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ELECTROACOUSTIC TRANSLATING METHOD AND MEANS

Filed Jan. 23, 1940

FIG. 1

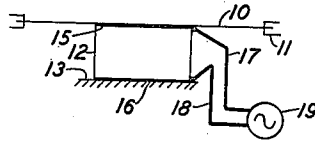


FIG. 2

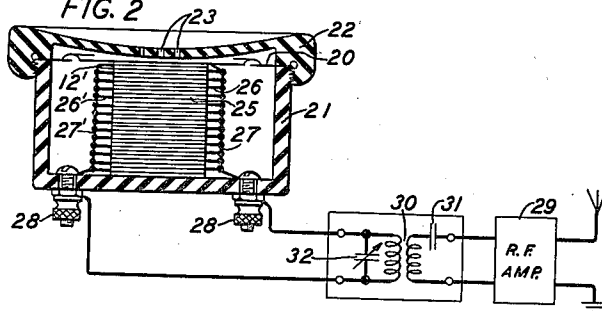


FIG. 3

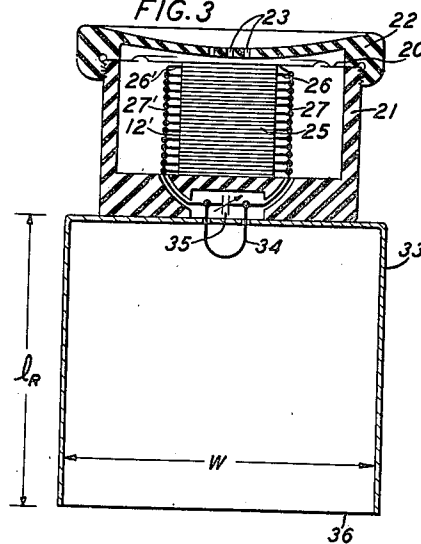
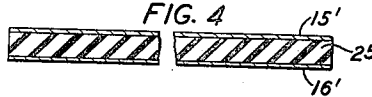


FIG. 4



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ELECTROACOUSTIC TRANSLATING
METHOD AND MEANS

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18 Claims. (Cl. 250—22)

This invention relates to electroacoustic translating systems, and, more particularly, to a method and means for translating directly from modulated high frequency waves to acoustic waves and vice versa.

An object of the invention is to translate modulated electric waves directly into acoustic waves, and to modulate an electric wave directly by acoustic waves.

A feature of the invention comprises a method of electroacoustic translation that comprises producing alteration or dimensional change in an electrostrictive medium or material corresponding to the acoustic disturbance to be translated.

Another feature comprises a modulating or a demodulating means embodying an electrostrictive medium or material.

In accordance with the invention, an amplitude modulated radio frequency wave is impressed directly upon an electroacoustic transducer comprising an element or unit of or including a material having a high electrostrictive constant. This member preferably comprises a plurality of superposed laminations of the material, plated on each side, with each plating of each lamination connected to a different electrode or terminal. An acoustic wave translating member or diaphragm is coupled to an outer lamination. The dimensional changes in the layers of electrostrictive material in response to the impressed modulated wave cause the diaphragm to vibrate in correspondence to the modulation component of the modulated wave. When the member is used as a modulating device, the vibration of the diaphragm in correspondence to the sound waves impressed thereon, produces dimensional changes in the electrostrictive unit upon which a carrier wave is impressed.

A more complete understanding of the invention will be obtained from the detail description that follows, read with reference to the appended drawing, wherein:

Fig. 1 shows an electroacoustic device embodying the invention;

Fig. 2 shows a telephone receiver embodying the invention, and whose electrostrictive unit comprises a portion of a band-pass filter;

Fig. 3 shows a telephone receiver embodying the electrostrictive unit of this invention and included in the circuit of a cavity resonator; and

Fig. 4 is an enlarged cross-sectional view of one of the laminations of the electrostrictive unit of the devices of Figs. 2 and 3.

An electrostrictive material is one which, when subjected to a potential difference, undergoes a

dimensional change or displacement which is proportional to the square of the applied potential gradient, i. e.,

$$\frac{d}{l} = KE^2 \quad (1)$$

where

d =dimensional change or displacement of the material

l =length or thickness through which the dimensional change occurs

E =potential gradient applied to the material

K =electrostrictive constant for the material.

Since the effect resulting from the electrostrictive property depends on the square of the potential gradient, it can be made greater with a particular material by using a laminated structure, composed of a number of thin layers or laminations, provided with a metallic coating or plating on each side, with alternate pairs of adjacent coatings connected to one electrode or terminal and the remaining pairs of adjacent coatings connected to a second electrode or terminal. For the latter case, the expansion of n layers each of thickness t , or a total thickness T , is

$$\frac{d}{nt} = K \left(\frac{V}{t} \right)^2$$

$$d = TK \left(\frac{V}{t} \right)^2 \quad (2)$$

where V is the applied voltage.

Such a laminated structure may be connected to a diaphragm and used as the driving unit of a sound wave translating device, e. g., a telephone receiver.

Suppose that there is impressed on this receiver's driving unit an amplitude-modulated high frequency wave given by

$$V = A_1 \sin pt + A_2 [\sin (p+q)t + \sin (p-q)t] \quad (3)$$

Insertion of this expression in Equation 2, and employment of the multiple angle formulae, gives:

$$d = \frac{TK}{t^2} \left[\frac{A_1^2 (1 - \cos 2pt)}{2} + 2A_1 A_2 (1 - \cos 2pt) \cos qt + A_2^2 \left(\frac{1 - [\cos 2(p+q)t + \cos 2(p-q)t]}{2} + \frac{\cos 2qt - \cos 2pt}{2} \right) \right] \quad (4)$$

Since p is a very high frequency, the only low frequency terms give

$$d = \frac{TK}{f^2} \left(2A_1 A_2 \cos qt + \frac{A_2^2}{2} \cos 2qt \right) \quad (5)$$

The first term represents the rectified component, and the second represents a distortion which can be made small by keeping A_2 equal to or small compared to A_1 .

By selection of appropriate values for A_1 and A_2 , and of a material having a high electrostrictive constant, a displacement of the electrostrictive unit of the order of that found in the moving member or diaphragm of most telephone receivers, i. e., about 10^{-5} centimeters, is obtainable. Hence, an applied high frequency field can be demodulated and the acoustic wave can be obtained directly by a first order effect. The driving element, which may be considered electrically as a capacitance and a resistance to represent the acoustic power absorbed and the electric loss in the dielectric, can be incorporated in an impedance transforming band-pass filter, to give a voltage step-up between the radio receiver and the acoustic receiver unit. For higher frequencies, i. e., of the order of megacycles, the electrostrictive unit may be incorporated as part of or as a section of a wave guide, or in a cavity resonator to step up the voltage.

The electrostrictive unit can also be used as a modulator. A suitable carrier wave is applied to the unit, and acoustic waves are caused to impinge on the unit, e. g., through the medium of a vibratable member or diaphragm, to vary the capacitance by causing dimensional changes of the unit in accordance with the sound waves. This is equivalent to generating the two sidebands, and, hence, the device will function as a transmitter, also.

Fig. 1 shows an embodiment of the invention. It comprises a vibratable member or diaphragm 10, mounted at its periphery on a support 11, and a unit or member 12 of electrostrictive material, for example, hard rubber, mounted between the diaphragm and a suitable support 13. The unit 12 is coated or plated on its upper and lower surfaces with a thin conductive film or layer 15, 16, with which electrical contact is made by conductors 17, 18 across whose free ends 19 may be connected a source of amplitude modulated high frequency wave, e. g., the radio frequency output of a radio broadcast receiver, or an antenna circuit, or a modulated carrier wave transmission line. The unit 12 may be secured to the diaphragm where adjacent thereto by any suitable means, for example, cement, or it may be maintained in position by being mounted under slight compression between the diaphragm and the support 13.

The unit 12 is of an electrostrictive material, preferably a material having a high electrostrictive constant. Such a material is hard rubber, whose electrostrictive constant K , expressed in terms of voltage per centimeter, is 7×10^{-14} .

When a modulated radio frequency wave is impressed on the unit 12, the electrostrictive material is caused to expand against the diaphragm and to displace it and to contract, in accordance with the waves of acoustic frequency by which the radio frequency wave has been modulated, i. e., the unit acts as a demodulator and experiences dimensional change or alteration in its size, which alterations are utilizable to produce movement of a diaphragm and, hence, acoustic

disturbances or sound waves in the air or other medium adjacent the diaphragm.

The arrangement of Fig. 1 will function as a modulating device, also. If a source of carrier wave is connected across conductors 17, 18 and the terminals 19 are connected to a transmitting amplifier, directly to an antenna circuit, or to a carrier wave transmission line, acoustic waves impinging on the diaphragm 10 produce dimensional change in the unit 12, and cause the carrier wave to be modulated in accordance with the acoustic disturbance.

Instead of a single block or layer of the electrostrictive material, it may be more advantageous, as explained hereinabove, to employ a laminated structure. This is shown in Fig. 2, which also illustrates, in more detail than does Fig. 1, a telephone receiver embodiment of the invention.

The diaphragm 20 rests at its peripheral portion on the rim of the case 21, and is clamped thereto by the cap 22, provided with central apertures 23 for the egress of sound waves. The driving unit 12' comprises a plurality of laminations 25, one of which is shown in enlarged cross-section in Fig. 4, of electrostrictive material provided with a very thin conductive coating or film on each side. The pile of laminations is mounted between the inner side of the diaphragm and the bottom of the case, and may be held together by cement, or under compression between the diaphragm and case. Alternate pairs of adjacent coated surfaces are connected through conductors 25, 26' and 27, 27' to terminals 28.

If A_1 and A_2 in Equation 5 are of the order of 50 volts, and the unit 12' comprises two hundred laminations, each two mils in thickness, i. e., constituting a unit approximately one centimeter in thickness, and of hard rubber, the displacement of the unit and, consequently, that of the diaphragm 20, will be of the order of 1.4×10^{-5} centimeters, in the range of telephone receivers in use at the present time.

The conductive coatings or films on the unit 12 or the laminations of the unit 12' may introduce a capacitance effect, but this is of negligible effect compared to that of the electrostrictive material.

The driving unit 12, 12' may be considered electrically as a capacitance and a resistance representing the acoustic power absorbed and the electric loss in the dielectric. It may be incorporated in an impedance transforming band-pass filter as shown in Fig. 2, to give a voltage step-up between the radio frequency receiver amplifier 29 and the receiver. The other parts of the filter may comprise the transformer 30, having condenser 31 in series with its primary winding, and tuning condenser 32 connected in shunt with its secondary winding.

The electrostrictive receiver may be incorporated in, as a section of, or, as a part of a wave guide, or a cavity resonator, as shown in section in Fig. 3. The resonant member or chamber 33, of copper, and of length l_R , width w and thickness t_R , e. g., cylindrical, closed at one end and open at its other end and hollow, is coupled through the coil 34 to a receiver similar to that of Fig. 2, like parts bearing similar identifying numerals, and may be fastened to the case 21 in any suitable manner, e. g., cement or screws (not shown). This chamber will be resonant to electric waves along its width, the resonant frequency depending on the length l_R if the width and the thick-

ness are of larger dimension (although the width and the thickness may be made of equal value), and can be proportioned to resonate at the desired frequency. The width and thickness are of equal values since the member 33 is cylindrical, and would be of equal values if the member 33 presented a square or equal-side cross-section in a plane parallel to the plane of its open or closed ends. When the width and thickness are of different dimensions, the cross-section in a plane parallel to the open or closed end might present the appearance of, for example, an elongated rectangle, or an ellipse. The electric waves to be received are accompanied by magnetic waves at right angles to the former, which will generate voltage in the coil 34, and, hence, the resonator will be coupled to the coil. The coil 34 is coupled to the electrostrictive unit through the variable condenser 35, and, through the latter, the coil and electrostrictive unit 12' are tuned to the same frequency as the chamber. Over a narrow frequency band, all of the energy received in the resonant chamber is transformed into electrical energy reaching the receiver. The electrical Q of the electrostrictive material is high, and, hence, substantially all of the energy received will be transformed into acoustic energy. To make the Q of the resonant chamber high, it may be necessary to restrict the size of the open end or opening 36 so that the radiation resistance of the opening will be of the appropriate value.

Although this invention has been disclosed with reference to several specific embodiments thereof, it is apparent that the inventive concept may find other and further embodiments; it is to be understood, therefore, that the scope of the invention is intended to be limited by the appended claims only.

What is claimed is:

1. The combination comprising a diaphragm, means for movement with said diaphragm comprising an electrostrictive material, said material having an electrostrictive constant of the order of that for hard rubber, and a superaudible frequency circuit coupled to said means.

2. The combination comprising a diaphragm, means coacting with said diaphragm and comprising a plurality of superposed laminations of an electrostrictive material having an electrostrictive constant of the order of that for hard rubber, and means to apply the modulated electric wave to opposed surfaces of said unit, and a superaudible frequency circuit coupled to said means.

3. The combination of claim 1, including means proportioned to constitute with said first means an electric wave filter.

4. The combination of claim 1, including means proportioned to constitute with said first means a band-pass electric wave filter.

5. The combination of claim 1, including wave guide means.

6. In combination, means for demodulating a modulated electric wave, comprising a unit of a material having an electrostrictive constant of the order of that for hard rubber, and means to apply the modulated electric wave to opposed surfaces of said unit.

7. The combination as claimed in claim 6, in which said unit comprises a plurality of superposed laminations of the electrostrictive material.

8. In combination, means for demodulating an amplitude modulated electric wave comprising a unit of a material having an electrostrictive constant of the order of that for hard rubber, and

means to apply the modulated electric wave to opposed surfaces of said unit.

9. The combination of an electrostrictive transducer comprising a plurality of superposed laminations of an electrostrictive material, a hollow electric wave resonator, and a coil in said resonator having its ends connected to opposed surfaces of each lamination for coupling said resonator and said transducer.

10. The combination comprising a diaphragm, a unit of said unit and said diaphragm being positioned so that movement of one is transferred to the other, a material having an electrostrictive constant of the order of that for hard rubber, a hollow electric wave resonator, and a coil in said resonator having its ends connected to opposed surfaces of said unit for coupling said resonator and said unit.

11. The combination of a casing, a diaphragm supported on said casing, a unit of electrostrictive material in said casing and coacting with said diaphragm, said material having an electrostrictive constant of the order of that for hard rubber, a hollow electric wave resonator adjacent said casing, and means coupling said resonator and said unit.

12. The method of translating the modulation component of a modulated electric wave into acoustic vibration that comprises establishing a potential gradient in accordance with said electric wave between opposed surfaces of a unit of an electrostrictive material having an electrostrictive constant of the order of that for hard rubber.

13. The method of translating an acoustic vibration into a modulated electric wave that comprises producing dimensional change in the electrostrictive material in accordance with said acoustic wave while simultaneously applying to said material an electric wave to be modulated.

14. The method of translating an acoustic vibration into a modulated electric wave that comprises vibrating a diaphragm in accordance with the acoustic vibration, producing dimensional change in an electrostrictive unit in accordance with said diaphragm vibration, and simultaneously applying to said unit an electric wave to be modulated.

15. A system for translating an amplitude modulated electric wave directly into acoustic vibrations, that comprises a source of amplitude modulated electric wave, demodulating means comprising a member of electrostrictive material coupled to said source, the electrostrictive constant of said material being of the order of that for hard rubber, and a sound radiating member for movement with said member of electrostrictive material for translating the dimensional changes of said member of electrostrictive material into sound waves.

16. The method of translating a modulated electric wave directly into acoustic vibrations corresponding to its modulation component, that comprises establishing a potential gradient in accordance with said electric wave between opposed surfaces of a unit of a material having an electrostrictive property to produce dimensional change therein corresponding to said modulation component, and actuating an acoustic wave vibratable member in accordance with such dimensional change.

17. The method of translating a modulated electric wave directly into acoustic vibrations corresponding to its modulation component, that comprises establishing a potential gradient in

accordance with said electric wave between opposed surfaces of a unit comprising a plurality of superposed layers of a material having an electrostrictive property to produce dimensional change in each layer corresponding to said modulation component, and actuating an acoustic wave vibratable member in accordance with such dimensional change.

18. The method of modulating an electric wave

in accordance with an acoustic vibration that comprises establishing a potential gradient in accordance with said electric wave between opposed surfaces of a unit comprising an electrostrictive material, and altering the dimension between said opposed surfaces in accordance with the acoustic vibration.

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