June 30, 1931. E. C. WENTE 1,812,389

ACOUSTIC DEVICE

Original Filed April 1, 1925

Fig. 1

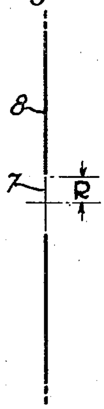


Fig. 2

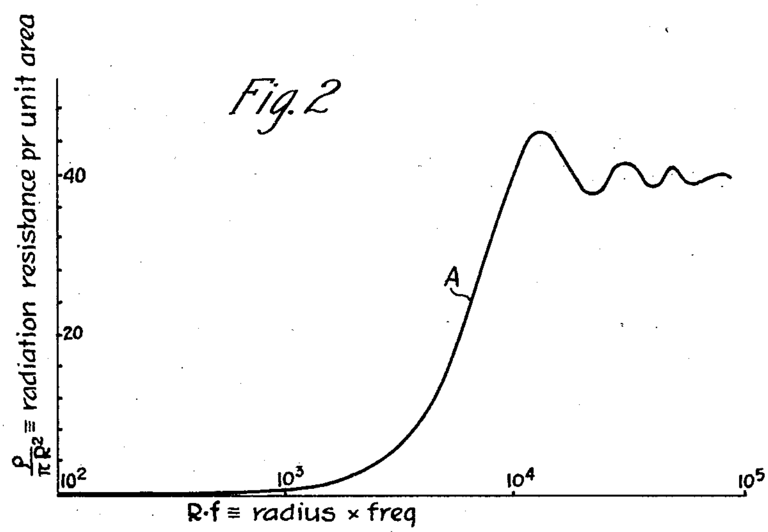


Fig. 3

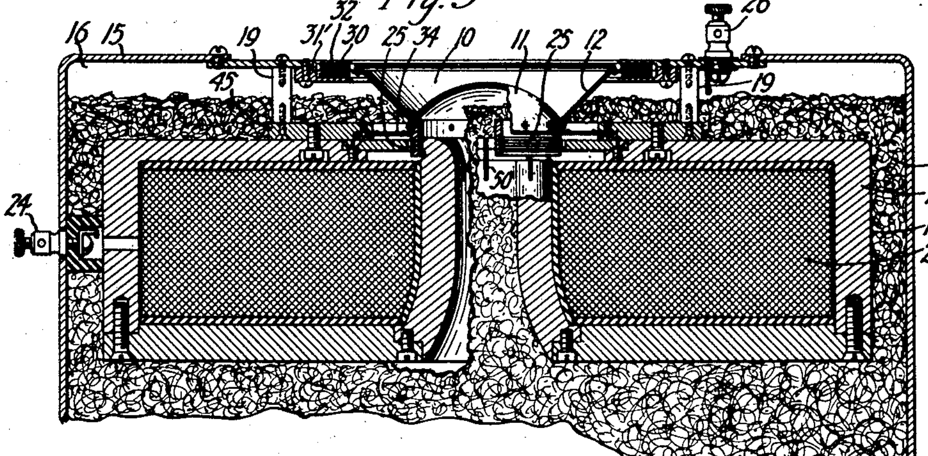


Fig. 4

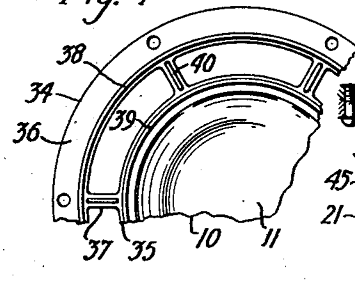
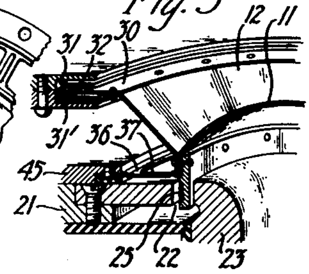


Fig. 5



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Patented June 30, 1931

1,812,389

UNITED STATES PATENT OFFICE

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ACOUSTIC DEVICE

Application filed April 1, 1925, Serial No. 19,793. Renewed September 11, 1930.

This invention relates to producing sound waves corresponding to electrical waves or mechanical force waves, or vice versa, and aims to provide means capable of faithfully reproducing complex waves, and especially to provide a loud speaking telephone receiver capable of faithfully reproducing electrical variations as sound such as speech or music.

The invention will be described hereinafter with especial reference to such a receiver. In accordance with such application of the invention, an inflexible diaphragm is so mounted and so actuated, as set forth hereinafter, that the ratio of the power output in the form of sound to the electrical power input due to the current corresponding to the sound to be reproduced, is substantially the same for all frequencies in the range of frequencies to be reproduced.

Fig. 1 of the accompanying drawings is a diagram, and Fig. 2 a graph, for facilitating explanation of the invention; Fig. 3 is a sectional elevation of an embodiment of the invention; Fig. 4 is a top plan of a detail of Fig. 3, partly broken away; and Fig. 5 is a fragmentary sectional perspective view of the device of Fig. 3.

Before describing the structure of Figs. 3 to 5 in detail, it will be well to set forth certain theoretical considerations regarding an electromechanical loud speaker without a horn.

When a body vibrates in an elastic medium such as air, the power that is developed in the form of sound waves may be expressed by $P=\rho v^2$ where P is the power,

v is the velocity with which the body vibrates,

ρ is a factor which we may call the radiation resistance.

The analogous equation for an electrical circuit is power$=RI^2$. In the latter case the resistance, R, is as a rule constant, at least to the first order of approximation, ρ is, however, in general a function not only of the character of the vibrating body and the medium but also of the frequency of vibration.

If a plane disc 7 situated in an infinite plane 8, as shown in Fig. 1, vibrates as a unit perpendicularly to its plane, ρ will vary after the manner shown in the curve A of Fig. 2, as may be seen if values of the radiation resistance per unit area of the diaphragm, for values of the product of diaphragm radius times frequency which lie between 10^2 and 10^5, are calculated (all in c. g. s. units) from Equation 10, page 164, section 302, volume 2 of Rayleigh's "Theory of Sound" (published by MacMillan and Company, London, 1894), and plotted as in Fig. 2. Here R is the radius of the disc, f is the frequency, and

$$\frac{\rho}{\pi R^2},$$

the ordinate, is the radiation resistance per unit area of the disc. For values of R.f up to 10^4 c. g. s. units, the quantity

$$\frac{\rho}{\pi R^2}$$

varies approximately as $(R.f)^2$. Up to this value of R.f for a disc of given radius the radiation resistance would vary as the square of the frequency, e. g. if we made $R=4$ cm., we would have

$$\frac{\rho}{\pi R^2}\,\alpha f^2$$

from 0 to 2500 p. p. s. or ρ Kf^2 and $P=Kf^2v^2$ up to 2500 p. p. s.

In any practical case such a disc would have to have some form of elastic support. This would mean that the disc, which has a certain mass, would have a resonant frequency of some finite value. Above this resonant frequency the velocity of the disc is given, to a close approximation by

$$v=\frac{F}{m\omega}$$

where F is the force acting on the disc, m is the mass of the disc $\omega=2\pi f$. For the region above resonance and below 2500 p. p. s. we should then have

$$P=Kf^2.\frac{F^2}{m^2(2\pi f)^2}=\frac{K}{(2\pi m)^2}F^2$$

This equation shows that, P, the sound developed by the disc would be independent of frequency for a constant applied force. If now we apply the force F by electrical means in such a way that F is proportional to the current, I, we shall have the ratio of sound output to electrical power input (which is proportional to I^2) the same for all frequencies between resonance and 2500 p. p. s.

Above 2500 p. p. s ρ varies comparatively little with frequency. At 5000 p. p. s. the velocity of motion of the disc under the assumed condition would have one half the value it has at 2500 p. p. s. From 2500 to 5000 p. p. s. the sound output would, therefore, drop 6 T. U. and up to 10,000 p. p. s. another 6 T. U. (The abbreviation T. U. is for the transmission unit discussed in the following articles: "The Transmission Unit", by R. V. L. Hartley, in Electrical Communication, July, 1924, published by the International Western Electric Co., Inc., New York; and "The Transmission Unit and Telephone Transmission Systems", by W. H. Martin, and "Practical Application of the 'Transmission Unit' ", by C. W. Smith, both in the Bell System Technical Journal, July, 1924, published by the American Telephone and Telegraph Co., New York.) This variation is not excessive for this large expanse of frequency.

In practice it might not be advisable to use the disc in a plane of very large extent as was assumed in the preceding discussion. If the back of the disc is closed off so as to prevent radiation from the side, the sound output will be reduced by 6 T. U. at the lower frequencies by the removal of the infinite plane. The omission of the infinite plane thus in part offsets the drop at the higher frequencies because of the fact that there ρ approaches a constant value. A receiver constructed as described below renders it possible to transmit a band of frequencies extending from, say 100 to 7000 cycles per second, with the transmission loss varying less than 6 T. U. throughout such frequency band, and at the same time, to maintain the diameter of the diaphragm large enough to economically obtain satisfactory value of sound output.

Construction of the receiver

To operate on the principles just set forth, a receiver should preferably satisfy the following conditions: The disc or diaphragm should be constructed so that it will move as a unit at all frequencies at which the receiver is to operate, or if not as a unit, its mode of motion should not change throughout the frequency range; the natural frequency of the diaphragm should lie below the lowest frequency we wish to reproduce; one side of the disc should be completely shut off from the outside air; the force on the diaphragm should be proportional to the current input; the impedance of the receiver winding should not vary greatly with frequency; and the disc should be mounted so that it is free to execute large amplitudes of motion, in order to obtain a sound output of sufficiently large volume.

One construction adapted to meet these conditions is shown in Figs. 3 to 5. In that construction, the diaphragm 10 comprises a circular central portion 11 bulging in one direction, and an annular rim 12 flaring from the periphery of the central portion in that direction, the diaphragm thus having a W-shaped cross section, as indicated in Fig. 3. The central portion 11 is preferably dome-shaped, as shown, since a structure of this shape is specially adapted to move as a unit up to very high frequencies when driven from its base as described hereinafter. However, the portion 11 may be of any shape, for instance conical, suitable for obtaining the requisite stiffness, and may, if desired, be annularly or radially corrugated to increase its stiffness. For the sake of rigidity, the rim or outer portion 12 of the diaphragm 10 is preferably frusto-conical, as indicated in Figs. 3 and 5. However, the rim 12 may be of any suitable shape, for instance, downwardly concave and upwardly convex, suitable for obtaining the stiffness requisite to enable the rim to be vibrated as a unit up to very high frequencies when driven from its inner periphery as described hereinafter. If desired, the rigidity of the rim 12 may be increased by annular or radial corrugations, not shown. Preferably, the diaphragm 10 is of thin light metal, for instance duralumin or aluminum. Its diameter should be sufficiently small to insure the desired degree of uniformity of transmission efficiency over the frequency range to be transmitted. The mass of the diaphragm should be sufficiently small to enable the receiver to have the desired sensitivity. Preferably the diameter should be as small as 5 inches, and the mass as small as 5 gr.

The diaphragm is so mounted as to close an opening in a wall 15 of a casing 16 which closes off one side of the diaphragm from the surrounding air. The magnet 18, which is shown as an electromagnet but may, if desired, be a permanent magnet, is enclosed in the casing 16 and rigidly connected to the casing by any suitable means such, for instance, as rods 19. As shown, the magnet comprises a winding or coil 20 surrounded by a paramagnetic flux path 21 having an annular air-gap 22 therein at the end of the hollow core 23 adjacent to the diaphragm 10. Terminals 24, only one of which is shown, are provided for coil 20, so that the coil may be energized by direct current.

The driving system for the diaphragm is shown as of the movable coil type, the coil 25 for receiving the telephonic current being situated in the radial magnetic field in the air-gap 22. This type of driving unit has a large force factor, and the impedance of the coil is substantially the same for the frequencies of importance in music. Binding posts 26, only one of which is shown, form terminals for the coil 25. This coil is rigidly connected to the diaphragm at the junction of the central portion 11 and the rim 12, as shown in Figs. 5 and 3, so that the elements 11, 12, and 25 form a rigid unit. A ring 30 preferably of very thin metal, for instance duralumin or aluminum extends outwardly from the periphery of the rim 12, in the plane of that periphery. Ring 30 is supported from the wall 15. Preferably the outer periphery of the ring engages the outer cylindrical wall 31′ of an annular recess 31 in the inner edge of the wall, and above and below the ring 30 the recess is filled with paper rings 32, such as are used for so-called book damping. If desired, the paper rings may be caused to hold ring 30 tightly near its outer periphery and loosely near its inner edge, for instance by tapering (not shown) the recess so that it is narrower near wall 31′ than near the periphery of the diaphragm. The paper rings offer only slight opposition to movement of the diaphragm 10 in the direction perpendicular to the plane of the ring 30, and thus permit substantially free vibration of the diaphragm as a unit in that direction, with large amplitude, for instance a double amplitude of two millimeters, while at the same time maintaining the coil 25 in proper position for vibration in the air-gap 22. A member 34 preferably in the form of an annular spider comprising a hub portion 35, a rim 36, and radial spokes 37 connecting the hub and the rim, is rigidly connected to and extends outwardly from the junction of the central portion 11 and the rim 12 of the diaphragm 10. Preferably, the hub 35 of the spider 34 is integral with the central portion 11 of the diaphragm, as indicated in Fig. 5, and is of thin light metal, for instance duralumin or aluminum, with the rim annularly corrugated as at 38, the hub annularly corrugated as at 39, and the spokes radially corrugated as at 40 (see Fig. 4). All of these corrugations open into the plane of the spokes.

The rim of the spider is supported from the structure of magnet 18 and casing 16, preferably by being clamped in the inner edge of a ring 45 rigid with magnet 18. The spider 34, as well as the ring 30, supports the diaphragm and moving coil for substantially free vibration perpendicularly to the plane of the spider, with large amplitude, while maintaining the coil in proper position in the air-gap. The annular corrugations 38 and 39 allow the width of the spider 34 to increase when the spider is flexed from its normal position and the radial corrugations 40 tend to prevent undesirable vibrations in the spider.

In order to keep the resonant frequency of the diaphragm low, preferably as low as 100 cycles per second, the chamber formed by casing 16 is of such size that the volume of air in the chamber is large compared to the maximum volumetric displacement executed by the diaphragm during its normal operation. For instance, with a diaphragm having a diameter of the order of 3½ inches, and a magnet having a diameter of the order of 6 inches and a length of 4 inches, the casing 16 may be a box-like casing having dimensions of the order of 12″ by 12″ by 8″ in depth. To reduce standing waves within the casing, preferably the hole through the magnet core is flared and the portion of the chamber not occupied by the magnet is substantially filled with some damping material such as loose wool or down 51 as indicated in the drawing.

To reduce eddy currents, slits 50, parallel to the axis of core 23, are provided in the end of the core adjacent coil 25.

The paper rings 32 effectively prevent passage of air or sound waves around the edge of the diaphragm 10, from the outside to the inside, or vice versa, of the chamber formed by casing 16, and yet, as noted above, permit substantially free vibration of the diaphragm, as a whole, through large amplitudes, at the frequencies to be reproduced. The paper rings also prevent sound originating at one face of the diaphragm from impinging on one face of the ring 30 and being transmitted through that ring to the air on the other side of that ring. The paper rings also prevent resonant vibrations of the ring 30 itself.

In the operation of the device as a telephone receiver, coil 20 is energized by direct current, to create a steady, radial electromagnetic flux across gap 22; and the binding posts 26 (only one of which is shown) of coil 25 are connected to the source (not shown) of telephonic current, the variations of which are to be reproduced as sound. The diaphragm and the coil 25 vibrate as a whole, in accordance with the variations in the latter current, the diaphragm giving off the sound corresponding to those current variations. The device is of course reversible. That is, sound waves impinging on the diaphragm will cause the device to function as a transmitter, generating in coil 25 a correspondingly varying E. M. F.

By properly fixing the extent of the wall 15 beyond the periphery of the diaphragm 10, the effect of the wall in increasing the sound output of the receiver at low frequencies more than at high frequencies, can be made such as to give the best results under the particular operating conditions encountered. For instance, if the range of frequencies which it be desired to transmit with substantially uniform efficiency lies below 2500 cycles per second and the radius of the diaphragm be 4 cm., it may be advisible to have the wall 15 wide enough to maintain the efficiency as high as practicable over that frequency range; whereas, if the frequency range which it be desired to transmit with substantially uniform efficiency extends from 3500 cycles per second or 5500 cycles per second down to quite low frequencies, and the radius of the diaphragm be 4 cm. and 3 cm. in these cases, respectively, it may be desirable to have the extent of the wall only great enough to raise the efficiency at the low frequencies sufficiently to attain the greatest practicable equalization of transmission efficiency over the frequency range up to 3500 cycles per second or 5500 cycles per second in these two cases, respectively. The specific frequency and radius values here mentioned are merely illustrative. As a further example, if the frequency range which it be desired to transmit with substantially uniform efficiency extends from 5000 cycles down to quite low frequencies, and the radius of the diaphragm be 4 cm., then it may be desirable to have the extent of the wall negligibly small, in accordance with the principles hereinbefore explained.

Distortion due to non-linear response

Not only may the receiver of this invention be made to have practically a uniform response over the whole frequency range to be reproduced, as for instance the range of frequencies of importance in music, but it is, moreover, free from another type of distortion introduced by most loud speakers. This latter type of distortion is produced if at a given frequency the displacement is not proportional to force. Since this receiver operates above the resonant frequency of the diaphragm, the amplitude,

$$a=\frac{F}{m\omega^2}$$

if the diaphragm moves as a unit m, the effective mass of the diaphragm, is constant and a and F are proportional.

The broad features involving the general principles disclosed herein may be embodied in many organizations widely different from those specifically shown and described, without departing from the spirit of the invention defined in the appended claims.

What is claimed is:

1. An acoustic device comprising a diaphragm, an air chamber for which said diaphragm forms a closure member, the air inclosed in said chamber forming a cushion for said diaphragm, and means mounting said diaphragm on said air chamber, the volume of said inclosed air being sufficiently large and the stiffness of said mounting means sufficiently small in magnitude to maintain the resonance frequency of the diaphragm below the frequency range of importance in music.

2. An acoustic device comprising a direct acting diaphragm, an air chamber for which said diaphragm forms a closure member, the air inclosed in said chamber forming a cushion for said diaphragm, and means mounting said diaphragm on said air chamber, the volume of said inclosed air being sufficiently large and the stiffness of said mounting means sufficiently small in magnitude to maintain the resonance frequency of the diaphragm below the frequency range of importance in music.

3. An acoustic device comprising a plunger type diaphragm having a W-shaped cross section and an air chamber for which said diaphragm forms a closure member, said chamber being too large to cause resonance of the diaphragm above 100 cycles per second.

4. An acoustic device comprising a plunger type diaphragm having its natural frequency below the frequency range of importance in speech, an air chamber for which said diaphragm forms a closure member, and a driving coil rigid with said diaphragm, said chamber being too large, in comparison to the maximum volumetric displacement executed by said diaphragm in normal operation, to cause resonance of the diaphragm in said frequency range.

5. A device comprising a diaphragm having a natural frequency of vibration below the range of frequencies of importance in speech and having a radiation resistance varying substantially as the square of the frequency of vibration of the diaphragm over said frequency range, and means responsive to current of speech frequencies for driving said diaphragm with a force proportional to said current.

6. An acoustic device comprising a diaphragm having a natural frequency of vibration below the range of frequencies of importance in music and having a radiation resistance varying substantially as the square of the frequency of vibration of the diaphragm over said frequency range, and means responsive to current of frequencies of said range for driving said diaphragm with a force proportional to said current.

7. A device comprising a diaphragm having a natural frequency of vibration below the range of frequencies of importance in speech and having a radiation resistance varying substantially as the square of the frequency of vibration of the diaphragm over said frequency range, and means responsive to power variations representing sound waves for causing said diaphragm to generate sound wave power proportional in magnitude to said first mentioned power variations.

8. A device comprising means responsive to electromotive force, of the frequencies of the range important in music, for generating mechanical force substantially proportional to the electrical current delivered to said

means due to said electromotive force, and a diaphragm movable as a whole, in response to said mechanical force, with velocity substantially inversely proportional to the frequency of said electromotive force for a given value of said mechanical force.

9. A device comprising a direct acting diaphragm having a natural frequency of vibration below the range of frequencies of importance in speech and having a radiation resistance varying substantially as the square of the frequency of vibration of said diaphragm over said frequency range, means responsive to current of speech frequencies for driving said diaphragm with a force proportional to said current, and a wall extending outwardly from, and substantially in the plane of, the periphery of said diaphragm, and increasing the sound power produced by said diaphragm.

10. A device comprising a piston type, direct acting diaphragm having a natural frequency of vibration below the range of frequencies of importance in music, means responsive to current of the frequencies of said range for driving said diaphragm with a force proportional to said current, and a wall extending outwardly from, and substantially in the plane of, the periphery of said diaphragm, a distance of such magnitude, with regard to the diameter of the diaphragm, as to substantially equalize the sound power output, per unit of said force, over said range.

11. An acoustic device comprising a diaphragm, an air chamber for which said diaphragm forms a closure member, the air inclosed in said chamber forming a cushion for said diaphragm, and means mounting said diaphragm on said air chamber, the volume of said inclosed air being sufficiently large and the stiffness of said mounting means sufficiently small in magnitude to maintain the resonance frequency of the diaphragm below the frequency range of importance in music, said first mentioned means comprising book damping means for said diaphragm.

12. A device comprising a diaphragm having a W-shaped cross section, book damping means for said diaphragm, and driving means for said diaphragm attached to the symmetrical cusps of said cross section.

13. A device comprising a diaphragm provided with book damping means and having a natural frequency of vibration below the range of frequencies of importance in speech and having a radiation resistance varying substantially as the square of the frequency of vibration of the diaphragm over said frequency range, and means responsive to current of speech frequencies for driving said diaphragm with a force proportional to said current.

14. An acoustic device comprising an inflexible diaphragm having a natural frequency below a range of frequencies to be reproduced, means closing off one side of said diaphragm from the surrounding sound propagating medium, means supporting said diaphragm for substantially free vibration, as a unit, with large amplitude, at the frequencies of said range, and means responsive to current of the frequencies of said range for driving said diaphragm with a force proportional to said current.

15. A loud speaking telephone receiver comprising a diaphragm having a forwardly bulging central portion and a rim flaring backwardly from the bulging portion, means closing one side of said diaphragm off from the surrounding air and mounting said diaphragm for vibration as a whole, at the frequencies of importance in speech, and means attached to said diaphragm at the junction of said bulging portion and said rim and responsive to current of said frequencies for driving said diaphragm.

16. A device comprising a paramagnetic body forming a flux path with an air gap therein, an inflexible diaphragm for vibration as a whole, a coil, means rigidly connecting said coil to said diaphragm, and means supporting said diaphragm for vibration as a whole, at the frequencies of importance in speech, with said coil centered in said gap, said means including annularly and radially corrugated means connected to said diaphragm and extending outwardly from said diaphragm, with respect to the axis of said diaphragm in the direction of said vibration.

17. A loud speaking receiver comprising a paramagnetic body forming a flux path with an air gap therein, a diaphragm having a forwardly bulging central portion and a rim flaring backwardly from said bulging portion, a coil, means rigidly connecting said coil to the junction of said central portion and said rim, an annular web extending outwardly from the periphery of said diaphragm, an annular spider extending outwardly from the periphery of said central portion, and means, including said web and said spider for supporting said diaphragm and said coil for vibration with said coil centered in said air gap.

18. An acoustic device comprising a diaphragm, an air chamber for which said diaphragm forms a closure member, the air inclosed in said chamber forming a cushion for said diaphragm, loose fibrous material occupying the major portion of said air chamber, and means mounting said diaphragm on said air chamber, the volume of said inclosed air being sufficiently large and the stiffness of said mounting means sufficiently small in magnitude to maintain the resonance frequency of the diaphragm below the frequency range of importance in music.

19. A loud speaking receiver comprising a piston type, direct acting diaphragm having a natural frequency of vibration below

100 cycles per second, means closing one side of said diaphragm off from the surrounding air, and means responsive to current of frequencies of the range between one hundred and five thousand cycles per second for driving said diaphragm, said diaphragm having a diameter sufficiently small to maintain the minimum value, for said frequency range, of the ratio of sound power output to the square of said current, as high as 25% of the maximum value of said ratio for said frequency range.

20. An acoustic device comprising a direct acting, piston type diaphragm, an air chamber for which said diaphragm forms a closure member, fibrous material in said air chamber for reducing standing waves therein, the air enclosed in said chamber forming a cushion for said diaphragm, and means mounting said diaphragm on said air chamber for vibration of said diaphragm as a whole, the volume of said enclosed air being sufficiently large and the stiffness of said mounting means sufficiently small in magniture to maintain the resonant frequency of the diaphragm below one hundred cycles per second, said diaphragm having a diameter sufficiently small to render said device capable of transmitting a band of frequencies extending from one hundred cycles to seven thousand cycles per second with a maximum variation in transmission loss, with frequency, of six transmission units.

21. A loud speaking receiver comprising a piston type, direct acting diaphragm having a natural frequency of vibration below one hundred cycles per second; means closing one side of said diaphragm off from the surrounding air, and means responsive to current of the frequencies of importance in music for driving said diaphragm, said diaphragm having a diameter sufficiently small to render said receiver capable of transmitting a band of frequencies having a width of approximately seven thousand cycles per second with a maximum variation of transmission loss as low as six transmission units.

22. A loud speaking receiver comprising a piston type, direct acting diaphragm, means closing one side of said diaphragm off from the surrounding air, and means responsive to current of frequencies of the range of importance in music for driving said diaphragm, said diaphragm having a diameter sufficiently small to render said receive capable of transmitting, with a maximum distortion as low as six transmission units, a band of frequencies extending from a frequency of the order of one hundred cycles per second to a frequency of the order of six thousand cycles per second.

23. An acoustic device comprising a diaphragm, a coil secured thereto for driving the diaphragm, a pair of concentric pole-pieces separated by a gap in which said coil is positioned, one of said pole-pieces having an axial opening therein, and means in said opening for absorbing sound waves.

24. An acoustic device comprising a rigid diaphragm having a curved inner portion and a flat peripheral portion, means for supporting the diaphragm at its peripheral portion so that it is capable of vibrating as a whole, means for actuating said diaphragm comprising a pair of concentric pole-pieces separated by an annular gas and an actuating coil secured to said diaphragm, and means for centering said coil in said gap, said means being expansible when said coil is moved from its normal position to enable the coil to move axially.

25. An acoustic device comprising a rigid diaphragm, means at the periphery of the diaphragm for supporting it so that it is free to move bodily, means for actuating said diaphragm comprising pole-pieces separated by a narrow gap and an actuating coil secured to said diaphragm, and a spider-like member for preventing lateral movement of said coil in said gap, said member being provided with annular corrugations to allow the width of the member to increase when it is flexed form its normal position and with radial corrugations to prevent undesirable vibrations in said member when the coil is vibrated.

26. An acoustic device comprising a diaphragm having one face thereof exposed directly to the surrounding air, means attached to said diaphragm at points removed from the center thereof for driving it, means to prevent the sound waves radiated by the exposed face of the diaphragm from interfering with those radiated by the other face of said diaphragm, and means for damping the waves given off by said other face of the diaphragm.

27. An acoustic device comprising a casing having a front wall with an aperture therein, side and back walls, a magnet mounted within said casing having annular pole pieces spaced to form an annular air gap, a diaphragm comprising a curved portion and a surrounding annular portion, a coil in said air gap secured to the diaphragm at the edge of the curved portion thereof, means for supporting the outer rim of said diaphragm in the aperture in said casing so that it is free to move substantially as a whole, and means within said casing and surrounding said magnet for damping sound waves given off by one side of the diaphragm.

28. A loud speaking device comprising a dished diaphragm having one face thereof exposed directly to the surrounding air and of sufficient size to radiate sound directly into the surrounding air without the employment of a horn, means including a coil attached to said diphragm at points removed from the center thereof for driving it, a casing having

an aperture into which said diaphragm fits, and means within said casing for damping the sound waves given off by the unexposed face of said diaphragm.

29. The combination of a diaphragm for radiating sound waves directly into the surrounding air without the employment of a horn, means including a coil attached to said diaphragm and a magnet structure for driving it, a casing having an aperture in one wall thereof in which said diaphragm is disposed and a filling of sound deadening material in said casing and surrounding said magnet structure.

In witness whereof, I hereunto subscribe my name this 30th day of March, A. D. 1925.

EDWARD C. WENTE.