MEANS FOR AIDING HEARING

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FIG. 1

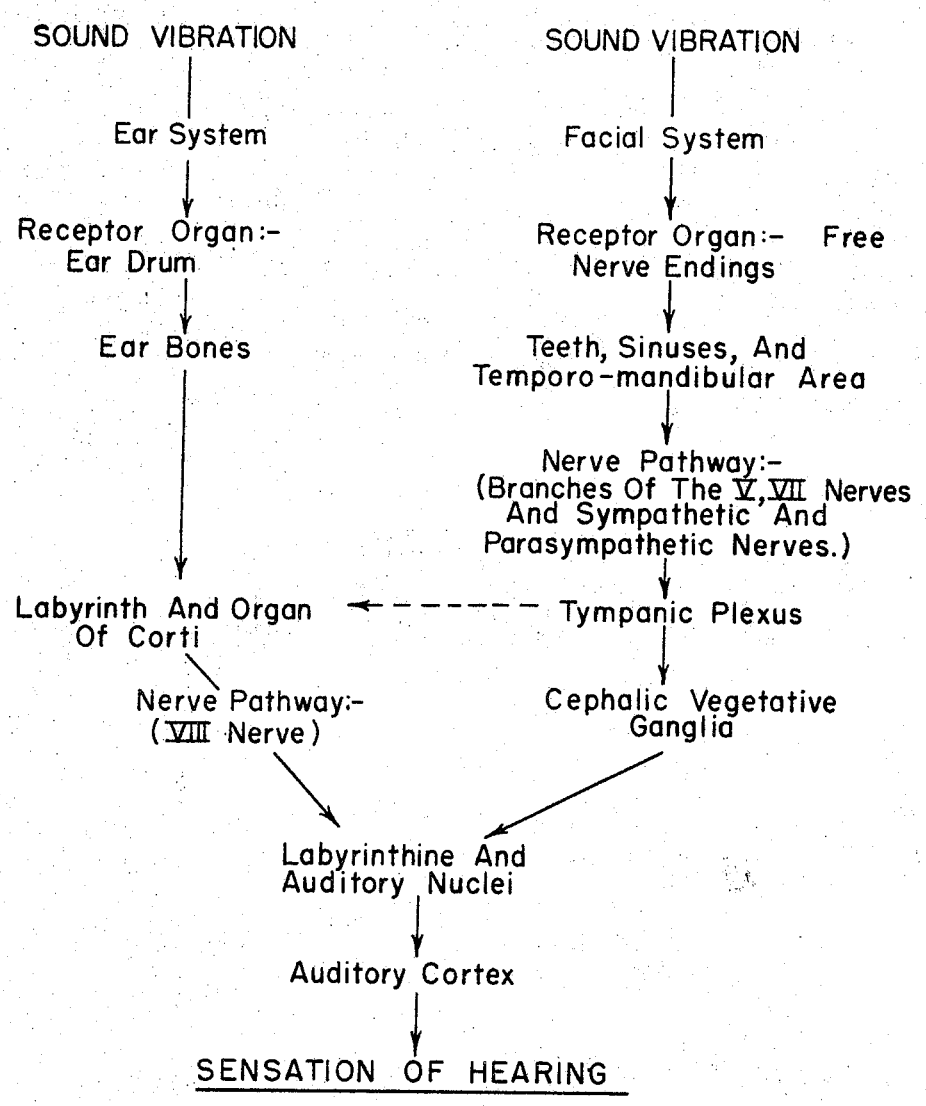

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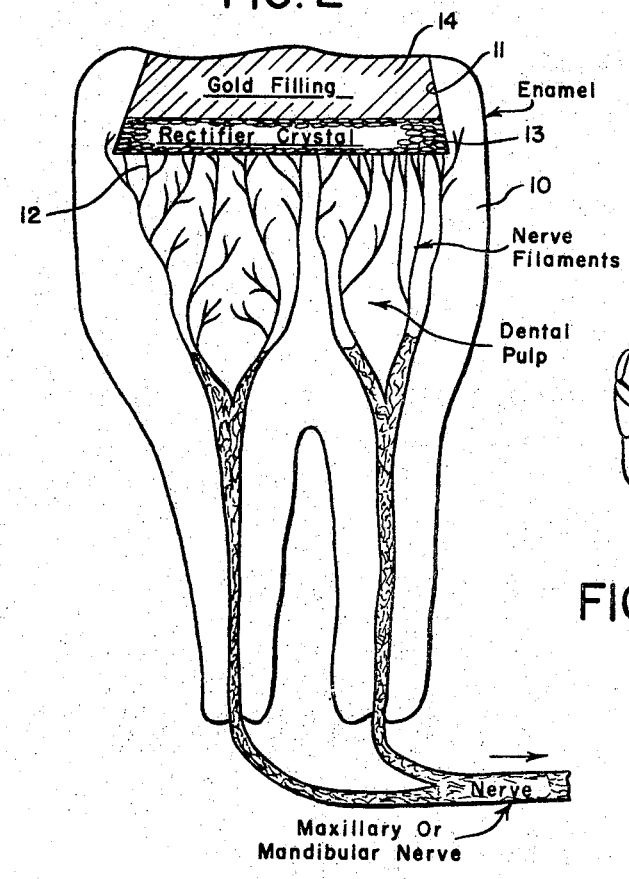
FIG. 2



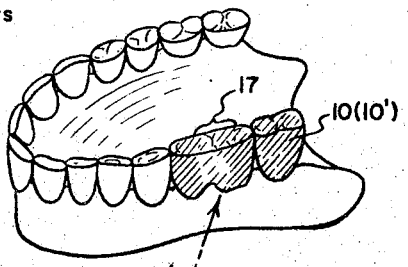


FIG. 4

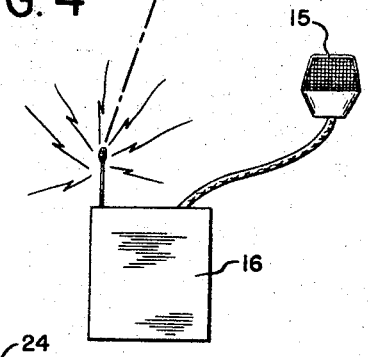
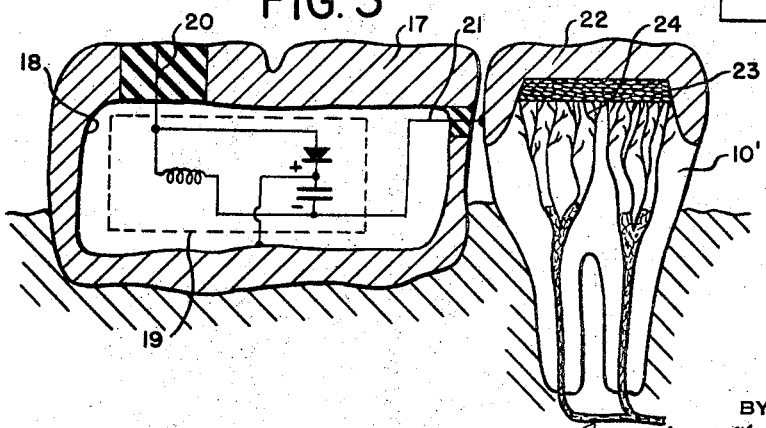


FIG. 3



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MEANS FOR AIDING HEARING

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The present invention is directed to means for auxiliary hearing communication, useful for improving hearing, for example, and relates more specifically to novel and improved arrangements for auxiliary hearing communications by effecting the transmission of sound signals through the dental structure and facial nervous system of the user.

In the normal human hearing system, sound waves travelling through the air or through the bone structure are received in the ear and are transmitted, in a more or less mechanical manner, to the organ of Corti, which acts as a transducer to convert mechanical vibrations into electrical signals in the nervous system. These electrical signals are transmitted to the auditory centers of the brain and there give rise to sensations of sound.

In cases where hearing ability is subnormal, for example, it is frequently possible and desirable to employ a so-called hearing aid to assist in carrying out the functions of the hearing system. All such hearing aids, insofar as we are aware, function as amplifiers of sound waves travelling through the air and/or through the bone structure. And, while these devices may operate satisfactorily where the hearing deficiencies are substantially of a mechanical nature, there are certain hearing defects which are not correctible by mere amplification. For example, in cases of impairment or destruction of the organ of Corti, the system may be unable to translate the mechanical vibrations of sound into the proper electrical signals for transmissions to the auditory centers. In such cases mere amplification of the sound waves cannot give rise to sensations of sound in the brain.

Although, the normal facility for hearing in the human body is the above described system, which may be referred to as the ear system, there is present in the human body a second, dormant system, referred to herein as the facial system, which, if properly energized, will effect the transmission of signals to appropriate areas of the brain, sometimes referred to herein as auditory centers, to give rise to sensations of sound. The facial system, although coupled to the organ of Corti, is substantially parallel to the normal ear system, at least to the extent of having a branch bypassing the organ of Corti and apparently extending up to the point where signals are transmitted through the labyrinthine and auditory nuclei to the auditory centers. Substantially normal hearing is thus possible, even by persons whose normal or ear system has been substantially impaired or destroyed, upon proper energization of the facial system. Accordingly, the present invention, in its broadest aspects, provides a novel and wholly practical arrangement for artificially exciting or energizing the facial hearing system in the human body, to the end that substantially normal sensations of hearing may be realized by persons utilizing the invention, even though such persons may have substantial defects in their normal hearing systems.

In the facial hearing system of the human body there are included, as receptor elements, free nerve endings, such as those found in the teeth, sinuses and temporomandibular area. That is, these nerve endings, properly excited, are capable of transmitting the desired signals to the auditory centers of the brain. Accordingly, one of the more specific aspects of the invention resides in the aiding of hearing by, and in the provision of means for, controllably artificially exciting or stimulating the nerve

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endings of the facial system, to the end that signals capable of producing sound sensations are transmitted through the facial system to the auditory centers of the brain. In its most advantageous and practical form, the device of the invention comprises means, in the form of a dental prosthetic device, for imparting or transmitting to viable nerves of a tooth electrical signals which, when transmitted to the brain, will give rise to sound sensations. Advantageously, the device or means of the invention comprises an element applied to a viable tooth, for receiving electromagnetic signals at radio frequency, and a transducer element coupled with the receiving element and with live nerve endings of the tooth for converting the electromagnetic signals to electric signals at audio frequency, and imparting the electrical signals to the nerve endings of the tooth for transmission to the brain.

In one practical form of the invention, a dental prosthetic device as described in the foregoing paragraph is utilized in combination with means, such as a microphone and radio transmitter positioned on or about the body of the user, for receiving sounds at audio frequency and translating such sound into electromagnetic energy at radio frequency for transmission to the receiving element of the prosthetic device. The prosthetic device, receiving the electromagnetic signals, translates or converts such signals to appropriate audio frequency electrical signals which are transmitted through the facial nervous system to the brain. The signals thus transmitted are of such a character as to provide the sensation of the sounds transmitted audibly to the microphone, so that the user of the device is able to hear as though through the regular ear system.

Where necessary or desirable, suitable arrangements may be provided for the amplification of the radio frequency electromagnetic signals. To this end, an auxiliary dental prosthetic device may be provided, which takes the form of a crystal diode receiver tuned sharply to the frequency of the transmitting set. Such an amplifying device may be housed in an enclosure having the form of a false tooth or a plurality of false teeth advantageously positioned immediately adjacent the viable tooth containing the transducer element.

In some advantageous forms of the invention, an element positioned in electrical contact with nerve endings of a tooth has piezoelectric properties and functions not only to impart the desirable electrical signals but to agitate the enrve endings and render them highly responsive to the electrical signals. This form of the invention may best be utilized in conjunction with an auxiliary prosthetic device housing a crystal diode receiver, since rectifying functions may be carried out by the receiver.

For a better understanding of the invention, reference should be made to the following detailed description and to the accompanying drawings, in which:

FIG. 1 is a simplified, diagrammatic representation of the ear and facial hearing systems found in the human body;

FIG. 2 is an enlarged representation of a viable tooth incorporating, as an insert, means for receiving radio frequency signals and for converting such signals to audio frequency electrical signals capable of producing sensations of sound in the brain;

FIG. 3 is an enlarged representation of a combination dental prosthetic device, including crystal diode amplifier means and means for converting amplified radio frequency signals to audio frequency electrical signals; and

FIG. 4 is a simplified, diagrammatic representation of a complete hearing aid system incorporating means of FIGS. 2 and 3.

Referring now to the drawing, and initially to FIG. 1 thereof, the normal or ear system for hearing in the human body is represented by the left hand column.

Sound vibrations transmitted through this system are first picked up by the ear drum and ear bones, which act as the initial receptor means. Through the mechanism of the ear, such vibrations are transmitted to the organ of Corti, which acts as a transducer to convert the mechanical vibrations into electrical signals of appropriate amplitude and frequency, which are transmitted to the VIII nerve. These signals are directed through the labyrinthine and auditory nuclei to the auditory centers of the brain to produce the usual sensation of hearing.

In the facial hearing system at the right hand side of FIG. 1, free nerve endings, such as those of the teeth, sinuses and/or temporomandibular area, act as the receptor organs, where excited initially by appropriate piezoelectrical signals, as distinguished from mechanical vibrations. The piezoelectrical signals are transmitted through a nerve pathway, including branches of the trigeminal nerve (V) and the facial nerve (VII), as well as their accompanying sympathetic and parasympathetic vegetative nerves. These signals are further transmitted primarily through the tympanic plexus and the cephalic vegetative ganglia to the labyrinthine and auditory nuclei and thence to the auditory centers of the brain, although, to a more limited extent, they also are transmitted to the organ of Corti. Assuming the piezoelectrical signals imparted to the free nerve endings of the facial system to be similar in nature to those transmitted by the organ of Corti, the signals directed to the auditory centers of the brain may be appropriate to provide sensations of sound as if provided through the ear system.

In accordance with the invention the desired piezoelectrical signals are imparted to the facial nerve system by a dental prosthetic device, in the nature of a filling or insert, adapted, in response to the reception of sound-generated electromagnetic signals, to produce or generate electrical signals which, when transmitted to the brain, produce sensations according to the sound initiating the entre chain of signals. To this end, a live or viable tooth **10** is advantageously provided with a recess **11** in the crown thereof which is of sufficient depth to expose the fine nerves **12** of the dental tissue. Directly on top of the exposed nerve ends is applied a layer **13** of material suitable for forming a piezoelectric transducer element, crystal rectifier material such as silicon, germanium or Carborundum being suitable and advantageous for this purpose. The recess **11** is then capped by a layer **14** of conductive material, advantageously gold or silver, substantially in the form of a conventional metal filling.

Electromagnetic signals transmitted to the cap or filling **14** in the tooth **10** are conducted to and converted by the transducer layer or element **13** in the manner desired, so that audio frequency piezoelectric signals are imparted directly to the fine nerve endings **12** of the live tooth. These signals are then transmitted to the auditory centers in the manner described to produce sound sensations.

Advantageously, the user of the device carries on his person a transmitting device, such as shown generally in FIG. 4. The device may include a suitable microphone **15**, placed conveniently to receive sounds which would otherwise be picked up by the ears, and a suitable amplifier and transmitter unit **16** capable of transmitting radio frequency electromagnetic signals through a short distance at a fixed frequency. Sounds directed at the user are thus picked up by the microphone and transmitted by the unit **16** to the modified tooth **10**. The metal filling or cap, acting as an antenna, picks up the signals and transmits them to the transducer layer **13** in the manner described, whereby the user receives the sensation of the audible sound picked up by the microphone.

In some cases it may be necessary or desirable to provide means adjacent the modified, viable tooth for amplifying the radio frequency signals emitted by the transmitter **16**. In such cases it is advantageous to employ an auxiliary dental prosthetic device, such as indicated at **17** in FIG. 3. The illustrated auxiliary device is in the form of a false tooth signal or multiple which has a hollow cavity **18** in which is housed an elementary form of crystal diode amplifier, as indicated at **19**. The amplifier **19**, which is intended to be illustrative only, is sharply tuned to the frequency of the transmitter and is adapted to receive and amplify only such signals as are received on the transmitter frequency. The radio frequency signal may be picked up by an antenna **20**, amplified, and directed by a conductor **21** (negative polarity with respect to body tissue) to a metal cap **22** of a viable tooth **10'**. The tooth **10'** may be substantially the same as the modified tooth **10** shown in FIG. 2, except that the tooth **10'** is illustrated as having a cap **22**, formed of gold, silver or other suitable conductive material, which covers the entire crown of the tooth, whereas the cap **14** of the tooth **10**, is merely an insert. In the arrangement of FIG. 3, the complete cap is advantageous in that it facilitates making connections with the conductor **21** projecting laterally from the adjacent false double-tooth.

The device of FIG. 3 may be substantially identical in its operation to the device of FIG. 2, except that the radio frequency signal received by the conductive cap **22** is first amplified, whereas the signal imparted to the cap **14** is received directly from the transmitter. The tooth **10'** has a layer **23** of material forming a transducer element which contacts the fine nerve ends **24** of the tooth in the manner desired. The cap **22** is advantageously applied in such a manner as to avoid any substantial contact with these nerve endings.

In the form of the invention shown in FIG. 3, especially satisfactory results may be realized if the transducer element is formed of a material, such as Rochelle salt crystal, having substantial piezoelectric characteristics. When signal voltage is applied to the piezoelectric material, the nerve endings are agitated, presumably simultaneously and in accordance with the frequency and amplitude of the signals, and this appears to render the nerves more sensitive or receptive to the applied voltage. This advantageous form of the invention is best embodied as shown in FIG. 3, since rectification of the electromagnetically induced signals may be accomplished in the auxiliary receiver, and the element **23** need not exhibit the rectification characteristics otherwise required.

Although we do not consider our experimental evidence to be conclusive in this respect, and therefore do not wish to be limited strictly thereby, we have found that best results are achieved when the signal applied to the nerve endings is not substantially in excess of 0.4 volt. Our findings to date are that some unpleasantness may be experienced if the applied signal voltage is in the range of 0.4–1.2 volts and that pain may be experienced in the upper portion of the range. There is also a practical lower limit of signal voltage, which our findings to date indicate to be about 0.15 volt. It should be understood, however, that the operative ranges of signal voltage vary with different subjects, possibly because of variations in nerve sensitivity.

The improved method and hearing device represent a substantial improvement in respect of providing assistance for the hard of hearing, principally in that the stimuli directed to the auditory centers of the brain largely bypass the normal ear system. Accordingly, hearing may be restored to persons who may otherwise be totally deaf by reason of impaired or destroyed elements of the hearing system at any point up to and including the organ of Corti. Thus, in many cases where conventional hearing aids would be totally ineffective the method and means of the invention may be employed to restore hearing.

The invention may also be utilized to substantial advantage where the organ of Corti of the user is at least partially operative. Thus, as indicated in FIG. 1, the natural system of the human body provides substantial

mechanical interrelation between the tympanic plexus and the organ of Corti. This may be utilized to advantage where the transducer layer or element has piezoelectric characteristics and is mounted in contact with the hard structure of the tooth. In such cases, sonic vibrations may be imparted to the tooth and directed by bone conduction to the organ of Corti, there to be converted in the usual manner to electrical signals. The improvement in hearing thus provided is residual or secondary in nature, however, in relation to the benefits derived through direct electrical excitation of the facial nervous system.

Perhaps the outstanding feature of the invention resides in the fact that use is made of otherwise dormant sound translating systems found in the human body and known to be effectively parallel to the normal hearing system, at least in large part. Accordingly, the means of the invention may be substantially more than a hearing aid in the usual sense and may be utilized to restore the hearing of otherwise totally deaf persons.

It should be understood that the invention as herein specifically illustrated and described is intended to be representative only, as certain changes may be made therein without departing from the clear teachings of the disclosure. Accordingly, reference should be made to the following appended claims in determining the full scope of the invention. Where reference is made to nerves of the facial system, it is intended to refer to the facial network comprising the trigeminal or V nerve, the facial or VII nerve, the glosso pharyngenal or IX nerve and the autonomic nerves together with their sympathetic and parasympathetic branches. This system is illustrated on the right in FIG. 1 and referred to in published literature, such as "The Growth Concept of Nervous Integration" by Daniel E. Schneider, Monograph No. 78, The Nervous and Mental Diseases Monographs, New York, 1949 (see p. 78). The nerves of this system are confined to facial areas according to such recognized works as "Human Anatomy," Morris Jackson, 9th Ed., 1933, Blakiston & Co., Philadelphia. Likewise, where reference is made to a dental insert, it is intended to include a filling, cap or like element applied to the tooth for closing an opening and/or securing another element to the tooth.

We claim:

1. Means for aiding hearing which comprises an electrically conductive member mounted in electrical communication with viable nerves of the facial system of a user, means for converting audible signals to corresponding modulated electrical signals, and means including said electrically conductive member for imparting said modulated electrical signals to said viable nerves.

2. The means of claim 1, in which said electrically conductive member is mounted in contact with viable nerves of the tooth, and means are provided for securing said electrically conductive member in operative relation to said tooth.

3. The means of claim 1, in which said electrically conductive member is formed of material having piezoelectric characteristics, and means are provided for mounting said electrically conductive member in effective contact with facial bone structure of the user whereby supplemental hearing assistance is afforded through bone conduction.

4. The means of claim 1, in which said electrically conductive member is formed of material having piezoelectric characteristics, and means are provided for mounting said electrically conductive member physically adjacent said viable nerves, whereby said nerves are physically stimulated upon electrical energization of said electrically conductive member to improve the receptivity of said nerves to said modulated electrical signals.

5. The means of claim 1, in which said electrically conductive member is positioned within a viable tooth of the user in electrical contact with viable nerves of the tooth, and a dental insert is mounted on said tooth to secure said elecrically conductive member in its operative position.

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