April 29, 1947. W. W. HAYES 2,419,894

ACOUSTIC SYSTEM FOR UNIFORM DISTRIBUTION OF SOUND

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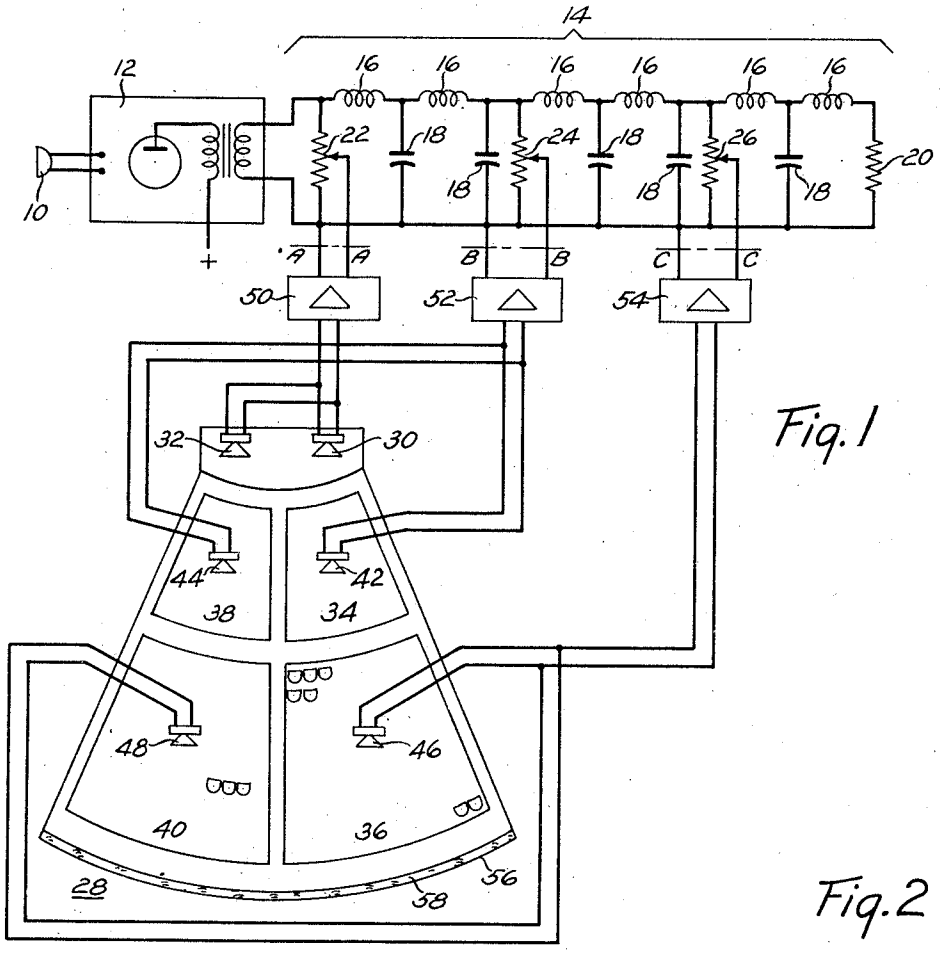


Fig. 1

Fig. 2

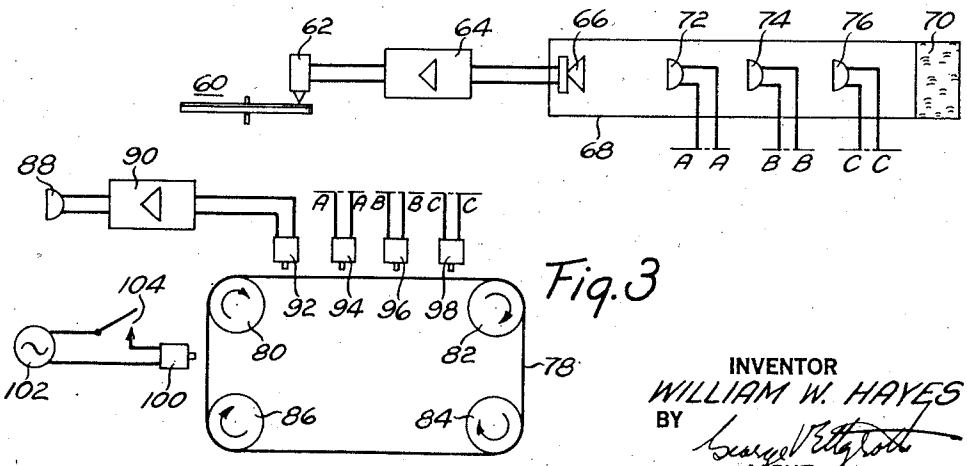


Fig. 3

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ACOUSTIC SYSTEM FOR UNIFORM DISTRIBUTION OF SOUND

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4 Claims. (Cl. 179—1)

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This invention relates to systems for the radiation of acoustic energy and more particularly to such systems in which a plurality of spaced radiation means are employed in diffusing program material.

In the dissemination of program material in large auditoria, open-air gatherings, and the like, the use of a number of spaced sources to secure substantially uniform sound energy distribution throughout the auditorium has been consistently avoided in the past because of the distortion, confusion and unintelligibility resulting from the successive arrival of the same program material at the listener spaced in time by intervals equal to the difference in transmission time of accustic energy from the various reproducing means. The presently accepted method of overcoming the disadvantages attendant upon systems of this nature is to use a single high power radiator or a group of closely associated acoustic radiators acting substantially as a single source, thus eliminating the multiple overlapping transmission of the program to the listener. To insure a comfortable and easily understood sound level at the most remote reaches of the audience, the acoustic level in the immediate region of the main radiator must be quite high and, in the case of extended gatherings, may well exceed the threshold of pain for those of the audience nearest the point of sound radiation. In such cases the acoustic output must be reduced to the point where it is yet bearable to the listeners in the immediate vicinity of the acoustic radiator, with the result that those most remote therefrom lose a part or all of the intelligence in the program material for failure of the energy on arrival to override the ambient noise level.

A principal object of the invention is to improve the uniformity of coverage and the intelligibility of sound reproduction systems intended for use in serving large audiences.

Another object of the invention is to avoid the multiple responses presently characteristic of reproducing systems employing spaced radiators and which have been a source of great annoyance to audiences served by such systems.

A further object of the invention is to provide a multiple source acoustic radiation system in which successive time spaced arrival of the program material from the various radiators is avoided by the insertion of compensatory delays in the apparatus exciting said radiators.

Yet another object of the invention is to provide means for supplying acoustic energy to an auditorium or other closed chamber from a plurality of spaced substantially co-linearily located radiators in which multiple responses due both to echo in a direction opposite the intended direction of sound transmission and multiple responses from the spaced reproducers are eliminated.

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Other objects and advantages of the invention will in part be disclosed and in part be obvious when the following specification is read in conjunction with the drawing in which:

Figure 1 illustrates the installation of an acoustic radiation system in an auditorium together with electric means for securing proper co-action of the elements.

Figure 2 illustrates an alternate form of delay compensation relying upon acoustic phenomena.

Figure 3 illustrates an alternate means of securing signal delays utilizing a moving recording medium.

Generally speaking, the apparatus herein described attains the desired objects by the use of a signal delay means in conjunction with a series of spaced radiators to introduce delays in the application of program material to the radiators substantially compensating the differing distance between the radiators and the individual members of the audience.

Referring now to Figure 1 of the drawings, there is shown the microphone 10 which receives acoustic impulses from any desired source of program material, translating them into electrical energy, which is then applied to the input terminals of the amplifier 12, which may take any conventional form. The output of amplifier 12 is connected to the input terminals of the artificial transmission line 14, made up of lumped inductors 16, shunted at their junction points by the capacitors 18. The line 14 is preferably terminated in an impedance 20 substantially equal to the characteristic impedance of the line itself, to avoid line reflections which might impair the operation of the apparatus. Adjustable potentiometers 22, 24 and 26 are connected at points spaced along the line in the direction of transmission, the potentiometer 22 being connected at the input end, while the potentiometer 24 is connected across the line at a point two sections removed in the direction of transmission, and the potentiometer 26 connected across the delay line at a point two sections further removed along the line in the direction of transmission. The resistance value of potentiometers 22, 24 and 26 is selected to present negligible conductance with respect to the line constants, thereby preventing

the introduction of irregularities otherwise setting up reflections on the line itself.

The audience chamber to be served by the system under discussion is represented by the auditorium 28 having the radiators 30 and 32 situated behind the stage thereof. As indicated by the symbolic notation for these radiators, or electro-acoustic transducers, they may be provided with horns or other directive elements to secure a directional radiation pattern characterized by a large lobe which extends out, over and into the audience area. The same is true of the remaining radiators to be discussed. The audience is normally located in the seat blocks 34, 36, 38, 40. Since the sound level resulting from radiators 30, 32 drops with increasing separation therefrom, an additional pair of radiators 42, 44 is installed in the auditorium 28 at a distance removed from the stage about one-half the length of the first seating block. The decrease in energy resulting from further travel of the sound toward the rear of the auditorium is made up by a third pair of radiators 46, 48 installed at a point more rearwardly located approximately at the lower end of the second seat block. The stage radiators 30, 32 are excited from the output of the amplifier 50 deriving its input at A—A from the movable tap on the potentiometer 22 at the input end of the delay line. The first supplemental radiator pair 42, 44 is energized from the output of amplifier 52, deriving its input at B—B from the movable tap on potentiometer 24. The second supplemental pair of radiators 46, 48 is supplied with electric energy from the output of amplifier 54 whose input is connected to the delay line and to the movable tap on potentiometer 26 at C—C.

From a brief consideration of Figure 1, it is evident that, were all the radiators to be excited from a common output, a listener in the rear row of the audience would first hear a program message unit from the transducer 48, since its transmission path to him would be the shorter. Next, energy from transducer 42 would arrive and finally that from transducer 30. The sequential arrival of the same program matter materially impairs the intelligibility and enjoyment value to be derived. The operation of the arrangement just described, however, is such that this objectionable feature of multiple source acoustic radiation is eliminated.

The electric delay line 14 retards the arrival at amplifier 52 of a program unit passing along the line 14 beyond the input to amplifier 50 a time substantially equal to the transmission time of acoustic energy through the air from the radiator 30 to the radiator 42, whereby the radiator 42 is at any time emitting the same program material reaching its vicinity from the radiator 30 through the air. A similar delay is introduced between potentiometers 24 and 26, resulting in similar correspondence between the program energy radiated from transducer 42 and that arriving at the transducer 46 by acoustic transmission through the air from transducers 30 and 42. The introduction of these delays, compensating for the finite time of transmission between the various reproducing elements, results finally in the simultaneous arrival of the same program impulse at the previously assumed hypothetical listener in the rear row, from all three spaced transducers. The original quality of the signals applied to the speakers is thus preserved, from the subjective viewpoint, and the entertainment value to be derived greatly enhanced.

The rear wall 56 of the auditorium is surfaced with any of the well known forms of acoustic absorbers, such as perforated acoustic tile 58, whereby the reverse flow of sound energy is avoided. Failure to suppress the reverse flow of energy may result in echo effects, which may well destroy the advantages gained from the installation of the foregoing system.

Immediately after the installation and with an audience in place the position of the adjustable taps on the potentiometers 22, 24 and 26 is adjusted to make up for the gradual absorption of energy resulting from the furnishings and audience to secure substantially uniform sound energy level.

While the electric delay line in Figure 1 affords a convenient and readily proportioned method of introducing the requisite delays in application of the program material to the amplifiers and associated reproducers, it is to be recognized that there are other expedients which may be employed for the same purpose with equally good or, in some cases better, results. The dotted lines A—A, B—B and C—C of Figure 1 indicate the point at which the circuits may be broken for the introduction of equivalent systems, one of which is shown in Figure 2, wherein the turntable 60, carrying a recording, and pick-up 62, adapted to engage said recording, serve as the source of signal energy providing electrical impulses impressed on the input of the amplifier 64, whose output drives the electro-acoustic transducer 66, situated within and at one end of a fluid column or path, defined by the enclosure 68. The far end of the column is rendered non-reflecting by the introduction of suitable absorbing means at 70, expediently, rock wool, loose felt, etc. To hold the over-all required length of the column within reasonable limits, it may be preferably filled with a gas having relatively high molecular weight, dichlorodifluoromethane, CCl_2F_2 in which sound travels with a velocity of approximately 500 feet per second. Microphones 72, 74, 76 are situated within the acoustic delay line thus formed at intervals calculated to introduce transmission delay substantially equal to the transmission times between the associated reproducers through the medium surrounding them. The balance of the apparatus employed with this delay line is substantially identical to that of Figure 1, connection being made at the points A—A, B—B, C—C.

A further alternative expedient to be employed in securing the necessary delays in applying the program material to the various reproducers is to be seen in Figure 3, wherein a magnetic wire or strip 78 continuously travels about a loop formed by the four rollers 80, 82, 84, 86, one of which may be driven in any convenient manner. A microphone 88 serves to convert incident acoustic energy into electrical impulses applied to the input of the amplifier 90, whose output circuit energizes the magnetic recording head 92 situated in close proximity to the continually moving magnetic strip or wire 78. As well known, there are thus produced changes in the magnetic state of the strip 78, corresponding to the original sound waves, which variations in magnetism passing under the successively spaced pick-up heads 94, 96 and 98 induce in the associated windings thereof voltages corresponding in form to the original acoustic impulses, but spaced in time an amount determined by the head separation. This time spaced program data is then connected into a circuit similar to that of Fig-

ure 1 at the indicated points A—A, B—B, C—C. The operation from this point forward is substantially identical to that outlined in connection with Figure 1. On the completion of each circuit by the recording medium 78, it is stripped of the previous intelligence by the erasing head 100 to prepare it for the recording operation to follow. The erasing head consists simply of an electro-magnet supplied with high frequency current by connection to the high frequency source 102, in series with the energizing and de-energizing switch 104 and functions in the manner well known in the art.

It will be obvious that many changes and modifications may be made in the invention without departing from the spirit thereof as expressed in the foregoing discussion and in the appended claims.

What is claimed is:

1. In a system for the radiation of mechanical vibratory energy, a source of electric signals, a first electro-acoustic transducer having a substantially unidirectional radiation characteristic, a second electro-acoustic transducer spaced from said first transducer substantially in the direction of the radiation maximum of said first transducer, an acoustic path terminated at one end by acoustic absorbent material preventing reflections along said path, means responsive to said electric signals for impressing acoustic signals on the other end of said line, means for exciting said first transducer from a first point on said acoustic path, means for exciting said second transducer from a second point on said acoustic path displaced from said first point in the direction of signal transmission along said acoustic path an amount introducing a time delay substantially equal to the transmission time of acoustic energy from said first transducer to said second transducer through the medium surrounding said transducers.

2. In a system for the radiation of mechanical vibratory energy, a source of electric signals, a first electro-acoustic transducer having a substantially unidirectional radiation characteristic, a second electro-acoustic transducer spaced from said first transducer substantially in the direction of the radiation maximum of said first transducer, a moving magnetic medium, adapted to take on and retain changes in state in response to a varying magnetizing field, means responsive to said electric signals for impressing on said medium a varying magnetic field, a first magnetically responsive means intercepting flux emanating from said medium, means for impressing upon said first transducer signals from said first magnetically responsive means, a second magnetically responsive means intercepting flux emanating from said medium spaced from said first magnetically responsive means in the direction of travel of said medium by an amount introducing a time delay substantially equal to the transmission time of acoustic energy from said first transducer to said second transducer through the medium surrounding said transducers, and means for impressing upon said second transducer signals from said second magnetically responsive means.

3. In a system for the radiation of mechanical vibratory energy, a source of electric signals, a first electro-acoustic transducer having a substantially unidirectional radiation characteristic, a second electro-acoustic transducer spaced from said first transducer substantially in the direction of the radiation maximum of said first transducer, a medium adapted for variation of a characteristic thereof, means responsive to said electric signals for varying said characteristic, means for producing relative motion between said medium and said characteristics varying means, a first pick-up means engaging said medium, means for impressing upon said first transducer signals from said first pick-up means, a second pick-up means engaging said medium and spaced from said first pick-up means to introduce a time lag in the signals appearing thereat over signals appearing at said first pick-up means substantially equal to the transmission time of acoustic energy from said first transducer to said second transducer through the medium surrounding said transducers, and means for impressing upon said second transducer signals from said second pick-up means.

4. In a system for the radiation of mechanical vibratory energy, a source of signals, a first directional radiator having a lobe of its directional characteristic oriented in a predetermined azimuthal direction, a second radiator of vibratory mechanical energy spaced from said first radiator and situated within said lobe, means for impressing signals from said source on a delay line, means for exciting said first radiator from a first point on said delay line, means for exciting said second radiator from a second point on said delay line displaced from said first point in the direction of signal transmission along said line an amount introducing a time delay substantially equal to the transmission time of acoustic energy from said first radiator to said second radiator through the medium surrounding said radiators, and means for adjusting the relative power input levels to said radiators.

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