Nov. 12, 1946. A. J. SANIAL 2,411,004

SOUND AMPLIFYING APPARATUS

Filed Sept. 1, 1943 2 Sheets-Sheet 1

Fig. 1

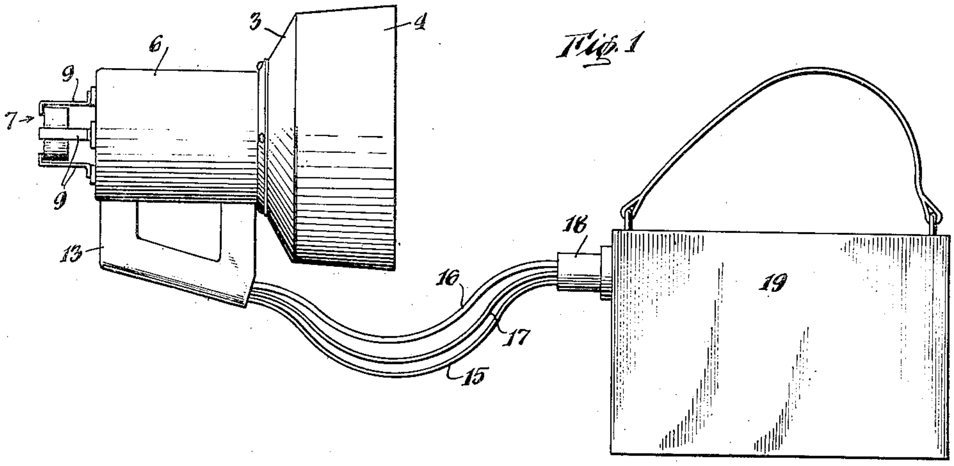

Fig. 4

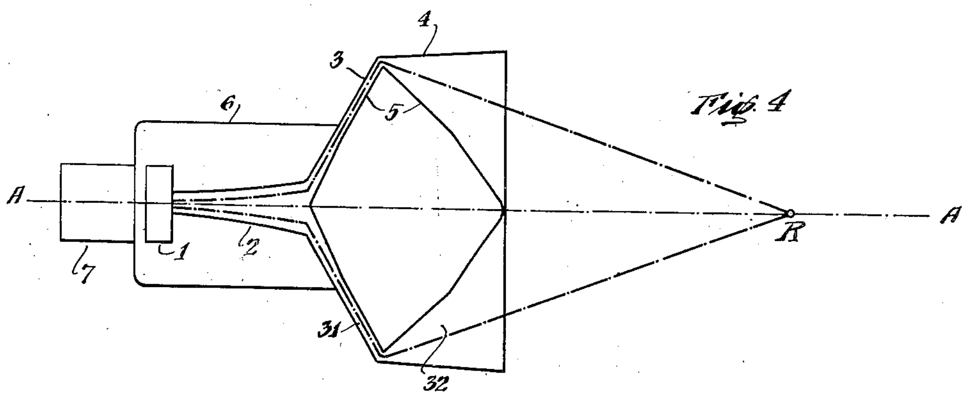

Fig. 5

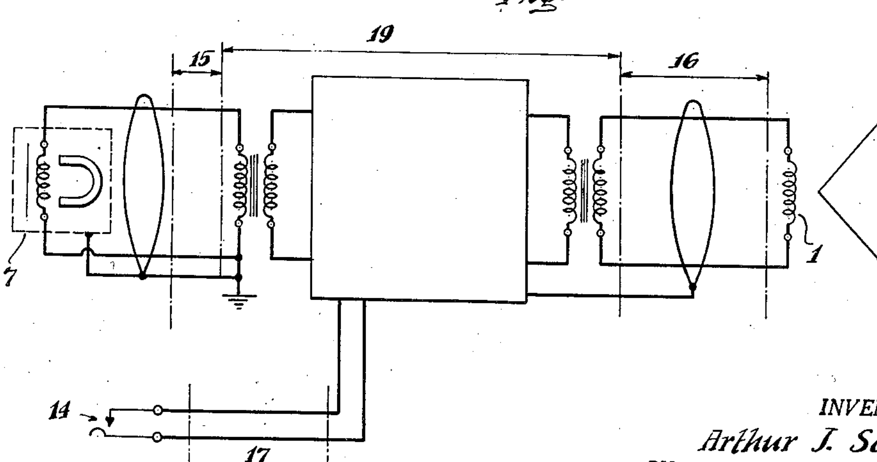

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Fig. 2

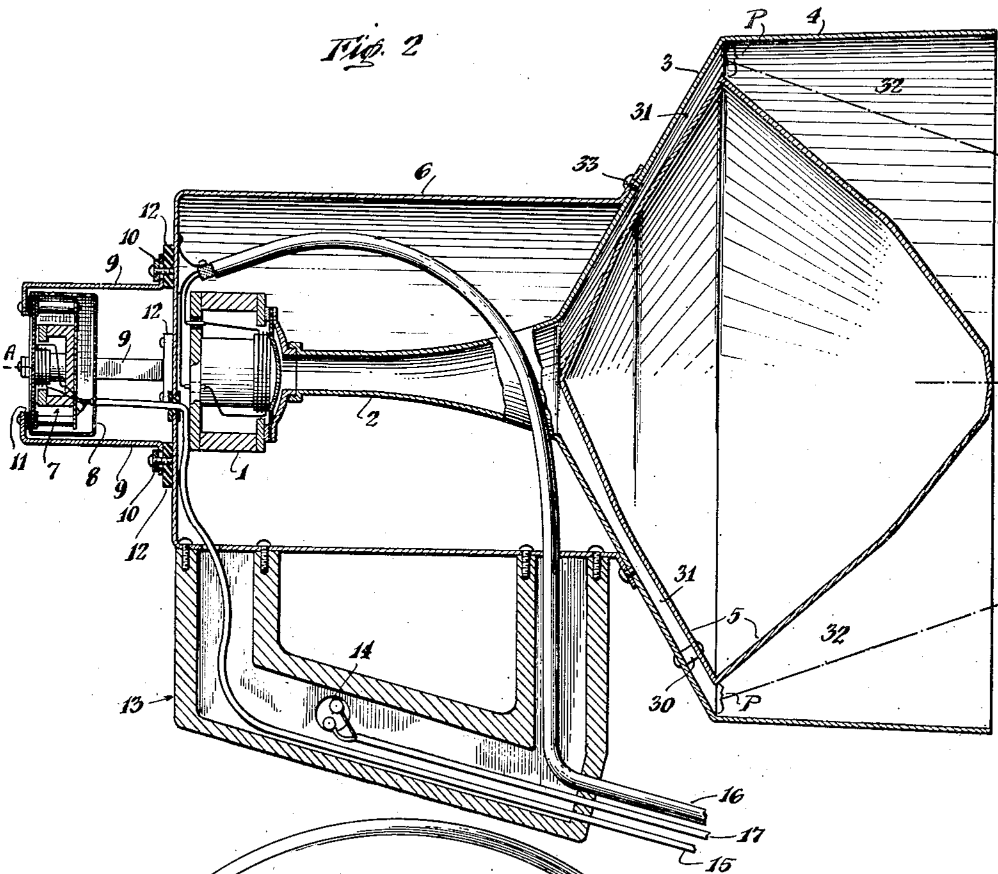
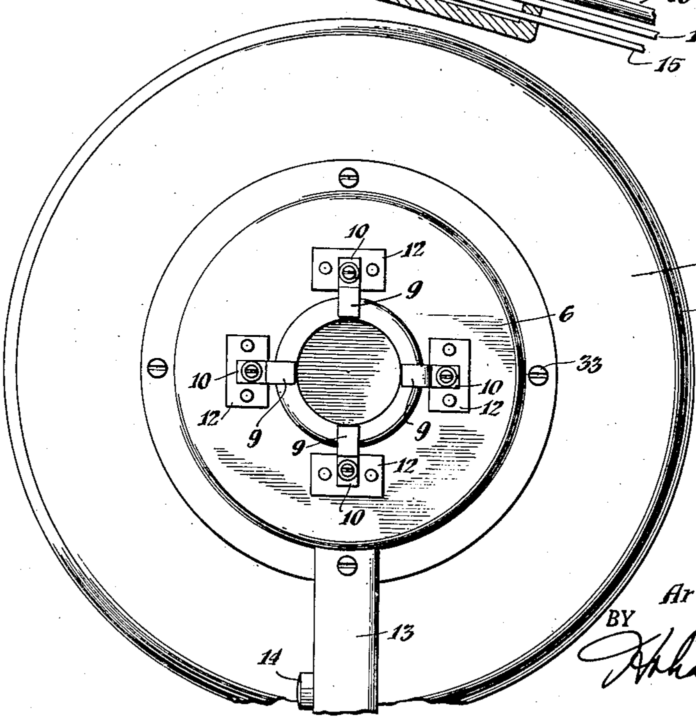


Fig. 3



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SOUND AMPLIFYING APPARATUS

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Application September 1, 1943, Serial No. 500,785

13 Claims. (Cl. 179—1)

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This invention relates to sound amplifying apparatus, more particularly to electronically powered sound amplifying apparatus embodying both microphone and loudspeaker units.

Objects and advantages of the invention will be set forth in part hereinafter and in part will be obvious herefrom, or may be learned by practice with the invention, the same being realized and attained by means of the instrumentalities and combinations pointed out in the appended claims.

The invention consists in the novel parts, constructions, arrangements, combinations and improvements herein shown and described.

The accompanying drawings, referred to herein and constituting a part hereof, illustrate one embodiment of the invention, and together with the description, serve to explain the principles of the invention.

An object of this invention is to provide an electronic megaphone unit with which sounds delivered to the input will issue from the output in greatly amplified volume.

Another object of this invention is to provide new and improved electronic sound-amplifying apparatus which is compact and portable so that it can readily be carried by an individual and with which the amplified sounds can be readily directed where desired.

Another object of this invention is to provide a combination microphone and loudspeaker unit of which the microphone and loudspeaker are in close physical relationship and which when held close to a person's mouth, but not touching, will amplify the voice to a very great volume without acoustic feedback.

Another object of this invention is to provide a combination microphone and loudspeaker unit which will be free of undesirable energy transfer either by electrical, acoustical or mechanical means between the loudspeaker and the microphone, when they are interconnected by means of an amplifier.

Of the drawings:

Fig. 1 is a view in side elevation of an electro-acoustic megaphone unit and its amplifier constituting a typical and illustrative embodiment of this invention;

Fig. 2 is a sectional view in elevation of the megaphone unit of Fig. 1;

Fig. 3 is a view in end elevation of the megaphone unit of Fig. 2, as viewed from the left;

Fig. 4 is a somewhat diagrammatic view of the megaphone unit of Fig. 1 schematically illustrating the sound focusing operation of the unit; and,

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Fig. 5 is a schematic view of the electrical circuit of the embodiment of Fig. 1.

In accordance with the illustrative embodiment of the invention, the electronic megaphone unit is made up of a microphone and a loudspeaker, each of special type, positioned in definite, and preferably fixed, spatial relationship and interconnected by an amplifier.

The microphone has both sides of its diaphragm, or other sound wave sensitive element, open to the atmosphere, at least to the extent that sound waves will have access to both back and front. Thus, sounds directed at it from a distance will travel substantially along paths of almost the same length from the source to the front and back of the diaphragm, so that they will have a comparatively small vibrating effect. On the other hand, however, sounds directed at the front of the diaphragm from a source close thereto will not be subject to this cancelling effect due to the large difference in path length of the sound from the sound source to front and back of the diaphragm, respectively.

The loudspeaker is of such construction that the sounds emanating therefrom will be converged and directed thereby toward a region on the central axis in front of the horn. Projecting the sound to a region in space a distance in front of the horn actually creates what may be thought of as a virtual source of the radiated sound. This gives the effect of a longer horn than the physical length of that actually used. The source of sound is thus removed farther from the microphone so that the acoustic feedback tendency is reduced. Even though the sound ultimately diverges beyond the focal region, the degree of divergence is much less from this device than from a conventional horn exit. Hence, even such sound as does diffuse backwards from beyond the focal region is largely attenuated in the distance it must travel back to the microphone location and is of substantially no consequence at the microphone because of the cancellation effect arising from both sides of the microphone diaphragm being open to the atmosphere.

A spatial relationship of the microphone and loudspeaker is established such that the microphone is centered on, and is normal to the central acoustic axis of such sound waves as may radiate backward from the loudspeaker mouth. This is not necessarily the geometric central axis, so that the microphone is located by trial in this null position when first mounted, or the mounting is provided with means to permit it to be adjusted to the null position when in use.

The microphone and loudspeaker may be separately supported having regard to the requirement of the null position of the microphone. Preferably, however, suitable means are provided for incorporating them in a single unit which may also incorporate the amplifier if so desired. Suitable provision for reducing mechanical vibration impressed by one upon the other or upon either or all from external sources is preferably made in the form of cushioning devices of resilient material located at the most advantageous points of support. Similarly the various electrical circuits that are above ground potential are grounded and dissimilarly polarized, to prevent regeneration and electrical feedback.

It will be understood that the foregoing general description and the following detailed description as well are exemplary and explanatory but are not restrictive of the invention.

Referring now more particularly to the accompanying drawings, there is provided as is best shown in Fig. 2 a conventional loudspeaker driver unit 1 of any suitable type, to which is connected an intermediate or inner baffle member or horn 2, of any suitable type which may be straight, folded or re-entrant, the latter terminated by a second or outer horn of novel type comprising baffle members 3, 4 and 5, for the purpose of providing a focusing effect for the radiated sound.

It is not intended to confine the rate of expansion through the inner horn 2 to any specific formula. On the contrary, the rate may be in accordance with any conventional design formula familiar to one skilled in the art. However, a specific configuration of the second or outer horn should preferably be adhered to from the point where it joins the inner horn. For purposes of illustration in Fig. 1 the inner horn 2 is shown as of the straight horn, tubular extension type, which expands uniformly at a chosen rate along the center axis A—A.

The outer or terminal horn is attached to the end of the inner horn 2 in the following manner. The external portion of the terminal horn comprises a baffle member 3, preferably frusto-conical, the small end of which is sealed to the terminal periphery of inner horn 2. At the large end of member 3, a second baffle member or bell 4, preferably frusto-conical in contour, is secured and sealed in the same manner.

The internal portion of the terminal horn comprises a plug baffle member 5 forming an annular expansion passageway with the baffle members 3 and 4 serving to direct and focus the sound issuing from the terminal horn at a focal point R, Fig. 4, in front of and on, or substantially on, the central axis A—A of the assembly.

The plug 5 may be solid, but as here preferably embodied, is of hollow construction and tapers from a locus of maximum diameter and circular contour intermediate its ends, in either direction to its ends so as to form front and back tapered surface portions having a common axis of symmetry. The plug is nested in the space formed by the baffle members 3 and 4, being supported therefrom in annularly spaced relation thereto, as by means of studs 30, coaxially with the center axis A—A of the assembly. The plug is suitably dimensioned in length so as to terminate at its inner end substantially in the plane of the terminal periphery of the horn 2 and to terminate

at its outer end substantially in the plane of the outer periphery of the bell 4.

The annular passageway which the plug forms with the members 3 and 4 comprises front and rear sections 32 and 31 respectively, which for convenience are sometimes hereinafter referred to as the annular passageways 31 and 32 respectively.

The annular passageway 31 may follow any desired rate of acoustic expansion. The passageway 31 serves to conduct the sound waves issuing from the horn 2 angularly outwardly therefrom in a confined path to the junction at P with the annular passageway 32. Thus, in the initial portion of their travel through the outer horn, the sound waves are carried radially outwardly from as well as along the central axis A—A of the assembly.

The annular passageway 32 diverges from its junction at P with the passageway 31 to the outer periphery of the bell 4 so as to provide an expanding passageway from which the sound waves issue in the form of annular rings travelling in the forward direction. This annular passageway is of uniform width at any plane normal to the central axis A—A, the rate of expansion being uniform, exponential or at such other rate as may be most suitable to the purpose. It will be understood in this regard that the rate of expansion of the air column so chosen may have different values in different portions of the horn as a whole, this being governed by the acoustical design requirements of the particular type of frequency characteristic.

The minimum diameter of baffle member 3 where it joins baffle member 4 is substantially equal to the maximum diameter of member 4 where it is exposed to the atmosphere, that is, the open end. In this manner the diameter of the annular ring section of the air column in the plane of the greatest diameter of plug 5 can be made as large as the maximum limiting diameter of the structure as a whole will permit. In addition, the actual width of the annular ring section that results is as small as can be obtained at this maximum diameter for a given expansion rate of the air column. Each element of the thin annular ring of sound at the opening, P, can be then considered as a small source of sound originating at the small end of the expanding air column formed by the outer section of plug 5, and the bell 4.

As the acoustic axis, indicated by the dash-dot lines in Figs. 2 and 4, of any section of the annular horn formed by these members is directed toward the central axis A—A of the assembly as a whole and substantially to the same region R, Fig. 4, because of symmetry, the greater portion of the sound emanating from the horn is thus focused in a manner similar to that occurring with light in an optical lens system.

It is recognized that due to the relatively wide frequency spectrum embraced in acoustic sounds that the focusing point R will not be exactly the same for all frequencies. However, the converging effect is present over the entire band of important speech frequencies as contrasted to the more diverging pattern present with conventional types of loudspeaker horns.

It is apparent that if the amount of sound radiating backwards from the region in front of the loudspeaker is reduced to a low value, less energy will be available to cause acoustic feedback between the radiated sound and the microphone. The design of the outer radiating horn is therefore such as to converge and direct the greater proportion of the sound emanating from the horn 2 toward a region on the central axis in front of the horn at a distance that can be determined within limits by the designer. As the natural tendency of radiating sound from a source is to diverge, the ability to converge a large portion of it to a small region results in a greater transfer efficiency. There is thus less sound radiated in diverse directions i. e. toward the rear, hence the great reduction in the tendency for the device to cause acoustic feedback into the microphone.

Even though the sound ultimately diverges beyond the focal region, the degree of divergence is much less from this device than from a conventional horn exit. Projecting the sound to a region in space a distance in front of the horn actually creates what may be thought of as a virtual source of the radiated sound, which gives the effect of a longer horn than the physical length of that actually used. The source of sound is thus removed farther from the microphone which as one skilled in the art knows, reduces the acoustic feedback tendency. Hence, even such sound as does diffuse backwards from beyond the focal region is largely attenuated in the distance it must travel back to the microphone location.

A tubular housing 6 is secured to the horn structure as by means of screws 33 engaging the baffle member 3, to serve as an enclosure to protect the inner working parts, but is proportioned to guide any backward radiated sound as described hereinafter.

A microphone unit 7 is provided which is of a type so designed that both sides of its diaphragm or other sound wave sensitive element, are open to the atmosphere to the extent that sound waves have access to both back and front. Covering screens 8 of such design that will pass the sound waves but prevent foreign matter, spray, etc., from reaching the diaphragm may be added. The microphone is held in a position separated from the rear of housing 6, as by adjustable legs or similar means 9, sufficiently far so that sound waves can freely pass between it and the housing. Further, the microphone is so positioned that it is centered on, and is normal to, the central acoustic axis of such sound waves as may radiate backward from the loudspeaker mouth. This is not necessarily the geometric central axis A—A although it may coincide substantially therewith, so that the microphone is located by trial in this null position when first mounted, or the mounting is provided with means to permit it to be adjusted to the null position when in use, by adjustable mounting means, 9 and 10, or other methods.

The front opening to the microphone diaphragm is substantially equal to, or less than, the size of the average mouth when talking, to provide as high an acoustic impedance as possible without sacrificing efficiency. Any chamber formed by an aperture or mounting means on front and back of the diaphragm is constructed so that its cavity resonance is at a frequency other than those uniformly transmitted in the speech frequency band of the system.

Some means of protecting the microphone from mechanical vibration, in accordance with a requirement well known by those skilled in the art, is provided in its mounting, such as pads of resilient material 11 and 12, (rubber, etc.). This material may be used to electrically insulate the microphone housing from the horn structure in accordance with a requirement described hereinafter.

It will be apparent to one familiar with the art that a microphone so mounted is most efficient for close talking purposes, as sounds directed at it from a distance will travel substantially along paths of almost the same length from the source to front and back of the diaphragm, so that they will have a comparatively small vibrating effect. When talking close to the front of the diaphragm this cancelling effect is insignificant due to the large difference in path length of the sound from the talker's mouth to the front and back of the diaphragm, respectively.

This effect of cancellation of sounds other than those originating close to the front of the diaphragms is utilized in this combination. With the microphone located on the acoustic axis of the sound which radiates backward from the loudspeaker opening, as described above, the path lengths from any point in a sound wave in space originating from the loudspeaker, to opposite points on either side of the diaphragm is substantially the same. This effect is assisted by the shape and size of the tubular housing 6 and the space between the microphone 7 and housing 6, which tend to bend the direction of travel of the stray sound from directly backwards parallel to the axis, to a direction more nearly parallel to the plane of the microphone diaphragm.

Thus, the sound pressure of a sound wave strikes opposite sides of a point on the diaphragm substantially simultaneously, so that the net force exerted on the microphone diaphragm by sound radiating back from the loudspeaker is practically zero, provided the constants of the device are correctly designed and constructed. The tendency for acoustic feedback between the loudspeaker and the microphone is therefore reduced to an insignificant value, permitting very large ratios of amplification to be used between the microphone and the loudspeaker, without producing audible oscillation or howling.

Thus it will be seen that because the configuration of the horn, the housing, and the microphone and its mounting, and the spatial relationship between these parts, a much greater increase in volume of amplified speech than has heretofore been possible with similar devices, can be obtained without acoustic feedback.

A handle 13 is attached to the assembly under the center of gravity for ease in holding the unit A push button switch 14 such as used on portable electric tools, etc., is mounted in the handle to permit the electric circuits to be turned on and off easily when using the electronic megaphone, so that current is only drained by the amplifiers from its batteries or power supply, when it is desired to talk.

Separately shielded conductors are run through the handles and switch from the microphone 7 and the loudspeaker driver unit 1, respectively. They cannot be connected haphazardly however. It is necessary to electrically phase the two circuits so that the input and output conductors that are above ground potential are dissimilarly polarized, to prevent regeneration and electrical feedback.

The microphone is connected through the cable 15 to the amplifier input. Means are provided, such as the rubber insulation 12, to have the structure of the microphone electrically separate from that of the horn housing, and the microphone is connected to the electric shield of the cable 15 to isolate the microphone from the horn electrically.

The loudspeaker 1, is connected through cable 16 to the amplifier output, the shield of this cable being connected to the horn structure as shown in Fig. 2. The shields of cables 15 and 16 are properly connected into the amplifier circuit as is shown diagrammatically in Fig. 5. The switch 14 may interrupt either circuit 15 or 16 or preferably the circuits to the power supply of the amplifier unit 19 through a separate cable such as 17.

The combination comprising the complete system, Fig. 1, shows how the input and output conductors referred to above are connected through a receptacle 18 in a conventional manner, to a suitable electronic tube amplifier 19, such as, a portable type operated by batteries. Fig. 5 shows the electrical schematic connections between the microphone and the amplifier input, and the loudspeaker and the amplifier output.

It will be apparent, therefore, that this device is to be used with an amplifier, such as a portable type, which can be carried by a strap over the shoulder or rest on a convenient support within the limits of the extension cables 15, 16 and 17, so that the electronic megaphone unit may be held by the handle to the user's mouth. As soon as ready to talk the operator closes the switch in the handle thereby energizing the amplifier circuits so that speech directed into the microphone diaphragm opposite the talker's mouth generates electrical currents in the microphone.

The electric energy from the microphone is fed through the cable 15 to the amplifier input and is increased many-fold in power by the amplifier. The amplified output is fed through the cable 16 to the loudspeaker driver unit 1. The force exerted by these amplified currents actuates the diaphragm, setting up sound waves of a greatly amplified pattern of those directed into the microphone. In this way the power of a human voice is amplified tremendously and is then directed by the electronic megaphone to the desired location by simply aiming the device at this region.

The operation is therefore, similar to that when using an ordinary megaphone except for one great difference: whereas with an ordinary megaphone the talker may, and usually does, bring the small end up to and touching the area around his mouth without muffling the speech so as to render it unintelligible, with the electronic megaphone, the megaphone must not actually touch the speaker's mouth which is open to the atmosphere, no matter how small this space may be, and indeed it is desirable for the greatest efficiency to keep the distance betwen the two as small as possible. Inasmuch as the inlet of the microphone must be at all times open to the atmosphere, by virtue of this spacing, in all known devices or systems using a microphone and amplifier and loudspeaker, so as to maintain intelligible speech reproduction, all such devices are inherently subject to acoustic feedback due to the sounds from the speaker entering the front of the microphone.

This invention therefore greatly overcomes this inherent tendency to acoustic feedback by sounds entering the front of the microphone both by converging the projected sound from the loudspeaker toward the region to which communication is desired and by permitting the microphone to be free to the atmosphere not only on the front of the diaphragm but also on the back.

It is thereby understood that although the proportions of the horn, the radiating mouth, and other parts of the loudspeaker will be maintained as described hereinbefore, the absolute values of the dimensions are only limited by the maximum size within which it is desired to keep the device. However, it is well known to the art that all acoustic radiating devices tend to produce more divergent sounds at lower frequencies, particularly below the frequency at which the diameter of the radiating aperture is less than approximately ½ wave length of the sound. It is a common practice to attenuate proportionately frequencies below this value in acoustic loudspeaker systems, a practice which is intended to be followed in the invention described herein.

In like manner following conventional practice known to the art, mechanical vibrations and mechanical energy transferred from external sources and from the body of the loudspeaker portions are reduced to an insignificant amount by cushioning the microphone in its support.

Other combinations of the electronic megaphone and its amplifier may be used, such as incorporating the two in one unit or detaching the microphone from its supports on the loudspeaker in the event that it may be desirable to mount the loudspeaker on a separate support such as a tripod, with the user holding the microphone in his hand. In this event the user only has to observe the restriction of holding the microphone on the null acoustic axis at the rear of the loudspeaker as described above in order that the device may be operated at optimum efficiency. In like manner a conventional power operated amplifier in place of a battery operated amplifier may be used, if power from an electric generator is convenient.

The invention in its broader aspects is not limited to the specific mechanisms shown and described but departures may be made therefrom within the scope of the accompanying claims without departing from the principles of the invention and without sacrificing its chief advantages.

What is claimed is:

1. An electronic megaphone comprising in combination a loudspeaker; and, a microphone located out of the direct soundpath of the loudspeaker, the microphone having openings for the entry of sound waves on opposite sides of its diaphragm so that sound waves emanating from a source relatively remote therefrom will strike opposite sides of said diaphragm substantially simultaneously and effect substantially no energizing of said diaphragm whereas sound waves emanating from a source closely adjacent to one side of said diaphragm will strike opposite sides of said diaphragm successively and energize said diaphragm.

2. An electronic megaphone comprising in combination a microphone and a loudspeaker, with the microphone positioned behind the exit of the loudspeaker horn, said horn comprising an inner horn of conventional exponential or conical design, terminated by an additional outer horn comprising outside baffle members and an inner plug baffle member together forming a sealed annular passage extending forwardly from the inner horn to the exit of said outer horn for sound to follow from the inner horn through said passage to the exit of the outer horn.

3. An electronic megaphone comprising in combination a loudspeaker; and, a microphone supported therefrom, said microphone having both

sides of its sound sensitive unit open to the atmosphere and said loudspeaker having its mouth facing in the opposite direction to the far side of said unit.

4. Electronic sound amplifying apparatus comprising in combination a loudspeaker having a driver unit and baffle members forming a sound passage from said driver unit to the exit of the loudspeaker for focusing the sound waves generated by said unit at a locus in front of said exit substantially on the geometric axis of the loudspeaker; and, a microphone back of the loudspeaker mouth having a diaphragm unit open at both sides to the atmosphere, said diaphragm unit being substantially centered on and substantially normal to the central acoustic axis of said loudspeaker so as to be in an acoustic null position with respect to sound waves which radiate backward from the mouth of said loudspeaker.

5. An electronic megaphone comprising in combination a loudspeaker capable of focusing sound waves at a locus ahead of its mouth; and a microphone in back of the loudspeaker at a fixed distance therefrom, said microphone being normal to the central acoustic axis of the loudspeaker and adjustable relative thereto whereby said microphone may be centered on said axis.

6. An electronic megaphone comprising in combination a loudspeaker capable of focusing sound waves at a locus ahead of its mouth, said microphone having both sides of its sound sensitive unit open to the atmosphere; a housing for the rear of said loudspeaker; and, a microphone supported by said housing out of the direct soundpath of said loudspeaker.

7. An electronic megaphone comprising in combination a loudspeaker, said loudspeaker comprising baffle members forming an annular sound passage terminating at the mouth of the loudspeaker, the acoustic axis of said passage at the exit converging toward the central geometric axis of the loudspeaker; and, a microphone supported from said loudspeaker.

8. An electronic megaphone comprising in combination a loudspeaker, said loudspeaker comprising baffle members forming a sound passage of annular shape having a central axis of symmetry, said passage increasing in maximum diameter for a distance and thereafter increasing in width to the loudspeaker mouth so as to provide a terminal portion converging toward a point on said axis; and, a microphone located out of the direct soundpath of the loudspeaker.

9. An electronic megaphone comprising in combination a loudspeaker capable of focusing sound waves at a locus ahead of its mouth; a housing for said loudspeaker; a microphone having its sound sensitive unit exposed at opposite sides to the atmosphere; and, means for adjustably supporting said microphone from said housing in a position out of the direct soundpath of said loudspeaker and with its sound sensitive element substantially centered on and normal to the central acoustic axis of the loudspeaker.

10. An electronic megaphone comprising in combination a loudspeaker, said loudspeaker comprising a driver unit, inner and outer horns, said outer horn comprising a terminal baffle member of larger diameter than the exit diameter of said inner horn, an intermediate baffle member connecting said inner horn with said first baffle member; and a plug baffle member positioned in the chamber formed by said first mentioned baffle members and forming with said baffle members an annular sound passage from said inner horn to the loudspeaker mouth, said sound passage commencing at said inner horn being directed outwards from the central axis of symmetry so as to form at the junction of said intermediate and terminal baffle members an annular ring of sound of large diameter substantially equal to the diameter of said terminal baffle member and said passage commencing at said junction having a cross section in the plane of the axis of symmetry which has a geometric axis from said junction to the loudspeaker mouth which slants toward a point on the central geometric axis of the loudspeaker in front of its mouth; and a microphone carried by said loudspeaker in a position out of the direct soundpath of the loudspeaker.

11. An electronic megaphone comprising in combination a microphone and a loudspeaker of which the horn focuses a substantial portion of the radiated sound to a region on the central geometric axis of the loudspeaker in front of its mouth, housing means for the rear of said loudspeaker of such shape that sounds from the loudspeaker which diffuse to the rear are refracted towards the central axis of the loudspeaker, a microphone unit spaced from the rear of said housing means so that the refracted sound may pass between the microphone and housing, the front and rear of the microphone diaphragm being open to sound waves in the atmosphere and said diaphragm being so positioned that the diffuse sound from the loudspeaker acts upon opposite sides of any point on the diaphragm at substantially the same time and with the same pressure.

12. Electronic sound amplifying apparatus comprising in combination a sound focusing loudspeaker unit, a microphone unit carried by said loudspeaker, an electronic amplifier, electric conductors interconnecting the microphone, loudspeaker and amplifier, a handle unit for the loudspeaker-microphone assembly by which the operator can direct the focused amplified sound to a chosen region, and a switch in said assembly for energizing the electronic circuits, said microphone having a diaphragm unit open at front and rear to sound waves in the atmosphere, and said amplifier unit having high amplification such that if the back or front of the microphone diaphragm were closed to the atmosphere, acoustic feedback would occur between the loudspeaker and microphone.

13. An electronic megaphone comprising in combination a microphone and a loudspeaker, the loudspeaker comprising an inner horn terminated by an outer horn with a two section sound passage of substantially annular shape, the first section of said passage forming the sound into thin annular rings during its passage therethrough from the exit of said inner horn, said first section soundpath being directed angularly outwards from the central axis of symmetry to the junction with said second section so as to form an annular ring of sound of large diameter substantially equal at said junction to the diameter of the second section of said passage, said second section being formed by an outer baffle member and an inner plug baffle member positioned so as to provide an annular entry to said second section equal to the exit of said first section, the cross section of said second section from its entry to its exit having a geometric axis which slants toward a point on the central geometric axis of the loudspeaker.

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