.g., an accelerometer or vibration-based microphone) adapted to be placed on the non-boney and non-cartilaginous part of the user's head. Specifically, the vibration-sensing transducer is placed on the non-boney and non-cartilaginous, i.e., the fleshy, part of the head of the user - either on the bucca (also known as the cheek or the mala) or under the chin (under-chin), where vibrations of both voiced and unvoiced human speech are adequately sensed and the transients are largely undistorted. For sake of brevity, the vibration-sensing transducer will be termed :accelerometer~ henceforth, although these terms may be used interchangeably.

The accelerometer may be replaced by an acoustical microphone, such as an electret microphone, whose input acoustical port is adapted to be placed on the said non-boney and non-cartilaginous part of the human head. The adaption of the input acoustical port of the acoustical microphone includes an arrangement such that it is fully closed, i.e., sealed where the input acoustical port is covered by a membrane or the input acoustical port is covered by the skin of the said non-boney and non-cartilaginous part of the human head. This fully closed input port microphone, termed :enclosed microphone~ herein, prevents the environmental acoustical sounds from being sensed by the acoustical microphone. The enclosed acoustical microphone when placed on the said non-boney and non-cartilaginous part of the human head would sense the vibrations thereon.

In the embodiment of the invention, there are several methods for obtaining high speech-intelligibility from an accelerometer or enclosed microphone adapted to be placed on the fleshy part of the user's head, specifically his bucca or his under-chin. The methods described herein include seven configurations, some with several variations, ranging from simply adhering the accelerometer or enclosed microphone, to different types of earsets (earphones-sets), headsets (headphone-sets) and helmets; and combinations of accelerometer and acoustical microphone outputs. The accelerometer or enclosed microphone may be used in conjunction with a miniature loudspeaker that may be placed in/on/over the pinna as a earbud, earphone, headphone or within a helmet as part of a communications earset, headset, or helmet.

In the description of the six configurations of the embodiment of the invention, the accelerometer refers to either the accelerometer or/and the enclosed microphone - they function as a vibration-sensing microphone. The seventh configuration of the embodiment of the invention refers to the enclosed microphone.

This summary does not describe an exhaustive list of all aspects of the present invention. It is anticipated that the present invention includes all methods, apparatus and systems that can be practiced from all appropriate combinations and permutations of the various aspects in this summary, as well as that delineated below. Such combinations and permutations may have specific advantages not specially described in this summary.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments of the invention are illustrated by way of example and not by way of limitation in the figures of the accompanying drawings in which like references indicate similar elements. It should be noted that references to "an" or "one" embodiment of the invention herein are not necessarily to the same embodiment, and they mean at least one. It should also be noted that references to "he" and "his" are gender-neutral and may be replaced by "she" and "her".

FIG. 1 shows the prior-art placement of an accelerometer - either on the boney part (top of skull, mastoid or temple) or on/in cartilaginous part (throat, concha or ear canal) of the head.

FIGs. 2(a) and 2(b) respectively shows the anterior view and lateral view of a human head, illustrating the non-boney and cartilaginous parts where an accelerometer may be placed in accordance with the embodiment of the invention.

FIG. 3 shows a thin earhook-type earset embodying a pair of earhooks, back headband, and the integration of an accelerometer, and in accordance with the embodiment of the invention. The earhook-type earset may be worn as is or under a helmet where most parts of the earset are sandwiched between the user's head and helmet.

FIG. 4(a), 4(b) and 4(c) show three different variations of a earset with the integration of an accelerometer, and in accordance with the embodiment of the invention. They are respectively without a earhook or headband, with a earhook, and with a headband.

FIGs. 5(a) and 5(b) respectively shows two helmets in accordance with the embodiment of the invention where the accelerometer, in the first helmet, is embedded into the section of the helmet that covers the user's bucca, and in the second helmet, embedded in its straps.

FIGs. 6(a), 6(b) and 6(c) show headsets having two earcups that is generally used as a hearing protector (e.g., ear muff), communications headset, aviation headset, and the like, and are in accordance with the embodiment of the invention. The three variations respectively integrate an accelerometer into an arm mounted on one of the earcups, into an arm protruding from one earcup near the interface of the earpad, and embedded in the extended part of the earpad.

FIGs. 7(a), (b) and (c) show three systems, in accordance with the embodiment of the invention, comprising in various variations, an accelerometer, an acoustical microphone, a sensor, a switching means, signal conditioners, and signal processor. In the first system, the switching means may be mechanical or automatic to select the accelerometer or the acoustical microphone, or a combination thereof. In the second system, the output of the accelerometer and the acoustical microphone may also be signal-conditioned in different ways. In the third system, the output of the accelerometer is connected to the input of a signal processor whose output is in turn connected to the input of an external electronic

device (e.g., 2-way radio or smartphone). The signal processor is powered from the input of the external electronic device.

FIGs. 8(a) and 8(b) respectively show an acoustical microphone with its acoustical input being closed (sealed, thereby obtained an enclosed microphone), and the enclosed microphone adhered to an adhesive patch. The enclosed microphone serves as a replacement of the accelerometer, and in accordance with the embodiment of the invention.

In FIGs. 2-8, in accordance with the embodiment of the invention, the accelerometer or enclosed microphone is adapted to touch or press against the user's bucca or under-chin.

DETAILED DESCRIPTION

Numerous specific details are set forth in the following descriptions. It is however understood that embodiments of the invention may be practiced with or without these specific details. In other instances, circuits, structures, methods and techniques that are known do not avoid obscuring the understanding of this description. Furthermore, the following embodiments of the invention may be described as a process, which may be described as a flowchart, a flow diagram, a structure diagram, or a block diagram. The operations in the flowchart, flow diagram, structure diagram or block diagram may be a sequential process, parallel or concurrent process, and the order of the operations may be re-arranged. A process may correspond to a technique, methodology, procedure, etc.

FIG. 1 depicts the prior-art placement of an accelerometer as a contact microphone where it is strictly placed either on the boney part of the head 10 (specifically the top of skull 11, mastoid 12 or temple 13) or on the cartilaginous part of the head 10 (specifically, the throat 14, or in the concha or ear canal 15). The accelerometer senses the vibration from the surface of these boney or cartilaginous parts of the human head 10. In particular, note that prior-art placements are never on the fleshy part of the human head.

FIG. 2(a) and 2(b) depict an embodiment of the invention where an accelerometer adapted to be placed on the non-boney and non-cartilaginous part of the user's head 10 viewed respectively from the anterior and lateral perspective. The specific placement of the

accelerometer is on his bucca 21 on either side of his face or under-chin 22. As the accelerometer touches or presses against his bucca 21 or under-chin 22, the accelerometer senses the vibrations arising from the user's voiced and unvoiced sounds, thereby providing high speech-intelligibility. There are several ways for the aforesaid adaption and these are described as variations of this embodiment of this invention.

FIG. 2(a) depicts the first configuration of the embodiment of the invention where the accelerometer 1 is placed on the bucca 21 on the right (or left) side of the user's face. The accelerometer 1 may alternatively be placed on the under-chin 22 of the user's face as depicted in FIG. 2(b). An adhesive material or a double-sided tape may be applied on one surface of accelerometer 1 such that when it is placed onto the user's bucca 21 or under-chin 22, it remains in said position. Alternatively, the accelerator 1 may be placed under a larger sticky patch, similar to a plaster whose adhesive part extends beyond the accelerator 1, where the patch with the accelerometer 1 is placed on the bucca 21 or the under-chin of the user; see FIG. 8(b) later. This means of adapting the accelerometer 1 to be placed either on the bucca 21 or the under-chin 22 of the user is preferably used in applications where a small factor is required, e.g., in applications where the user desires as little obstruction as possible on his face, such as when wearing a gas mask, etc.

FIG. 3 depicts the second configuration of the embodiment of the invention involving an earset 30 comprising accelerometer 1 mounted on one end of arm 31. This earset resembles that used by speakers making presentations where an acoustical microphone is used in place of accelerometer 1. The other end of arm 31 is attached to left earhook 33 as shown on arm mount 36 or it may be (not shown) attached to the right earhook 34 on arm mount 37. The left earhook 33 is connected to the right earhook 34 by the back headband 35. The user uses the earset 30 by placing left earhook 33 over his left pinna 24, placing right earhook 34 over his right pinna 23, and with back headband 35 placed around the back base of his head. The arm 31 may be a flexible pre-formed arm or it may be a gooseneck-like arm that may be bent, such that the accelerometer 1 touches or presses against the bucca 21 or the under-chin 22 of the user.

The frame of earset 30, including left earhook 33, right earhook 34 and back headband 35, is preferably thin. Being thin, the user may wear a helmet while wearing this earset 30, i.e., the helmet is worn over the earset 30 where the left earhook 33, right earhook 34 and part of the

back headband 35 will be sandwiched between the user's head 10 and the helmet. Depending on the helmet type, part or all of the arm 31 and the accelerometer 1 may also be sandwiched between the user's face and the helmet. In cases where the helmet frame does not cover the bucca 21 of the user, a part of arm 31 extends beyond the helmet and the accelerometer 1 may be arranged such that the accelerometer 1 touches or presses against the bucca 21 or the under-chin 22 of the user. The earset 30 may also include a miniature loudspeaker (not shown), such as a earbud or earphone. The accelerometer 1 and loudspeaker may be connected to an electronic communications device such as a 2-way radio, smartphone, etc.

FIGs. 4(a) - 4(c) depict the third configuration of the embodiment including an accelerometer 1 that is adapted to be placed such that it touches or presses against the bucca 21 or the under-chin 22 of the user. This configuration involves a number of possible variations in the form of different earsets or headsets. These different variations may involve a miniature loudspeaker that may be in the form of a earphone/earbud that is placed in the ear canal/concha 15 of the user or in the form of a headphone that is placed on his pinna 23 or 24.

FIG. 4(a) depicts the first variation of the third configuration where the earset 40 embodies an accelerometer 1, a earphone 42 and an arm 41 connecting the accelerometer 1 and the earphone 42. The earphone 42 may be placed into the concha or ear canal 15 of the user. The accelerometer 1 is placed by means of the arm 41 such that it touches or presses against the bucca 21 or the under-chin 22 of the user. For example, when the user wears earset 40 under his helmet, the accelerometer 1 is arranged to touch or press against the bucca 21 of the user. Alternatively, without the helmet, the accelerometer 1 may be adhered to the bucca 21 or the under-chin 22 of the user by means of an adhesive or double-sided tape. Also alternatively, the user may physically place (or press) the accelerometer 1 on his bucca 21 or his under-chin 22 when desired, for example when he wishes the accelerometer 1 to pick up his voice vibrations.

FIG. 4(b) depicts the second variation of the third configuration where the earset 50 embodies an accelerometer 1, a earphone 52, a earhook 53, and an arm 51 connecting the accelerometer 1 and the earphone 52 or the earhook 53. The earphone 52 may be placed into the concha 15 of the user or in the form of a headphone that is placed on/over the pinna 23 or 24 of the user. The earhook 53 may also be in the form that completely encloses the back of the pinna 23 or 24, thereby providing more secure placement of the earset 50 than that depicted in FIG. 4(b).

The accelerometer 1 is to be placed, by means of the arm 51, such that it touches or presses against the bucca 21 or the under-chin 22 of the user. For example, when the user wears earset 50 under his helmet, the accelerometer 1 is arranged to touch or press against the bucca 21 of the user. Alternatively, without the helmet, the earhook 53 placed over and under the pinna 23 or 24 may provide sufficient anchorage for the accelerometer 1 to touch or press onto the bucca 21 or the under-chin 22 of the user. Should the anchorage be insufficient, the user may physically place (or press) the accelerometer 1 on his bucca 21 or under-chin 22 when desired.

FIG. 4(c) depicts the third variation of the third configuration where the headset 60 embodies an accelerometer 1, a headphone 62, an over-the-head band 63, and an arm 61 connecting the accelerometer 1 to either the headphone 62 or the over-the-head band 63. The headphone 62 is preferably placed on/over the pinna 23 or 24 of the user, thereby covering his concha or ear canal 15. The accelerometer 1 is placed, by means of the arm 61, such that it touches or presses against the bucca 21 or the under-chin 22 of the user. The over-the-head band 63 and headphone 62 would provide sufficient anchorage for the accelerometer 1 to touch or press the bucca 21 or the under-chin 22 of the user. Should the anchorage be insufficient, the user may physically place (or press) the accelerometer 1 on his bucca 21 or under-chin 22 when desired. The over-the-head band 63 may also be in the form of an over-the-neck band. The other end of the headband 64 may be another headphone or simply a pad that sits on or near the right pinna 24 of the user.

FIG. 5(a) and 5(b) depict the fourth configuration of the embodiment of the invention where the accelerometer 1 is either embedded into the helmet 70 or in the straps 81 of helmet 80 or helmet 70 (not shown) respectively. The accelerometer 1 is adapted to be placed such that it touches or presses against the bucca 21 or the under-chin 22 of the user. Helmet 70 may further embody a loudspeaker (not shown) that is preferably physically flat such that when the user wears the helmet 70, the loudspeaker is placed over the user's pinna 23 or 24. In the case of helmet 80, it may also embody a loudspeaker that is also preferably physically flat such that it is placed in the strap or under the helmet 80 such that the loudspeaker is close to the pinna 23 or 24 of the user.

FIG. 5(a) depicts the first variation of the fourth configuration where the accelerometer 1 is embedded into the helmet 70. This would largely be appropriate only if the frame of the

helmet 70 covers at least part of the bucca 21 of the user and helmets types such as the Full-Face, Open-Face, Modular, Off-Road, and Dual-Sport may be appropriate; some Open-Face helmets may also be appropriate. For the helmet to be appropriate, it is necessary for the frame of the helmet 70 to cover at least part of bucca 21 of the user as a means for the accelerometer 1 to be placed such that it touches or presses against the bucca 21 of the user when he wears the helmet 70. The helmet 70 may also embody a flat loudspeaker (not shown) such that it is placed near or over the pinna of the user when he wears the helmet 70.

FIG. 5(b) depicts the second variation of the fourth configuration where the frame of the helmet 80 does not cover the bucca 21 of the user. Examples of such helmets include the Half Helmet and some Open Face helmets. In this second variation, the accelerometer 1 is placed within the straps 81 of the helmet 80 and there are two preferred locations. The first preferred location is the location 82 in the straps 81 where the accelerometer 1 touches or presses against the bucca 21 of the user when the user wears the helmet 80 and straps the straps 81 of the helmet 80. The second preferred location is the location 83 in the straps 81 where the accelerometer 1 touches or presses against the under-chin 22 of the user when the user wears the helmet 80 and straps the straps 81 of the helmet 80.

Further to the placement of the accelerometer 1 into the straps 81 of helmet 80 in FIG. 5(b), the accelerometer 1 can likewise be placed into the straps (not shown) of helmet 70 in FIG. 5(a). The placement in this case is preferably in the bottom of the straps similar to the location 83 in the straps 81 of helmet 80 such that when the user straps the straps of his helmet 70, the accelerometer 1 touches or presses against the under-chin 22 of the user.

FIG. 6(a), 6(b) and 6(c) depict the fifth configuration of the embodiment of the invention involving a headset 90 or 100 or 110 where accelerometer 1 is adapted to be placed such that it touches or presses against the bucca 21 or the under-chin 22 of the user. The headset having two earcups, right earcup 91 with earpad 92 and left earcup 93 with earpad 94, is generally used as a hearing protector (e.g., ear muff) for communications, as an aviation headset, communications headset, and the like. When the headset 90, 100 or 110 is worn by the user, the earpad 92 or 94 makes contact with the user's face around his pinna 23 or 24. The earcup 91 with earpad 93 and earcup 93 with earpad 94 enclose the entire pinna 23 and 24 of the user. Each earcup 91 or 93 may embody a loudspeaker as part of a communications headset.

FIG. 6(a) depicts the first variation of the fifth configuration involving a headset 90 where one end of the arm 97 may be attached to or pivoted at pivot 98 of the casing of the earcup 93, and the other extension arm 96 (of arm 97) that extends beyond the earcup 90 embodies an accelerometer 1. The accelerometer 1 is adapted to either touch or press against the bucca 21 or the under-chin 22 of the user. This may include having the arm in a form of a two-part arm 97 and 96 as depicted in FIG. 6(a) or a gooseneck or the like that may be bent accordingly. The accelerometer 1 may be connected by a wire 99 as part of the communications headset 90.

FIG. 6(b) depicts the second variation of the fifth configuration involving a headset 100 where a short arm 101 may protrude out of the earcup 91 near the interface between the earcup 91 and the earpad 92. In this fashion, the arm 101 is considerably shorter than the combined length of arms 96 and 97 of headset 90 in FIG. 6(a), and is hence less obstructive and more easily manipulated. The far end part of arm 101 that extends beyond the earcup 91 embodies an accelerometer 1. By means of this arm 101, the accelerometer 1 is adapted to either touch or press against the bucca 21 or under-chin 22 of the user.

FIG. 6(c) depicts the third variation of the fifth configuration involving a headset 110 where an accelerometer 1 is embedded into the extended earpad part 112 of earpad 92 of earcup 91. This extended earpad part 112 of earpad 92 is supported by extended earcup part 111 of earcup 91. Unlike the headsets 90 and 100 in FIGs. 6(a) and 6(b) respectively, there is no arm in headset 110. The extended earpad part 112 that sits around the temple of the user is an enlarged or extended such that at least a part of the extended part 112 of earpad 92 sits on the bucca 21 of the user. The accelerometer 1 is embedded in this extended earpad part 112 of the earpad 92 such that it senses the vibrations on the bucca 21 of the user.

FIGs. 7(a) and 7(b) depict the sixth configuration of the embodiment of the invention involving a system that includes an accelerometer 1 and an acoustical microphone 121, and a switching means 122 that selects either the accelerometer 1, the acoustical microphone 121 or both, or the switching can be adapted such that either the accelerometer 1, the acoustical microphone 121 or both is disabled. When this sixth configuration of the embodiment of the invention is used in a communications device such as a smartphone or 2-way radio, the switching connects either the accelerometer 1, acoustical microphone 121 or both as the

external microphone to the communications device, or they be either or both disabled. The accelerometer 1 is adapted to be placed such that it touches or presses against the bucca 21 or the under-chin 22 of the user as in accordance with the embodiment of the invention. The acoustical microphone 121 may be placed anywhere, preferably adapted to be placed close to the mouth of the user. This placement includes the acoustical microphone 121 placed physically close to the accelerometer 1, and they collectively placed near or touching/pressed on the bucca 21 and near or touching/pressed on the under-chin 22 of the user. This placement includes any of that depicted in FIGs. 3-6 herein. FIG. 7(c) depicts this sixth configuration where there is no switching, i.e., the embodiment of the invention involves system 170 where the accelerometer 1 is connected to the signal processor 160 which is in turn connected to electronic device 150, e.g. a communications device such as a smartphone or 2-way radio. The signal processor 160 is powered from the communications device 150.

FIG. 7(a) depicts the first variation of the sixth configuration embodying system 120. The outputs of accelerometer 1 and acoustical microphone 121 are connected to switching means 122. The output 123 of the switching means 122 is the transducer (either accelerometer 1, or microphone 121, or a combination thereof) output of the system that is in turn connected to an electronic device, e.g., 2-way radio or smartphone. The switching means 122 is mechanical and may be a single-pole double-throw switch where the user manually selects either the accelerometer 1 or the acoustical microphone 121. The accelerometer 1 may be preferably selected to be used in a noisy environment where the accelerometer 1 is arranged such that it touches or presses against the user's bucca 21 or under-chin 22. The acoustical microphone 121 may be selected to be used in a quiet environment or where the environmental noise is tolerable.

In the second variation, the switching means 122 is automatic where there is a sensor 124 that detects when the accelerometer 1 effectively touches the human skin. There are several sensors that can sense this, including capacitive sensors and mechanical switches such as microswitches. When the sensor 124 detects that the accelerometer 1 touches or presses against the human skin, the switching means 122 will select the accelerometer 1. Otherwise, the switching means 122 will select the acoustical microphone 121.

Further, in this second variation, the accelerometer 1 and the acoustical microphone 121 may be enclosed in the microphone housing of the ubiquitous earphone set that embodies a pair of

earphones and a microphone. The said microphone housing further embodies the sensor 124. In environments where the environmental noise is low or tolerable, the microphone housing may be placed away from (i.e., not touching) the user's head 10 (or skin). With this sensed by the sensor 124, the switching means 122 selects the acoustical microphone 121. When the environmental noise becomes intolerable, the user pushes microphone housing to touch his skin of his head, preferably against his bucca 21 or under-chin 22. With the sensor sensing the skin contact, the switching means 122 selects the accelerometer 121 which would sense the vibrations thereon according to an embodiment of the invention.

In a variation to this second variation, the connected electronic device, e.g., 2-way radio or smartphone, may embody computation means to ascertain if the (acoustical) environment is noisy from the signals picked up by the acoustical microphone 121. If it is noisy, the acoustical microphone 121 is disconnected and the accelerometer is selected. The computation means also be embodied in the switching means 122.

In the third variation, the switching means 122 in said second variation may be overridden by the user.

In the fourth variation, the outputs of the both the accelerometer 1 and the acoustical microphone 121 are combined, and if necessary individually weighted, as the output 123 of the switching means 122. The individual weighting may involve either the output of the accelerometer 1 or the acoustical microphone 121 having more than 50% of the combined output of the system. For example, in a quiet, moderately noisy and noisy environment, the ratio of the output between the accelerometer 1 and acoustical microphone 121 may respectively be 0:100, 60:40 and 100:0. This weighting may be obtained by means of an attenuators or amplifiers with different gains.

FIG. 7(b) depicts the fifth variation embodying system 130. In system 130, the output of the accelerometer 1 is conditioned by signal conditioner 131, and the output of acoustical microphone 121 is conditioned by signal conditioner 132. In general, the electrical signal output levels of the accelerometer 1 and the acoustical microphone 121 are different, e.g. for the same sound pressure level of the user's voice, the acoustical microphone 121 is higher. By means of the different signal conditioning in signal conditioners 131 and 132, the

electrical output of the accelerometer 1 and acoustical microphone 121 may be adjusted accordingly as the inputs to switching means 122.

In the sixth variation of the sixth configuration, the signal conditioning in signal conditioners 131 and 132 may further include other signal conditioning parameters other than level adjustments (or amplifications), including frequency shaping of the output of the accelerometer 1 and the acoustical microphone 121 outputs. For example, it may be desirable to shape the magnitude of the frequency response of the accelerometer 1 so that its magnitude frequency response is similar to that of the acoustical microphone 121.

Fig. 7(c) depicts the seventh variation of the sixth configuration where in system 170, no switching is involved, i.e., there is only one transducer, the accelerometer 1. Here, the output 11 of the accelerometer 1 is connected to the input 161 of signal processor 160. The output 162 of the signal processor 160 is connected to the input 151 of the electronic device 150. An example of the input 151 of the electronic device 150 is the microphone input of a smartphone or 2-way radio. A typical microphone input has a voltage bias and signal processor 160 derives its power from this voltage bias, and by this means provides signal processing functionality. For example, by utilizing the bias voltage, speech processor 160 can amplify the voltage of the output 11 of accelerometer 1, i.e., the output 162 of speech processor 160 is an amplified voltage of the output 11 of accelerometer 1. The design of such amplifiers is well known to one skilled in the art of microphone amplifiers.

There are also further variations to FIG. 7(c). For example, speech processor 160 may embody more than one input and the speech processor 160 can perform electronic switching, similar to the function of switching means 122 in FIGs. 7(a) and (b). The speech processor 160 may also embody other signal processing functions.

Figures 8(a) and 8(b) depicts the seventh configuration of the invention where the accelerometer 1 is replaced by an acoustical microphone 121 whose input acoustical port 141 is closed (sealed) - henceforth, termed the "enclosed microphone" 1210. The acoustical microphone 121 may be of various types, including the inexpensive condenser electret microphone with a subminiature form-factor. Being inexpensive, the enclosed microphone 1210 may be disposable for hygiene reasons, ease of replacement, etc.

In FIG. 8(a), acoustical microphone 121 has an input acoustical port 141. To close (seal) the input acoustical port 141, a membrane 142 is placed over the top surface (the surface having the input acoustical port 141) of acoustical microphone 121. This closing of the input acoustical port 141, hence sealing the input acoustical port 141, by the membrane 142 may be facilitated by the back surface 143 of membrane 142 having an adhesive. The back surface 143 of membrane 142 may be adhered to the top surface of the microphone 121 in the direction pointed to by arrow 144. As an embodiment of the invention, the top surface of microphone 121 with the sealed input acoustical port 141 is placed or pressed against the user's bucca 21 or his under-chin 22. The membrane 142 is preferably non-rigid so that it is compliant to vibrations, thereby allowing the microphone 121 to sense vibrations. This compliance may be facilitated with a large-sized input acoustical port 141.

The closing or sealing of the input acoustical port 141 of acoustical microphone 121 may also be sealed if the top surface of microphone 111 is properly placed against the bucca 21 or under-chin 22 of the user. This may be facilitated by placing the base (145 in FIG. 8(b)) of the acoustical microphone 121 on a large adhesive patch (146 in FIG. 8(b)) and adhering the large adhesive patch 146 on the user's bucca 21 or under-chin 22.

In FIG. 8(b), the enclosed microphone 1210 - an acoustical microphone whose input acoustical port 141 is sealed - is placed on a patch 146 whose top surface 147 is adhesive. This placement involves having the base 145 of the enclosed microphone 1210 placed preferably near the center 148 of the patch 147 as indicated by arrow 149. With the enclosed microphone 1210 adhered to patch 146, the patch may thereafter be placed on/adhered to the user's bucca 21 or his under-chin 22 in accordance to an embodiment of the invention. Preferably, the membrane 141 touches or presses against the user's bucca 21 or his under-chin 22, and being compliant to vibrations, the sealed microphone 1210 senses the vibrations thereon.

In all aforesaid configurations and variations, the accelerometer 1 or enclosed microphone 1210 is adapted to be placed to touch or press against the user's bucca 21 or his under-chin 22. The accelerometer 1 or enclosed microphone 1210 may be adapted to have direct contact with the skin of the user's bucca 21 or his under-chin 22, or encapsulated in other material(s) or placed against other materials that may in turn have contact with the skin of the user's bucca 21 or his under-chin 22. The materials may be provide mechanical vibration

amplification such as an air bubble to increase the mechanical vibrations arising from the user's voice on his bucca 21 or under-chin 22.

The aforesaid descriptions are merely illustrative of the principles of this invention and many configurations, variations, and various modifications can be made by those skilled in the art without departing from the scope and spirit of the invention. The foresaid embodiments may be designed, realized and implemented individually or in any combination or permutations.

Patent Citations

Cited Patent	Filing Date	Publication Date	Applicant	Title
US 4607383 A	Aug 18, 1983	19 Aug 1986	Robert Ingalls	Throat microphone
US 3787641 A	5 Jun 1972	22 Jan 1974	Santori C	Bone conduction microphone assembly
US 20050244020 A1	1 Sep 2003	3 Nov 2005	Y oshitaka Nakajima, Makoto Shozakai	Microphone and communication interface system
US 20100172519 A1	8 Dec 2009	8 Jul 2010	Tominori Kimura	Bone-conduction microphone built-in headset
US 5282253 A	26 Feb 1991	25 Jan 1994	Masao Konomi	Bone conduction microphone mount
US 9363596	15 Mar 2013	7 Jun 2016	Sorin V Dusan, Aram Lindahl, Esge B. Anderson	System and method of mixing accelerometer and microphone signals to improve voice quality in a mobile device