ELECTRO-MAGNETIC SOUND-TRANSMISSION APPARATUS

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This invention relates to improvements in electromagnetic sound transmission devices especially for use in hearing aids and other sound transducers.

Although the invention will be described with special reference to a hearing aid device, it will be evident that the novel magnetic control of the sound output will have similar use and application in other sound transducers such as telephones, loudspeakers, etc.

When deafness is due to a defect of the middle ear, sound can be transmitted to the auditory nerves through the skull. This system, known as the bone-conduction method, employs a microphone for transforming sound waves into alternating electric current, and an electro-magnetic device containing a flexible member, for example a reed, adapted to be set in vibration by the current and to transmit the mechanical vibrations thus produced to the skull, through the skin.

This conduction of the vibrations is handicapped by the compliance of the skin and the tissues underlying it, which is considerable compared with that of the massive bones underneath and with their high impedance for high-frequency components of the sounds. Consequently, these components are filtered out in various degrees, and the vibrations not only are weakened in transmission but also become distorted.

Another source of faulty reproduction is distortion due to the microphone, but greater still is the distortion through the electro-mechanical conversion of the energy by means of a vibratory reed or equivalent element which has pronounced resonances through which some of the frequencies are unduly amplified and others practically suppressed.

Although resonances and electrical amplification may be used to create a sense of loudness, the reproduction may be so distorted as to make speech intelligible only with difficulty, particularly if the pitch of the voice is not in harmony with the basic resonances of the apparatus. Furthermore, distorted music is, of course, very unsatisfactory.

An object of the present invention is to overcome these disadvantages of known bone-conduction deaf-aid systems by substantially reducing the distortion of the vibrations affecting the auditory nerves and by increasing their loudness.

A further object of this invention is to provide electro-magnetic sound-transmission apparatus, designed for deaf-aid or other purposes, in which corrective resonances are created.

Another object of this invention is to provide an electro-magnetic sound-translating device adapted to provide a measure of magnetic amplification.

These and other features of this invention will be apparent from the following description of embodiments thereof, given by way of example, with reference to the accompanying drawing, in which:

Fig. 1 shows diagrammatically the improved deaf-aid apparatus in use.

Fig. 2 shows in section to a larger scale a modified form of armature applicable to the apparatus shown in Fig. 1.

Fig. 3 is an elevation of the part shown in Fig. 2.

Fig. 4 shows diagrammatically an alternative arrangement of electro-magnetic sound translating device, and

Fig. 5 is a graph illustrating the operation of the device shown in Fig. 4.

Referring to Fig. 1, an armature includes a ferro-magnetic plate 10 and a projecting element in the form of a peg 11 which is driven into the mastoid bone 12 or other bone of the skull by a minor surgical operation, the armature plate 10 lying under a relatively thin layer 13 of skin and tissue, a relatively thick layer of fleshy tissue 14 being interposed between the armature plate and the bone. The armature is rendered non-injurious to the subject for instance by plating with silver.

For co-operation with this armature there is provided a removable magnet which is generally denoted by 15. This magnet includes two pole pieces 16 provided with speech coils 17 and it is polarized by a permanent or electro-magnet 18. The speech coils 17 are included in an electric circuit 19 adapted to carry speech currents derived from any desired source. In the present example the source is controlled by means of a microphone 20 in the input circuit of an amplifier 21 which feeds the circuit 19. With sufficiently thin skin 13, no amplifier is required.

When the magnet 15 is held (or holds itself by means of magnetic attraction) in the position shown over the armature plate 10 and speech currents flow in the circuit 19, the armature cooperates with the poles 16, owing to the interposition of the resilient barrier 13 of skin and tissue, and the mechanical impulses thereby generated in the armature are conveyed by the direct action of the peg 11 to the skull of the subject.

It is preferred to place the armature plate close under the surface of the skin and to connect it by a transmission member such as the peg 11 to the skull, rather than apply the whole armature plate as close as possible to the bone, because...
firstly it is desirable to keep the air gap between the armature and the pole pieces as small as possible, secondly, the armature and the skull would have to be shaped to fit one another if in direct contact, for example by corning the armature or by flattening the mastoid surface during the fitting operation, and thirdly there may be a tendency for tissue to grow between the armature and the bone and thus introduce a component between the armature and the bone.

The armature plate may for example be about 1 in. long, ½ in. wide, and ¼ in. thick. In order to minimise any tendency to thickening of the tissue defining the working gap between the armature and the pole pieces, the armature plate may be of the form denoted by 18A in Figs. 2 and 3, which is provided with as many perforations as are possible without spoiling its magnetic properties, with the object of reducing the area of metal to be enveloped locally by tissue.

Furthermore the armature may be provided with a peg 19, the form of a screw-threaded stud 11A adapted to be screwed into the bone.

For correcting the frequency response of a deaf person, adjustment may be made of the inherent natural frequencies of the skull itself, which, for the purpose of such adjustment, may be regarded as a resonator damped through the deviation of energy into its interior, including the vibrations passing to the auditory nerves. The basic resonance frequency may be influenced by the weight and size of the armature and the peg, their relative position and their shape and natural frequency.

Correcting a defective tonal response of a deaf subject by tuning the skull itself, i.e. the “output” side, will evidently give the best results, but corrective resonances may be created also in the free circuit.

These may be of a mechanical nature. For instance in the electro-magnetic translating device 18A shown in Fig. 4, which is shown as part of a deaf-aid apparatus, a reed 22 is placed across the poles of the magnet 18, with a small leakage gap 2, so that it diverges part of the polarising flux, its position being asymmetrical such that magnetic forces tend to keep the reed under bending stress. In Fig. 5 are plotted the relationships of the elastic force Fp and the magnetic force Fm to displacement z of the reed. As shown in Fig. 4, the magnetic shunt contained by the reed 22 may be between the polarising magnet 18 and the pole pieces 10 carrying the speech coils 11, so that the reed forms a by-pass for the alternating flux and the leakage gap automatically decreases and increases as the pulsating flux in this gap rises and falls. If the characteristics of the elastic and magnetic forces are made similar to each other, an appreciable measure of magnetic amplification may be achieved, quite apart from the resonance effect, the reed opening and closing the gap and acting like a valve in the magnetic shunt.

The response and loudness of any ordinary electro-magnetic receiver may be improved by providing the leakage reed on one side of the speech coils and the armature in the form of a reed or diaphragm on the other side, as shown in Fig. 4, both moving in even phases over the magnetic frequency ranges below the resonance points and thus extending the load response downwards.

I claim:

1. The combination with an electro-magnetic sound transducer comprising a polarising magnet, a speech winding and an armature, of means to produce a magnetic shunt circuit across a portion of the main magnetic flux path through said magnet and armature and including a resilient vibrating ferro-magnetic member supported at one end and arranged to have its other end move freely and to provide an air gap in said shunt circuit, the vibrating characteristics of said member being such as to vary said air gap according to the magnetomotive force pulsations there through across said gap and the pole pieces to the sound current pulsations in said winding, and said shunt circuit being so arranged in relation to said polarizing magnet and said speech winding that the polarity relation between the polarizing flux and the pulsating flux due to sound currents through said winding in the main magnetic circuit will be opposite to the polarity relation between the polarized and magnetic flux in said magnetic shunt circuit.

2. The combination with an electro-magnetic sound transducer comprising a polarising magnet, a speech winding and an armature, of means to produce a magnetic shunt circuit across a portion of the main magnetic flux path through said magnet and armature and including an elongated resilient ferro-magnetic vibrating member supported at one end and having its other end arranged to move freely and to provide an air gap in said shunt circuit, the characteristics of the elastic force exerted by said member and of the magnetic force thereon due to the flux through said shunt circuit being substantially alike, whereby to vary said air gap according to the magnetomotive force pulsations in said winding, and said shunt circuit being so arranged in relation to said polarising magnet and said speech winding that the polarity relation between the polarizing flux and the pulsating flux due to sound currents through said winding in the main magnetic circuit will be opposite to the polarity relation between the polarized and magnetic flux in said magnetic shunt circuit.

3. An electrical sound transducer comprising a polarising magnet to provide a steady magnetic flux, a speech winding associated with said magnet to produce a pulsating flux in accordance with sound current fluctuations exciting said winding and superimposed upon said steady flux, a vibrating ferro-magnetic member secured at one point to said magnet and having its opposite end spaced from another point of said magnet and arranged to move freely to provide a magnetic bypass including an air gap varying in accordance with the magnetic flux therethrough, said element being so arranged relative to said magnet and said winding that the polarity relation between the steady and pulsating flux therethrough is opposite to the polarity relation between the steady and pulsating flux through said magnet.

4. An electromagnetic sound transducer comprising a polarising magnet, a pair of pole pieces therefor and a vibrating armature cooperating therewith to form a main magnetic circuit, a speech winding carried by said pole pieces to produce a pulsating magnetic flux in accordance with sound current fluctuations applied thereto and superimposed upon the steady magnetic flux through said main circuit, and a vibrating ferro-magnetic element having one end secured to one of the said pole pieces cantilever-fashion and having its opposite end spaced from and cooper-
ating with the other pole piece to provide a magnetic bypass including an air gap varying in accordance with the flux therethrough, the polarity relation between the steady and pulsating magnetic flux through said main magnetic circuit being opposite to the polarity relation between the steady and fluctuating flux through said element.

5. An electromagnetic sound transducer comprising a polarizing magnet, a pair of pole pieces and a vibratory armature to form a main magnetic circuit, a speech winding associated with said pole pieces to produce a pulsating magnetic flux in accordance with sound current fluctuations applied thereto and superimposed upon the steady magnetic flux through said main circuit, and a ferro-magnetic vibrating reed having one end secured to one of said pole pieces cantilever-fashion and having its opposite end spaced from and cooperating with the other pole piece to provide a magnetic bypass including an air gap varying in accordance with the flux therethrough, the polarity relation between the steady and pulsating flux through said main magnetic circuit being opposite to the polarity relation between the steady and pulsating flux through said reed, said reed having vibrating frequency characteristics of the order of the frequency of the sound current fluctuations.

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