

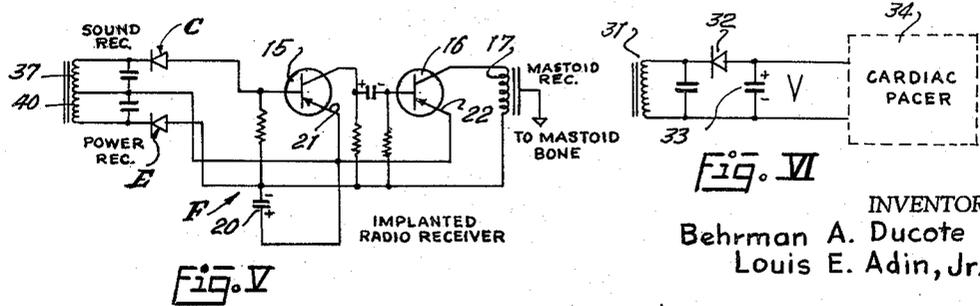
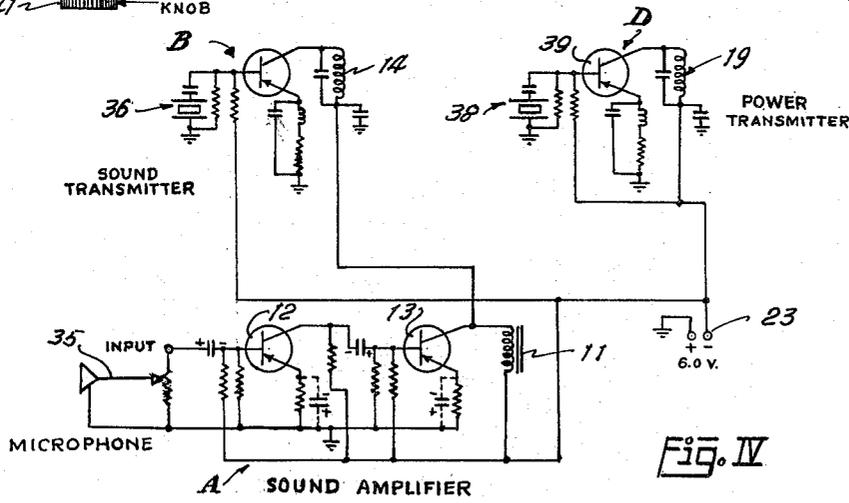
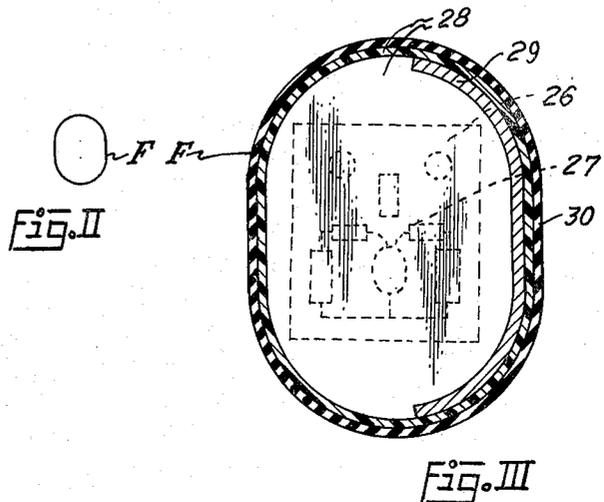
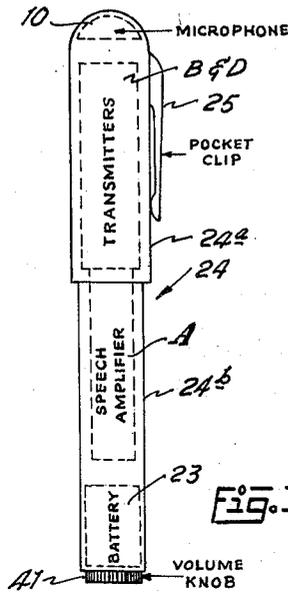
Sept. 28, 1965

B. A. DUCOTE ETAL

3,209,081

SUBCUTANEOUSLY IMPLANTED ELECTRONIC DEVICE

Filed Oct. 2, 1961



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3,209,081

SUBCUTANEOUSLY IMPLANTED ELECTRONIC DEVICE

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 Filed Oct. 2, 1961, Ser. No. 142,375
 4 Claims. (Cl. 179-107)

This invention is primarily concerned with a hearing aid to assist persons with defective hearing, and is particularly concerned with a hearing aid including a sound amplifier and transmitter unit arranged to be conveniently carried on the body of the user, and a remote receiver, unconnected physically with the sound amplifier-transmitter unit, which may be implanted subcutaneously against the skull of the user in concealed position, so that the hearing aid is completely invisible. The mastoid bone is a convenient part of the skull in which to implant the receiver, because it assures sufficient thickness to recess the receiver therein.

Hearing aids have customarily included a sound amplifier-transmitter unit carried on the person, with a wire connecting the transmitter to a receiver which is struck into the ear or is suspended to the ear. In some instances the speech amplifier-transmitter unit has been mounted in eyeglass frames with a wire connection between the eyeglass frames and a receiver unit inserted in the ear.

Bone conduction type receivers have not been entirely satisfactory, in that they do not make direct contact with the mastoid bone, but sound transmission is interfered with by skin and tissue therebetween, so that completely satisfactory reception is not attained.

The present invention includes among its objects the provision of a transistorized receiver unit molded into a plastic case, which may be sterilized, and subcutaneously implanted directly against the skull of the patient, so that the receiver makes a direct contact with the bone through which sound may be conducted to the inner ear via bone conduction, without interference by skin and tissue therebetween.

No wires or other physical connection is required between the speech amplifier-transmitter unit, and the implanted receiver, because of a unique arrangement wherein power for operating the electrical components in the implanted receiver is supplied by an RF transmitter carried in the speech amplifier-transmitter unit, which power is detected, rectified, and impressed upon a capacitance in the circuit of the implanted receiver in the form of a D.C. potential which is applied to the emitters of the transistor amplifiers in the implanted radio receiver.

The speech amplifier and transmitter unit are miniature transistorized circuits mounted in a convenient carrying case, in the form of a fountain pen or otherwise and carried on the person of the user in concealed position, so that in conjunction with the embedded receiver unit provides a hearing aid which is completely invisible in that there is nothing in the ear, behind the ear, in the hair, or worn in eyeglass frames, as in previous hearing aids and devices, and there are no cords, or other connections, between the speech amplifier-transmitter units and the receiver which could hinder normal activity of the patient.

In the use of the hearing aid receiver as herein described, the ear canal is unobstructed and can receive sounds in a normal manner. This is impossible when the ear canal is obstructed by the ear mold of a conventional air conduction hearing aid. This is of particular advantage to those users whose reception for low frequency tones is much better than for the high frequency tones.

The receiver unit may be implanted in or on the skull of the patient by a simple surgical procedure with local

anesthesia, and is so constructed that after normal post-operative care to allow the rather minor incision made to implant the receiver to heal, the receiver unit requires no further care, in that there is no battery carried therein which requires replacement, power is supplied thereto by remote transmission, and all circuit units are implanted and sealed in a protective coating of tissue tolerant plastic, and are not subject to deterioration by exposure to body fluids and elements. The volume control for the receiver is accomplished by a volume control knob on the speech amplifier-transmitter unit, which controls the amplitude of the input signal supplied to the speech amplifier. Therefore, no direct volume control for the receiver is required, and it may be implanted in or on the skull in inaccessible position.

The implanted power supply, described herein, could be employed to supply power to other tissue implanted electronic devices than hearing aid receivers.

Other and further objects of the invention will become apparent upon reading the detailed specification hereinafter following, and by referring to the drawings annexed hereto.

A suitable embodiment of the invention is shown in the attached drawing wherein:

FIGURE I is a side elevational view of the speech amplifier transmitter unit case, which takes the form of a fountain pen with a clip thereon to be inserted in a concealed position in the pocket of the wearer;

FIGURE II is a side elevational view of the implanted receiver unit which, as shown, is approximately full size;

FIGURE III is an enlarged transverse, cross-sectional view of the receiver unit to be implanted;

FIGURE IV is a schematic view of the electrical circuit of a sound transmitter, power transmitter and speech amplifier, the components of which are mounted in the fountain pen-like casing of FIGURE I;

FIGURE V is a schematic view of the implanted receiver, the components of which are molded and encased in the receiver unit of FIGURES II and III; and

FIGURE VI is a schematic view of a modified form of remote power supply used with the implanted receiver but which could be used in conjunction with any body implanted electronic equipment, such as a cardiac pacer.

Numeral and letter references are employed to designate the various parts and components shown in the drawings, and like numerals indicate like parts throughout the various figures of the drawings.

The sound amplifier, sound transmitter, power transmitter units are shown in schematic form in FIGURE IV, and the components thereof are mounted in the fountain pen-like casing 24, shown in FIGURE I.

The sound amplifier unit is indicated by the letter A, and includes a conventional transistorized circuit including the microphone 10 which is coupled to the transistor amplifier 12 and therefrom to the transistor amplifier 13. The audio signal is picked up by the microphone 10, the amplitude thereof being controlled by the rheostat arm 35, which is operated by the knob control 41 on the casing section 24b shown in FIGURE I. The amplified signal is transferred across the output transformer 11 to the transistorized circuit of the sound transmitter unit B, where the audio signal modulates the radio frequency signal supplied by the crystal oscillator 36. The modulated signal is transmitted through space from the tank circuit 14, and is picked up by the tuned LC circuit 37 of the receiver F, which is tuned to the radio frequency of the sound transmitter, and is detected and rectified by the sound receiver solid state diode C. The rectified signal is fed through the transistor amplifiers 15 and 16 to the output transformer 17, and to the skull of the patient from whence it is transferred through bone conduction to the inner ear of the patient.

Power is supplied to the amplifier transistors 15 and 16 of the implanted radio receiver F from a power transmitter, indicated at D. This is a transistorized oscillator circuit which emits a radio frequency signal provided by the crystal oscillator 38 and transistor 39. This amplified radio frequency signal is transmitted through space from the output tank circuit 19, and is picked up by the tuned circuit 40 in the implanted receiver. This radio frequency signal is detected and rectified by the crystal diode E, and the electrical potential produced thereby is impressed across and stored in the capacitor 20.

The positive plate of the capacitor 20 is connected to the emitters 21 and 22 of the amplifier transistors 15 and 16, so that a continuous voltage sufficient to cause the emission of the transistors 15 and 16 is applied thereto, and such voltage is continuously and constantly applied as long as the power transmitter D is functioning.

The power is supplied for the operation of the speech amplifier A, sound transmitter B, and power transmitter D, by a miniature 6-volt battery 23. The battery 23 is mounted in the casing 24, shown in FIGURE I, and such constitutes the external power supply for the hearing aid, including the speech amplifier-transmitter unit, and the remote receiver unit.

The fountain pen-like casing, generally indicated at 24, includes a cap 24a and a base portion 24b in which the various physical components of the speech amplifier, transmitter, battery and volume control are mounted. The microphone 10 is mounted in the top of cap 24a, and suitable perforations should be provided through the cap for admission of sound to the microphone. The cap 24a has a spring clip 24c thereon which may be clipped to the pocket of the wearer in a concealed position. The volume is controlled by rotation of the volume control knob, indicated at 41.

The implant receiver unit F is shown drawn to approximate full scale in FIGURE II, and is preferably generally elliptical in shape and is actually less in overall dimension than a dime, and is relatively thin.

The receiver components, shown schematically in FIGURE V, are preferably mounted on a mounting board 26, the said receiver components being indicated diagrammatically in FIGURE III by the numeral 27. After the receiver components are mounted on the board 26, they are thoroughly tested, to assure operability of the receiver circuit. After being tested, the board 26 with components 27 mounted thereon, are encased in a plastic covering or casing, indicated generally at 28. The plastic covering may be applied about the board 26 and components 27 by any suitable method. However, the plastic material used would necessarily be of a type which is tissue tolerant, that is, it is not harmful or destructive to body tissues, and which may be embedded within the body tissues without causing infection or nerve, bone, or tissue damage. Several types of such plastic material are available, such as Polyethylene and certain epoxy resins which are tissue tolerant. A suitable epoxy resin material for this use is that known as Minnesota Mining Scotch Cast No. 5.

Before molding the receiver components in the plastic material 28, a layer of tantalum metal 29, or other suitable sound conducting metal is preferably affixed about the components, on the side of the implant receiver device which will contact the skull, and is molded therein. The actual molding of the plastic material 28 about the receiver components 27 may be accomplished by either dipping the components in a fluid state plastic material, and allowing the plastic material to harden and set thereabout, or the components 27 may be molded in the plastic material under moderate heat and pressure, so as not to damage the receiver components.

Preferably a layer of relatively soft plastic material, such as vinyl plastic or silicon rubber, is molded and formed about the plastic material 28. However, this last layer of plastic material could be eliminated, without

affecting the operation and utility of the implant receiver. Whatever plastic material is employed, it must be of a type which will withstand sufficient heat for sterilization. Before implanting the completed receiver unit F, in the manner hereinbefore described, the said receiver unit must be sterilized so that it may be placed in the tissues in a sterile state.

The receiver unit F is implanted in the following manner:

The surgeon makes an incision through the skin and tissues overlying the skull, which may be the mastoid portion of the skull, sufficiently to drill a cavity of sufficient depth and size in the outer surface of the skull to receive the implant receiver F. Since the mastoid bone is insensitive, there is no pain involved in such procedure, except that attendant upon making the incision in the skin and tissue, and reclosing same. As a matter of fact, the operation can be easily performed in the doctor's office with local anesthesia.

After the receiver unit F has been placed in the cavity formed in the surface of the skull bone, the tissue and skin is sutured thereover to close the incision. Other than the application of antiseptic and dressing over the sutured incision, the post-operative care is of slight consequence. Within a short time the bone will reform about, and adhere to, the implanted receiver, so that it is firmly set in place, and is, in effect, integrated with the bone by direct contact. The receiver unit could be effectively subcutaneously mounted against any portion of the skull without forming the cavity therein.

The receiver unit F will be thoroughly checked and tested for operability before subcutaneously implanting into or against the skull bone, so that there is slight chance that the receiver will become inoperable to such an extent as to have to be replaced, but if replacement becomes necessary, only a minor operation would be required.

Since the receiver has a self-contained power supply charged from an external source as hereinbefore described, no wires or connections are required between the transmitter and the receiver.

The remote implanted power supply of the type herein described could be employed in any application where an electrical or electronic device is required in or on the human body as a therapeutic agent. One example of another use of such an implanted power supply is in supplying power for the operation of a cardiac pacer. A cardiac pacer, which has come into recent use, is an electrical circuit which is implanted in the patient's body to provide intermittent electrical impulses to the heart to regulate the heart's beat. Heretofore it has been necessary to provide an electrical connection between the cardiac pacer and a power supply externally of the body, such as a battery. With the use of the power supply herein described, same could be implanted in the body of the patient and supplied with power from a transmitter externally of the body without physical connection. A suitable form of such an implanted cardiac pacer is shown schematically in FIGURE VI, wherein a pickup transformer 31 picks up a radio frequency signal from a radio frequency transmitter of the type hereinbefore described, which signal is detected by the solid state diode rectifier 32 to charge the capacitor 33 and store the power therein for the operation of the cardiac pacer 34.

Thus it will be seen that the implanted power supply has other and separate uses from use in connection with a hearing aid receiver.

It will be understood that other and further uses and embodiments of our invention may be made without departing from the spirit and scope of the appended claims.

Having described our invention, we claim:

1. A hearing aid comprising an integral audio amplifier, audio transmitter and power transmitter unit encased with-

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in a common casing arranged to be carried on the person of the wearer of the hearing aid, said unit including an audio amplifier with an input for picking up audio signals for amplification; a volume control on the input including a volume control knob accessible from outside the casing, an audio transmitter connected to the output of the audio amplifier arranged to transmit signals picked up and amplified by the audio amplifier by electromagnetic impulse, a radio frequency oscillator and transmitter in said casing, said audio amplifier, audio transmitter and radio frequency transmitter being supplied by a common power supply within the casing; an audio receiver-amplifier and a radio frequency receiver encased within a plastic, tissue tolerant material mounted in a cavity formed in the skull of the wearer of the hearing aid beneath the skin of the wearer, said radio frequency signal receiver including a detector to detect the signal transmitted by the radio frequency signal transmitter, and a capacitance in parallel therewith arranged to store the detected voltage of the radio frequency signal, said capacitance being connected to the audio receiver-amplifier unit to supply power thereto for operation thereof; and means to transfer the audio signal picked up and amplified by the audio receiver amplifier to the mastoid bone of the wearer.

2. A receiver-amplifier unit for use in a hearing aid including, an audio receiver-amplifier; a radio frequency signal receiver including a detector to detect a radio frequency transmitted by electromagnetic energy thereto; a capacitance in parallel with the detector arranged to store the detected voltage of the radio frequency signal, the said

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capacitance being connected to the audio receiver-amplifier, to supply power thereto; a board member on which all of the components of the audio receiver-amplifier, radio frequency signal detector and capacitance are mounted; a quantity of tissue tolerant plastic material molded about the board and the components thereon to provide an audio receiver-amplifier and power supply permanently sealed within tissue tolerant material whereby it may be implanted underneath the skin of a wearer thereof.

3. The combination called for in claim 2 wherein a layer of metallic material such as tantalum is provided adjacent the exterior surface of the tissue tolerant material on one side thereof.

4. The combination called for in claim 2 wherein the tissue tolerant material is overlaid with a layer of relatively soft tissue tolerant plastic material such as vinyl plastic.

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