United States Patent [19]

Gabr

[11] **3,922,488**

[45] **Nov. 25, 1975**

[54] **FEEDBACK-CANCELLING ELECTRO-ACOUSTIC TRANSDUCER APPARATUS**

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[21] Appl. No.: **425,527**

[30] **Foreign Application Priority Data**

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Jan. 9, 1973 United Kingdom 1071/73

[52] **U.S. Cl.** ..... **179/1 HF;** 179/1 FS; 179/81 B
[51] **Int. Cl.²** **H04M 1/60**
[58] **Field of Search** ..... 179/1 HF, 1 FS, 81 B

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Primary Examiner—Thomas W. Brown
Attorney, Agent, or Firm—Young & Thompson

[57] **ABSTRACT**

Electro acoustic transducer apparatus having a loudspeaker and one or two microphones includes positional and/or electric arrangements for reducing or cancelling feedback from the loudspeaker. Also, a microphone apparatus has positional and structural features for reducing or cancelling echo.

3 Claims, 34 Drawing Figures

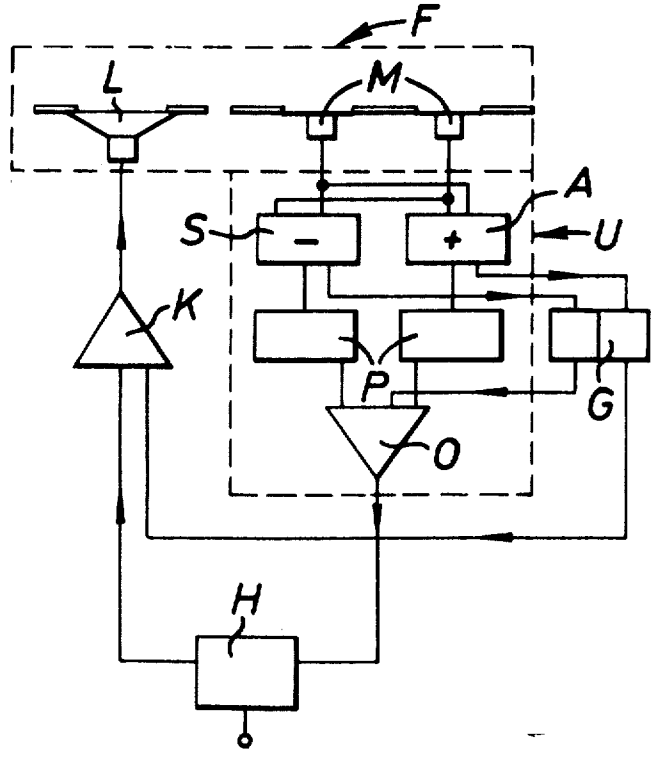


FIG.1A

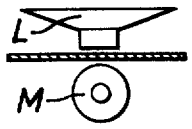


FIG.1B

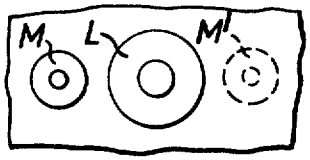


FIG.1C

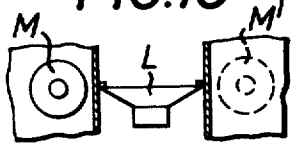


FIG.1D

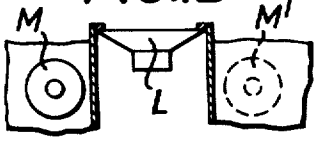


FIG.2A



FIG.2B

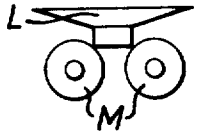


FIG.2C

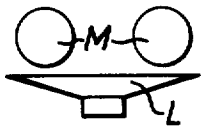


FIG.2D

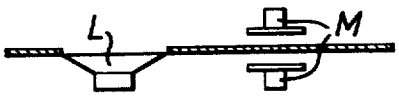


FIG.2E

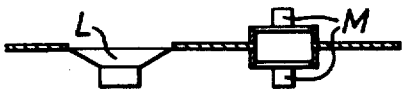


FIG.2F



FIG.2G

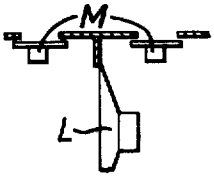


FIG.2H

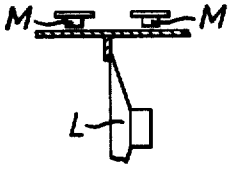


FIG.2J

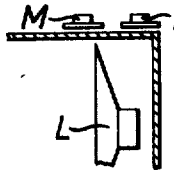
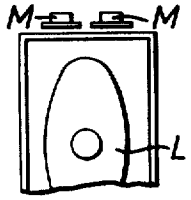


FIG.2K



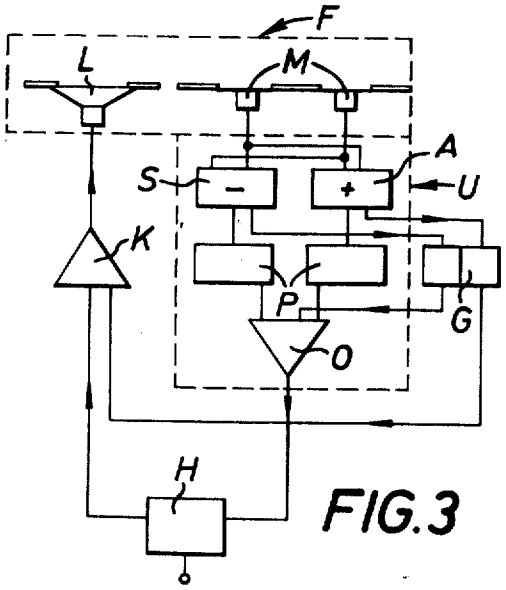


FIG.3

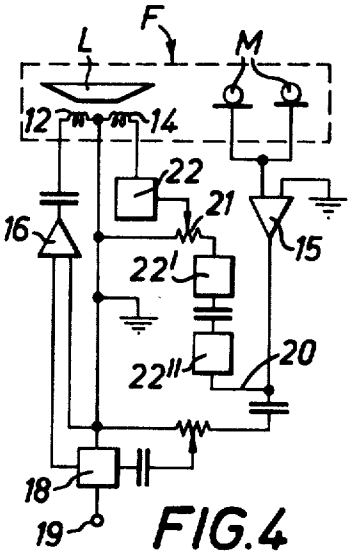


FIG.4

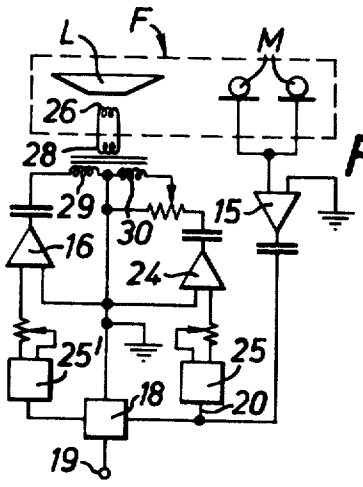


FIG.5

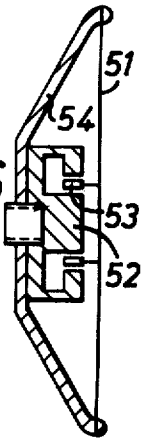


FIG.6

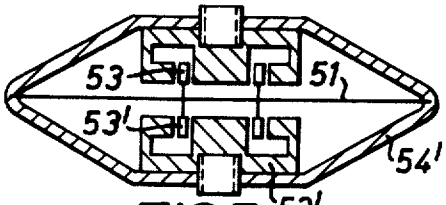


FIG.7

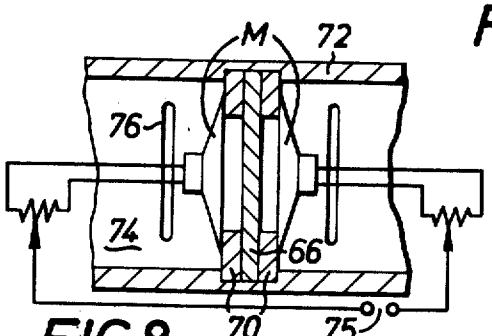


FIG.8

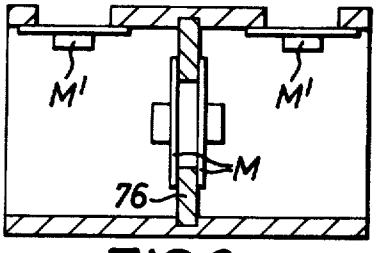


FIG.9

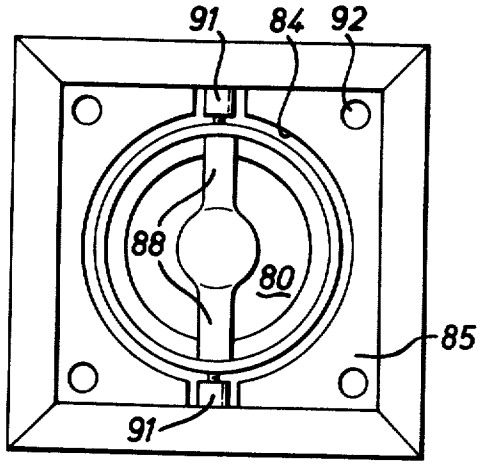


FIG.10

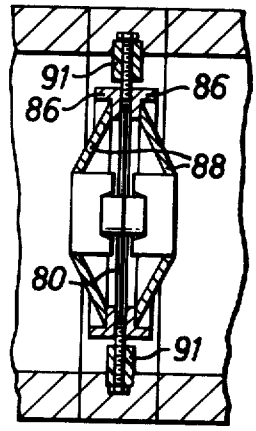


FIG.11

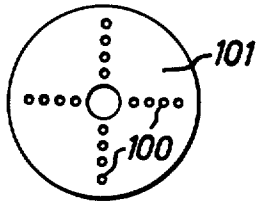


FIG.12

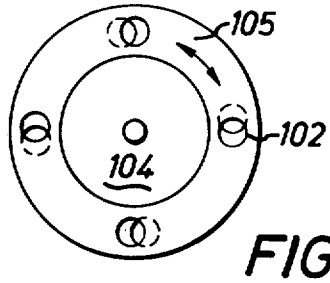


FIG.13

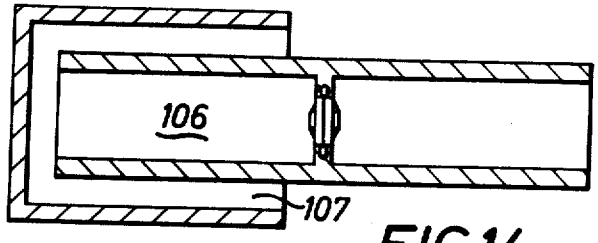


FIG.14

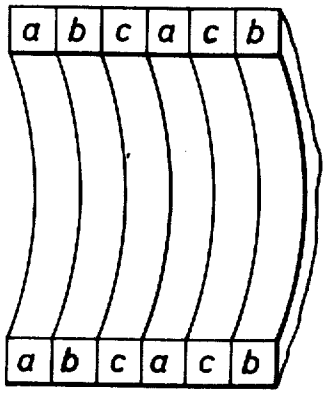


FIG.15A

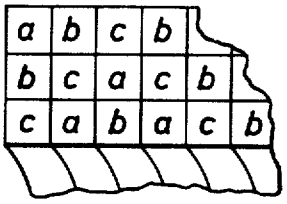


FIG.15B

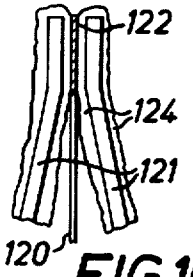


FIG.16

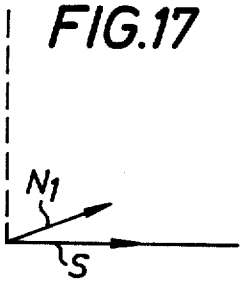


FIG.17

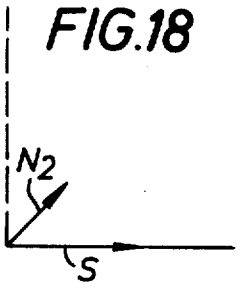


FIG.18

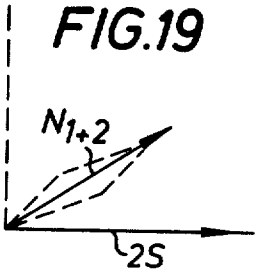


FIG.19

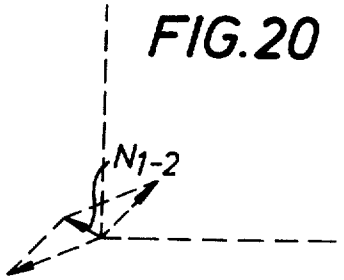


FIG.20

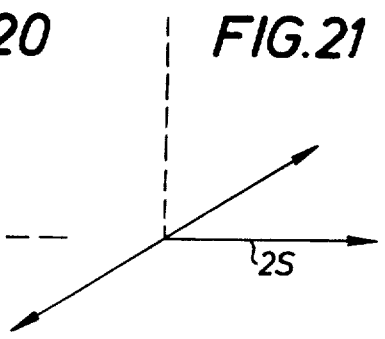


FIG.21

FEEDBACK-CANCELLING ELECTRO-ACOUSTIC TRANSDUCER APPARATUS

The invention relates to duplex or two-way communication systems, particularly loudspeaking systems.

All such known systems suffer from the effects of acoustic feedback, that is, from the effects of sound from the loudspeaker reaching the microphone, and from the effects of acoustic echoes and ambient noise. The intelligibility of communication is diminished by both effects.

Acoustic feedback, that is the undesired transmission of sound from the loudspeaker to the microphone, whereby the electrical output signal of the microphone includes an unwanted component corresponding to and caused by the loudspeaker sound reproduction, takes place mainly because of the transmission of loudspeaker sound reproduction to the microphone through one or more of three channels. One channel is the airborn transmission of sound from the loudspeaker directly to the microphone diaphragm. The second channel comprises loudspeaker sound reproduction reaching the microphone through mechanical vibration of means or media other than air, for example the loudspeaker and microphone housing means and associated fixed structures. The third channel is the transmission of loudspeaker sound reproduction to the microphone by vibration of the microphone housing due to airborn sound (microphony).

Echo and ambient noise reach the microphone diaphragm through the air and by microphony.

It is the object of the invention to eliminate or at least reduce both acoustic feedback and acoustic echo and ambient noise to a point such that a satisfactory signal to noise ratio is obtained whereby the stable sound levels and the intelligibility required for a duplex, two-way, loudspeaking telephone conversation is achieved without the need for voice operated switching.

In accordance with the invention, this objective is achieved in three ways, acoustically, electrically, and electroacoustically. In all cases the acoustic measures provide for the basic high signal to noise ratio needed. The microphone means is designed and positioned in combination with the loudspeaker so as to discriminate between the loudspeaker sound reproduction and the wanted speech or other sound input desired for transmission, which represents information to be communicated. They provide for the prevention by cancellation or at least the reduction of the undesired acoustic feedback noise and acoustic echoes, whereby the electrical output of the apparatus acquires the required signal to noise ratio which allows satisfactory stable loudspeaking duplex communication. Further improvement in the overall signal to noise ratio is achieved if necessary by using non-linear amplifiers and components and/or automatic gain control operated by and dependent on the noise level, or arrangements giving similar effects. The acoustic measures adopted in accordance with the invention consist in arranging the microphone or microphone means in such a position with relation to the loudspeaker or loudspeakers that sound from the latter falls equally on two sides of the diaphragm of the microphone means. This can be readily effected as far as directly transmitted sound as well as acoustic echo are concerned, but is less readily controlled in respect of reflected sound, due to objects not forming a part of the equipment, the position of which is variable or unknown. The acoustic measures of the invention likewise provides constructions for the cabinet or housing means, including sub-housings for the individual transducers, which effectively reduce or eliminate microphony, and sound transmission through media other than air. The effects of sound from uncontrollable local sources, and of loudspeaker sound reflected from likewise uncontrollable objects, cannot be effectively dealt with in either of these ways. To deal with such sources of unwanted sound components in the microphone output, the invention provides electrical circuit arrangements, to reduce the effects. The electro-acoustic meansures of the invention comprise electrical circuit arrangements in combination with complex electro-acoustic transducer assemblies. The function of the combination of circuitry and transducers is firstly to discriminate between the electrical output signals of the microphone caused by the loudspeaker sound reproduction and the speech or other signal desired for transmission. Secondly, the combination functions to deal with each and to arrange for the cancellation or reduction of the undesired signals caused by and corresponding to the loudspeaker sound reproduction and echoes so that the final electrical output signal of the combined microphone means and electrical circuits acquires the high, satisfactory ratio of signal to noise, to allow the stable reproduction of the required sound levels from a duplex loudspeaking communication or other sound reproduction system.

In addition to the acoustic measures, the cancellation of the undesired noise can be achieved by simple electrical circuits to allow for the addition and subtraction of the outputs of the microphone means, or by complex arrangements for summing the signals resulting from the addition and subtraction and also by arranging for phase and amplitude adjustment if necessary to achieve the required cancellation of noise. It is of course within the invention to apply one, more than one, or all of these measures as is deemed appropriate in any particular piece of equipment.

The invention will be more readily understood from the following illustrative description and accompanying drawings, in which:

FIGS. **1A, 1B, 1C** and **1D** are somewhat schematic showings of various suitable arrangements of microphones and loudspeakers relative to each other;

FIGS. **2A–2K** are arrangements similar to FIGS. **1A–1D,** but in which the microphones receive sound directly from the loudspeaker;

FIG. **3** is a circuit diagram of apparatus according to the present invention;

FIGS. **4** and **5** are views similar to FIG. **3** but showing other embodiments of the invention;

FIGS. **6–11** are views of suitable microphone arrangements for use in the present invention;

FIG. **12** is a view of a microphone diaphragm and FIG. **13** is a view of a microphone baffle for use in the present invention; FIG. **14** is a cross-sectional view of a modified housing for use with the present invention;

FIGS. **15A** and **15B** are fragmentary cross-sectional views of tubular embodiments of housing;

FIG. **16** is a fragmentary cross-sectional view of a diaphragm mounting; and

FIGS. **17–21** are vector diagrams of signal and noise components involved in the present invention.

According to a first aspect of the invention illustrated diagrammatically in FIGS. **1A, 1B, 1C** and **1D,** a microphone M and loudspeaker L are so relatively located

that both sides of the microphone diaphragm receive sound directly from the loudspeaker. The resultant effect of this incident sound will be ideally zero, so that there is no electrical output from the microphone due to this sound. The microphone and loudspeaker must be relatively close together, preferably they should be in close proximity within a housing means which advantageously comprises sub-housings, one for each transducer, suitably connected together in a manner or by means whereby sound transmission between the sub-housings is eliminated or nearly eliminated. The housing means are shown schematically in or omitted from the drawings. A variety of relative positions are possible, of which some only are shown in the accompanying drawings. In particular, the microphone can be arranged with its own diaphragm in any plane containing the loudspeaker axis. The arrangement of FIG. **1A** is found to be particularly advantageous, it is thought because the sound wave front radiated by the loudspeaker is not broken up or impeded by the rim of the microphone and associated housing. The rim and housing should preferably in any event be generally small and thin in particular to afford better cancellation. Alternatively, the microphone and loudspeaker diaphragms can be co-planar and in adjacency. The arrangement must be such that the loudspeaker sound reaches the two sides of the microphone diaphragm directly or substantially directly, that is without reflection or undue obstruction. In particular, the housing means should not cause undue reflected sound from the loudspeaker to fall on either side of the diaphragm. One or both sides of the microphone and/or the loudspeaker can however be covered with a conventional grill or fabric.

It will be understood that these configurations of loudspeaker and microphone can be used in any position; these do not in themselves do anything to counteract acoustic feedback due to reflected sound from the loudspeaker, and it is accordingly an advantage to have the loudspeaker diaphragm substantially horizontal to provide for acoustic echo reduction or cancellation. At least the majority of any reflected loudspeaker sound which reaches the microphone is then due to reflection from the ceiling of the room in which the apparatus is used. The distance of the ceiling will normally result in considerable atenuation of this reflected sound, which is moreover a constant factor in any one room, which facilitates compensation.

Whilst the arrangements shown comprise only a single microphone and a single loudspeaker, it will of course be appreciated that the actual tranducer units employed as loudspeaker and microphone can be duplicated or used in any desired numbers. Thus a loudspeaker may have one or more additional microphones M' positioned similarly with respect to the loudspeaker as the microphone M. For example four microphones can be located in planes containing the loudspeaker diaphragm axis and angularly spaced at right angles around the axis. The microphones could thus receive speech from speakers grouped around the apparatus as at a conference.

It is also within the invention to arrange a pair of microphones in a position with relation to the loudspeaker such that each microphone diaphragm receives on one side thereof equal or substantially equal sound signals directly from the loudspeaker. Some possible arrangements are diagrammatically shown in FIGS. **2A – 2K.** If the arrangement is such that the signals received are in phase, the outputs of the two microphones must be reversed, so that the electric signal components due to the loudspeaker sound cancel, and are thus absent from the common microphone output. If the arrangement is such that the sound signals are out of phase, the microphone outputs are simply added to provide the common electrical output. It will be evident that the or each microphone of any of the arrangements of FIG. **1** can be replaced by a pair of microphones arranged with their diaphragms parallel and spaced some distance apart, and either separated acoustically by a baffle, or in substantially direct acoustic coupling to realize the present aspect of the invention. It is however also possible to arrange the two microphones in other ways. As with the arrangements of FIGS. **1A – 1D,** it is of course readily possible to add one or more additional pairs of microphones, each pair being appropriately positioned relative to the loudspeaker. Again, more than one loudspeaker can be employed, provided the correct relative positions are preserved.

In order to ensure that the loudspeaker sound signals reaching the microphones are as nearly as possible identical in all respects, the distance between the axes of the microphone diaphragms should be kept small compared to the acoustic wavelength of the signals. Preferably, the greatest distance involved should not exceed ¼ of the wavelength of the highest frequency to be handled by the apparatus, which may be regarded as 3,000 Hz where only speech is being transmitted.

It is within the invention to arrange for the operation of the loudspeaker or loudspeakers and the microphone or microphones alternately or on a time division basis for example by direct switching or by switching the energisation of associated amplifiers. The frequency of alternation should be high enough not to cause interference with the reproduction. With this method, the distance between the loudspeaker and microphone diaphragms must be kept small to avoid an undesirable time lag in transmission. Otherwise, it is advantageous for this distance to be relatively large, to allow the wave front of loudspeaker sound to be in phase across the microphone diaphragms.

It will be understood that the arrangements of FIGS. **2A – 2K** will include housing means preferably of the kind described with reference to FIGS. **1A – 1D.** The measures so far described provide a substantial improvement over known arrangements, which have dealt only with acoustic feedback due to transmitted sounds reaching the microphone diaphragm or diaphragms via the air directly, that is, direct air-born sounds from the loudspeaker.

In any of the two-microphone arrangements of the invention, the microphones can be constituted by the so-called button or midget microphones, the inlet nozzles or tubular apertures of which will as regards position replace the diaphragms illustrated. The use of these button microphones provides the closest possible spacing between the microphone sound input positions so that the phase difference between the microphone outputs is minimised.

FIG. **3** shows an acoustic feedback-free transducer unit F providing a high signal to noise ratio and including two microphones M. Within a phase adjustment unit U incorporating electric circuit arrangements for further improving the signal to noise ratio the outputs of the two microphones M are applied both to an additive circuit element A and to a subtractive circuit element S, for example a transformer or a differential am-

plifier. The additive and subtractive outputs are then taken through phase and amplitude control means P and summed either simply or repeatedly, preferably in a further amplifier O, to provide the electrical output signal to be transmitted. The treatment of the microphone outputs is described in detail below with reference to FIGS. 17 - 21. The circuitry can include the circuit elements necessary to effect appropriate phase and/or amplitude adjustment. Each of the various circuit elements is preferably adjustable and may be arranged either for presetting or for control from outside the unit. The unit F includes a loudspeaker L, the relative positioning of the microphones M and the loudspeaker shown diagrammatically being of course only one of various possible arrangements.

It will be appreciated that this aspect of the invention consists in isolating an electric signal produced by unwanted sound falling by any channel on a microphone or microphones, and subtracting this electric signal from a microphone output containing both an unwanted sound component and also a wanted sound component. The output of the unit U and the input to the loudspeaker L and its associated amplifier are connected through a hybrid H if required, to a line and thereby to like apparatus at a remote station. A conventional automatic gain control circuit G, e.g. in the form of two conventional units, may be included as shown to control a loudspeaker amplifier K and the output amplifier O to improve efficiency, but this can often be omitted if desired.

Two other circuit arrangements for the electrical cancellation of feedback are illustrated respectively in FIGS. 4 and 5. These can also include automatic gain control arrangements as described with reference to FIG. 3 if desired. In each arrangement, an acoustic feedback free transducer unit F of any desired kind comprises housing means mounting loudspeaker means represented by a single loudspeaker L and microphone means represented by a pair of microphones M.

Referring now to FIG. 4 the loudspeaker L has two speech coils 12, 14. The microphone outputs and the loudspeaker reproduction coil 12 are connected through respective amplifiers 15, 16 to a hybrid 18 and thus to a line terminal 19. The hybrid 18 enables the station to be connected to a two-wire transmission system but may be omitted if a three or four line transmission system is employed.

In FIG. 4, part of the output of the transmission amplifier 15 is taken on a line 20 through an adjustable resistor 21 to the coil 14, the transmission signal cancellation coil, of the loudspeaker. The line 20 also extends through a phase adjuster 22 which may instead be in either of the alternative positions indicated at 22' and 22''. When there is a sound input to the microphone, part of the resultant signal reaches each of the coils 12, 14 through the hybrid or through coupling between the lines caused by the other station or stations. In order to remove this a part of the signal is fed through the line 20 and the circuit components 21 and 22 such that these signals are equal and 180° out of phase.

In FIG. 5, an amplifier 24, preferably of variable gain, is included in the line 20 together with an adjustable phase shifter 25 which can instead be placed at the position indicated by 25'. The operation of the circuit is essentially the same as that of FIG. 4 except that the amplifier 24 is provided to ensure that the signal applied to the coil 14 is of adequate strength. Also, the loudspeaker 11 has only a single speech coil 26 connected with the secondary winding 28 of a transformer having primary windings 29, 30 performing the functions of the coils 12, 14 of the loudspeaker of FIG. 4.

It will be evident that the circuits of FIGS. 4 and 5, operating between the hybrid and the transducer unit, can be employed in loudspeaking telephones and can be adapted to systems using two pairs of wires for transmission as for intercommunication or public address systems. Although cancellation takes place at the loudspeaker in both circuits, cancellation in a like manner at the microphone, additionally or instead, can be provided. Moreover, the circuit arrangement of FIG. 3 can be employed in combination with the arrangements of FIGS. 4 and 5 whenever the transducer unit F includes two microphones.

Whilst the feedback free transducer unit of the invention can include loudspeakers and microphones of any suitable construction, microphones of preferred construction are shown in FIG. 6 and 7.

Referring to FIG. 6, an electro-acoustic transducer for use as a microphone or loudspeaker consists of a diaphragm 51, a speech coil 53 and a frame 54 for rigidly supporting a magnet 52. The frame 54 exposes a major area of the adjacent side of the diaphragm. The diaphragm 1 therefore may be exposed to sound waves on both sides. Such a microphone has bi-directional characteristics and therefore is particularly useful for acoustic suppression of the feedback. Ideally, the microphone should have symmetrical bi-directional characteristics and to this end the planar diaphragm 51 is used as distinct from the conventional conical diaphragm. As the magnet, coil and frame structure are on one side only of the diaphragm, the microphone is mounted, in accordance with the invention, in a housing providing dummy, elements (not shown) on the other side the dummy elements being of at least approximately the same shape and location. The apparatys comprisisng the microphone and the housing thus has the desired symmetry. The diaphragm 51 can if required be corrugated whilst retaining its generally planar form.

The operative sensitivity curves for such a transducer depends on the mechanical suspension or electrical sensitivity control of the diaphragm. As the former cannot be readily adjusted, it is convenient to provide for electrical sensitivity control by biasing to obtain the required performance. The microphone can thus be provided with biasing coils in addition to the normal speech coil.

An electro-acoustic transducer apparatus which is itself physically and electrically symmetrical will avoid the need to provide dummy elements in its housing, and is shown in FIG. 7. This transducer corresponds in its general form on one side of the diaphragm to the transducer of FIG. 6. However the speech coil, magnet and frame structure is repeated symmetrically on the other side, the parts on this side being marked with primed reference numerals corresponding to those on the one side. A biasing coil can be provided to adjust the suspension of the diaphragm, as previously described.

FIG. 8 shows a microphone unit having a pair of like electro-acoustic transducers M mounted one on either side of a baffle board 66. The transducers can be of conventional moving coil construction, with the axes aligned.

The conical diaphragms of the transducers face one another and are spaced apart at their edges only by the edge mounting boards 70 (which may be omitted) and

the thickness of the board **66.** The transducers are each mounted in an open ended loading chamber or baffle box **72** having one wall constituted by the board **66** and adjacent four sides **74** at right angles to the board and surrounding the transducer. Slits **76** can be provided in the walls **74** to ensure a communication between the interior of the box and outside. The walls **74** should not extend so far axially of the transducers as to impose directional characteristics on these, unless such characteristics are desired. The mounting arrangements thus comprise a housing providing for each transducer something approaching an infinite baffle.

Circuit arrangements associated with the transducers can comprise means for adjusting the phase and/or amplitude of the output of the transducers as previously explained. As shown, a potentiometer is connected across the coil of each, the tapping contacts of the potentiometers providing the output of the unit across terminals **75.**

In use, the microphone unit will be effectively echo-cancelling because reflected sound will in general fall in substantially equal intensities on the two transducers and will consequently cancel out in the electrical output signal from the unit. Desired sound, for example, from a speaker holding the unit so that he directly faces one of the transducers will be fully reproduced in the electrical output, as also will speech from a second speaker opposite the first. The potentiometers permit adjustment of the unit to compensate for departures thereof from exact symmetry, electrical or structural, about the central plane of the baffle board **66.**

In the embodiment of the invention, shown in FIG. **9,** one or more features of which may be interchanged with those of the unit shown in FIG. **8** as appropriate, two like transducers M are again employed. These transducers have substantially planar diaphragms are previously described. The transducers M are mounted coaxially on a baffle board **76** which is apertured either over substantially the whole area of the diaphragms, or over part of this area. In this arrngement, the microphone orientation can be reversed, to expose the full area of the diaphragms to incoming sound. The transducers M are connected into appropriate circuitry, for example, as shown in FIG. **8** or as previously explained with reference to FIG. **3.**

In use the microphone unit of FIG. **9** as so far described will be seen to have the same echo-cancelling properties as that of FIG. **8.** The acoustic coupling of the two transducers however causes both to respond to an incoming desired sound along the common axis from one side of the unit, so that the output and thus the ratio of this to any uncancelled noise is substantially doubled.

The microphone unit of FIG. **9** additionally incorporates two further electro-acoustic transducers M' for use as loudspeakers, so that the unit becomes a device for two-way communications, usable for example as a conventional or loudspeaking telephone. The transducers M' are mounted so as to preserve the symmetry of the device and with their axes at right angles or nearly at right angles to the common axis of the transducer M. Such an arrangement provides for acoustic cancellation of feedback without loss of the echo-cancelling properties of the microphone unit comprising the transducers M.

When a baffle is provided between the two diaphragms, the other diaphragm of course remains unaffected by this sound and the output from the diaphragm receiving this wanted signal is substantially unchanged by the sound travelling parallel to the diaphragm. If there is no baffle between the two diaphragms, the second diaphragm, which does not directly receive the incoming wanted sound, moves in sympathy with the first mentioned diaphragm because of the vibrations of the first mentioned diaphragm conveyed through the air between them.

The microphone unit shown in FIGS. **10** and **11** has a single transducer having a generally planar diaphragm **80** and a pair of speech coils, one on either side, co-operating with separate magnets. It is however to be understood that a pair of microphones can be used instead, and that appropriate features of the units of FIGS. **8** and **9** will then be included in the present unit. In the present embodiment, apertures, which may be selectively adjustable in effective area, are provided between the loading chambers associated with the respective sides of the transducer.

As shown in FIG. **10,** one form of such an aperture comprises an annular aperture **34** around the transducer and a baffle **35,** which functions as a by-pass or short circuiting aperture. Thus the diaphragm suspension can be clamped at its outer edge between a pair of rings **86** from each of which radial arms **88** extend to support one of the magnets. Two bolts or other fasteners extend outwardly from the rings **86** at diametrically opposed points and are the sole means of connection with the baffle **85,** which has an aperture of greater diameter than the rings. The resulting annular aperture **84** effects a degree of equalization of sound vibrations on opposed sides of the baffle. The bolts can extend through rubber or plastics grommets **91** so that the transducer is effectively isolated from sound vibrations transmitted through the housing.

Where the baffle is a square as in the unit of FIGS. **10** and **11** or rectangular, an aperture **92** in the baffle can be provided at each corner to minimise the effect of sound reflections at the corners between the walls of the loading chambers extending from the baffle **85.**

Instead of, or as well as, providing such apertures in the baffle, it is within the invention to provide them in the actual transducer diaphragm or diaphragms.

The effective cross-sectional area of all the various kinds of apertures described is preferable made selectively variable, and even reducible to zero, by any suitable form of closure or shutter to permit either pre-set adjustment or adjustment in use or both. As shown in FIG. **12,** apertures can be arranged for example as a series of holes **100** along a radius or a diameter of a diaphragm **101** and their area rendered adjustable by a blocking means (not shown) rotatable about the axis of the transducer. The blocking means can be rotatable disc but need comprise only a radial or diametral arm to function as required and can be constituted by a radial arm of the transducer structure by which the magnet is connected to the outer ring from which the diaphragm is suspended.

Alternatively, as shown in FIG. **13,** the apertures may comprise holes **102** towards the edge of a circular baffle **104.** The effective area of these holes can be adjusted by rotating of a ring **105,** mounted concentrically with the baffle, which has holes corresponding in shape and position to the holes **102.**

According to a further feature of the present invention, the transducer or transducers of the microphone unit are provided with a sound diffusing cover to minimise the directional effects of noise and the effects of

reflected noise. Such a cover can be constituted by a piece of acoustic transparent fabric secured over each side of the transducer frame. The diffusion effect can be controlled by controlling the acoustic transparency of the fabric.

The microphone units so far described are inherently bi-directional, being completely symmetrical about the plane of the baffle. The units can however be rendered uni-directional, as regards the incoming sound vibrations which are to be transmitted electrically, without loss of their noise and echo free properties. This can be achieved as shown in FIG. **14** by modifying the housing means to provide at the outer end of one of the loading chambers **106** passage means **107** communicating with the chamber at one end and with the desired direction of sound reception at the other, entry to this chamber of sound from the other direction being blocked. As the microphone unit is constructed as an elongated tube, the passage forming means **107** is constituted simply by a tube of larger diameter with one end closed, the bi-directional unit being mounted with one end extending concentrically into this tube. The other end of the unit functions normally but sound can reach the side of the diaphragm towards the tube only through the annular passage between the tube and the outside of the housing of the unit. As the force acting on the diaphragm is inversely proportional to the square of the distance between the source and the diaphragm and since ambient noise and echo can be regarded as from a distant source, the extra path length represented by the annular passage has no appreciable effect on the ambient noise and echo cancellation properties of the unit, whilst having appreciable effect on sound from a relatively near source. The annular passage will of course reduce the noise level as well as the microphony effect of the microphone housing but will also reduce the sensitivity, as it provides for the wanted sound to reach both sides of the diaphragm so that a degree of cancellation of this sound also occurs. however, the wanted sound will be from a source which is relatively close to the unit so that extra path length of the part of this sound reaching the remoter side of the diaphragm will cause a lowering of the intensity of this part as compared with the part reaching the near side of the diaphragm directly, so that an adequate net output is obtained. It will be evident that the means forming the passage which converts the bi-directional unit to a uni-directional unit can be constructed in various way other than as described.

Although the invention is not limited to the use of any particular material for the housing means, sub-housings, housing, baffle, etc., these are preferably built up in a manner similar to that illustrated in FIG. **15** which shows a tubular housing made from a plurality of rings of like inner and outer diameter arranged in co-axial alignment to form a tube in the manner shown in FIG. **15A.** The rings are made of different materials *a*, *b*, *c*, each having different sound conductive properties. Thus one ring may be formed of metal, the next made of glass fibre and the third of rubber or a hard or soft plastics material. Sound transmitted through any one ring to the next is very substantially attenuated at the interface and the whole structure is effectively acoustically "dead" or non-microphonous. Instead of repeating the sequence of, say, metal, glass fibre and plastics rings, it is preferred instead to use for the next three, rings of the same three materials but in a different order, again as shown in FIG. **15A**, for example, rings of glass fibre, metal then plastics. The next three rings can then be arranged in the order metal, plastics and glass fibre. In this way a sequence of rings of different materials is obtained, in which each ring has on either side of it a ring of different material, and the number of instances in which a sequence of adjacent rings is kept to a minimum. Obviously this aspect of the invention is not confined to the use of three materials only, to the materials mentioned above, or to any particular sequence in which the rings, or layers of other shapes, are arranged.

It will be appreciated that a tubular microphone housing built up as described will have almost infinite resistance to sound conduction in the axial direction. Sound conductivity within each ring radially of the housing will however be no more reduced than if the housing were constructed of an integral piece of the material of the ring. In order to obtain the required high sound attenuation characteristics in the radial direction also, the housing can be formed not simply of axially adjacent single rings but of axially adjacent concentric rings, preferably at least three in number and again of different materials, as shown in FIG. **15B.** Thus the concentric ring set just described may have on one side three similarly shaped rings of which the inner one is of fibre glass, the middle of metal and the outer of rubber, whilst on the other side the glass fibre is on the outside, the metal ring being the inner ring and with rubber inbetween.

It will be evident that the structure described for a microphone housing can be adapted readily to housings of any shape, and to housings and sub-housings for other apparatus than the echo-cancelling microphone units and transducer apparatus described. Thus flat panels can be formed from several layers of different material the layers themselves being made up of part of different material.

The various components of the housing described can be connected together in any suitable way, as by adhesive layers, or by snap-fitting inter-connections making use of resilience inherently possessed by some of the materials used.

The structure described can be applied, as well as to the housing, also to the mounting and actual structure of the electro-acoustic transducers. Each transducer as shown in FIG. **16** thus may have the planar diaphragm constituted by a circular metal disc **120,** a pair of speech coils one on each side, and a frame supporting magnets for co-operation with the coils. The frame consists of two like parts **121** which clamp the diaphragm suspension **122** between them. Each frame portion is made of metal or rigid plastics material but the two portions are at no point directly in contact. Instead, each portion is given a coating of a softer, resilient material **124** such as rubber or a plastics material. The symmetry of the arrangement is rigidly preserved and sound reflecting obstructions such as boards mounting connecting tags are eliminated as far as possible. The frame is thus a structure of three different materials, that of the frame portions, the coating, and the suspension.

In a modified form of the transducer, one of the speech coils and the associated magnet are omitted, the other features described being however retained.

The microphone can be mounted within the tubular housing described above by providing the latter with a pair of inwardly projecting flanges, advantageously of the same laminated construction as the housing, the

outer edge of the frame of the microphone being clamped or otherwise secured between them.

Throughout the unit, internal sound reflections are reduced or eliminated by the provision of rough, sound absorbent, surfaces. Any metal surfaces can be embossed or etched and all surfaces may be covered by flocking or by securement of a suede or other non-reflective fabric. A rubber compound can be applied by dipping or spraying to the various parts of the unit.

The invention can also be embodied in a telephone hand-set. The hand-set embodying the invention comprises three effectively acoustically separated portions, the walls of which may be built up from laminations in a manner similar to that already described in connection with the echo-cancelling microphone housing. These are a stem, an ear-piece at one end of the stem, and a microphone and its associated housing at the other.

The functioning of the apparatus of FIG. **3** is explained in FIGS. **17** to **21**. Each of the microphones M produces an output including a wanted component or signal S due to sound generated remote from the apparatus, typically the speech of someone using the apparatus. The signals S in the microphone outputs can be regarded as being effectively equal in all respects. In addition, each output includes a component due to sound from the loudspeaker, which is an unwanted component or noise. The noise components N_1, N_2 will differ in phases and amplitude from each other and from the signals S, as shown in FIGS. **17, 18** which represent the separate microphone outputs.

By the circuits A, S the two microphone outputs are respectively added and subtracted. The output of circuit A contains the signal S effectively doubled in amplitude, but the signal S is substantially lacking from the output of circuit S. As shown in FIGS. **19, 20**, the circuit outputs contain respective noise resultants N_{1+2}, N_{1-2}. The microphone outputs have thus been analysed and a component N_{1-2} has been separated out which represents substantially pure noise. Such a pure noise component can be regarded in practice as having a substantially fixed relationship with the noise components N_1, N_2 and with the additive noise component N_{1+2}. It can accordingly be produced and treated to be substantially equal in amplitude and opposite in phase, for the purpose of cancellation, to any one of N_1, N_2 and N_{1+2}. In the illustrated apparatus, the noise resultant N_{1-2} is amplified and shifted in phase through 180° in a circuit P and added to or combined with the output of circuit A as shown in FIG. **21**, as in the amplifier O. The output of this amplifier which constitutes a common microphone output is thus free or substantially free of components due to loudspeaker noise.

I claim:

1. An electro-acoustic transducer apparatus comprising a loudspeaker and microphone means having two closely spaced transducers, electronic circuit means, said circuit means including an additive circuit element and a substractive circuit element, each of said elements receiving output from both of said transducers, said elements providing two outputs one of which is wanted sound plus noise and the other of which is only noise, said circuit means comprising also phase adjustment means to receive said other output and to produce a noise component 180° out of phase with said other output, said circuit means comprising also means to combine said one output with said out-of-phase component to cancel noise from said one output.

2. Apparatus as claimed in claim **1**, and a housing mounting said loudspeaker and microphone means together.

3. Apparatus as claimed in claim **1**, and an amplifier for the microphone means and an amplifier for the loudspeaker, and automatic gain control means for controlling the gain of the amplifiers.

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