ELECTROMAGNETICALLY COUPLED HEARING AID
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This invention relates to hearing aids and hearing aid construction, and more particularly to hearing aids having no physical connection between the hearing aid microphone and the output sound transducer.

Several types of hearing aids have been designed to conceal or hide the telltale electrical leads or audio tube which in air conduction type hearing aids extend into the user's ear. Further the microphone and output transducer in a hearing aid are often mechanically connected providing a feedback path which can cause sound distortion. The present invention completely eliminates both of the above described objectionable features by electromagnetically coupling an amplified signal from a sound input unit on a user's body or head to a sound output unit attached to the user's head. The output unit intercepts the input unit's electromagnetic waves and converts same into sound vibrations. The output unit may be inside an ear mold insertable into the user's outer ear passageway, substantially out of view, to provide amplified sound vibrations to the user's ear drum.

In a modification of the invention a bone conduction unit is separately attached to the user's head; the same input unit being usable with either type of output unit. Further it has been found that simultaneous use of bone conduction and air conduction type output units can greatly improve the user's benefit from an aid.

The input unit may be enclosed in an eyeglass temple member or may be worn elsewhere on the user's body. In any event there is preferably no physical connection between the input and output units.

Accordingly it is an object of this invention to provide a hearing aid having physically independent and electromagnetically coupled sound input and sound output units.

It is another object to provide a sound output unit insertable into a user's ear passageway substantially out of view.

It is a further object to provide a hearing aid sound input unit attachable to a user's body and with an electromagnetic wave generating coil which directs the waves toward the user's ear.

It is a still further object to provide an electromagnetically coupled hearing aid having a modulated carrier frequency for transferring amplified electrical signals to a sound output unit.

It is another object to provide a hearing aid which produces both air and bone conducted amplified sound waves.

These and other more detailed and specific objects will be disclosed in the course of the following specification, reference being had to the accompanying drawings in which:

Fig. 1 is a side elevational view of the presently preferred embodiment of the air conduction type hearing aid as attached to a user's head in operating position.

Fig. 2 is a cutaway side elevational view in approxi-
The electronic circuits of the sound input unit 10 will now be described with particular reference to FIG. 4. The microphone 16 in response to sound waves 16A induces a signal in the coil 36 to vary in a usual manner with the transistor base 38 drive current. The transistor base D.C. bias is provided through the resistance 40 and switch 41 from the subminiature battery cell 42. The capacitor 44 serves to couple the signal (A.C. coupling) from the coil 36 to the transistor 38. The resultant audio frequency electrical signal is amplified by the capacitively coupled amplifier 18 including the class A operated transistors 38, 46 and 48. A volume control is provided at 58. The amplified signal is transferred to the base electrode of the emitter follower transistor 52 in the modulator-oscillator 20. The emitter follower 52 controls the collector current amplitude of the carrier frequency oscillator transistor 54 to amplitude modulate the oscillator frequency. The Hartley oscillator includes the coil 22 in its inductive-capacitive frequency determination portion 55. The coil 22 current magnitude varies with the transistor 54 collector current changes as is well understood by those skilled in the art.

The modulator-oscillator 20 is tuned by the axially adjustable magnetically permeable slug 56 in the coil 22. The carrier frequency is preferably between 150 kc. and 250 kc. for permitting small size components while avoiding difficulties encountered with much higher frequencies. Alternately the audio frequency electrical signal may be directly provided to the coil 22 as by connecting the coil 22 between the transistor 52 emitter and the plus terminal of battery 42.

The coil 22 serves as a helical transmitting coil with the modulated carrier electromagnetic wave being strongest along the aligned axes 26 and 58. The slug 56 permits tuning for maximum power transfer easier. The carrier frequency usage also increases the insensitivity of unit 14 to interference from electrical power lines.

The output sound unit 14 coil or lumped inductance 28 is preferably axially aligned with the coil 22 for maximum coupling therebetween. With momentary reference to FIG. 1 the unit 14 coil is so aligned by mounting the unit 14 into a preformed plastic ear mold, such as seen in FIG. 5 and inserting the mold into the outer ear aligns the coil 22 and 28. With the unit 14 coil, it is tuned for maximum sound level and inserted into the ear canal.

When initially using the input sound unit 10 with a different unit 14 or 34, it is desirable that the modulator 20 oscillator be retuned for matching the modulator carrier frequency with the output unit tuned circuit frequency. In the modification of this invention using both air and bone conduction, it is preferred that both the units 10 and 34 respective coils be tunable to match the frequency of the unit 14 circuits.

It should be noted that the coil or inductance 22 of FIG. 1 is vertically elongated. This serves to provide a maximum electromagnetic wave intensity traversing a vertically widened horizontally extending plane along the side of the user's head. This provision introduces a tolerance whereby there is good coupling between the units for users with differently shaped ears—making the aid usable to best advantage by a greater number of people. Further the vertical positioning of the output unit 24 on a user's head with the FIG. 1 unit 10 is less critical with the elongated coil than with a round coil.

The sound output units 14 and 34 may have identical electronic circuits. In the preferred output unit circuit the tuned tank circuit consisting of the coil 28 and shunt capacitor 60 has a portion of the coil connected between the base and emitter electrodes of transistor 62. The audio frequency modulated carrier electromagnetic wave is intercepted by the coil 28 to vary the transistor 62 conductivity of the modulating audio frequency rate. A subminiature cell 64 provides current through the transistor 62 and the sound output transducer 66 coil only upon reception of a modulated carrier.

The unit 14 preferably includes an ear mold in either of two shapes. FIGS. 5 and 6 show a mold 68 formed to fit into a user's outer ear with a sound passageway and aperture 70 for opening into the ear canal. The FIGS. 5A and 6A show a mold 68A insertable into a user's ear canal with the aperture 70 on the inner end. In both molds the speaker 66 is inside a box having the sound aperture 72 next to the passageway 70. As seen in FIG. 1 the mold 68 places the coils 22 and 28 closely adjacent each other on respective sides of the outer ear and this mold is preferred for that reason.

The coil 28 is mounted separately from the other components to reduce the effects of detuning the tank circuit 28—60. The transistor 62 and the capacitors are mounted in a box 74 disposed in a non-interfering manner with respect to coil 28 as seen in FIG. 5. Note the coil 28 axis 58 does not intersect either the transducer 66 or box 74.

A completely passive sound output unit 34 is illustrated in FIG. 7 wherein the tank circuit 28A—60A is coupled by the semi-conductor diode detector 76 to the inductance in coil 78. The output transducer, diagrammatically indicated by the symbol 80, is mechanically vibrated by the coil 78 in a usual manner to reproduce sound waves through the user's bones as at 82. It is understood that the speaker 66 may be substituted for the output transducer 78—80, and vice versa, in the two illustrated sound output units.

The output transducer 78—80 may be of the usual bone conduction type wherein the coil 78 is held in a first mass 78A. The current magnitude variations in the coil 78 cause the magnetic mass 78 to vibrate providing the bone conducting waves 82A. Mass 78A must be greater than mass 80 for causing it to vibrate.

The audio frequency response of the FIG. 1 embodiment is shown as line 84 in the FIG. 8 audiograph. The line 86 is an audiograph of a single unit hearing aid, i.e., one in which there is a physical connection between the microphone and the output transducer. The several peaks 88 result from mechanical vibrational feedback. Note the audiograph 84 provides a somewhat smoother and broader frequency response curve indicating a higher fidelity sound reproduction.

It is understood that suitable modifications may be made in the details of the described circuit, provided such modifications come within the spirit and scope of the appended claims. Having now therefore fully illustrated and described my invention, what I claim to be new and desirable to protect by Letters Patent is:

1. A hearing aid having two physically separate and independent units comprising in combination: an eye-glass temple member having a downwardly extending rear portion adapted to fit over and behind a user's ear and being adapted to be carried by an eyeglass frame; a first unit mounted within said temple member and including a microphone, a signal amplifier, and a carrier frequency modulator-oscillator means having a frequency determining circuit including an inductance disposed in the downwardly extending rear portion of said temple member and circuit means interconnecting all of said last named devices in electrical cooperating relationship whereby a modulated carrier frequency output signal is emitted from the inductance for coupling the electromagnetic output thereof to a second unit; and a second unit mounted within a preformed ear mold having a second outlet and adapted to be positioned within a user's auditory canal, said second unit including a sound output transducer, a capacitor-inductor tank circuit tuned to the carrier frequency output of said first unit, and means, including demodulating means, interconnecting said tank circuit and said transducer, said inductor being positioned in electromagnetic signal receiving relationship to the inductance in said first unit.
5. A hearing aid of the class above described wherein two separate units are adapted to be electromagnetically coupled to transmit amplified sound energy impinging thereon to the auditory canal of a user, comprising in combination: a first unit contained within an eyeglass frame templar member adapted to be mounted upon an eyeglass frame and which has a downwardly curved rear portion to position over and behind a user's outer ear in a substantially vertical plane and having a sound transmitting aperture therein, transducing means, electrical signal generating means and a coil mounted within said member so that the coil is disposed in the rear portion of said member and the axis thereof is in said vertical plane, and circuit means interconnecting said transducing means, signal generating means and coil whereby the coil may be energized to transmit a signal comprised of electromagnetic energy along said axis; and a second unit including an ear mold having an aperture therein, an output transducer and a coil mounted within said mold, said output transducer being in sound energy transmitting relationship to the aperture, said coil being mounted whereby its axis is substantially coincident with the axis of the coil in said first unit, and electromagnetic energy responsive circuit means interconnecting said transducer and said last named coil.

6. In a hearing aid comprising two electromagnetically coupled units, the combination comprising: a first unit being mounted within an eyeglass frame templar member which has a downwardly extending rear portion adapted to fit over and behind a user's outer ear and transmitting aperture therein, microphone means, modulating means, and a vertically elongated inductance means positioned in said downwardly extending rear portion, circuit means interconnecting said microphone means, said modulating means and said inductance means so as to provide a field of electromagnetic energy primarily along a predetermined axis of said inductance means in response to signals applied thereto; and an ear mold for positioning entirely within a user's ear, said mold having an aperture in one end, transducer means in sound transmitting relation to said aperture and electromagnetic field detecting means rigidly connected to said transducer means, said field detecting means including a coil having an axis to be positioned substantially coincident with the axis of said coil in said transducer means, and a second coil mounted inside said mold, said coil having an axis to be substantially coincident with the axis of said coil in said transducer means and being elongated along the vertical plane, and circuit means interconnecting said transducing means, said sound detecting means, said signal generating means and said coil whereby said coil is energized in accordance with sound impinging on said sound detecting means to radiate an electromagnetic signal substantially along said axis; the other unit comprising an ear mold having an aperture, an output transducer and a second coil mounted inside said mold, said coil having an axis to be positioned substantially coincident with the axis of the coil in said one unit, and circuit means interconnecting said transducer and said coil.

7. An electromagnetically coupled hearing aid comprising a transmitter and two physically separated and independent receivers, said transmitter having interconnected microphone means, modulating means and electromagnetic field generating means, said generating means terminating in a long wire loop for positioning around a user's neck, one receiver including interconnected helical coil means, detecting means and sound output transducer means mounted within a preformed ear mold so that the axis of said coil means is substantially vertical and the transducer means is in sound vibration communicative relation to the user's head whereby the output of said transducer is simultaneously applied through electromagnetic coupling to each of said receivers.

8. A hearing aid comprising two separate electromagnetically coupled units, one unit being inside an eyeglass frame templar member having an aperture and which has a downwardly curved rear portion to be positioned over and behind a user's outer ear in a substantially vertical plane, sound detecting, electrical signal generating means and a coil mounted within said member and being positioned in the rear portion of said member and having an axis in said plane directed toward the ear of a user and being elongated along the vertical plane, and circuit means interconnecting said sound detecting means, said signal generating means and said coil whereby said coil is energized in accordance with sound impinging on said sound detecting means to radiate an electromagnetic signal substantially along said axis; the other unit comprising an ear mold having an aperture, an output transducer and a second coil mounted inside said mold, said coil having an axis to be positioned substantially coincident with the axis of said coil in said transducer means.
axis of the coil in said one unit, and circuit means including 
demodulator means interconnecting said transducer 
and said coil.

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